UNIVERSITY OF GAZİANTEP
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DESIGN, CONSTRUCTION AND PERFORMANCE TESTS OF A NARROW CIRCULAR KNITTING MACHINE IMPROVED FOR FANCY YARNS

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IN
MECHANICAL ENGINEERING

BY
SERHAT KÖKÇEOĞLU
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Design, Construction and Performance Tests of a Narrow Circular Knitting Machine Improved for Fancy Yarns

M.Sc. Thesis
in
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Supervisor
Prof. Dr. Sedat BAYSEÇ

by
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ABSTRACT

DESIGN, CONSTRUCTION AND PERFORMANCE TESTS OF A NARROW CIRCULAR KNITTING MACHINE IMPROVED FOR FANCY YARNS

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M.Sc. in Mechanical Engineering
Supervisor: Prof. Dr. Sedat BAYSEÇ

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In this thesis, three different colors fancy yarn production method with a narrow circular knitting machine was studied, which is completely new technique in the world. A narrow circular knitting machine was used for producing three different colors fancy yarn. Adding the third colors onto the two colors circular knitting fancy yarn machine caused to decrease production speed of the machine from 4 m/min to 3 m/min. Motion of the rotating part was inverted to avoid this problem and decrease the inertia of the rotating parts. Inverting motion of the rotating parts allowed the system to produce fancy yarn at higher speeds than that of the existing machine. This method enabled to machine to be operated at high production speeds of up to 20 m/min. The inverting of the motion also reduced the magnitude of any unbalanced forces, which in turn allows vibration free, and silent operation of the system. Design and manufacturing methods of the new type of machine were described in the thesis. Also, dimensions of the all the machine parts are shown in the thesis. These dimensions were used to manufacture a new type of machine at Jakarsan Ltd. Şti. As a result, production speed of the machine was increased at about 2.5 times when comparing old type of machine by inverting motion of the rotating components.

Key Words: Narrow circular knitting machine, Fancy yarn, Performance assessment, Production method of fancy yarn

ÖZET

Fantezi İplik İçin Geliştirilmiş Bir Dar, Dairesel Örgü Makinesinin Tasarım, İmalat ve Performans Testleri

KÖKÇEOĞLU, Serhat
Yüksek Lisans Tezi, Makine Mühendisliği Bölümü
Tez Yöneticisi: Prof. Dr. Sedat BAYSEÇ
Şubat 2011, 193 sayfa

Bu tezde, bir dar yuvarlak örgü makinesi ile üç farklı renk fantezi iplik üretim yöntemi incelenmiştir, bu dünyada tamamen yeni bir tekniktir. Üç farklı renk fantezi iplik üretimi için dar yuvarlak örgü makinesi kullanılmıştır. İki renk yuvarlak fantezi iplik makinesi üzerine üçüncü rengi ekleme makinenin üretim hızında dakikada 4 metreden dakikada 3 metreye düşüşe neden olmuştur. Bu sorunu engellemek ve dönen parçaların ataletini düşürmek için dönen parçaların hareketi evirilmiştir. Dönen parçaların hareketinin evirilmesi sisteme mevcut makineden daha yüksek hızlarda fantezi iplik üretimini sağlamıştır. Bu yöntem makineye dakikada 20 metreye kadar üretim hızlarında çalıştırılmayı sağlamıştır. Üstelik hareketin evirilmesi balans olmayan kuvvetlerin büyüklüklerini düşürmüştür, bu da sırasıyla sistemin titreşimsiz ve sessiz çalışmasını sağlamıştır. Yeni makinenin tasarım ve üretim yöntemleri bu tezde tarif edilmiştir. Bu ölçüler Jakarsan Limited Şirketinde yeni bir makine üretmek için kullanılmıştır. Sonuç olarak, dönen parçaların hareketinin evirilmesi ile makinenin üretim hızı eski makine ile karşılaştırıldığında yaklaşık olarak 2.5 kat artmıştır.

Anahtar Kelimeler: Dar yuvarlak örme makinesi, Fantezi iplik, Performans değerlendirmesi, Fantezi iplik üretim teknikleri

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LIST OF SYMBOLS/ABREVIATIONS

C_v	Flow factor for valve
D_p	Diameter of the yarn package
G	Gravitational acceleration (9.81 m/sec^2)
I_G	The centroidal mass moment of inertia (kg.m^2)
L	Length of the string sin meters
m	The mass of the body
N_s	Spindle speed (rev/min)
P_s	Supply pressure (bar)
r	Radial distance
Q	Air flow rate (litre/sec)
t	Amount of twist
V_d	Delivery speed (m/min)
ΔP	Pressure drop across the valve (bar)
τ	Period of oscillations (sec)

CHAPTER 1

INTRODUCTION

Textile is a developing market in the world and technology has affected this evolution many years. As consumer demands from the textile technology is increasing steadily and gradually, technology of textile has been developing within years to keep abreast of this evolution. Producers satisfy the needs of the consumer by developing textile technology and they manufacture new types of machines which are producing new types of yarns. New yarn types can be used for knitting or weaving new fabric types. Increase of fabric varieties perpetuates further developments in textile fashion areas.

Fancy yarns have been in use for many years to satisfy the needs of consumers. Fancy yarns increase the effectiveness of the final fabric and it captivates the consumers. So, people's demands in fancy areas gradually evolve. Rise in the types of fabrics and also yarns, in turn, increases the volume of textile productions.

Fanciness of a yarn has two aspects. One is the shape and structure of the yarn and the other is the multitude of its colors. Most of the yarns are of a single color. If a yarn can be made to change its color cyclically by some means, it would certainly be a very valuable tool in the field of fashion and this particular yarn would sell in great volumes and at higher prices. In the past years, fancy yarns have been produced by using different types of manufacturing methods such as by ring spinning systems, hollow spindle systems and etc. But none of these types could achieve to produce a three different color fancy product. In this thesis, methods of creating new fancy yarns with relatively new techniques are examined. Some of these techniques are not widely known and so products, yarn and fabric, embedding such technologies are expensive. One yarn on which a special emphasis is given, can switch between two different colors. The yarn is a narrow circular knitting, inside of which a number of different yarns with different colors run. These yarns are plucked out of the knitting cyclically, to form feather like extensions protruding from the knitting. Present machines can keep two different yarns of different colors inside the knitting and hence can make protruding extensions of two different colors. Here in this thesis, a similar yarn which can switch between three different colors is studied, which is completely new throughout the world. Greater part of the thesis and work lying beneath of it, is the design and construction of a circular knitting machine which produces this certain type of fancy yarn. The intended machine is to be designed to place one more yarn inside and hence will produce the same fancy yarn with three alternating colors.

1.1 Definition of the Fancy Yarn

Fancy yarns are produced by spinning, texturing, printing, knitting, etc. Until finding an alternative of the fancy yarn, it will be always manufactured in masses and will be used for the public. According to the fashion clothing demands, the amount of fancy yarns used in making fabric is almost equal to that of normal, non-fancy yarns. Some of the fancy yarns are also used for making decorative textile materials such as carpets, curtains and upholstery. Nowadays, materials made of fancy yarns are also used for adorning unlikely habitable volumes, such as inside of a car, airplane or train or a hotel lobby. In their famous book entitled “Fancy Yarns: Manufacture and Applications” [1], R.H.Gong and R.M.Wright have given a good treatise on where fancy yarns and fancy materials are used in search of the market volume, in the last chapter. In the first chapter of the same book, the fancy yarn is described as :

A fancy yarn is almost invariably complex in construction, with the natural result that the application of these more time-consuming or complex manufacturing processes makes the yarn more expensive than a plain yarn would be. It may contain many different components, filament or staple, natural or synthetic. The most luxurious yarns involve the noble fibres such as cashmere, mohair, angora, or other more expensive natural fibres such as linen or silk. In some cases, however, an effect may best be obtained by the use of a synthetic - for example, the gleam of a metallic *thread has no natural fibre counterpart, and slit films can also be used to remarkable effect.*

From this definition we understand that they are complex in construction and methods of manufacture, can contain the most expensive fibres and are visually effective. Actually the main goal is to develop or improve the aesthetics of the final product. The fancy yarn is most often, not uniform in form or color or both. Almost invariably it is shiny and bright, which is provided by the metallic components used or silk.

The types of fancy yarns, classified according to their shape and appearance is shown in Figure1.1. This figure is extracted from the Technical Article written by Chidambaram Rameshkumar and N. Anbumani [2]. There are eight distinct types, as Gimp, Spiral, Slub, Knop, Cover, Loop, Snarl and Chenille.

These yarns all look different but actually they are evolved from one another and hence at least some stages of their production are common. S. Petrulyte has described these yarns and tried to group them according to their production techniques in his paper published in 2004 [3]. Jaganathan Sudhakar has tried to put forth

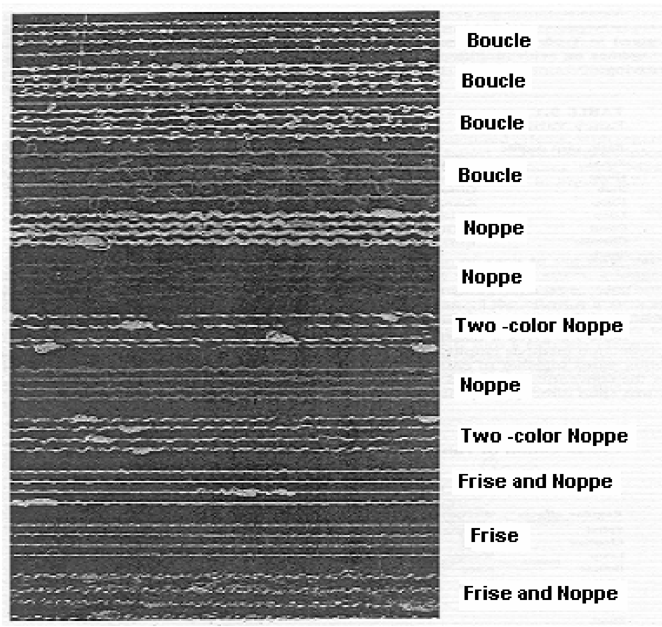


Figure 1.1: Twist effect on the fancy yarn [2]

characterization methods of novel yarns in his M.Sc. dissertation published in 2005 [6]. As more and more different yarn types come up, it becomes difficult to name them and generate vocabulary required in describing the production techniques. To solve this problem, people put effort, and the M.Sc. thesis prepared by Erin Suzanne Meadwell is a good example, putting together the related lexicon [4]. Many more different yarns have been given in the Handbook of Yarn Production, written by Peter R. Lord [5]. Similar works have been under progress in Turkey too. For example studies on Slub yarn manufacturing at Cukurova University under O. Babaaslan's management is remarkable [7]. H.G. Ortlek's work on the abrasion of chenille upholstery fabrics, which is a great problem in practice, is remarkable at the Uludag University [8].

1.2 Types of Fancy Yarn

1.2.1 Gimp Yarn

Gimp yarn consists of a base yarn which is wrapped by another, called the effect yarn to give a design to the produced yarn, structure as shown in Figure 1.2. Yarn is produced in two stages to ensure stability of the final product [1]. Thin and thick yarns are used together and they wrap each other, thick around thin, and then thin around thick. Second process is called as the reverse winding process which removes most of the twist occurred during the first wrapping process [1]. This process leaves the thinner base yarn straight and the thicker effect yarn slack and wound around the base. To make the structure stable, that is, to prevent the unwinding of the effect yarn, the two are fixed together by the binder yarn. These two processes make final profile of the yarn. The length of the finished yarn at the end of the second process is longer than the length at the end of the first process [1].

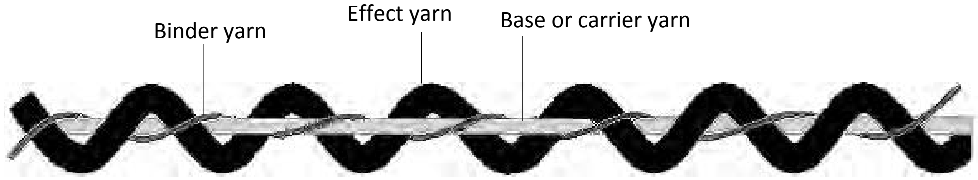


Figure 1.2 Structure of the Gimp Yarn. Fanciness is due to the slackness of the thicker effect yarn. Structure is carried by the core or base yarn. [1]

1.2.2 Spiral Yarn

Spiral yarn consists of two yarns. One component of yarns is a straightforward, non-fancy one and the other yarn, often thicker, which provide the fanciness is wound around that component. (Figure 1.3). This type of fancy yarn has very similar structure of a Marl Yarn, which is actually obtained by twisting two non-fancy yarns of different colors together, which in fa, can not be considered fancy. Doubling frame system and ring spinning system can be used for producing spiral yarn [1, 2]. "It is more textural in appearance than a marl yarn, and the finer counts may also appear in some of the laces used in lingerie." says R.H.Gong and R.M.Wright in [1].

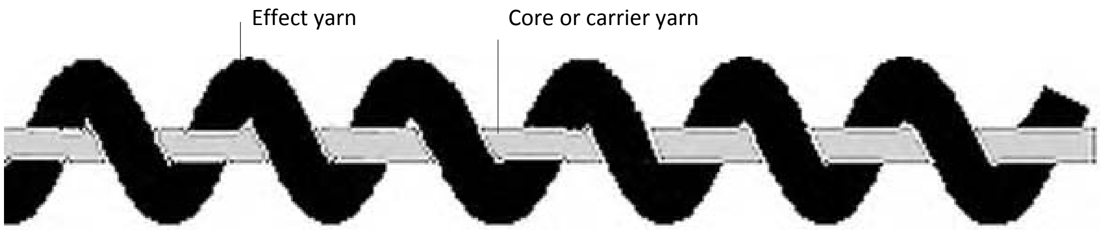


Figure 1.3: Structure of the Spiral Yarn. A thicker yarn in fancy color and brightness is wound over a carrier yarn [1]

There are several methods to get this type of yarn, basic ones as follows:

1- Twist direction of a yarn is specified by the letters S and Z, as shown in Figure 1.4. When S or Z twist yarns, which have equal length, are assembled with twist, length of one component decreases and the other component increases when the combination is twisted in either direction [1]. At the end of this second twisting operation, one of the components may become straight while the other becomes winding around this, as shown in Figure 1.3.

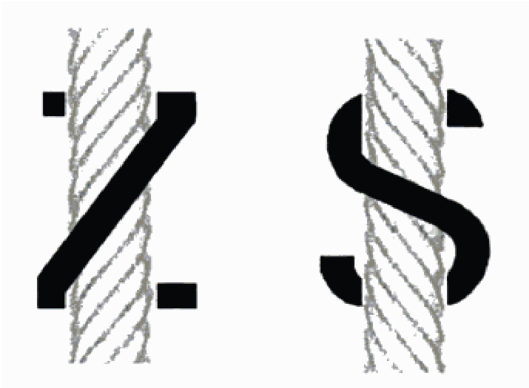


Figure 1.4 Twist direction of a yarn is specified by the letters
Z and S as shown in this figure. [5]

This production technique is called the unbalanced-twist spiral yarn says Peter R. Lord [5].

2- Twist density is also important in the spinning process. It is denoted as the number of twists-per-meter of the finished yarn. Twist density is adjusted by the “Delivery rate”, that is, the feeding speed of the yarn to the loom rotating at constant speed. If delivery rate is small, twist density becomes greater and vice versa. While twisting two yarns to each other, if delivery rates are kept different, the one which is fed faster will wind over the slow one in form of a spiral, The component, which has shorter length, makes up the base of the final product while the other component spirals around it [1, 2, 5].

3- If two yarns have equal lengths but thickness of one is greater than that of the other, the coarser yarn spirals around the other which forms the base of the final product [1].

Twist yarn is the simplest fancy yarn, with lowest production cost. It has been in use extensively in any requirement of fancy fabric or knitting. In Figure 1.5 two different spiral yarns are shown. The one on the top seems to be composed of two yarns of different thickness, but actually it is not. Relatively thin one is tightly twisted, fine and lustrous while the second is less compact. This yarn is produced by using the first method specified above. The one at the bottom, a fine viscose spiral yarn, where two component yarns are of much more similar count and structure [1]. It is made by using the second method specified above.

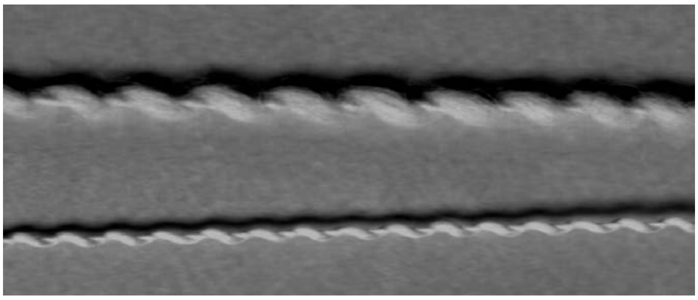


Figure 1.5: Spiral Yarn Types. In both, there is one carrier or base yarn and a fancy yarn wound around it in a spiral. [1]

1.2.3 Slub Yarn

A Slub yarn contains some bulk of material accumulated at points with small distances of separation. Slubs in the fancy yarn are deliberately obtained for producing discontinuity in the combination of the yarn. Thick places of the final product, which can be three or four times of the base yarn in thickness, called as slubs [1, 2]. In their 2007 paper [7], Osman Babaaslan and his research team have described the characteristics of the slub yarn and describe the mechanism which produces it. There are many aims to produce slub effect in the final product. Slub effect is generally used for giving good appearance to the fabric such as upholstery and apparel fabrics. Moreover, fabric containing slubs look good and stronger. Slubs also add to the fabric toughness, and wear resistance. In the slub yarns, a thick place is followed by a thin place and this structure may cause some weak patches to occur in the woven fabric. To avoid this, slub yarn delivery speed must be done very carefully, slubs not too far apart from each other [1].

There are several methods to produce slub yarns and these methods also categorize the produced yarn. R.H. Gong, R.M. Wright lists these methods in their Fancy Yarns: Manufacture and Applications book [1] as:

1-Slub yarns produced at the spinning frame are known as spun slubs. They can be produced by blending fibres of different dimensions, as for example woolen slubbing with worsted top sliver – the imperfect fibre control during drafting produces randomly distributed slubs of varying size.

2-Plucked or inserted slub yarns are composed of two foundation threads and periodic short lengths of straight-fibred materials that have been plucked from a twistless roving by roller action. This method tends to give a neater, cleaner appearance than is achieved in producing spun slubs.

3-An alternative method is to modify the spinning frame such that the intermittent acceleration of the rollers causes varying degrees of draft to be applied. Such a slub is shown in Fig. 1.6: in this case it is a relatively fine yarn with a fine and fairly long slub. This method might also be used to produce a slubbed roving from which a yarn could be spun using constant draft; of course the yarn created in this way would have very long slubs that become apparent only gradually.

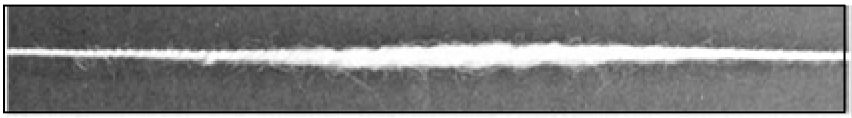


Figure 1.6 Slub Yarn. The thick portion is the slub. Yarn is thinner before and after the slub. [1]

4-A further method would lie in the injection of additional material into the drafting zone. The setting must be varied over a very long repeat to avoid patterning the material. This method allows the production of 'flake' (very long slub) yarns.

5-Finally, recent developments in open end spinning have made it possible to create rotor spun slub yarns.

1.2.4 Cover Yarn

Cover yarn consists of two yarns. A carrier yarn called the core, is wrapped around by the other yarn is wound [1]. The yarns are often of the same denier but presumably of different color. They are twisted onto each other. These two yarns are fed by two pairs of rollers. The speeds of the feeding rollers are variable, alternately speeding up and slowing down. When one yarn is fed fast the other is fed slowly and vice versa. The slowly fed one becomes the carrier and the fastly fed one wraps around it.

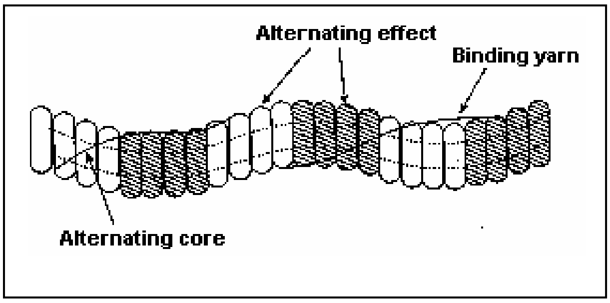


Figure 1.7 Cover Yarn. Yarn is composed of two identical deniers, different color yarns, slightly spiralled, alternating in color. [2]

Then speed alters and the yarn which was winding previously starts to be fed slowly, hence becoming the carrier, and the core yarn of the previous step starts to be fed fast and wraps around the slowly fed core. This process ends up with a yarn structure with alternating color and with some spiralty as shown in Figure 1.7.

1.2.5 Loop Yarn

Loop yarn is similar to the Gimp yarn. It has three types of yarns, an effect yarn a core and a binder. Effect yarn is wrapped around the carrier forming loops and the two are fixed together by the binder yarn as seen in Figure 1.8. In the structure shown in the figure, core yarn is shown as two bars, as it is often a two ply twisted yarn [1, 2]

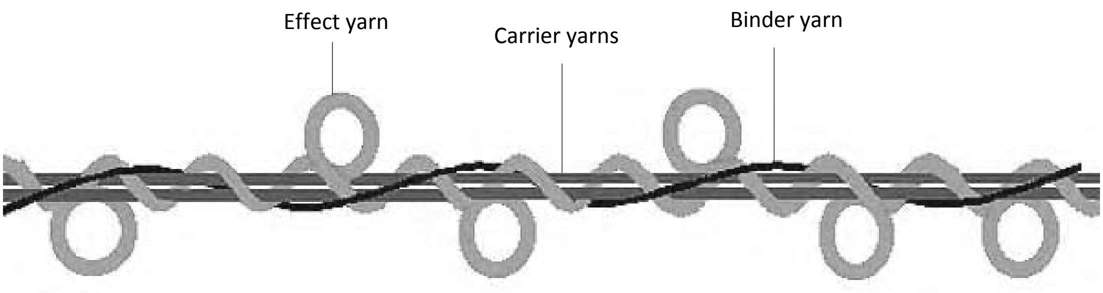


Figure 1.8 Loop Yarn Structure. Effect yarn is in loops and bound to the base yarns by the binder yarn. [1]

Suitable yarns must be selected for the effect. Best yarns for this purpose are of low twist, elastic and pliable, such as the mohair fibre. Percentage of overfeed of the effect yarn, tension on the yarn and level of twist can affect loop size. In Figure 1.9, a loop yarn made of mohair is shown. By “Elasticity”, it is meant to be resistant to bending, and not “stretchable”.

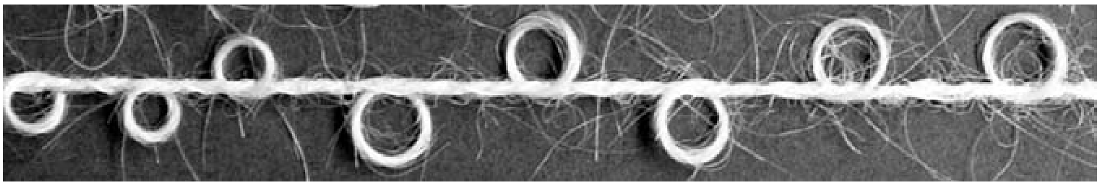


Figure 1.9: Mohair Loop Yarn [1]

1.2.6 Knob Yarn

"A knob yarn is one that contains prominent bunches of one or more of its component threads, arranged at regular or irregular intervals along its length, as shown in very simplified form in Fig. 1.10. [1]" It can have two effect yarns of presumably different colors and may be used in making the knobs alternately, hence resulting yarn having alternating color knobs on it. If there is color alteration as described, the machine can not be a simple twisting machine. There must be an additional mechanism which changes the thread in the process of knob making.

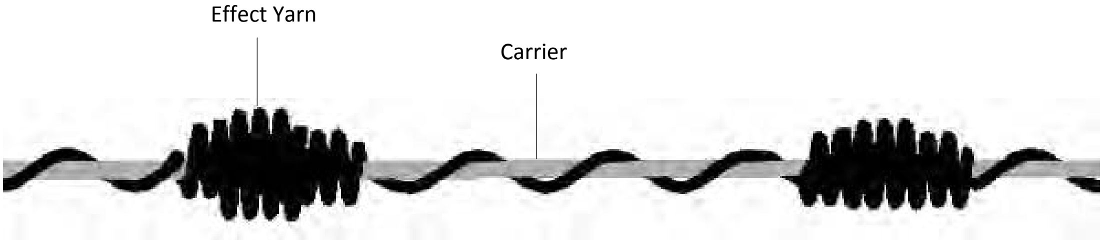


Figure 1.10 Structure of Knob Yarn. There can be two effect yarns running in parallel, used alternately to produce knobs after alternating color [1].

1.2.7 Snarl Yarn

"Snarl" is the extensions protruding from the yarn in perpendicular direction. A two ply twisted yarn acts as the carrier. An effect yarn running along the carrier periodically leaves the core, makes a snarl and returns to the core. Core and effect yarn are fixed together by a binding thread [1, 2], as seen in Figure 1.11. Process is similar to that of the loop yarn, but the feed rate of the effect yarn is greater here [1]. Intervals between snarls and its size can be controlled by the degree of twist and overfeed ratio and also tension given to the effect yarn. Also tension on the spinning device affects size of snarl.

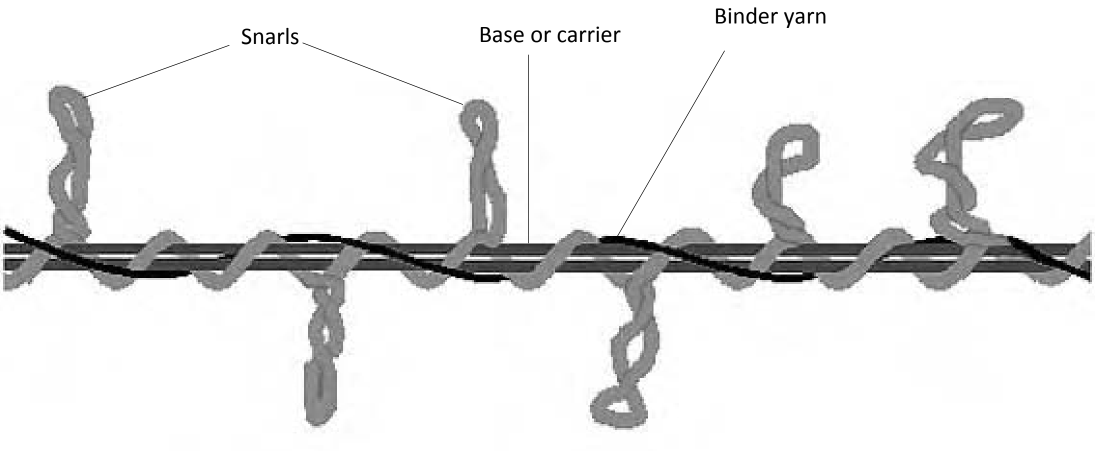


Figure 1.11 Structure of Snarl Yarn. Snarls occur when the effect yarn leaves the carrier but keeps on twisting. [1]

Figure 1.12 shows an example snarl yarn. White worsted yarn is in use to give snarl effect and black cotton is used as the core [1]. This type of yarn is used in conjunction with plain yarns to make a fabric, snarling is not continuous, it is only used to give alternating effect on the fabric [1].

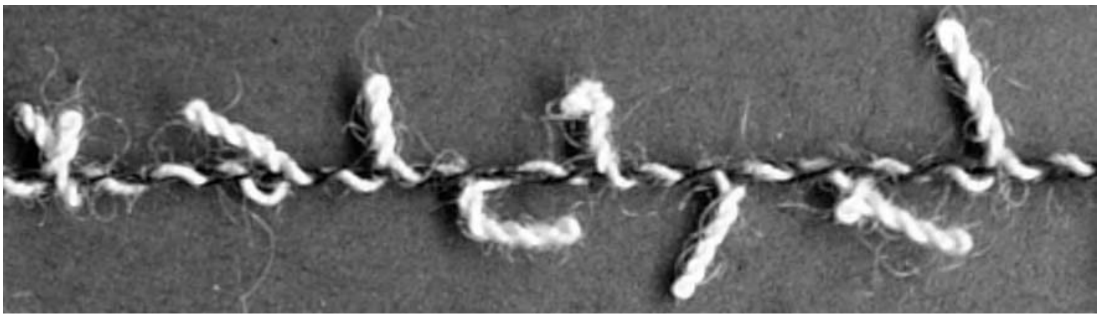


Figure 1.12: Snarl Effect on fancy yarn. [1]

1.2.8 Chenille Yarn

Chenille yarn consists of shortly cut wefts called piles inserted between a pair of twisted warps or the carrier yarn as shown in Figure 1.13. Different types of materials such as viscose, acrylic or cotton can be used for producing the chenille yarn, both as the pile and the carrier [8]. If untwisted filament yarn is used as core yarn, it can cause losing piles because of low friction effect between the piles and the

Figure 1.13 Chenille Yarn Structure. [1]

filament [8]. Friction is important not to lose the piles hence elongates the life of the fabric. Research on the abrasion resistance of fabrics made of chenille yarns is an important subject. In their 2003 paper, H.G. Ortlek of Uludag University and his Chenille yarns are traditionally used in the manufacture of furnishing fabrics and team investigate on the abrasion resistance of upholstery fabrics made of chenille yarn. The diameter of the pile yarn can be changeable between Nm 0.2 and Nm 15.0. Chenille yarns are traditionally used in the manufacture of furnishing fabrics and trimmings, fashion knitwear, and as decorative threads in many types of broad and narrow fabrics. Figure 1.14 shows chenille yarn that has three different colors and different weft lengths so that this gives an advantage to the final product to bear different thickness and color whether be it a fabric or knitting.

Figure 1.14: Three Different Color Chenille Yarn

Chenille yarn is manufactured on a machine designed to bring the pile yarns and lock yarns together, mechanism shown schematically in Figure 1.15. During manufacture, the pile yarns are wrapped around a short stem of polished metal *called a caliper or gauge (Figure 1.15-a), through which a reciprocating razor blade passes to cut the pile yarns into short lengths. The lock yarns are pressed onto the short lengths of pile with a pair of rotating wheels which are called a plywoods. The resulting yarn is then fed onto a traditional ring-twisting take-up mechanism. In the twisting process, the two ends of the lock yarn twist and trap the short piles between them. The neck thickness of the caliper determines the diameter of the resulting yarn. The count of the lock and pile yarns, the number of the pile yarns and how many of them are fed onto the lock yarns determines the length and toughness of the yarn. After the twisting process, chenille yarns are rewound onto a cone or dye tube. An electronic clearer is located in the yarn path in order to detect lengths of yarn that are missing pile in this rewinding process. When the electronic clearer detects a section of missing pile greater than the minimum setting specified (usually 3 mm), a cutter is electronically activated. The yarn is cut, and the winder operator then pulls the yarn back and cuts out the missing pile section, reties the yarn, and continues winding the package.* [8]

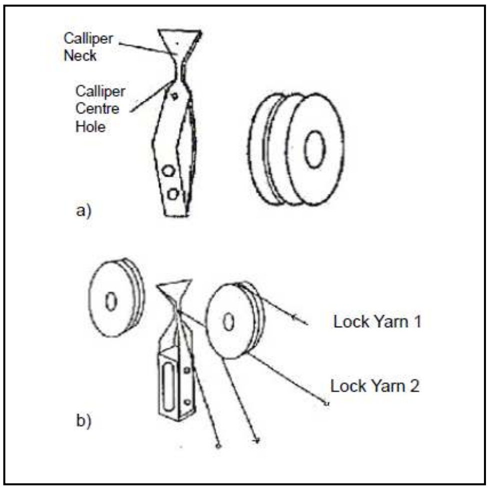


Figure1.15: a) Caliper and Plywood devices, b) Caliper and plywoods location [8].

Another method of producing chenille yarn is by circular knitting. Three yarns are taken from the creel and fed to the machine after giving some tension. One is knitted into an elastic narrow circular tube, which becomes the carrier of the final structure. Other two, often at different colors are used to make the piles, laid into the circular knitting in transverse direction and cut. If two different colors are used, a changing mechanism is required to switch the thread used.

Novel Yarns come up into the market quite frequently and the machinery which produces them. This is an important sector, making good income as demand for new yarns is ever existing in the fashion, textiles and interior decoration sectors.

CHAPTER 2

SOME WELL KNOWN TECHNIQUES
IN THE PRODUCTION OF FANCY YARNS

2.1 The Ring Spinning System

In recent years several methods have been developed for producing fancy yarns, but ring spinning system is still in use for fancy yarn production. It gives an advantage not only from economic point of view, as a fancy yarn is produced on an already existing machine, but provides controllability on every aspect of the yarn while in production [1].

Roller drafting system, which is schematically shown in Figure 2.1, is generally the mechanism used to draw the combed fiber strip called “sliver” from stock and feed the machine [1]. The sliver passes through a set of two rollers in positive drive, rotating at a constant speed. Fiber strip then passes through a pair of drafting aprons, which are merely surfaces of flat belt, stretching between parallel rollers.

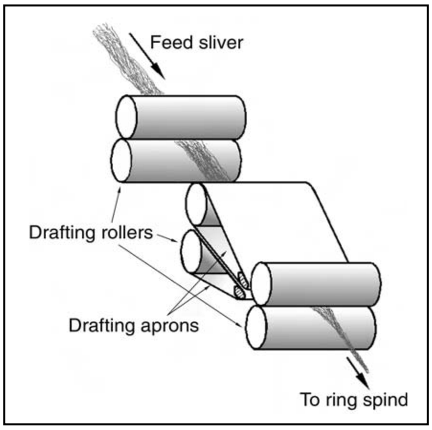


Figure 2.1 Drafting mechanism of the Ring Spinning System [1]

The surface speed of the drafting aprons is not necessarily the same as that of the feeding rollers. If the speed of apron surfaces is greater than the feeding rollers, sliver elongates, loses in lateral dimension and the yarn spun then after, becomes thin. In the opposite case, that is, the surface speed of the apron is greater than that of the feeding rollers, fiber stacks up between the two and pressed between the surfaces in that form. Resulting yarn after spinning becomes dense, thick and bulky. This ratio of surface speed is called the “mechanical draft”. “If we ignore any shrinkage of the fibre strand after drafting, the mechanical draft is the same as the actual draft, which is defined as the ratio of the linear density of the feed to that of the delivery [1].” The draft is adjustable by changing the gear ratio between the shafts of the roller sets in older machines and is achieved by PLC setting and control in newer versions. The most important step in adjusting a ring spinning machine to produce fancy yarns is at this mechanism. The distances between two pairs of rollers must be carefully adjusted otherwise it can cause rupture in the fancy yarn produced.

The first pair of rollers called as “feed rollers” and next pair of rollers called as “delivery rollers” [1]. In this system drafting aprons are used to increase control of sliver while passing between rollers [1]. Achieving maximum yarn evenness in the final product depends on decreasing variation in yarns density. But obtaining yarn evenness in final product is not easy because different length fibres act to move independently during the drafting process and it cause to increase unevenness in final product. The drafting aprons are in use for controlling and reducing variation of density while producing of a normal yarn in ring spindle process [1]. But in producing fancy yarn process the aprons may not be used because of increasing variation in the final product [1]. “This effect may be enhanced by mixing fibres of different lengths to exaggerate these variations in yarn thickness. For example, woolen slubbing can be mixed with worsted top sliver, to create a yarn in which the imperfect fibre control during drafting produces randomly distributed slubs or thick places of varying dimensions [1].” The output of the drafting mechanism is then sent to the ring spindle to twist into the final product. A schematic picture of the ring spinning system is shown in Figure 2.2. Direction of the twist can be controlled by the direction of rotation of the spindle, which is also controllable by adding an idler to the gear train driving the spindle or by doing the necessary settings on the controlling PLC. Front rollers send yarn to the yarn guide which is located directly above the axis of spindle. Yarn guide enables the yarn to wrap around the spindle properly, without knotting [1]. Traveller is a second guide used for holding the yarn and returns it around the spindle. Ring makes vertical movement to wind the final product vertically around bobbin, which is mounted on the spindle. The aim of this motion provides to wind maximum amount of yarn, increase stability of the bobbin and facilitate an easy unwinding of the bobbin [1]. The amount of twist on the final product is related with speed of spindle and yarn delivery speed and it can be calculated by using the following formula [1]:

$$t = \frac{N_S}{V_d} - \frac{1}{\pi D_P} \tag{2.1}$$

Where N_s is the spindle speed in rev/min, V_d is the delivery speed of the yarn in

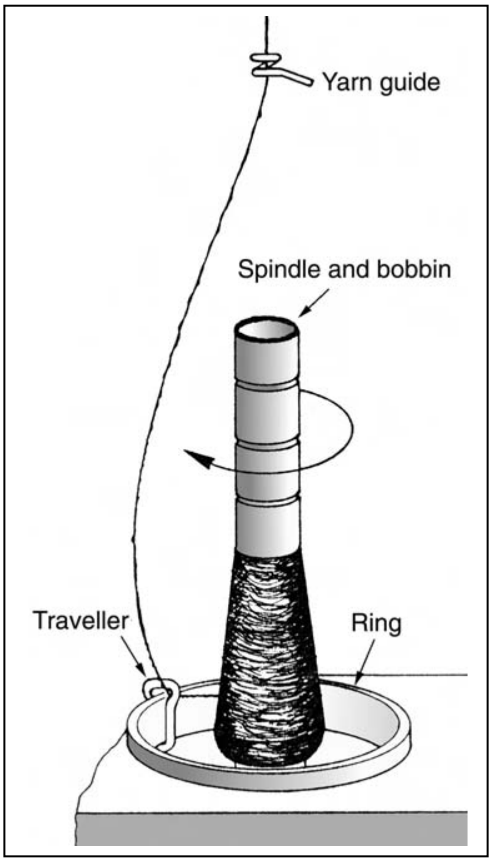


Figure 2.2: The Ring Spindle [1]

m/min. And D_p is the diameter of yarn package in meters. t hence is twist in revolutions-per-meter of yarn. But generally in practice the second term in the formula is negligibly small in comparison to the first term and hence, is not written and used [1].

Fancy yarn generally consists of a core yarn and an effect yarn, fancy effect can be increased by using more effect yarn. Several stages are applied on yarns for getting fancy effect from this yarn combination. After producing fancy effect from this combination, base yarns and effect yarns can be twisted in one direction or the other to fix them to each other [1]. In some designs an additional binder yarn is used to fix the effect yarn onto the carrier or core. Binder yarn itself can add extra fanciness such as in boucle and snarl. If binder yarn is not used while producing boucle and snarl yarn, the effect yarn can slide up and down on the core yarn.

2.2 The Hollow Spindle System

The “spindle”, which is indeed a rotating shaft, is the component which gives twist to a yarn in twisting machines. “Hollow spindle” is hence hollow and the yarn passes through this hole and gets the twist there. In Figure 2.3, a schematic picture of a Hollow Spindle yarn twisting system is shown. Main advantage of using hollow spindle process for producing fancy yarn is reducing production stages. Fancy yarn can be produced in a single stage with this method [6]. Twist given to the yarn by the hollow spindle is “false”, as the portion of the yarn between the bobbin and spindle and the portion between the spindle and yarn feeder takes equal amount of twist but in opposite directions. False twist is lost in case of tension unless it is fixed by a binder thread for example. The rotation of the hollow spindle can be used to provide a hold of core yarns and effect yarns together, though false. The two must be fixed by a binder thread then [1, 2]. Various types of fancy effect can be produced by using hollow spindle systems such as loop yarn and spiral yarn. Ring spinning can be used for producing fancy yarn but there are some differences between hollow spindle yarn and ring spindle yarn. Wear resistance of hollow spindle yarns are lower than ring spindle and tend to be more bulky [1].

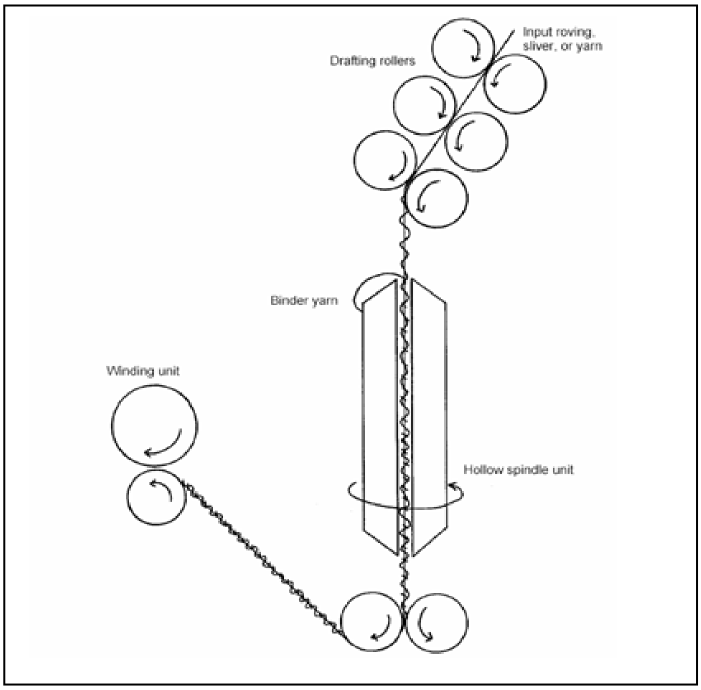


Figure 2.3: The Hollow Spindle yarn twisting system. Twist given by this system is false and is lost when the yarn is tensioned. [6]

A Combined system can be generated for providing benefits of the hollow spindle and ring spindle systems, a schematic picture of which is shown in Figure 2.4. Yarn passes through the hollow spindle first and gets a false twist. Then comes to the ring spindle where it gets a true twist. True twist winds the binder thread around the falsely twisted yarn or yarn combinations and fixes the whole yarn together. Binder thread can be of a bright color and can add to the overall fanciness of the yarn.

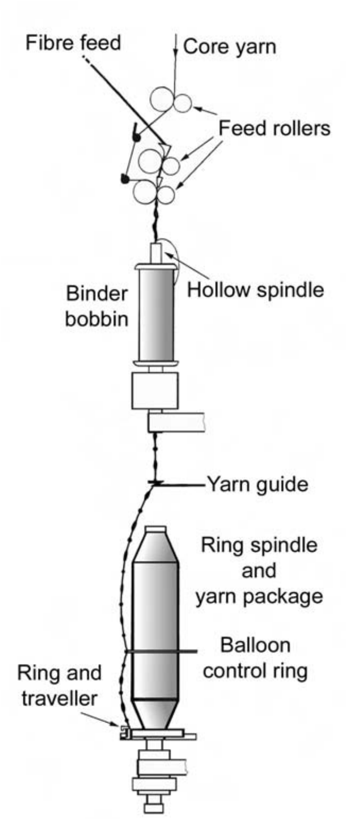


Figure 2.4: A system where a Hollow Spindle and a Ring Spindle are combined. [1]

2.3 The Rotor Spinning Machine

Another method of creating fancy yarn is the rotor spinning process, basic system is shown schematically in Figure 2.5. Rotor spinning is intended to twist a sliver into a thread or yarn, in a fast manner. There is a cup like rotor, which is running at great speed, as high as 8000 rpm. Sliver is directed into the rotating cup, to the rim and is twisted by the rotation of the cup. The forces that twist the fiber is only the friction between the cup and the fiber. Twisted yarn is then collected by an extractor located on the axis of rotation of the cup. This technique and related machinery are later found to be satisfactory in making some fancy yarns. The effect yarn and core are given simultaneously into the cup and leave it as twisted. Tension is generated in the rotor after giving this yarn to the rotor. Varying tension in core yarn and effect yarn provides to obtain loops in the yarn. In the rotor, tension of the core yarn is greater than tension of the effect yarn. Binder process is applied after core and effect yarn leave from the rotor [4]. An air bed can be used for increasing flow of fibre in the zone and it also provides a key to increase the variety of the final product [4].

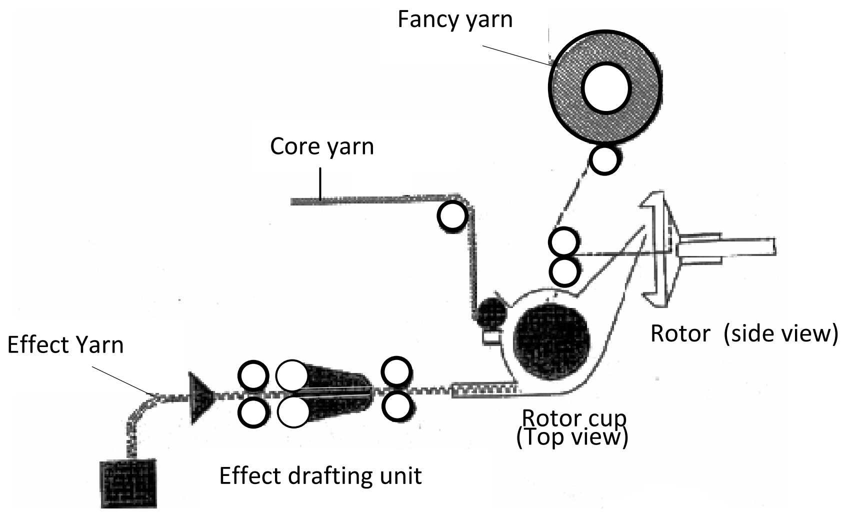


Figure 2.5 Rotor Spinning Machine [6]

2.4 The Air Jet Texturing Machine

Generally, types of synthetic flat filaments are in use for producing fancy yarn in an air jet texturing machine [1]. Firstly, flat filament is wetted for improving stability of the yarn and sent to the texturing jet system as seen in Figure 2.6. After this, an air jet is directed to the filament which forces it to buckle [1]. Air jet box, which is used for enclosing the air jet, reduces noise of the system and collects the water. Generally a heater is used for removing remaining water from the final product [1]. With earlier designs of the Air Jet Texturing Machines, only boucle and slub yarns could be produced [6]. In these systems effects are obtained by feeding the effect yarn intermittently to the feeding zone [6]. Adding some accessory devices like are hot pins, hot plates, tangling jets and slubing devices to the air jet texturing enables to produce different types of fancy yarn such as shrinkage yarn, two tone yarn and differential dye yarns [1].

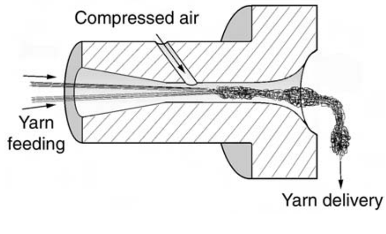


Figure 2.6: Continuous filament yarns can be textured by an air jet. [1]

2.5 Chenille Machines

One of the production methods of chenille yarn is cutting the effect yarn by using a razor blade [1]. Two ground or base yarns and an effect yarn are used for producing the fancy chenille yarn from this mechanism, a schematic view of which is given in Figure 2.7. “Take-up roller” and the “companion roller” are used for giving guide to the ground yarns as seen in Figure 2.7 [1]. The lengths of the effect wefts are adjustable with width of the bottom of the gauge. After producing effect from the machine, the knife is used for cutting the wefts. Final yarn is twisted together by a ring spinning process.

The other method for producing chenille yarn is by circular knitting. Three yarns are taken from the creel and are delivered to the circular head after giving some tension. Needles take one yarn and yarn and knits them into a narrow circular tubing, which becomes the carrier of the final yarn. Other two are the form yarns, which are placed in transverse direction while the tubing is knit. A time latch needle blade cuts the form yarn and piles are generated. Then the yarn is sent to the spindle to wound to bobbins.

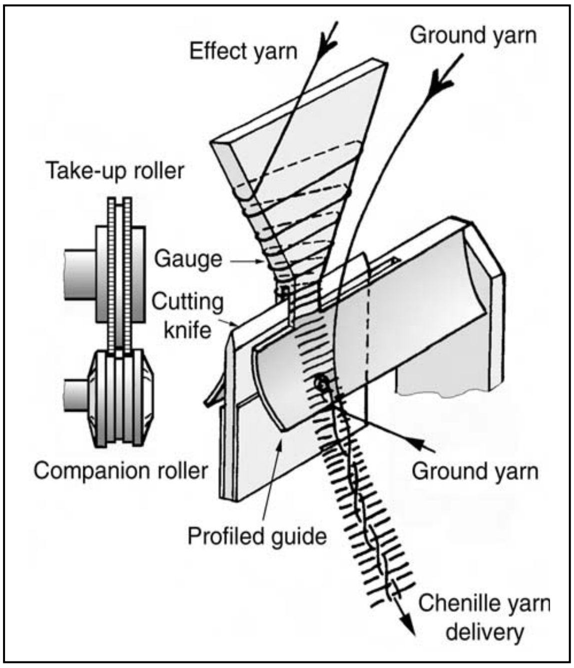


Figure 2.7: Mechanism of making Chenille Yarn. [1]

Yarn design is a business which incorporates the knowledge of textile machinery and materials and also artistic taste and ability. Once a new and novel yarn is thought of, machinery which produces it is designed and forwarded to the market. As these machines are not very cheap, many yarn designers work on obtaining fancy yarns by using the existing, more conventional machinery, like spinners, may be with the addition of some accessories. Today in the market, many different machines can be found and many yet, are being under design and development. A certain fancy yarn may attract the attention of fashion designers and all of a sudden, demand for this particular yarn may shoot up. Contrary is also true, a very expensive fancy yarn machine can be staying at rest because the yarn it is producing is currently out of fashion.

In the next chapter, a new novel fancy yarn is described. Then some improvements on the yarn are proposed.

CHAPTER 3

A NEW NOVEL YARN AND IMPROVEMENTS PROPOSED ON IT

Novel Yarns come up into the market quite frequently and the machinery which produces them. This is an important sector, making good income as demand for new yarns is ever existing in the world of fashion, textiles and interior decoration.

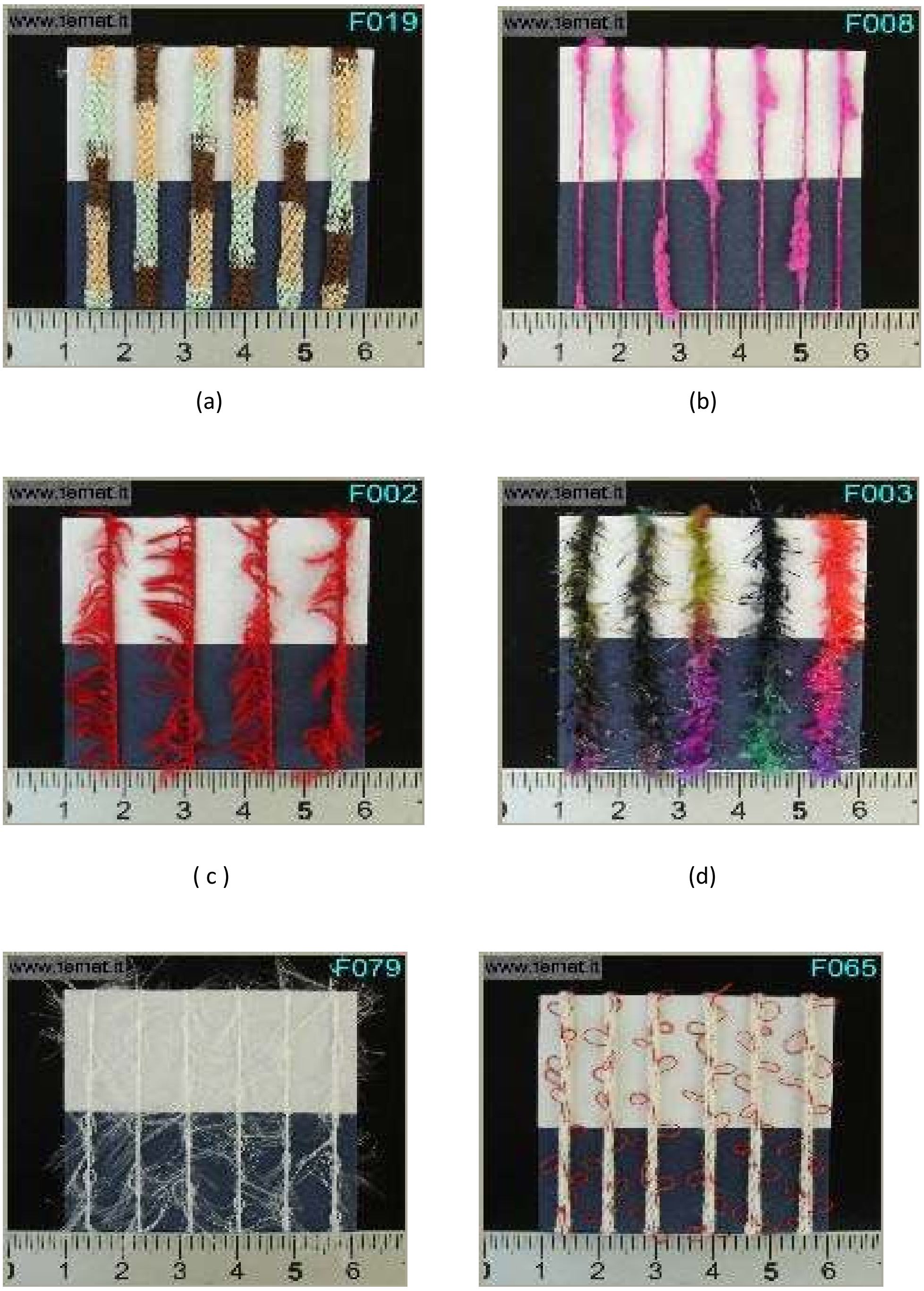
3.1 A New Novel Yarn by the Italian Company TEMAT Meccatronic

A new and novel yarn and a machine which produces it has been introduced to the market in early 2000’s. The company is specialised on making twisting and tubular knitting machines which can be rearranged to produce fancy yarns. Their latest

Figure 3.1: Sy/48SB Fancy yarn machine of the Italian company TEMAT meccatronic, placed here by its courtesy.

design Sy/48SB is for making Snarl and Slub Yarns by a different technique [9]. Their machine is shown in Figure 3.1. A rather small and compact machine composed of 16, 32 or 48 identical knitting heads produce a narrow tubular knitting at each head. Narrow knitting acts as the carrier or base of the yarn. In addition to the yarn used in making the tubular knitting, two more yarns come from the creels, all three presumably of different color. The machine can produce a narrow tubing in a steady operation. The yarn can be changed at will by a catch mechanism and hence only a narrow tube with three alternating colors can be made. This by itself, as seen in Figure 3.2 (a), is quite a fanciful yarn, which can be used in knitting or weaving. The yarns running inside the tubular knitting can be plucked out of the tube by a catching mechanism and sent back again forming a snarl. Snarls can be looped as seen in Figure 3.2 (f) or the loops can be cut by a needle blade and cut wefts form a different texture as seen in Figure 3.2 (c). Same machine can form slubs on the yarn by accumulating the form yarn locally, as seen in Figure 3.2 (b). The catching mechanism can catch either of the two fancying yarns, hence the resulting yarn has snarls or slubs in alternating colors. To enhance their colors, the tubular knitting is adviced to be made black. In Figure 3.2 (b) a slub yarn is shown, produced by this machine, where only one single color has been used. In Figure 3.2 (c),(d),(e) and (f) Snarl yarns are shown of different appearance. In (c) and (e) only one color is used in carrier and effect yarns. In (f) red looping snarls are superimposed on white carrier, where the carrier color also adds to the fanciness of the yarn. In (c), three different colors are used, all three are used cyclically to make snarls.

The finished fancy yarn is wound on cylindrical bobbins at the bottom, rotating on looms. Rotation of the bobbins give the yarn an overall twist. This twist may be wanted or not wanted according to the purpose. To unwind the twist or adjust its amount, another twisting mechanism is put before the winding. Yarn in (c) has no overall twist at all, while yarn in (d) has a great deal of twist, which has made it almost cylindrical in appearance. This type of the snarl yarn has been in great demand within the last half decade. It is preferred by the knitters. It provides a soft feeling to the skin. It feels warm, as the air entrapped within the volume is a good heat insulator. Two alternating colors enable a nice color combination. Actually three different yarns are used to make it, where one is used to make the carrier. Carrier is adviced to be black to enhance the fancy colors. But, the color of the carrier can also be made a part of the fanciness and then a 3 color yarn is obtainable. Many different fibers can be used, natural as cotton, wool, silk, alpaka and angora, or artificial as polypropylene, acrylic etc. Bright and shiny colors have always found customer at all times.



(a) (b)

(c) (d)

(e) (f)

Figure 3.2: Different fancy yarns produced by the Sy/48SB Fancy yarn machine of the Italian company TEMAT meccatronic. In (a) only tubular knitting is shown. (b) is a Slub yarn. (c),(d),(e) and (f) are different types of Snarl yarns. The scales underneath are in millimeters.
(By the courtesy of TEMAT Meccatronic.)

3.2 The TEMAT Sy/48SB Fancy Yarn Machine

The machine which produces the yarn described in section 3.1 is produced by the Sy/48SB machine, designed and produced by the Italıan company TEMAT meccatronic. Its operational system is a circular knitting system. A machine can come with a minimum 16 circular knitting heads up to a maximum of 96 positions, 165 mm. Spacing between the heads. The machine is fitted with the spindles, one for each head, winding the produced yarn on cylindrical bobbins placed on the spindles. The mechanism which provides a fast change of the bobbins is patented. The machine is equipped with two feeding cylinders of the yarn to be processed and a drawing cylinder of the yarn produced. In the event that one of the work yarns should break, a pneumatic system stops automatically the relevant head and disengages the feeding cylinders. The production speed of every single position varies from 4 up to 8 m/min according to the type of yarn produced. The machine can produce yarns from NM 2 to NM 24 thickness. The whole machine is under PLC control. Yarn catch mechanisms are also under the control of PLC and programmable by the operator.

3.3 Innovations Proposed to Improve the Yarn and the Machine

To the yarn described in section 3.1 and the machine described in section 3.2, some additions are proposed, which can be regarded as innovations perhaps. These proposals are as follows:

3.3.1 Innovations on the Yarn and its Application

The yarn described in section 3.1 is a good one, which has been in continuous demand within the last half decade. So there is no intention of the writer of this work to propose any changes in the structure and manufacturing method of this yarn. One not-very-important looking proposal is the use of three form yarns instead of two. The yarn hence will be composed of four yarns, one of which will be used to make the base or carrier narrow tubular knitting. This yarn may advisably be black to enhance the colors of the form yarns. With three different colors at hand, yarns with three different colors can be made, either in slubs or in snarls. With three colors nicer patterns and color combinations can be obtained on knitted garments.

Another advantage of using three different colors is that, theoretically, any multi-color pattern or motiff can be generated with it.

According to the color definition people with normal vision needed three wavelengths to create the normal range of colors. Absorption of human eye of the three basic colors, red green and blue are shown in Figure 3.3. By mixing these colors at certain proportions, any color can be generated. Colors can be from paint pigments or from monochromatic light sources. All color printing and color photography is based on primary colors cyan, magenta and yellow. Similarly, all color TV's, computer monitors and color films stand on the basic colors red, green and blue [11].

If a yarn can have in three different colors, by definition any multi color pattern can be made on a knitted garment. The motiff or picture pattern can be first done by an artist on a plain knitting. This knitting can be undone and the dominant color on a certain length of yarn can be determined and resolved into its basic colors by a color camera system.

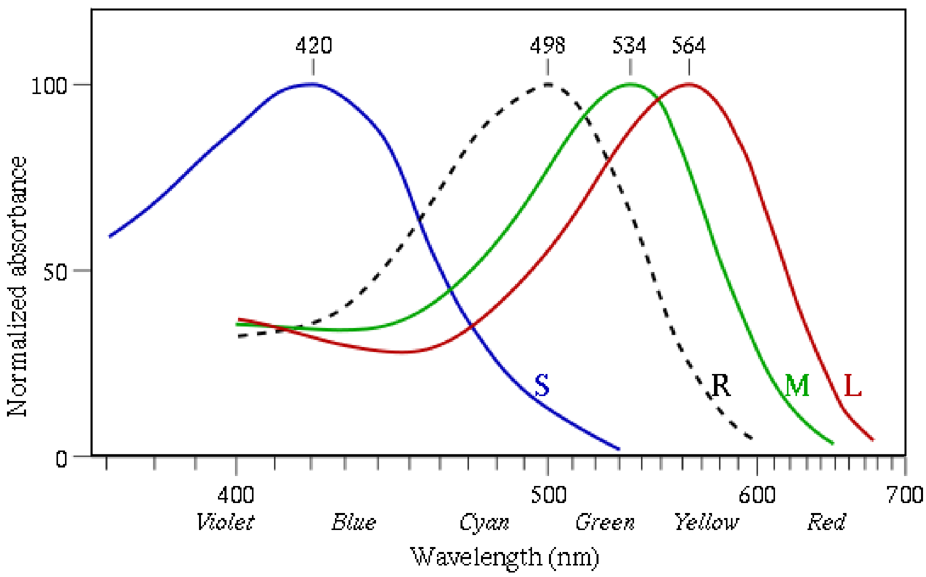


Figure 3.3: Normalised absorption spectra of human eye retina cells.

Then the yarn making machine can be programmed such that three basic color yarns can be put on the yarn in form of slubs or snarls. To generate the effect of shade and tint, the primary color yarns can be given a whitish or blackish tone while being fed to the machine. This resulting yarn, when knitted will make a with the same picture motiff on it. This is a tedious work, which requires a great deal of research and test runs. Nevertheless, a three color yarn is the key element of such an application.

3.3.2 Innovations on the Machine:

The circular knitting which comprises the carrier or base of the yarn is a simple interlooping structure as seen in Figure 3.4. The loops are made by a series of hooked needles coming up through the loops previously formed, hooks catch the yarn then needles move down, come out of the loops they were in a moment ago and then move up again to catch the next go of the yarn. The needles are placed side by side, along linear slots and slide to and fro in them by the action of a cam. The needles can be arranged in-line on a flat bed or circular around a cylindrical bed. The machine described in section 3.2 has cylindrical needle beds. In Figure 3.5, a photograph of the cylindrical needle bed with hooked needles inside is shown. The white yarn is being fed to the hooks of the needles by the thread guide. Thread guide rotates around the needle bed, delivering the yarn to the needles that have risen up, as seen in the figure. The needle bed and the needles are stationary, and the cam which moves the needles up and down and the thread guide are movable. This mechanism is quite old and well known, still in use. The tubular knitting that is to be the carrier or base of the fancy yarn must be very narrow in diameter, total number of the needles and the hoops around the knitting should be 6 or 8 or 10 perhaps at max.

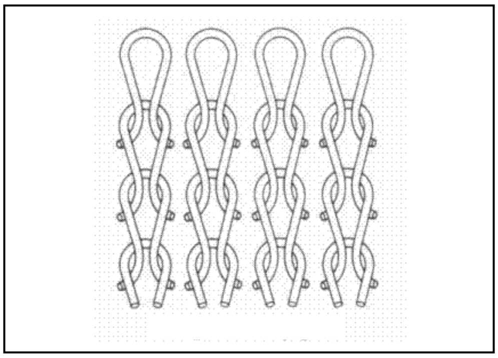


Figure 3.4: The simple interlooping matrix utilised in knitting.

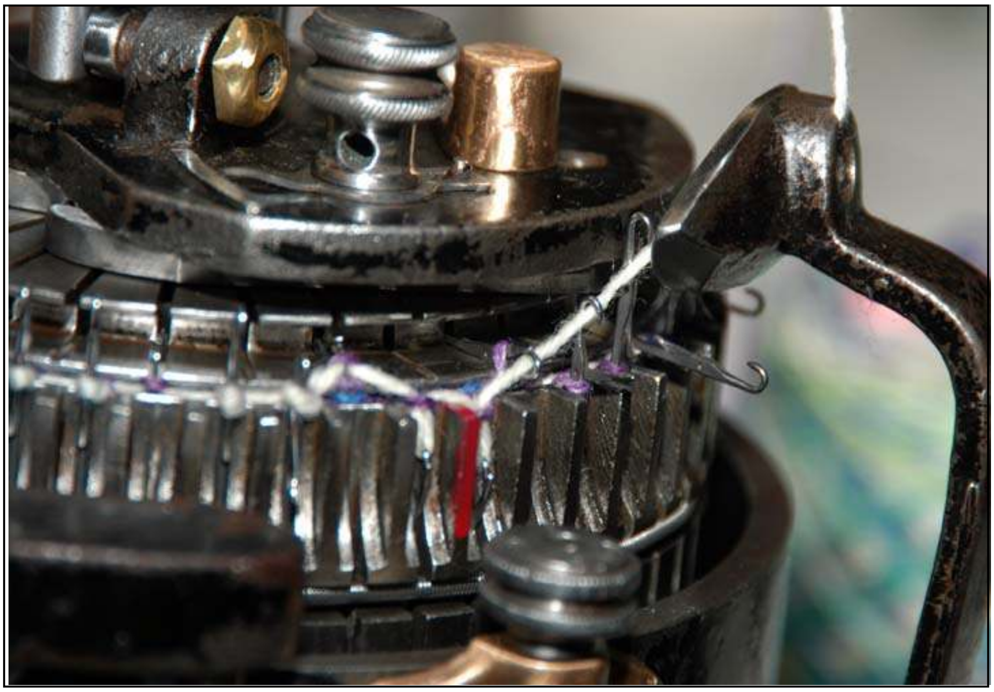


Figure 3.5: Cylindrical needle bed of a circular knitting machine. The thread guide is seen delivering the thread to the hooks of the needles.

Such a knitting is hence called a “narrow knitting”. The cam is essentially cylindrical, hollow in the middle and to the inside surface, cam profile is cut in form of a rectangular groove. The cam is centered and supported by ball bearings. The cylindrical needle bed and the needles are placed inside the hollow of the cam, extensions of the needles engaging into the grooved cam profile. With this configuration, the needle bed is smaller in diameter than the cam. The total mass of the needles and the needle bed, which are stationary, are much less than the total mass of the rotating components, the cam and the thread guide. The mass moments of inertias of the rotating parts must be similarly much less than that of the stationary components. At this point, inversion of the motion becomes a good innovation that can be put into that system. The stationary needle bed and needles will be centered and supported by ball bearings and let to rotate, the rotating cam and the thread guide will be made fixed. By inverting the motion, the operating speed of the system can be increased, and hence the yarn production rate will be greater.

Another innovation that can be added onto the machine described in section 3.2 can be the driving of knitting heads not from a main motor but by individual motors put for each head. The habit of using a single prime mover in each machine is an old habit of machine design, from the days when motors were expensive and motor control was not existent. Nowadays electric motors are quite cheap and lightweight. Alternating current motors can be easily controlled by low cost speed controllers. Master PLC's can control a limitless number of motors effectively from a single hand. The machine described in section 3.2 has a single motor to drive the knitting heads, and in the event that one of the work yarns should break, a pneumatic system stops automatically the relevant head and disengages the feeding cylinders. In a newer model version of this machine, there can be two motors for each head, one rotating the needle bed and the other feeding the yarn. So, in the event of a yarn breakage, only that particular head can be stopped electrically and not by mechanical and pneumatic means.

3.4 Characteristics of a Better Yarn Making Machine:

Under the light of the discussion in section 3.3.1 and 3.3.2, The newer version machine, which is actually the subject matter of this dissertation, will be a prototype in full size and will have the following overall characteristics:

i) There will be 36 circular knitting heads,
ii) Motion of the knitting heads will be inverted,
iii) Each head will be driven by two motors and all the motors will be under the control of a central PLC
iv) It will process 4 yarns in total, one will be for the carrier knitting and the other three for giving fancy form in three different colors.
v) It will have a motor to give a reverse twist to the yarn, whose speed will be steplessly adjustable, to give any twist to the resulting yarn.

The machine with inverted motion is expected to run much faster than the Italian design described in section 3.2. The discussion presented in this chapter and the required characteristics listed above are only preliminary. Within the oncoming sections these will be put into a more clear form and the design will commence.

CHAPTER 4

DESIGN CONSIDERATONS OF A CIRCULAR KNITTING MACHINE PRODUCING FANCY YARNS

4.1 Problem Statement

This thesis is on the design, development and prototype construction of a fancy yarn machine, which can be regarded a new generation of similar machines. Test runs will also be a part of the work too. Several reasons can be pointed out for initiating and conducting this thesis. One of them is increasing the production capacity of the existing narrow circular knitting machines. Another reason is to facilitate more number of colors in the fancy yarn produced. The basic matrix which comprises the carrier will be the same, simple looping. Method of generating snarls and slubs will also be the same. So, resulting new generation machine will be not too different from the existing machines, but will have some considerable advantages.

Different types of the fancy yarns have been in use for years in textile industry for making carpets, fabrics and interior decoration of habitable volumes. There are many types of fancy yarn production methods as summarised in Chapter 2. Yarns with varying colors is often more fashionable and hence preferable. Color variations have been done during the dying stage. Later, more sophisticated yarns, fancy not only in color, but in form have emerged. They are made of not a single yarn but several yarns, each of which can be in a different color, yet each color may have its own variation in shade and tint which can be given at the dying stage. In Chapter 3 one relatively new and popular yarn and its manufacturing method is described. It uses three yarns, one carrier and two for form, hence can be of two different form colors. Using three colors in fancy yarn production is very rare, if existant at all. Three different form colors have not been tried and applied on the yarn described in

Chapter 3, and hence the machine producing it has not the capacity of using three colors. As indicated in Chapter 3, all the colors perceptible by human eye are composed of three main colors which are yellow, cyan and magenta. Other colors are formed by mixing of these three primary colors of various intensity. In textiles, similar to color printing, any color theoretically can be obtained if use of three colors is facilitated. Therefore, adding the third colors onto the originally two color circular knitting fancy yarn machine is important. Also in this machine, production speed is increased by decreasing the total mass and mass moment of inertia of the rotating components in the knitting heads. This process reduces the magnitude of any unbalanced forces and moments, which in turn allows a smooth, vibration free, silent operation of the system. This characteristic will allow the system to be operated at higher speeds than that of the existing designs. Life of the movable components, not only the bearings and needles but of the yarn too, will be longer and constructional errors on the produced yarn will be of less frequency.

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4.2 Main Parts of the Circular Knitting Machine

In the circular knitting machine, weaving needles are arranged in a circular manner on the needle bed. Needle bed itself is a cylindrical component, and on the external surface, longitudinal slots are cut into which the needles are placed. The bed and the needles in this new design are rotating, as centered and supported by two ball bearings, about a vertical rotation axis. Needles in knitting machines are essentially moved by cams, so any needle design should have an extension which serves as the cam follower. Outside the needle bed, there is a cylindrical cam, which is fixed. On the inside surface of the cam assembly, there is the cam profile cut in form of a rectangular groove. Extensions of the needles are engaged in this cam groove and move up and down as the cylindrical bed rotates. As the needles are lifted up by the cam, their latches open and the thread guide gives the thread into the needle hook. After the needle has caught the thread it moves down into its slot, latch closing. The needle comes out of the thread loop it was in, and again moves up to form the next row of loops. The general appearance of the matrix formed is shown in Figure 3.4. The size of the machine and hence the diameter of the circular knitting depends on the diameter of the needle bed.

Figure 4.1: A Narrow Circular Knitting mechanism with five needles. The thread guide is delivering yarn into the needle hooks as it rotates about the needles.

Texture of the finished surface depends on the number of needles on the bed. The knitting that is considered here is called the 'narrow circular knitting' which should be as thin as possible. In Figure 4.1, a photograph of a narrow circular knitting machine is shown. As seen there, number of needles used is only 5. By inverting the motion, the total masses and mass moments of inertia of the rotating parts are reduced and this enabled the system to be operated at production speeds of up to 20 m/min, which is 2.5 times that of the Italian TEMAT Sy/48SB machine. This speed is regarded as a substantial success achieved in the work this thesis is about.

In the design stage first the knitting heads were designed. Once an operating prototype is obtained, doing only plain circular knitting, a machine bed is designed which will hold 36 identical knitting heads. Then yarn changing and cutting mechanisms were made and finally all the motors were connected to a master PLC for centralised control. The main stages of the design and the main components of the machine are described in the following sections.

4.2.1 The Main Body

Main body holds all of the other parts of the machine like. The functional, dimensional and strength design of the bed is done on the design software Catia. In Figure 4.2, a perspective picture of the machine frame is shown as produced by the Catia. On the machine frame some additions are shown as the creel, motors, shafts, spindles etc.

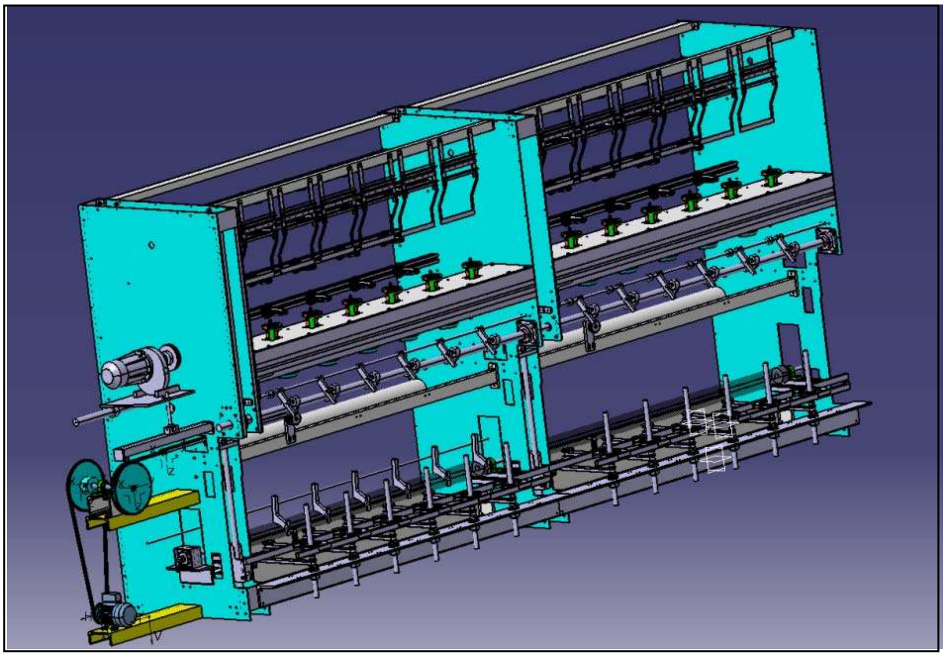


Figure 4.2: General views of machine and other parts assembled on it. Drawing is done by Catia.

The isometric drawings of the components of the machine frame with all the dimensions and tolerances are given in the Appendix. The machine frame is composed of sheet steel sections, precision machined by laser cutting, kept together by some U beams, equal arm angles and tension rods. Technical drawings of two opposing sheet steel plates are given with dimensions in Appendix A.35. The U beams used for bulk load carrying are given with dimensions on the technical drawings of Appendix A.11, 13, 14, 18, 36, 43, 55 and 56. A support beam which is loaded in different directions is made of pipe, as given in Appendix A.17, another support beam connecting the sheet metal parts together is made of box profile sectioned beam as given in Appendix A.16 and another support beam made of equal arm angle profile beams, as shown in Appendix A.43. The appendix contains 76 such drawings, some for components and some for assembly, all drawn on Catia and are presented with Catia format.

4.2.2 The Knitting Head

The Knitting Head consists of a hollow cylindrical cam assembly, inside of which the cylindrical needle bed is placed. The cam is fixed and the needle bed is rotating inside two ball bearings, which are in turn assembled into the bearing pockets made in the cam assembly. Figure 4.3 shows a perspective exploited picture of the knitting head assembly, different components in different color. Picture is drawn by Catia. The needle bed is at the center-most position, in white. The dimensions of this component are given in the technical drawing at Appendix A.34. The longitudinal lines on its outer surface represent the slots in which the needles are placed. The cam assembly is outside the needle bed and is shown in orange. The cam must have a partitioned structure to enable assembly. Cam surfaces are made in form of shells which are assembled into the component shown at Appendix A.39. There are two ball bearings between the cam assembly and the needle bed, shown in red. Grooves into which bearings go can be seen in the drawing given at Appendix A.39. The green component is the connection part which connects the knitting head to the machine frame. The dimensions of this component are given in the technical drawing at Appendix A.38. The needle head is rotated by elastic flat belts. The component in blue is the pulley assembly which is connected to the needle assembly and fixed onto it by a set screw. The dimensions of this component are given in the technical drawing at Appendix A.42. Drawing at Appendix A.40 is the assembly drawing of the knitting head in perspective, drawn on Catia. This new design has reduced the mass and mass moment of inertia of the rotating parts considerably, which then enabled the knitting head to be run at 2.5 times greater speed than that of the Italian design Sy/48SB machine.

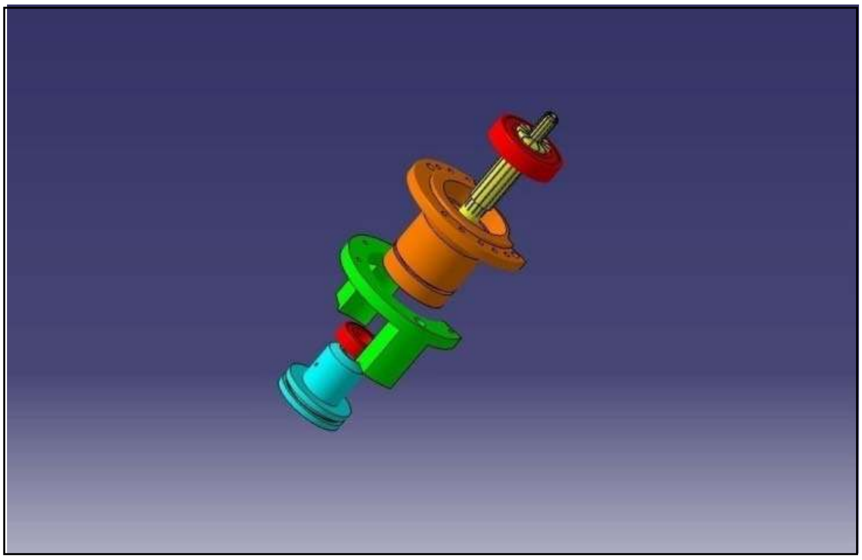


Figure 4.3: A schematic, exploited view of the knitting head.
In this new and novel design, motion is inverted.

4.2.3 Switching of the Form Yarns

In this machine, four different color yarns are coming from the creel, as one is for the base or carrier and the other three form yarns. In conventional circular knitting, a yarn guide holds the base yarn and rotates around the needles and delivery the yarn into the hooks of the needles. In this design, the motion is inverted and there is no need for a rotating thread guide. If a thread is fed to the center of the circular knitting it simply continues its movement along the circular knitting, untouched. For the needles to catch a thread, that particular thread must be moved radially, from the center where it originally was to the rim, where needles are found. So, to deliver a certain yarn to the needles, only a simple sliding motion is required. This simple sliding motion is obtained by translating thread guides, actuated by pneumatic pressure. The guides are fitted to the tip of small pneumatic cylinders. They have a small hole at their tips through which the thread coming from the creel passes. The system has an attachment which plucks a certain thread out of the knitting and converts it into a gimp or a snarl. The sliding thread guides also deliver the thread to be plucked out to the operating mechanism. The sliding thread guides are called as "pistons" in this text. There are three of them, one for each form yarn. The thread for the base knitting is not switched in making the fancy yarn. The positions of the pistons with respect to the knitting head is shown in Figure 4.4. The machine is equipped with a low power pneumatic system. Pressurised air is connected to the pistons via electric controlled plunger valves. Operations of the pistons are pneumatic in action and retracted by a compression spring when pressure is lost.

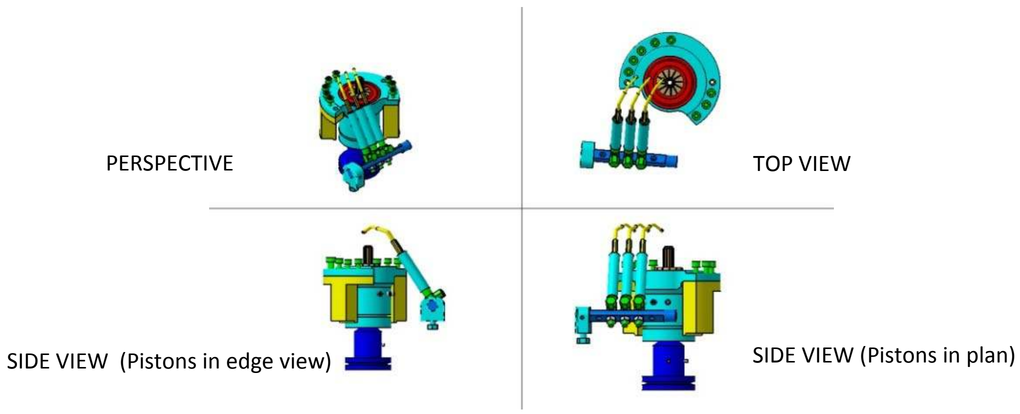


Figure 4.4: Different views of the circular knitting head and the thread switching guides. This picture is prepared on Catia.

The pneumatic valves are under the control of the central PLC. PLC keeps the real time. The duration at which a certain yarn is in form is controlled by the PLC on basis of real time, adjustable by the operator.

Technical drawings with dimensions and tolerances of the components comprising the linear thread guides are given in Appendix A73-77. In A.75, the pneumatic cylinder is shown. A.76 shows the so called “piston” or the guide which is protruding out of the pneumatic cylinder, holding the thread at one end is shown. The end cover of the cylinder is shown in A.74. With A.73, two drawings are given. In Part-1, a bracket is shown which is to hold a cylinder inside its circular hole. Three such brackets holding three cylinders are assembled on to the track given in Part-2 of A.73. In A.77, a perspective assembly drawing for the battery of thread guides is shown. All the drawings are done on Catia, and presented in Catia format.

4.2.4 The Needles

The needles are the most important parts of any knitting machine and are standardised. There are companies specialised in producing them. They are made of hard stainless steel, tough and resistant to wear. The type of needle to use depends on the matrix to be knitted, and to its texture. To do fine knitting, thinner models of the same needle are available. The needles used in the machine designed here is the type with a latch, as seen in Figure 4.5. The needles are entrapped in tiny rectangular slots cut around the cylindrical needle bed. The tolerances are close and needles can do only a smooth sliding motion inside their beds without any slackness. As seen in Figure 4.5, each needle has an extension which acts as a cam follower. The extension can be on the front or back of the needle. The needles are translated along their guides by the action of a cam. Cam pairs are essentially form closed, such that the motions of the needles are in complete control of the cam, even at high speeds. As seen in Figure 4.5, the tip of the needle is in form of a hook. This hook catches the yarn when fed. The latch simply closes the hook and prevents the yarn to escape from the hook. N. Ambumani defines a latched hook needle in his book [12] published in 2007 as:

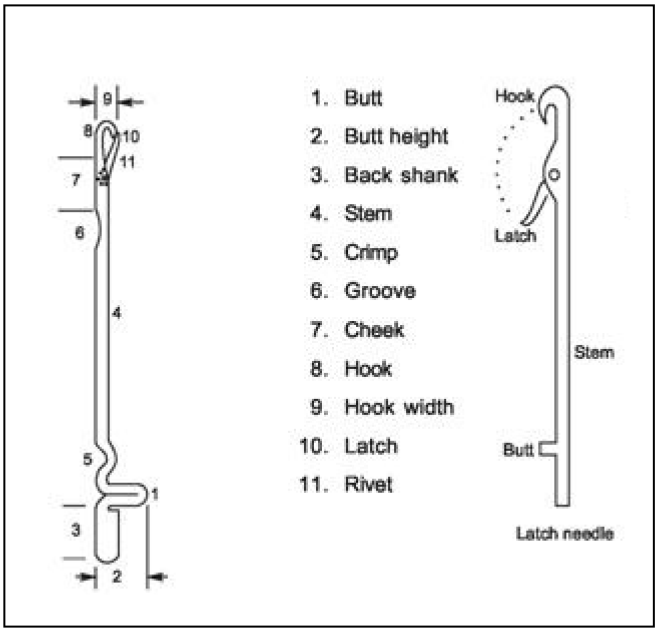


Figure 4.5: The Latch Needle [12]

It consists of a hook portion at the top and a latch riveted at certain distance from the needle head. Latch needles are given sliding movements in individual grooves called tricks of the cylinder. The latch swing freely and the stem is a straight portion with a protruding butt. Through the butt the reciprocating movement to the needles is given. The latch needles are self-acting, and requires only previous loop on the stem and do not require any outside agency to close the hook. The swinging latch has a cup at its end and is riveted to the stem. Therefore, the total thickness of the needle cannot be reduced.

4.2.4.1 Knitting or matrix formation by a latch needle

While producing circular knitting yarn, the independently moveable latch needles are arranged in axial position on the needle bed. While knitting yarns, the positions that a latch needle takes, in reference to the cam surface, are shown in Figure 4.6. This figure is taken from the book entitled ‘Circular Knitting’[10].

1. <u>Unused position</u>: Needle is in rest position in its bed, not sliding. The latch is closed. No yarn is in the hook. It does not take part in the operation at this position.

2. Catching Position: Needle moves out of its bed as cam surface pushes its butt. The latch is freed as it comes out of its bed. Latch falls down under the effect of gravity, open. The needle is now ready to catch the yarn.

3. Knitting Position: The previous loop is now on the needle stem, behind the needle latch. The latch must be open at this stage. A small brush connected to the yarn feeder may be adopted to help the opening of the latch.

4. Yarn Taking Position: New yarn is fed into the hook by the thread guide. Normally the needles are fixed and thread guide is moving but in the design presented here motion is inverted and needles are rotating. So at this stage, the empty needle moves against the non-moving thread and catches it in its hook. Needle starts to move down, latch closes by the restrictors on the bed.

5. "Knock-Over Position: The new yarn can now be drawn through the old loop. This process is over when the needle is at the lowest position of the drawn cam. If the knock-over point is shifted by altering the position of the draw-down cam vertically, the stitch length is changed [10]."

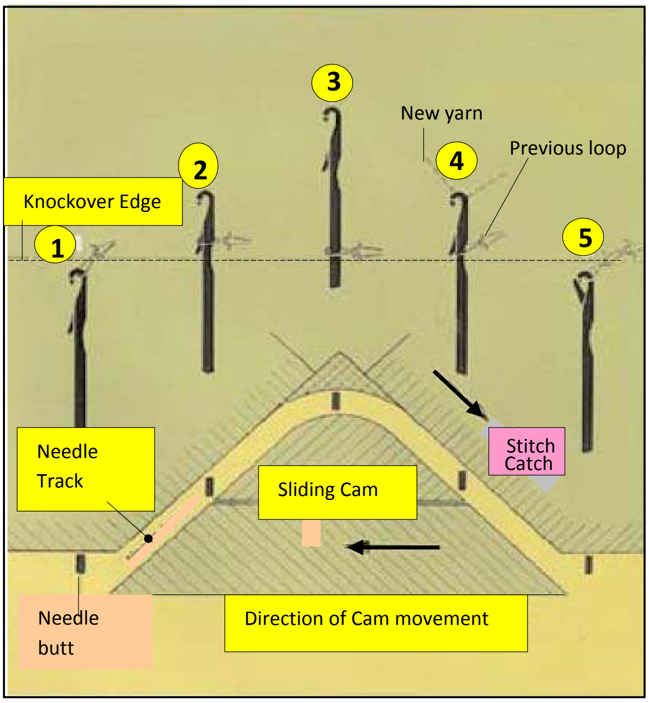


Figure 4.6: Loop formation of the needle in the cam [10]

4.2.5 The Cam

Cam of the knitting heads designed here are cylindrical cams, cam surface is in form of a rectangular groove. The groove width is equal to the height of the butt, hence butt moves inside the groove in form closing, snugly, without any slackness. To be able to insert the butts of the needles into the cam groove, the cam must be of two pieces. To keep the cam pieces together, they are fixed inside a cylindrical component. Generally hardened steels are used for making cams as there is a great deal of friction between the cam surface and needle butts. Needle movement follows the cam surface, hence dynamics of the needle is dependent on the cam profile. Because the masses of needles are small, the cam profile is seldom important. A Cycloidal or Versine Rise-Return-Dwell is presumably the best profile dynamically but most textile manufacturers put straight line portions for rise and return. Conjunction of the straight lines is often a circular arc. The importance of cam dynamics is stressed by the authors of the Circular Knitting Technology [10] as:

On modern high-speed machines it must be ensured that the needle is positively guided in the needle trick in all phases of its movement: it must be accelerated and retarded without jerks. Needle vibrations in the needle trick and impact waves, created by the impact of the needle butts on cam parts, must be avoided or at least strongly dampened. In this connection the optimal shape of the needle trick is as important as the need for a technical tuning of the needle vibration, especially in the transition from the needle butt to the needle stem and in the shapes of the needle stem and the needle head.

In Figure 4.8, a schematic exploited view of the knitting head designed here is shown. The cam is of two pieces, and shown in pink. The butts of the needles are shown inside the cam groove in blue. The innermost component is the needle bed. The needle bed is centered and supported in two ball bearings as shown. At the down end of the bed, there is the drive pulley, which is not shown here. The picture is drawn on Catia.

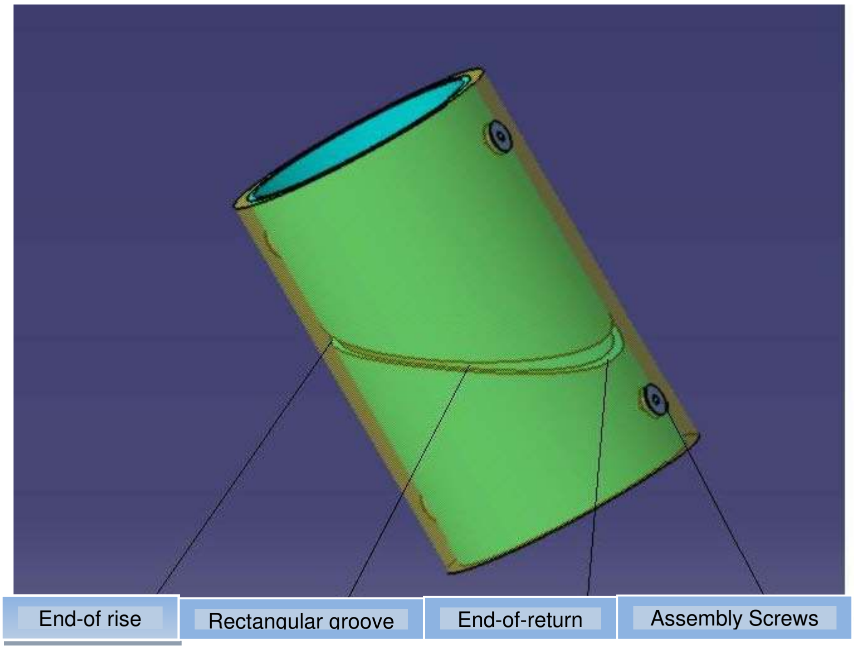


Figure 4.7: Schematic Picture showing the crossection of the cylindrical cam which drives the needles. To enable assembly, it is made in two parts, upper and lower portions are fixed to a cylindrical bushing by bolts.

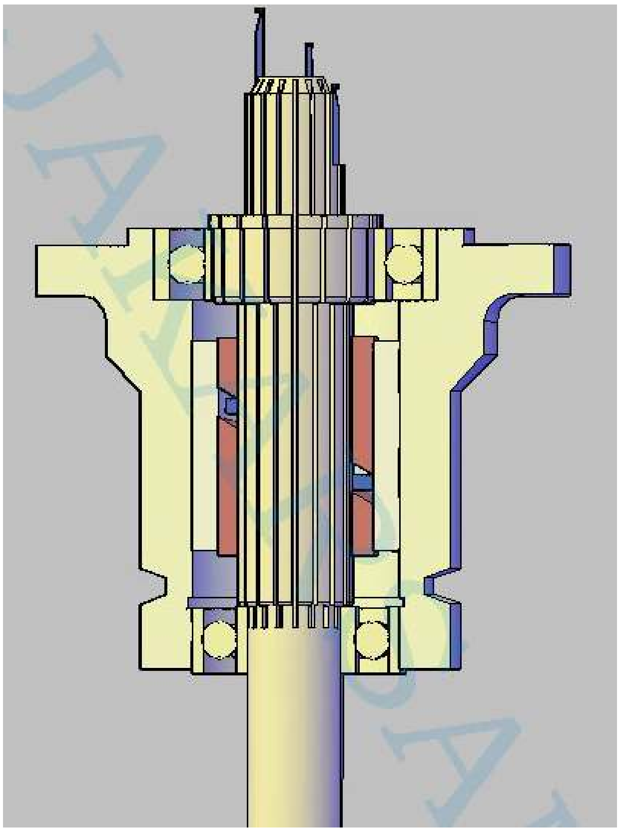


Figure 4.8 : A schematic exploited view of the knitting head. The cam driving the needles is shown in pink. Inside the cam grove the butts of the needles are seen in blue. This picture is prepared by using Catia.

4.2.6 The Thread-Break Detector

The threads used in making the fancy yarn come from the creel. Four threads come to each knitting head. In case of a yarn breakage, the head to which the broken yarn is going should be stopped and the broken thread should be knotted. Otherwise the resulting yarn will be defective. In contrast to the Italian design Sy/48SB, the machine designed here has two motors for each knitting head. One motor drives the knitting head while the other drives the spindle carrying the finished yarn bobbin. In case of a thread breakage, the motors belonging to that particular head must be stopped. Stopping mechanism is very simple, and is composed of an on/off switch, as shown in Figure 4.9. The package seen contains a miniature toggle switch inside, which is actuated by a spring loaded centilever arm. There are four such break detector switches for each knitting head, connected in series, hence forming a four-input OR Gate. The threads under tension leans on the cantilever arms and keep them switched on. A voltage passing through four switches is sensed by the central PLC and whenever voltage is cut off, stops the motors of that head. The switches are connected to a rail by the clipses behind.

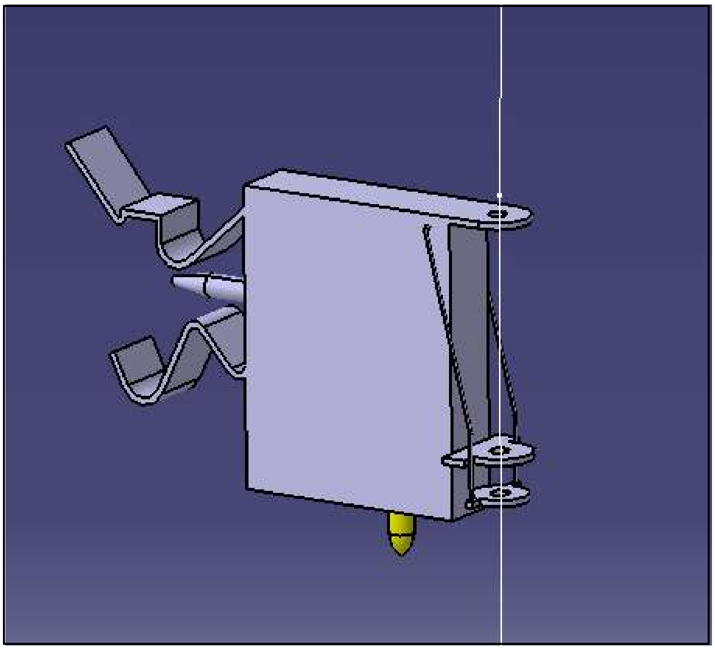


Figure 4.9 Thread-Break detector switches. There are four of them for each Knitting head, connected in series, hence forming a four-input OR Gate.

4.2.7 The Thread Tensioners

The threads coming to the knitting head should be tight not to make loops and knots. The tension is provided by a pair of spring loaded washers, one side convex. The convex sides are facing each other and are forced to each other by a compression spring, as shown in Figure 4.10. The thread is positively held such that it can not escape from the tensioner. The spring is given a certain compression by a thumb tightened nut. In the machine designed here, the assembly of thread tensioners and thread-break detectors are assembled on an aluminum alloy profile beam, whose dimensions are given in Appendix A.27. Assembly brackets used there are given in Appendix A59, 60, 61, 62, 63, 64 and A.65. In such spring loaded tensioners the tension given to each thread varies by the number of the threads that go through the tensioner, thickness of the threads, production speed of the knitted yarn, and the yarn type. Tensile force acts to extend the thread, but this extension is changeable with the material of the fiber. “Under similar conditions more extensible fibers like wool or acrylics react, in comparison with other fibers like cotton, more sensitively; the same holds true also for extensible textured yarns [10].”

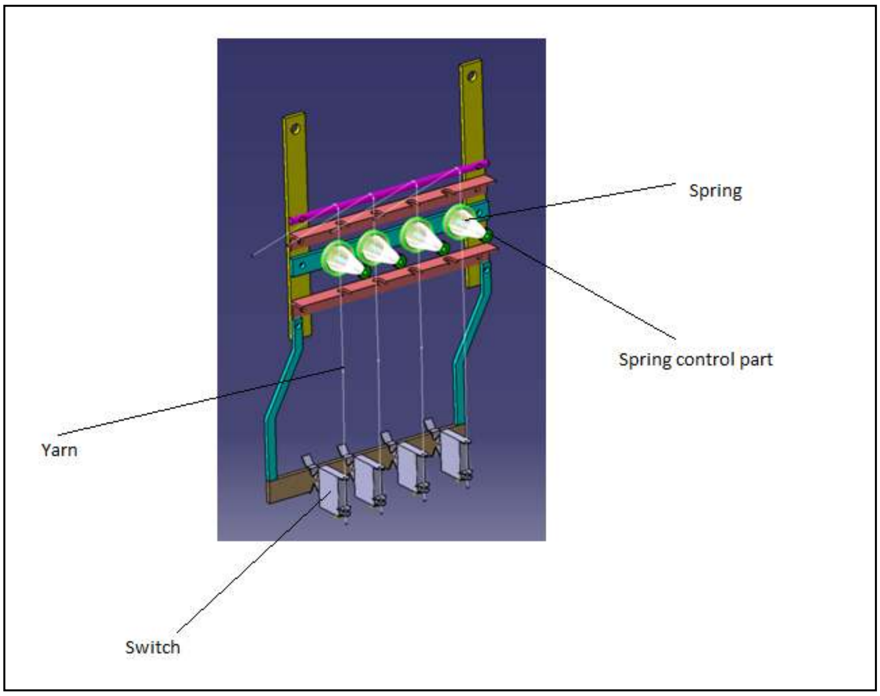


Figure 4.10: Spring loaded tensioning devices and thread-break detector switches shown together. This picture is prepared on Catia.

Production speed of the yarn affects the friction between the finished yarn and the package surface. “Package” is the bobbin winding the finished yarn. This friction also affects applied tensile forces to the yarn indirectly [10]. Friction between package surface and yarn can be reduced while increased pulling force of the yarn, but this operation causes a balloon between yarn and bobbin. Friction between yarn and package surface also depends on whether the package surface is cylindrical or conical [10]. The yarn moves faster from the package surface if the angle of inclination of the conical surface of the bobbin is increased. Conical bobbins are preferred at higher speed operations [10].

4.2.8 The Motors

Motor power drives the transmission shaft, spindles and the knitting head in the circular knitting machine designed here. Power of motor used depends on the physical power required from the motor. As calculation of many force components are difficult to calculate or estimate accurately, motors are often selected more powerful than required. This does not effect the service cost of the machine as electric motors drive power from the mains proportional to the external load. In industrial systems, most commonly used motors are of AC type, because of simplicity in selection and low initial cost. Yet, they can be directly coupled to the mains. There are two types of AC inductance motors, as single-phase and three phase. AC motor basically consists of two electrical parts in interaction with each other. One of them is stationary and called as “stator” and the other rotating and is called the “rotor”. Rotor is centered and supported by bearings, and rotate inside the stator. Motion of the rotor is generated by the electromagnetic forces of interaction between the stator and the rotor. Virtually all electrical motors use magnetic field forces to spin their rotors. A three-phase AC induction motor is the only type where the rotating magnetic field is created naturally in the stator because of the nature of the supply. DC motors depend either on mechanical or electronic commutation to create rotating magnetic fields. A single-phase AC induction motor requires extra electrical components to produce this rotating magnetic field. Two sets of electromagnets are formed inside any motor. In an AC induction motor, one set of electromagnets is comprise the stator and the AC supply is directly connected to the stator windings. The alternating nature of the supply voltage induces an Electro

Motive Force abbreviated as EMF in the rotor just like the voltage induced in the secondary coil of a transformer, as per Lenz's Law, thus generating another set of electromagnets at the rotor. The name "induction motor" comes from this induced EMF in the rotor windings. Interaction between the magnetic field of these electromagnets generates a shaft torque and motor rotates in direction of the generated torque [13].

4.2.8.1 Single-phase motor

The main reason why the single-phase motor is the most widely used type is because it has low initial cost and maintained cheaply. This type of AC motor takes its name from having only one type of stator winding. Single-phase motor does not start to rotate after being connected to the mains, if it does not have an auxiliary winding which is used for initiating the rotation. If the auxiliary winding is not put into effect, in a single-phase motor, generated electromagnetic forces will not rotate the rotor but will only vibrate it. Auxiliary winding is a start winding device that consists of a switch and a series capacitor. The current in the starting winding leads the current in the running winding, causing a rotating field. When the rotor reaches the design speed, which is about %75 of the rated a centrifugal switch stops the starting winding activity. This type of motor control system is called the "split-phase AC induction motor", which is schematically shown in Figure 4.11. Split-phase motors are suitable for low starting torque, low power applications. Another type of split-phase motor also exist, which has a capacitor in parallel to the centrifugal switch and the start winding. This kind of motors is called the "capacitor start AC induction motor" and has a greater starting torque [13].

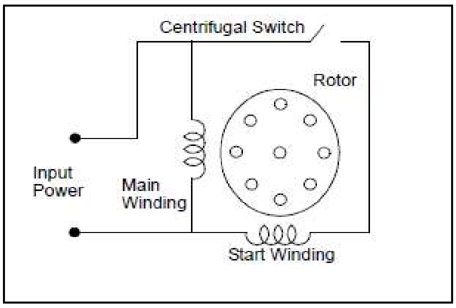


Figure 4.11: A Split-Phase AC induction motor [13]

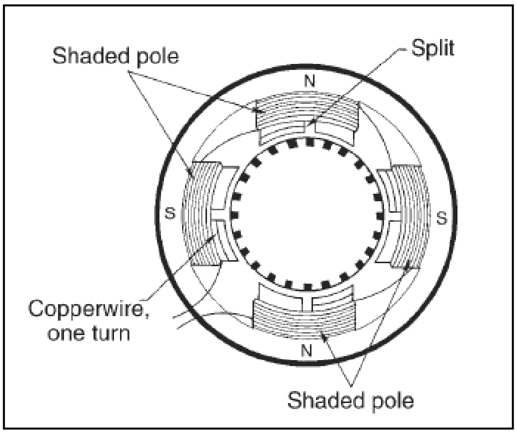


Figure 4.12: The Shaded-pole AC induction motor [13]

A third type of single-phase AC induction motor exists, which is called the "shaded-pole AC induction motor". As shown schematically in Figure 4.12, shaded-pole motors have only one main winding and no start winding. "Starting is by means of a design that rings a continuous copper loop around a small portion of each of the motor poles. This "shades" that portion of the pole, causing the magnetic field in the shaded area to lag behind the field in the unshaded area [13]." The reaction of the two fields gets the shaft rotating. Because the shaded-pole motor lacks a start winding, starting switch or capacitor, it is electrically simple and inexpensive. Also, the speed can be controlled merely by varying the voltage, or through a multi-tap winding. Mechanically, the shaded-pole motor construction allows high-volume production. In fact, these are usually considered as "disposable" motors, meaning they are much cheaper to replace than to repair. The shaded-pole motor has many positive features but it also has several disadvantages. It has a low starting torque. It has a high slip and its running speed is always 7% to 10% below the synchronous design speed and in general, its efficiency is less than 20% [13].

4.2.8.2 Three-phase AC induction motor

There are two types of three-phase induction motor as the "squirrel cage" and the "wound rotor" motors. These types of motors are widely used in industry. The main difference between the single and three-phase motors is that the three-phase is self starting and does not need starting gear. The power produced and efficiency of this type are higher than the single-phase [13].

The machine designed here has 2 motors for each knitting head. There are 36 knitting heads which are driven by a total of 72 motors. The ones driving the knitting heads are 0.18 KW, 1500 rpm asynchronous motors of brand name DEC. DEC is a Chinese company located at Fuan city of Fujian province. The commercial typification of the motor is Y2-632-4, a 4 pole, Aluminum casing, squirrel cage induction motor. Actual no load speed is 1330 rpm, supply voltage 380 V at 50 Hertz. The motors used to drive the winding spindles are 0.25 KW, 1500 rpm asynchronous motors of the same brand, with commercial typification Y2-711-4, also a 4 pole, Aluminum casing, squirrel cage induction motor, whose actual no load speed is 1360 rpm. All these motors have their own speed control invertors. Speed controllers are Telemecanique, Altivar-12model, with commercial typification ATV12H037M2, an alternating current motor control invertor suitable for loads up to 0.37 KW. The data sheet for this invertor is given in Appendix B.1.

The machine has two more electric motors, which are larger than the ones mentioned above. These are both manufactured in Turkey by the Bizcanlı Redüktör, situated in Konya, Both 0.37 KW 1500 rpm, three phase motors. Worm gear type gear boxes are attached to them. One of them drives the shaft which pulls the finished yarn from the knitting heads and its output speed is 150 rpm. Other drives the assembly frame which contains the yarn guides, and its output speed is 3 rpm. Both motors are driven by telemecanique Altivar-31 speed controller, which can support loads up to 0.75 KW, with commercial typification ATV31H075N4. It inputs and outputs 380 V 50 Hz, three phase alternating current. Data sheets of this invertor are given in App. B.2.

The machine designed here has an AC servo motor and a servo motor drive to guide the thread on cylindrical bobbins. The motor is a 0.9 KW AC servo manufactured by the Korean company Mecapion. The commercial typification of the motor is APM-HB09 A. This motor is driven by the AC servo controller APD-VS05N-P1 of the same company. A datasheet about the motor and servo drive is given in App. B.3.

4.2.9 The Creels

Creels are used for holding cones of the threads used to make the fancy yarn and feed them to the knitting heads. Maximum number of threads that can be used by each knitting head is four, hence four places to place thread cones are made for each knitting head. One of these threads is used to make the knitted carrier and the other three are for the fancifying form. For form one or two threads or yarns can be used. No fancy yarns can be used such that the resulting yarn becomes a single color narrow tubular knitting. To manipulate the form yarns, there are three guiding pistons. Number of the piston used in a particular batch depends on the number of yarns used. All the pistons may be active or two or one or none. In Figure 4.13, a schematic view of the creel rack of the machine designed is shown, picture orepared on Catia. Creels are passive devices, composed of merely fixed centilever beams of solid mild steel, in circular crossection. To each beam, a cone holder is placed. Cone holders are standard equipment which can be found in any textiles materials supplier. A schematic view of a cone holder is shown in Appendix A. 28.

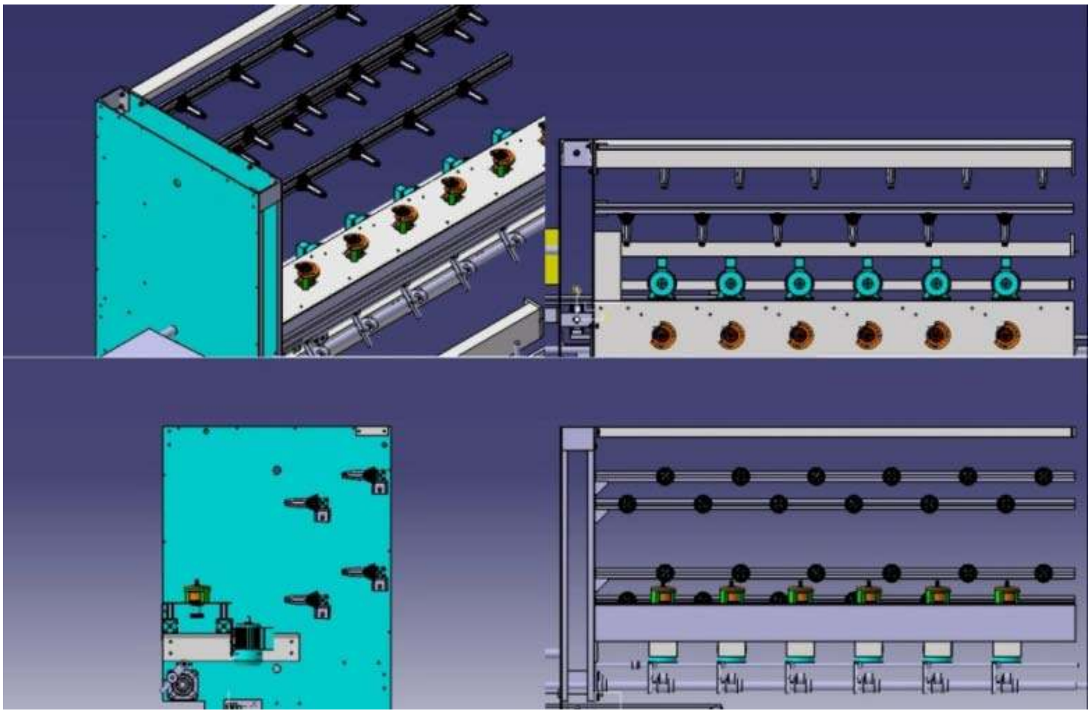


Figure 4.13: Creels of the fancy yarn machine. Picture is drawn on Catia.

4.2.9.1 The balooning problem of the advancing thread

The creel looks like a very simple part of any textile machine, which actually is, but the balooning problem of the advancing thread must be kept in mind while designing a creel. When a thread or yarn translates and rotates at the same time, it starts to oscillate in an envelope which looks like a baloon. If the yarn is dead flat, it will not display balooning, but a thread line always has a horizontal portion where it sags under the effect of gravity. This always initiates a balooning. So normally the lengths of horizontal yarn runs must be kept as short as possible. Secondly, if the axes of the free yarn run are in different directions at two ends, this will initiate or support a balooning. In Figure 4.14, the relative positions of the thread cones and the knitting heads are shown. As seen they are perpendicular, hence there is a great tendency of balooning. To prevent balooning, first a support is put in between and the thread run is separated into two parts, one vertical, less liable to baloon and one horizontal. The support point is where tension is given.

Another problem which is faced in the creel design of the machine is to find enough volumes for the total number of yarn or thread cones. There must be 4 cones for each knitting head. The cones could not be placed all in one line and so four lines of cones were made. If the directions of the cones were made as shown in Figure 4.15, the axes of the yarns and the cones would be different and this would support balooning.

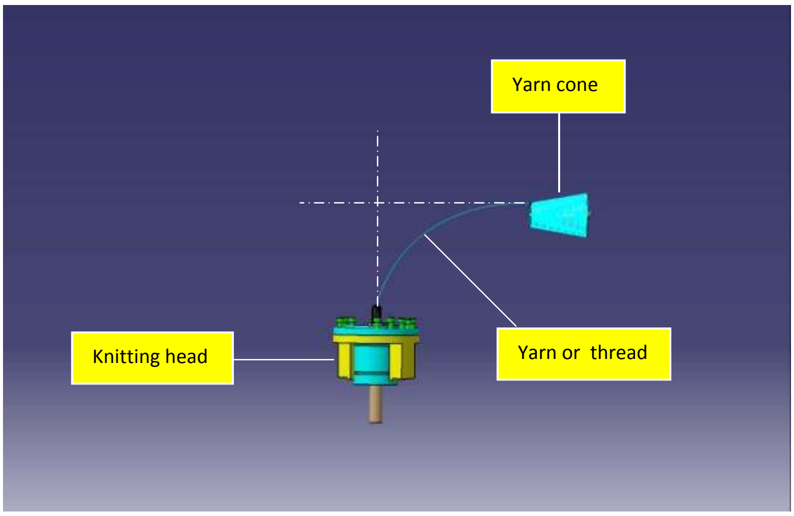


Figure 4.14: The balooning problem: when a thread translates and rotates at the same time, it starts to oscillate in an envelope looking like a baloon.

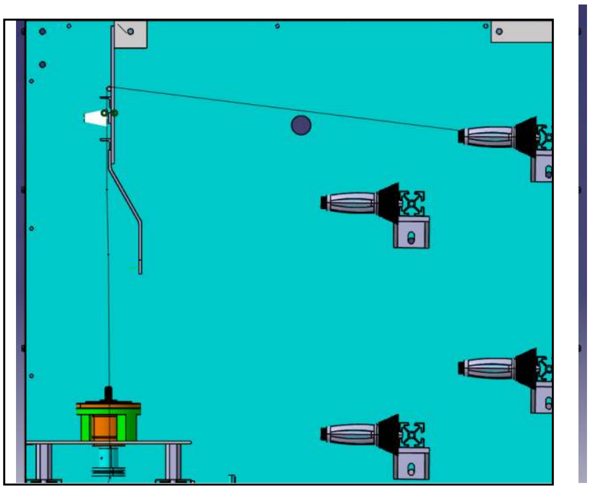


Figure 4.15: Relative positions of the four cones with respect to the tensionning device and the knitting head in the designed machine.

So, the final shape and appearance of the creel was made as shown in Figure 4.16, which has not generated any substantial balooning problem.

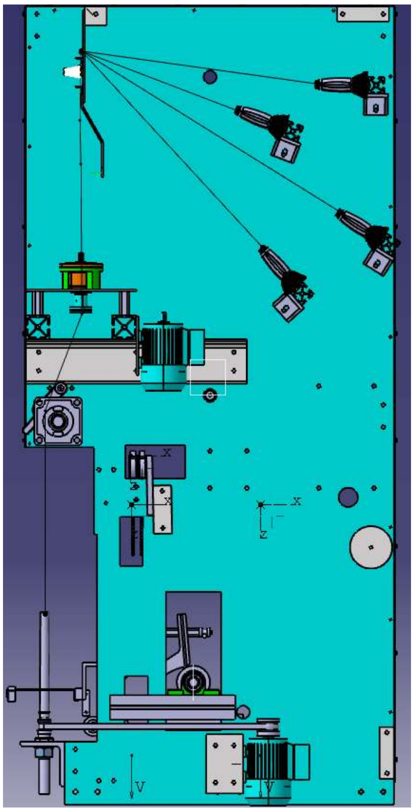


Figure 4.16: The relative positions of the thread or yarn cones at the creel and their angular orientation for the machine designed. The patch in sky blue is the side plates of the machine frame. As seen, creels with all the cones are enclosed within the volume occupied by the machine. Drawing is done by Catia.

4.2.10 The Yarn Advancing System:

The finished yarn at the knitting head must be advanced at a constant speed, which then will be wound around cones or cylindrical bobbins. Yarn advancing is done by the friction force generated by a rotating plastic roller and an idler metallic roller, leaning against each other by spring forces, and the finished yarn in between. The motorised shaft is a 40 mm diameter solid shaft, made of construction steel, with 50 kg/mm^2 ultimate tensile stress. It is a long shaft, going along the whole length of the machine, dimensions and details shown in Appendix A.8. The shaft is put into journal bearings at two ends. Journal bearings are of flange type and are bolted to the transverse sheet metal plates at the two ends of the machine frame. Details of these bearings are given in the drawing of Appendix A.29. The friction rollers that are put on this shaft are shown in Appendix A.9. This shaft is driven by the 0.75 KW motor and gearbox assembly described in section 4.2.8, with output speed 150 rpm. Not to increase the length of the machine or the width of the box containing the drives rather, the motor is not connected to the shaft directly by using a coupling. Instead, a multi groove flat belt pulley is mounted on the shaft via a setscrew. The motor motor-gearbox assembly has its own pulley mounted to the output shaft. A belt stretched between the two transmit the torque and motion from the motor to the shaft. The details of the multi groove flat belt pulleys are given in Appendix A.52. At the bottom of the machine, after the thread advancing mechanism, are located the winding systems. There are two winding systems. One winds the finished yarn on cones or bobbins placed on vertical spindles and the other on cylindrical bobbins rotating about a horizontal axis. This horizontal bobbin set takes its drive from the same motor. To power it, a sprocket is connected to its shaft. Another sprocket is connected to the 40 mm shaft just after the flat belt pulley. An idler compound sprocket is put in between. A chain is stretched between one part of the compound idler and the winder and another chain is stretched between the second part of the compound and the sprocket connected to the 40 mm shaft. The sprocket fixed to the 40 mm shaft is seen in detail in the drawing given in Appendix A.4. The idler compound sprocket is shown in Appendix A.2 and the centilever shaft carrying the idler sprocket is shown in Appendix A.3. The location of the 150 rpm motor powering these two shafts must be adjustable to stretch the flat belt. The motor is mounted on a 10 mm thick sheet metal. This plate is in turn connected to the main machine frame by a revolute joint. The base plate of the motor which can swivel about this revolute joint is fixed by a longish tensionning bolt. The details of the base plate for the motor are seen in Appendix A.53. The pin of the connection between the base plate and the machine frame is shown in Appendix A.51 and the tensionning bolt is shown in Appendix A.50. The chain connection between the 40 mm diameter main shaft and the idler compound sprocket is shown in the assembly drawing in Appendix A.5.

The opposing shaft which carries the spring loaded rollers is a 16 mm diameter solid steel shaft, this shaft does neither rotate, nor centered in bearings. It is a fixed component that goes through the whole length, in parallel to the 40 mm diameter yarn advancing shaft. There are threaded holes at each end and is assembled on the sheet metal plates at two ends of the machine by bolts. Details of this shaft can be seen in Appendix A.7. The compression rollers are idle and rotate in the bearings of a spring loaded rocker arm. Details of the rocker arm and the idle rollers are seen in Appendix A.19 and A.20. The shaft of the roller, in form of a peg goes into the hole at the middle of the rocker and fixed by a setscrew. The 16 mm diameter shaft goes through the hole at one end of the rocker arm. The other end of the rocker arm is simply a handle, which is used to lift the arm up when required, manually. To strengthen the sheet metal plates at the point where this shaft is connected, some supporting components are made and used, details shown in Appendix A.6.

4.2.11 The Yarn Winding System and Package Shape

The finished yarn is drawn from the knitting heads by the friction advancing system described in section 4.2.10, as explained above. This yarn then should be wound in a package. The resulting yarn may be required to have a twist, clockwise or counterclockwise or no twist. To be able to wind the yarn without any twist, a system is provided to rotate the cylindrical bobbins about a horizontal axis. The shaft is hollow, to reduce its weight and made of 85 mm pipe, as shown in Appendix A.24. At the two ends of this pipe two cover lids are placed, whose details are given in Appendix A.25. This shaft is powered by the motor driving the yarn advancing system and is driven by a chain between this shaft and the main shaft of the yarn advancing device, as explained in section 4.2.10 above. If a certain twist is required, the finished yarn is wound about bobbins placed on spindles rotating about a vertical axis. The spindles are standard components which can be purchased from any supplier of textile equipment. Spindles used in the machine designed here are also purchased from an external company. The details of the spindle are seen in the drawing given in Appendix A.31. This spindle has a shaft which is tapered for easy and fast assembly, without any clearance. The spindles are inserted into tapered holes on the machine frame. One machine unit contains 6 knitting heads and 6 spindles hence. A horizontal beam is made alongside of the machine frame of 120 mm by 120 mm equal arm angle. As seen in the details given in Appendix A.30, this beam has 6 sets of holes for fixing 6 spindles. A connection component with a tapered hole inside is designed and made one for each spindle and assembled on the beam. Details of this component are seen in Appendix A.33. Each spindle has its own motor, speed controlled as explained in section 4.2.8. Power transmission from the motors to the spindles is via flexible flat belt. The spindles have pulleys for the belt to engage. Pulley surface is a slightly barelling to center the belt. A similarly barelling pulleys are required to fix to the shaft of the motors driving the spindles. Details of this pulley are shown in Appendix A.32.

4.2.11.1 Yarn package shape

Yarn package is most often a pile of winding on a conical or cylindrical bobbin. The "Yarn package shape" is the profile of the finished bobbin. Package shape is important. If it is made cylindrical, the pile may collapse after a certain diameter. It can be made conical from one or two ends, but this time amount of yarn in a single bobbin will be reduced. This in turn, will be costly and also the bobbin changing frequency will increase. The actual shape and size of the package hence must be user definable.

In any spinning, folding or coning machine, which involves yarn or thread winding, the bobbin rotates with a constant speed and the yarn is guided along the axis of rotation in a to-and-fro manner. Translation of the guide can be by a cam, by a nut-and-screw mechanism or by direct motor action. If the thread guide moves fast, the thickness of each added yarn layer will be thin and if thread guide moves slow, the thickness of the added yarn layer will be thick. The lead of the guide, that is, its advance per revolution of the bobbin should not be less than the average yarn diameter. Otherwise next loop of yarn will try to climb over the previous loop. This may cause the collapse of the pile and even if not, individual yarn loops will be in interference fit in its place. This will not only deform the yarn but also will generate excessive friction force and unwinding of the yarn will be difficult. Often the translation speed of the thread guide is constant in steady operation. At the far end, there will be a deceleration and then an acceleration period in reverse direction will occur. A sinusoidal deceleration and acceleration generates a good reversing action. To make a conical shape, the bobbin on which yarn is wound is made conical itself. If a conical profile is required on a cylindrical bobbin, the stroke of the thread guide must be reduced gradually, from either or both ends. Solution towards obtaining stable packages can even lead to patent grantings. For example in [14], a 1975 American patent is explained on making steps on paper or plastic cones, thus replacing the tapered surface by a series of cylindrical steps.

The package shape control in the machine designed here is achieved by controlling the length of each stroke of the thread guide. The thread guide of the vertical spindles is in form of a ring. A ceramic bit fixed to the ring, called the “hook” incorporates the thread inside of it. The machine designed here has 36 knitting heads, in 6 identical machine units, hence each machine unit has 6 rings moving up and down along the vertical spin axis. The details of the rings are shown in Appendix A.23. Part described in Appendix A.22 is attached to the ring and carries the ceramic hook on it. In this configuration, the ring helps to reduce the amplitude of the baloon which may be formed by the yarn spinning on the vertical bobbins. 6 rings and thread hooks in conjunction, are connected to a frame, details of which are seen in Appendix A.21, to form a permanent set. The component shown in Appendix A.46 comprises the side parts of the frame which gives it a rigidity. These components also contain pairs of opposing rollers which embrace the vertical guideways. The details of the rollers are shown in Appendix A.44, and pads on which the pulleys are assembled in Appendix A.47. The dead weight of the ring frame is counterbalanced by balance weights. Two chains are connected to each end of the frame, which extend up, pass over fixed axis sprockets connected to the machine frame and two counter-balance weights attached to the other ends. The ring frame is driven by a 0.75 KW AC motor and a gear box connected to it as described in section 4.2.8. Force and motion is transmitted to the ring frame by chain drive. There is a 20 teeth sprocket, which is shown in Appendix A.71, fixed to the output shaft of the drive. A 52 teeth sprocket placed on a shaft, centered and supported in bearings, shown in Appendix A.77. A chain stretching in between hence provides a speed reduction of 1/2.6. The output shaft of the drive rotates by 3 rpm. At the other end of the centered shaft there are two identical sprockets side by side with 68 teeth on the periphery, details of which shown in Appendix A.70. One chain on one of these sprockets carries the ring frame from one end and another chain on the second sprocket carries the ring frame from the other end. The overall appearance of the ring frame drive system can be seen in the perspective assembly drawing given in Appendix A.72.

The spindles not only wind the finished thread onto the bobbins but also give twist to them. The related formula is Eq. 2.1. The difference between the rotational speed of the spindle in rpm and the winding on the bobbin in loops-per-minute is the twist the yarn takes every minute. The twist-per-meter is hence equal to the result of the previous subtraction divided by the length of yarn produced-per-minute. Twist can be increased by running the spindles at a greater speed. Spindles can rotate in one direction or the other under PLC control. By switching the sense of rotation, a right-hand twist or a left-hand twist can be obtained. If no twist is required, the rotational speed of the bobbin must be rather small, which can not be obtained by the ring-spinning system described. For this, another yarn winding system is designed and integrated onto the machine. This system is at the bottom of the machine, behind the spindles, by location. A long horizontal shaft on which the cylindrical tubes are placed rotate with rather a slow speed, driven by the same motor which drives the yarn advancing rollers. There are 6 bobbins on the shaft one for each knitting head. There must hence be 6 yarn guides to make the shape of the package. These guides are located on a long horizontal rod which is running along the whole length of the machine. This rod does not rotate, but is capable of translating along its axis confined within opposing roller pairs shown in Appendix A.49. As the translational speed is very low, a servo motor is preferred to actuate it. The servo-motor and servo drive referred to in section 4.2.8 is used for this purpose. The rotational motion of the motor shaft is converted into a translation by a rack-and-pinion. Appendix A.12 and A.48 show other auxiliary components of this system.

4.2.12 The Programmable Logic Controller

The machine designed here has 74 AC motors each having its own invertor type speed controller, and a servo motor, which has its own matching controller. Operation of all these motors must be in coordination. Coordination of all electrical systems is done by a central PLC. It controls the type and geometry of the produced yarn, its production speed and packaging shape and size on a bobbin are all facilitated by this motor coordination. The PLC used is the LS-K7M-DR60U type PLC manufactured by the Canadian company LS. This is a new generation high speed PLC, with 72 analog inputs and 72 analog outputs. All the outputs are used to control the smaller size motors driving the knitting heads and the spindles. Not all the analog inputs are used though, only 36 used, one to read the signal coming from the thread detector rupture sensor of each group. Three more analog outputs were required to drive the two larger motors and the servo motor. So an amendment of analog outputs was required. The commercial typification of the added accessory is 67F-DA2V of the same brand.

Programming a PLC is a tedious task. Therefore the manufacturers have produced user-friendly man-machine interfaces to program them. The abovementioned PLC also has two different interface, which is visual, program ladder generated by selecting functions from a menu, hence can be programmed by people who do not have an electrical engineering background. Arithmetical operations for calculating the numerical value of any command is also available.

The settings of the machine are facilitated by the PLC program done. Communication between the machine and operator is facilitated by the multi-color, touch sensitive operator console with commercial typification XP30-BTE/DC of the same brand. The technical specifications of the PLC and operator's console are given in Appendix B.4.

CHAPTER 5

DESIGN FOR THE STRENGTH OF MACHINE COMPONENTS ON CATIA

5.1 Statement of Engineering Problems

Design of a mechanical system is a rather difficult work. In a mathematical model of a certain mechanical phenomenon, many variables exist and hence a proper solution often requires optimization. Optimization can be on a completely mathematical basis, an objective function is defined and its derivative with respect to a variable is observed. Overall maximum is presumed to be the optimum solution, but when the derivatives with respect to other variables are derived, it comes up that often one value of a variable causing a maximum in one condition does not generate the same maximum in some other condition. The space where the objective function spreads is a hyper surface, which can not be understood or sensed by human brain.

Engineering solutions are rarely optimum, yet they are used and provide comfort for us and improve our living quality. Many such solutions, which are actually not too faraway from the optimum solutions are found out by relying on the experience, feeling and judgement of the engineer, which is gained at the end of long professional life.

Computers can do arithmetic and logic operations at great speeds. Therefore a mathematical model can be solved many times, may be several thousand or even millions, and the solution which has provided the greatest value of the objective function can be selected as solution and applied. Computer software engineers have developed many general purpose programs which can be used by those who can not do programming as efficiently. Catia is one such program, which has been in continuous development since it came up in early 80's. It has always been a good choice to solve engineering problems since then.

5.2 Catia

First and most primitive version of Catia was prepared in 1977 by the French Avionics company Avions Marcel Dassault. It was initially called CATI, a word formed by putting the first letters of the word string in French: "*Conception Assistée Tridimensionnelle Interactive"* which means *"Interactive Aided Three-dimensional Design "* in English. Originally designed to solve the mechanical construction problems of the company, being nothing more than a three dimensional draughting program. Then well known machine elements models were added and their multiple solutions in a matrix of variables. First four versions of Catia were developed in the time of mainframe computers and hence were run on them. Only large companies and universities could afford running a mainframe computer, hence use of Catia was not as large. Parallel to the advent of computers, Catia gradually developed and incorporated the finite element stress and strain calculations. The Fifth version was initially designed for mini and micro systems of Vax, HP, IBM and Sun. Then it is adapted to run on Microsoft Windows. With the advent of color-graphic screens, the sixth version came which can be run on windows and Macintosh systems only. Now it can do strength analysis of components with complex geometry, it can model the dynamics of multi degree of freedom systems, it can handle static and dynamic fluids. It has an even better user interface, by which data of the problem is given easily to the computer and the solution outputted. Solutions can be presented by numbers and letters, by graphs, by norm engineering drawings, by perspective solid figures. It can do color graphics and also animations. Documentation on Catia is massive. Its user catalogues and manuals are massive. Presumably very few people exist who know all of Catia. Normally proficiency on using Catia is achievable by doing more and more applications.

5.3 Strategy of Problem Definition

During the Design stage of the yarn making machine referred to here, Catia was selected to be a tool by which designs regarding the strength of mechanical components could be carried out. Although Catia can model and solve dynamics problems, no dynamic problems are considered in the design stage. The object to be manipulated is yarn, which is very light. Yet, many strength solutions do not require any intricate calculations at all. Some stress and strain calculations were done on Catia.

One example is the 40 mm diameter shaft which drives the yarn advancing system of the machine. The shaft is a long one which is composed of symmetrical sub-sections, one of which is shown in Figure 5.2. The yellow vectors indicate a distributed load coming from the bearings and the red vectors indicate a distributed load due to the pressing forces applied by the rocker arms. Both vectors are in a direction perpendicular to the shaft axis. There are no axial forces acting. Figure 5.2 shows the Catia screen showing the "boundary conditions" of the stress and strain problem.

MESH:

Entity	Size
Nodes	1095
Elements	2885

ELEMENT TYPE:

Connectivity	Statistics
TE4	2885 (100,00%)

ELEMENT QUALITY:

Criterion	Good	Poor	Bad	Worst	Average
Stretch	2884 (99,97%)	1 (0,03%)	0 (0,00%)	0,276	0,730
Aspect Ratio	2885 (100,00%)	0 (0,00%)	0 (0,00%)	4,309	1,525

Materials.1

Material	Steel
Young's modulus	2e+011N_m2
Poisson's ratio	0,266
Density	7,85g_cm3
Coefficient of thermal expansion	1,17e-005_Kdeg
Yield strength	5,2e+007N_m2

Figure 5.1: Catia screen showing the characteristics of material, which is construction steel here, and the mesh size and number of the finite element model.

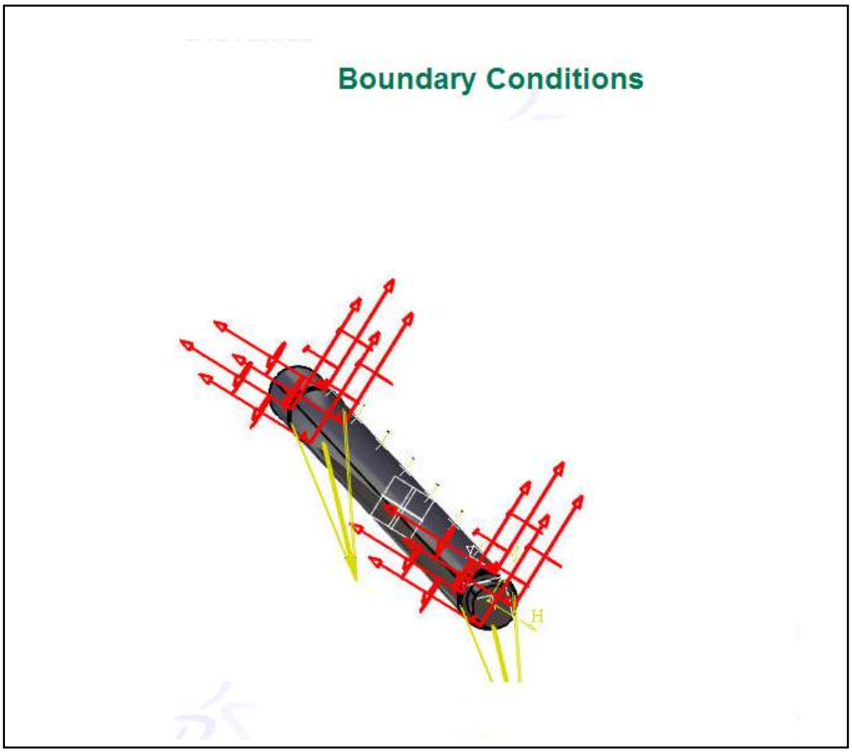


Figure 5.2: Catia screen showing the boundary conditions of the stress and strain calculation problem. Boundary conditions are the magnitude, place of application and distribution of the forces.

Figure 5.3 shows the Catia screen presenting the elastic curve of the shaft. Lateral deflections magnified a thousand times and the Von Mises stresses in color code. Figure 5.4 shows the Catia screen presenting the actual shape of the elastic curve where deflections are not observable by eye. Von Mises stresses are shown aside.

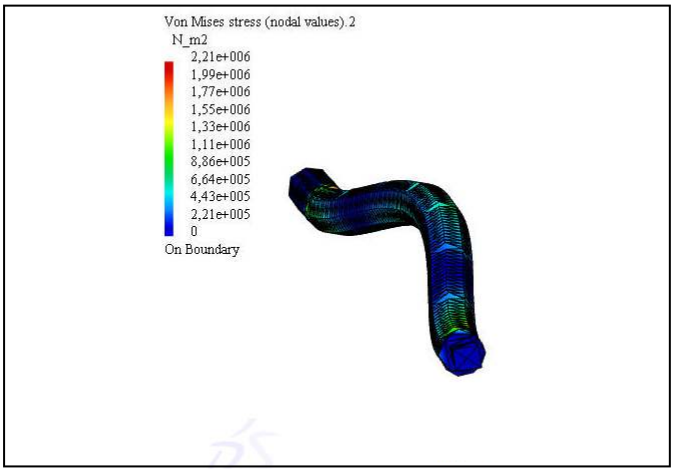


Figure 5.3: Catia screen showing the deflection, as magnified 1000 times.

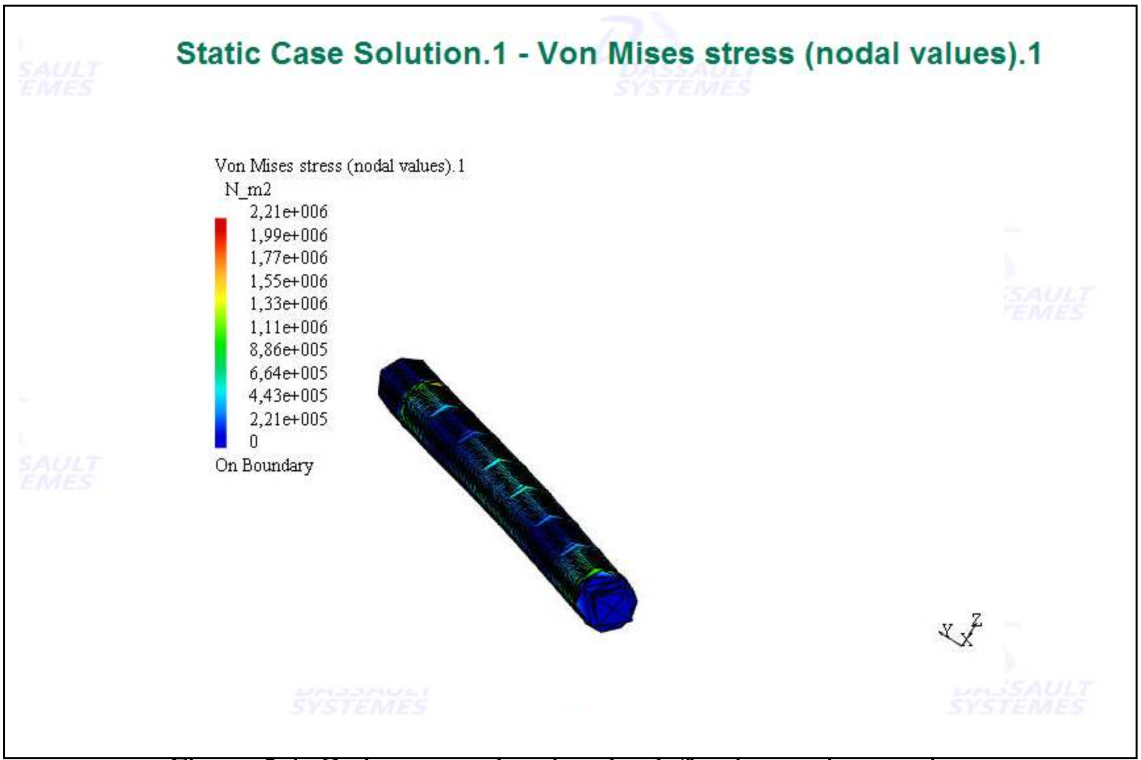


Figure 5.4: Catia screen showing the deflection, as in true size.

Figure 5.5 shows the shaft color coded according to stress levels.

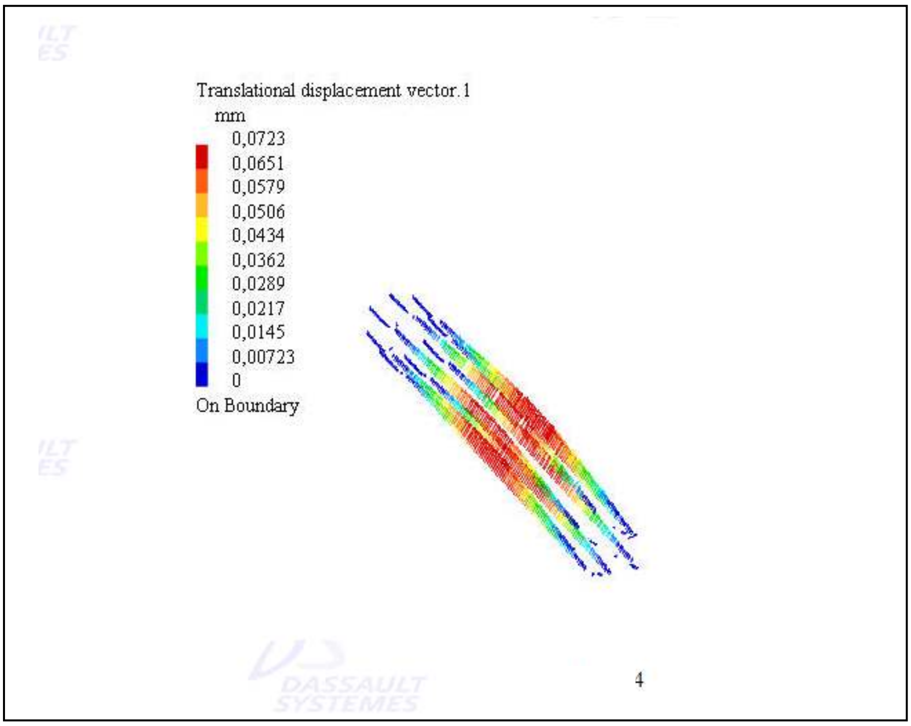


Figure 5.5: Catia screen showing the stress levels in color code.

Another problem which was examined and solved by Catia was the calculations of stress and deformations occurring on a sprocket. This sprocket is shown in Appendix A.71, a 20 teeth sprocket, connected to the output shaft of a motor-gearbox combination, carrying 0.75 KW and rotating at 3 rpm. Figure 5.6 shows the page where a sample sprocket comes up and parameters related with dimensions such as addendum and dedendum circle diameters, pitch circle diameter etc. are given. The next page coming to the screen is shown in Figure 5.7, where the material properties and mesh number and sizes are defined. The next operation is to define the boundary conditions. The sprocket specified is connected to a drive shaft, takes torque, force and motion from it. The boundary conditions are shown in Figure 5.8. The sprocket is surrounded by a chain for almost half a turn. So, the greatest stresses are expected at the center where the sprocket is connected to the shaft. There are stresses and deflections at the half circle along which the chain embraces the sprocket. Von Mises stresses are shown in Figure 5.9. Catia calculates the deflections as the relative slip occurring between the finite elements. The results are shown in graphical representation of Catia in Figure 5.10.

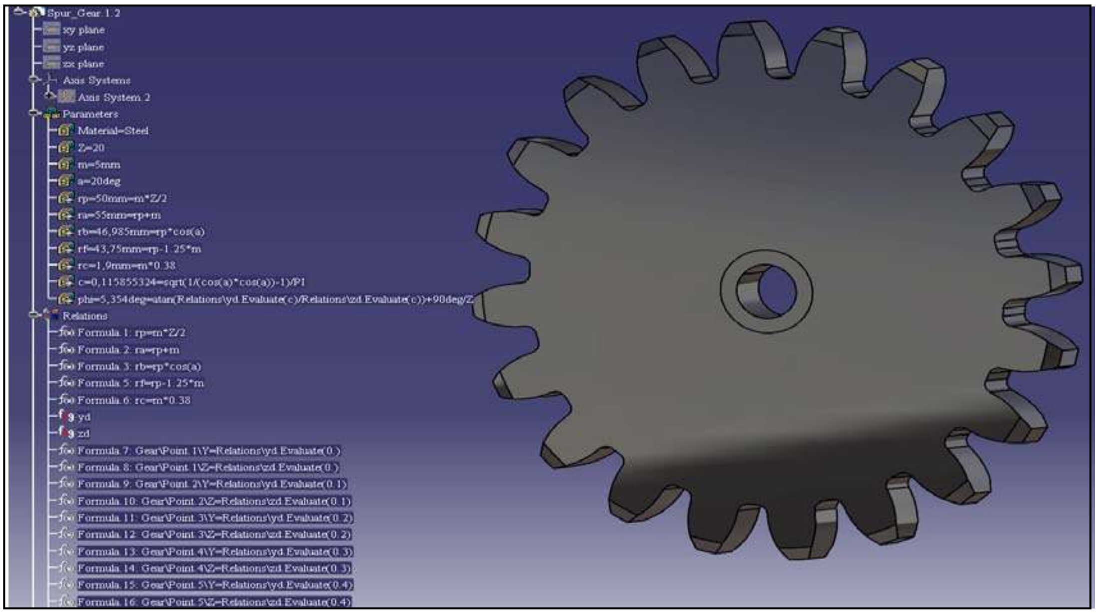


Figure 5.6: Catia page showing a sprocket. Through this page, sprocket parameters are given, as addendum and dedendum circle diameters, pitch circle diameter etc.

MESH:

Entity	Size
Nodes	44528
Elements	27420

ELEMENT TYPE:

Connectivity	Statistics
TE10	27420 (100,00%)

ELEMENT QUALITY:

Criterion	Good	Poor	Bad	Worst	Average
Stretch	27420 (100,00%)	0 (0,00%)	0 (0,00%)	0,369	0,632
Aspect Ratio	27420 (100,00%)	0 (0,00%)	0 (0,00%)	4,349	1,902

Materials.1

Material	Steel
Young's modulus	2e+011N_m2
Poisson's ratio	0,266
Density	7,86g_cm3
Coefficient of thermal expansion	1,17e-005_Kdeg
Yield strength	5,2e+007N_m2

Figure 5.7: Catia screen showing the characteristics of material, which is construction steel here, and the mesh size and number of the finite element model.

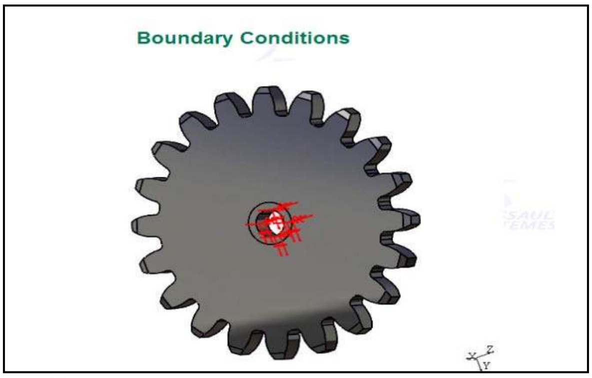


Figure 5.8: Catia screen showing the boundary conditions of the stress and strain calculations for a sprocket. Constraint forces only come from the shaft onto which the gear is leaning.

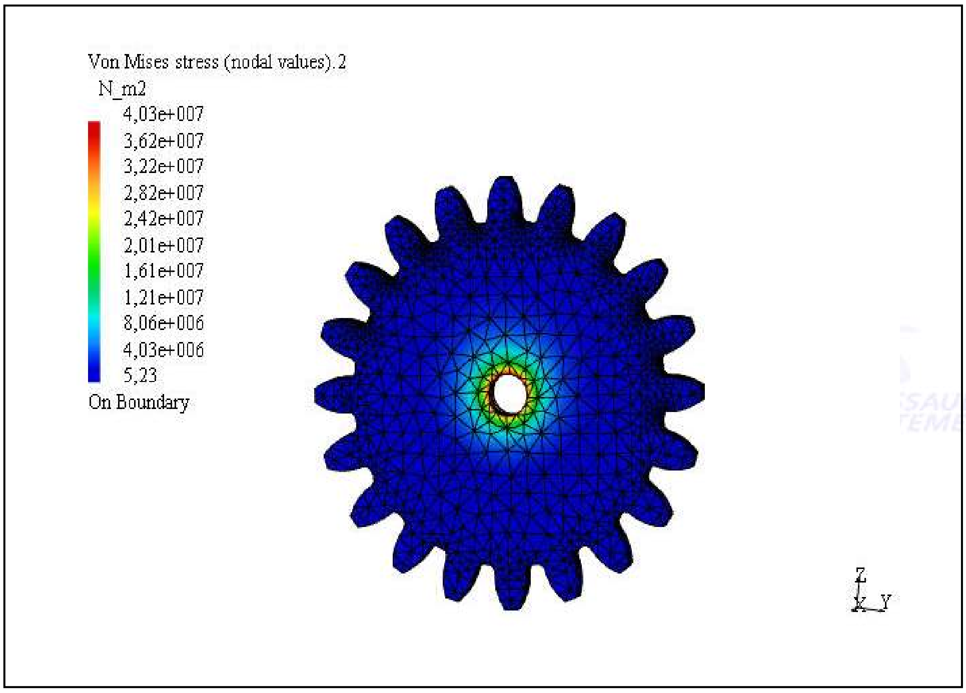


Figure 5.9: Von Mises stresses generated on the sprocket. Greatest stresses are occurring at the motor connection, around the hole.

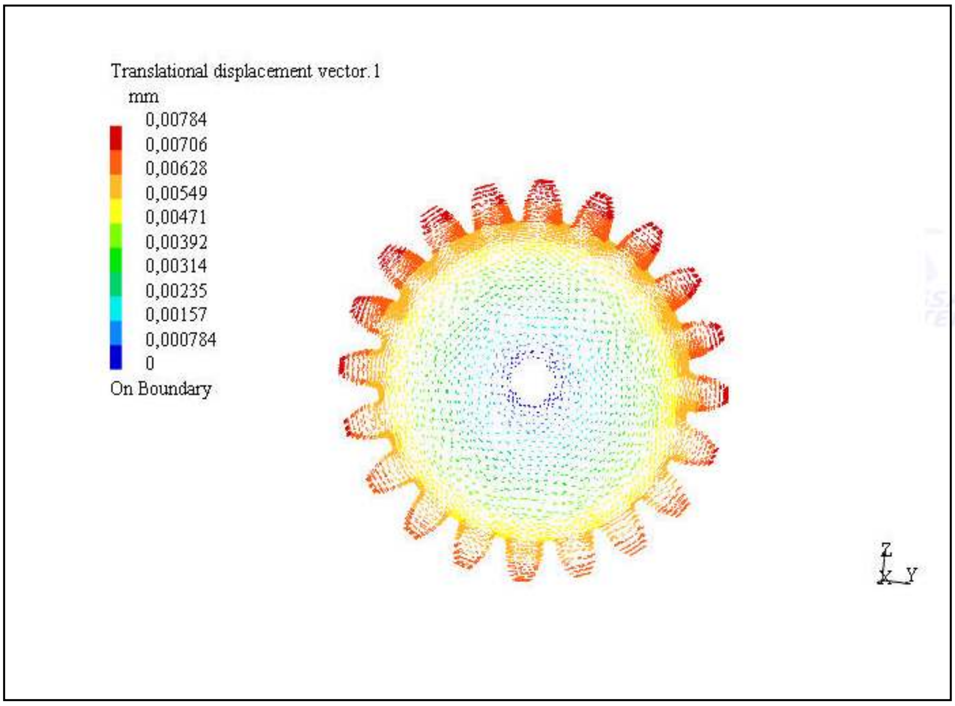


Figure 5.10: Deflections on the sprocket, figure generated by Catia.

CHAPTER 6

FACILITIES PROVIDED BY THE NEW DESIGN FANCY YARN MACHINE AND THE MAN-MACHINE INTERFACE

6.1 Facilities Provided by the New Fancy Yarn Machine

The machine whose design has been the subject matter of this thesis, and reported in this dissertation is a fancy yarn production machine, which is stemming from another, but simpler Italian design, the Sy/48SB type machine of the company TEMAT Meccatronic. Two basic additions on this machine is brought by this work.

Figure 6.1: The prototype of the new design fancy yarn production machine, in frontal view.

Firstly, the newly designed machine can process up to 3 form colors, one greater than the Italian machine, by which a much larger possibility of color motif making has been facilitated. Secondly, the motion of the operating mechanism is inverted. This enabled to reduce the total mass and mass moment of inertia of the moving components, which in turn facilitated a greater operation speed, 2.5 times that of the Italian design. The machine was designed and constructed at the facilities of the Jakarsan Company of Gaziantep-Turkey. An overall appearance of the machine is shown in Figure 6.1, in frontal view. In Figure 6.2, the back side of the machine is given, showing the creels, the yarn tensionning devices and the yarn rupture detectors. Figure 6.3 shows the yarn advancing and winding systems at the bottom part of the front.

This machine can produce two different fancy yarns, Slub and Snarl. It uses up to 4 different threads or yarns to make the final product. One of the yarns is used in production of the carrier or the base of the yarn. It is a narrow circular tubing, soft and elastic. Other three yarns are form yarns and are used to fancify the carrier with their different form and attractive colors. Form yarns run inside the base narrow tubing and hence can not be seen from outside. Whenever required these form yarns are taken by the yarn switching mechanisms and converted into slubs or snarls, whose frequency is adjustable via the central PLC.

Figure 6.2: The back side view of the prototype fancy yarn machine showing the creel, yarn tensionning devices and yarn rupture detectors.

The simplest yarn that this machine can produce is perhaps the carrier only. It can be of single color with no form yarns running inside. Such a single color tubing can be used for example in making shoe leashes. It is soft, elastic and stretchable. To reinforce it, a stronger yarn may be run inside to obtain stronger and thicker shoe laces that are used in sports shoes or boots. One important application is the parachute ropes. Parachute ropes are made multi-ply, to reduce the possibility of complete rupture. The plies are kept together by braiding them from outside. Braiding is nothing other than a narrow tubular knitting which can effectively be produced on this machine.

The machine can be loaded with two or more different color threads and they may be used alternatingly, only to make a carrier. The product obtained is now a yarn simpler in appearance but with alternating colors. This much of a yarn definition can certainly be assumed fancy itself. It can be strengthened and toughened by running a stronger and thicker thread inside.

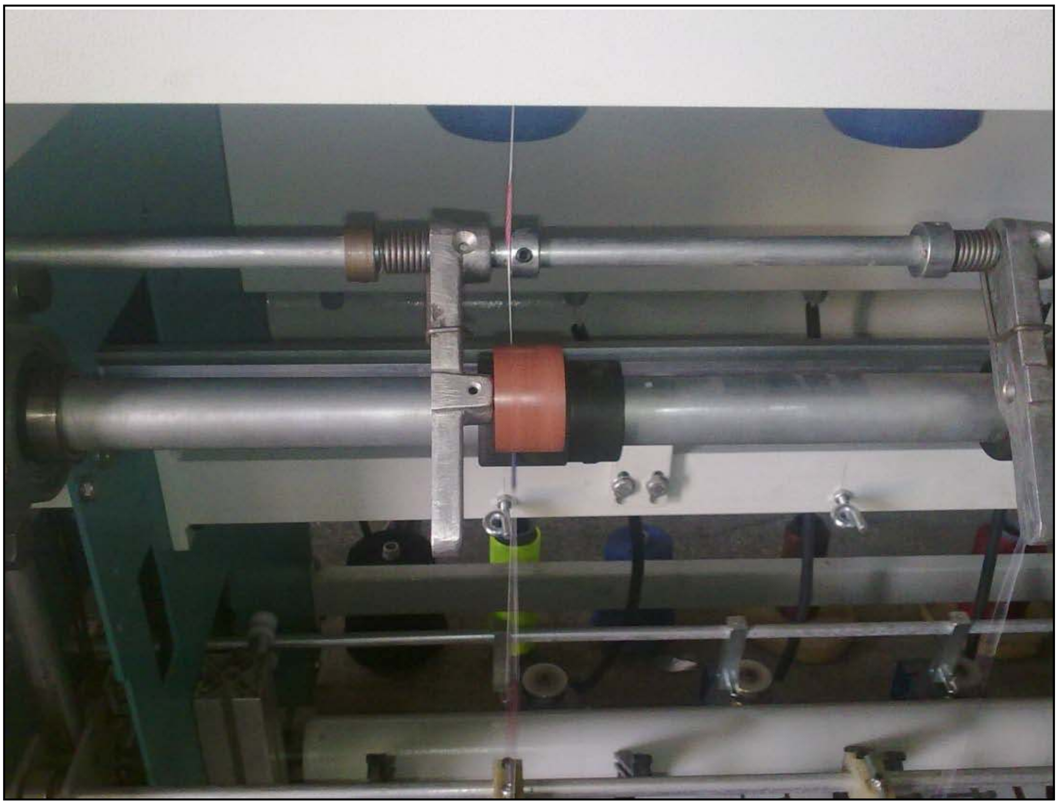


Figure 6.3: The bottom half of the frontal view of the prototype fancy yarn machine, showing the yarn advancing and winding system.

The normal and effective use of the machine is in making fancy slub or snarl yarns. The machine can process three form yarns which can be in different colors and forms. They themselves can be fancy, adding a greater fanciness on the finished yarn. Formation of a slub and a snarl are similar and conducted by the same system. A form thread or yarn is plucked out of the knitting by commanding a particular piston, the base is continued to be knit, and the same piston returns the thread back to the center where it keeps on inside the tubing. If these loops are made close to each other the formation becomes a slub. If the loop is cut, a snarl is formed.

The form, color and geometry of the final yarn and its production speed yet, the shape and size of the winding package depends on the timing and coordination of the operating motors. Each motor is under speed control of its individual invertor. The invertors are coordinated by a central PLC. The PLC has been programmed to take instructions from the machine operator through the operator’s console. So, the operator’s console comprises the man-machine interface and facilitates all the communication between the operator and the machine.

6.2 The Operator’s Console and the Man-Machine Interface

The operator’s console assembled to the machine is the model XP30-BTE/DC of the brand name LG. It is a multi-color, touch sensitive LCD screen. By definition it is a passive device, completely controlled by the PLC. It can display alphanumeric data, that is letters and numbers, and also bring multi color drawings to display. The screen can also sense pressure intensification on the screen, caused by the finger touches and return the position data to the PLC. The location of the pressure intensification then is dechiphered by the PLC. The man-machine interface pages are of 10, and are presented below. The Figures 6.4 - 6.6 show the screen of the operator’s console, graphics downloaded from the PLC programmer. The downloads are monochromatic, but the actual screen is color. The screen shown in Figure 6.4-a is the home page, the page which appears first. It displays the name of the company which manufactures this machine, the Jakarsan Company of Gaziantep, Turkey. From this screen the operator can enter the main menu.

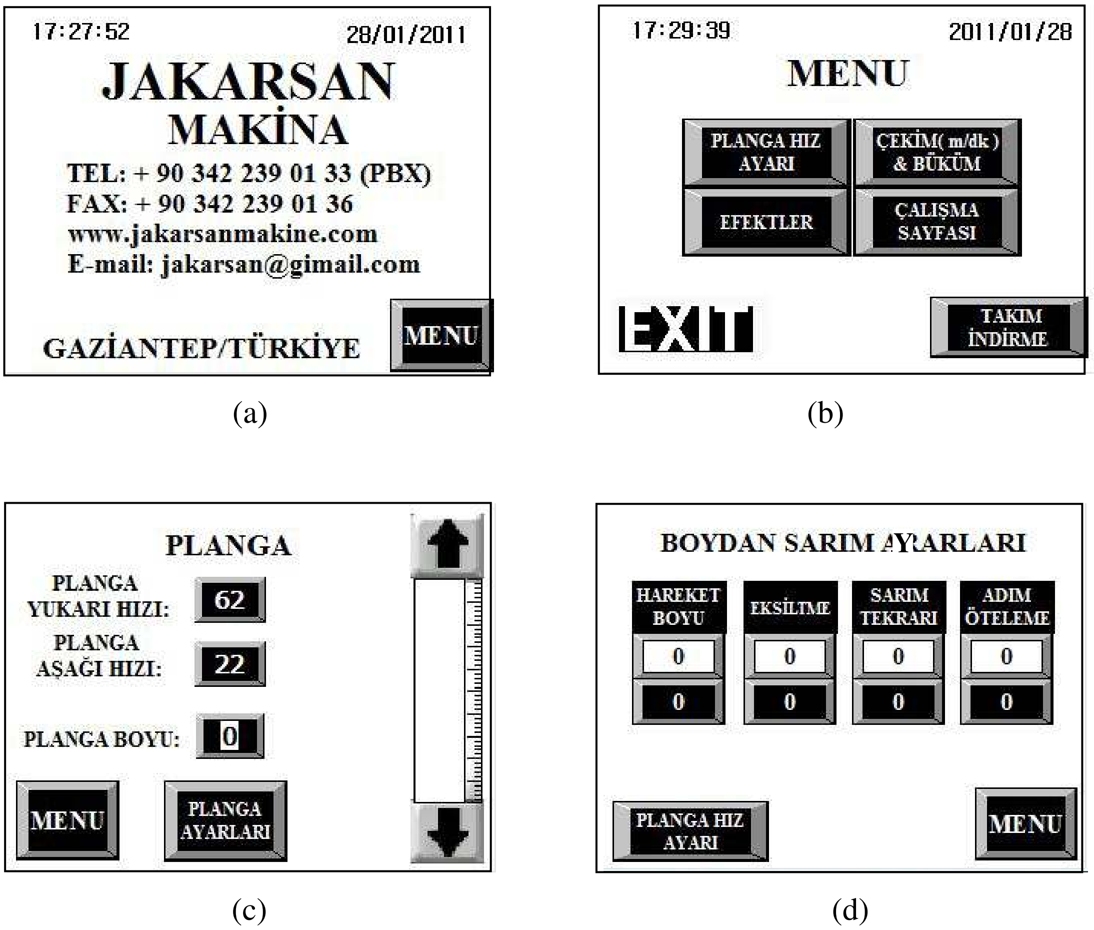
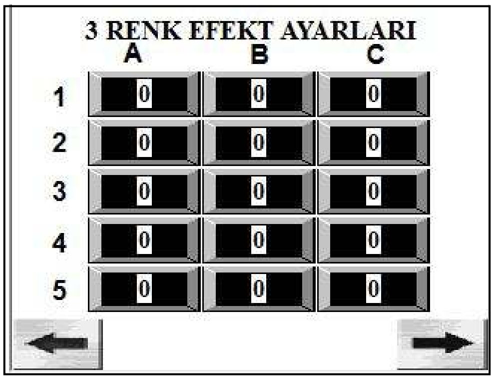


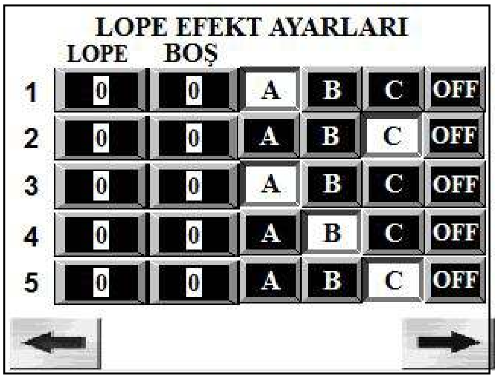
Figure 6.4: The first four screens that appear on the operator's console for man-machine interface. There are 10 such screens in total.

The scripture is in Turkis at the moment, but can easily be translated into other languages, as Jakarsan Company expects to export this machine in great numbers. Screen for the main menu is shown in Figure 6.4-b. As seen, there are four possible choices. Choices are for the control of the spin ring, Yarn advance and twist, Type of the fancy effect to make and the work sheet. By selecting any of these, the operator reaches to the menu of the corresponding activity. The choice at bottom right of the screen is for releasing all the operating systems and bringing them to park position. This state is often required when unloading the developed bobbins and loading empty ones and while controlling the production. The screen shown in Figure 6.4-c is the monitor of the motion of the spin ring frame as understandable from the heading. It has three numerical values, from top to bottom, upward speed of the ring frame, downward speed of the ring frame and its location. Numerical values are dynamic, continuously in refresh. They indicate the current values of the ring frame speed and its location. The numerical values shown are in part-per-hundred.

(a)



(b)



(c)

(d)

Figure 6.5: Four other screens that appear on the operator's console for man-machine interface. There are 10 such screens in total.

There are two menu selections at the bottom of the screen. The one on the left switches back to the main menu and the one on the right switches to the secondary menu of ring frame motion, the settings.

The screen shown in Figure 6.4-d is the place where the motion of the ring frame can be redefined. This menu is accessed by the screen shown in Figure 6.4-c. It shows four numerical quantities, from left to right: The stroke, Reduction of stroke at each repetition, number of winding layers that each repetition contains and inching of the stroke. When the operator opens this screen, he sees the current values there, which are shown as parts-per-hundred except the third one, which is simply a unitless integer number. If anyone of these is required to change, the operator presses the "Ring frame speed adjustments" choice on the bottom left of the screen. This then enables to enter new values as to increase or decrease from the current value, by slightly pressing the upper virtual button or lower of the corresponding display. After the required changes are done, the operator has to press the choice on the bottom left once more. Return to main menu is by selecting the bottom right choice. If a change is done on the previously set values and pressed this option, previous settings will remain.

The screen shown in Figure 6.5-a displays the second sub menu, about the fancy effects on the yarn as its heading implies. There are seven selectable choices on this screen. The topmost is to put the fancy effects into action or not. If it shows “Effects Active”, it means that the machine is producing fancy effects. To stop the fancy effects, this virtual button must be pressed. When done so, the operation of the pistons cease and machine produces only the carrier tubing with all the effect yarns enclosed inside, if any. The machine can do Slub or Snarl effects. Figure 6.5-a shows the “Slub” effect active, as written in the virtual button on the left on the third row from top. When this button is pressed, “Slub” effect is deactivated and automatically the “Snarl” effect becomes active. The left virtual button on the second row from top is currently showing that the “3 color changing” is off. When it is off, the machine keeps on making slubs but with a single effect yarn and color does not change. To activate the multi color effect, this virtual button must be pressed. The machine has a pre-defined plan of changing colors, and when color change is activated, it will start following this plan. If a change is required, the right virtual button on the second row from top must be pressed. This will open the screen shown in Figure 6.5-b and will direct the operator to do the required color change plan. A change in the geometry or dimension of the slubs may be necessary. A new geometry can be defined through the screen shown in Figure 6.5-c. To call this screen, the right virtual button on the third row from top should be pressed. The sub menu of Slub effect in Figure 6.5-a has a display at the bottom right. This is the duration in milliseconds of the pistons being active. If the pistons are kept active for longer durations, the length of the slubs will be greater. A new duration can be set by the screen of Figure 6.5-b. To exit from this menu, the virtual button on the bottom left should be pressed. This will bring the main menu of Figure 6.4-b onto the screen.

The screen shown in Figure 6.5-b displays the third level sub-menu about the color cycle of the yarn, and enables a new setting if required. The length of the screen is indefinite. Columns A, B, C represents the duration of colors A, B, C in milliseconds. Once a cycle is made on this screen machine replays it on and on. There are two direction arrows at the bottom of the screen. They advance a whole page of 5 successive color steps forward or backward. If backward is pressed when the screen is showing the first page, it will return to the one upper menu, which is the screen shown in Figure 6.5-a.

The screen shown in Figure 6.5-c displays another third level sub-menu about the slub effect cycle of the yarn, and enables a new setting if required. The length of the screen is indefinite. One line in the list defines one command defining one step of operation. A Slub "on" means that in this step the machine is making a slub and "off" means that it is not. Columns A, B, C represents the colors. Appropriate color is selected by pressing the virtual button A or B or C, default being A, that is, if nothing is pressed, A will be active and color A will be assumed selected. The numerical values on the "slub on" and "off" virtual buttons are the duration of formation of a slub or only the carrier in milliseconds. There are two direction control arrows at the bottom of the screen. They advance a whole page of 5 successive slub effect steps forward or backward. If backward is pressed when the screen is showing the first page, it will return to the one upper menu, which is the screen shown in Figure 6.5-a.Going back to second level menu screen in Figure 6.5-a, if the "slub effect active" button, which is the left button on the third row from top is pressed, "slub effect" becomes inactive. This means that the other effect available, which is the "Snarl effect" is active as long as "Fancy effects are active", adjustable by the topmost virtual button of the screen in Figure 6.5-a. This second form of this screen is shown in the screen of Figure 6.5-d. On this form of the menu, color adjustments can be done by calling the third level sub-menu of Figure 6.5-b and form adjustments can be made by calling the sub-menu of Figure 6.5-c.Continuing with the second level menu screen in Figure 6.5-a, if the "slub effect active" button, which is the left button on the third row from top is pressed, "slub effect" becomes inactive. This switches the machine to produce Snarl yarn. "Fancy effect" is made active by the topmost virtual button. At this position if "3 color" facility is deactivated, as seen in the screen of Figure 6.6-a, the machine produces snarl yarn, by using color or yarn A, without doing any color alterations.

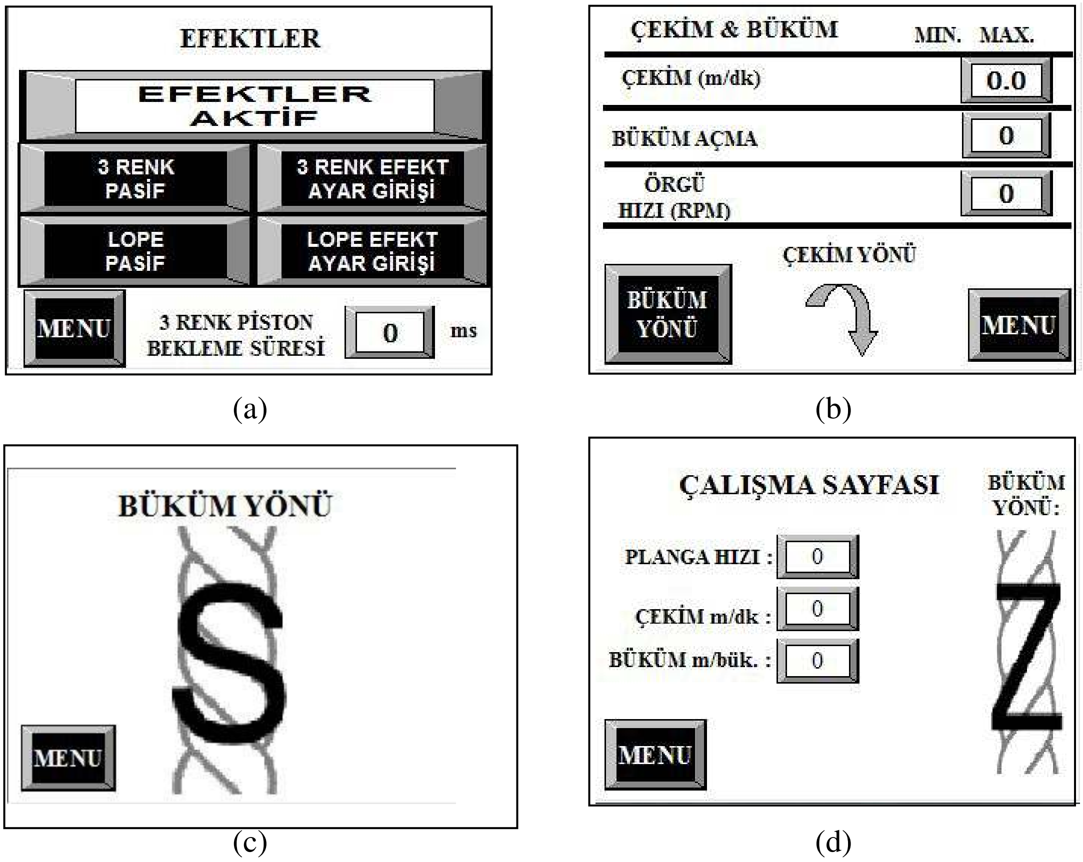


Figure 6.6: Four other screens that appear on the operator's console for man-machine interface. There are 10 such screens in total.

The screen shown in Figure 6.6-b displays another second level menu which is accessed from the main menu of Figure 6.4-b. This main menu has 4 virtual buttons apart from the "Exit" and "Park position" buttons on the bottom line. The above-right button, when pressed gives access to the "Yarn advance and twist menu" of Figure 6.6-b. This menu monitors the advance and twist of the produced yarn. It displays 3 numerical values, from top to bottom, these are the "yarn advancing speed" in meters-per-minute, twist in revolutions-per-meter of yarn and the speed of the knitting head in revolutions-per-minute. At the center bottom, a curly arrow indicates the direction of yarn winding on the vertical spindles. As they are rotated by separate motors, their sense of rotation can be easily controllable. This is not an important aspect to consider, but still controllable. The quantities listed in the screen of Figure 6.6-b can be redefined by pressing the corresponding virtual buttons. This screen has two more options to select, at the bottom. The one at the bottom-right sends back to the main menu of Figure 6.4-b. The one on the left is for changing the direction of twist on the yarn and when pressed, brings the screen shown in Figure

6.6-c onto the operator's console. This third level menu page allows the selection of the twist sense. There are two options, S and Z. S indicates a left-hand helix and Z, a right hand helix in twist.

The screen shown in Figure 6.6-d displays another second level menu which is accessed from the main menu of Figure 6.4-b, by pressing the bottom right button. With the heading "Work Sheet", this menu monitors the speed of spin ring frame in parts-per-hundred, speed of yarn advance in meters-per-minute and yarn twist in revolutions-per-meter of yarn.

6.3 Experience of the Operator

There are no specific formulas or charts which provide values for these variables for which the machine is set. They must all be determined according to the operation speed of the knitting head. The knitting head runs at a variable speed, maximum value 3500 rpm. One would wish to operate the machine at highest possible speed, but this maximum of 3500 rpm is applicable to only plain tubular knitting, without any fancy effect. As fancy effects are included, the intensity of the effects and their durations and also the number of yarns utilised causes the production speed to fall down. At excessively high speeds, the machine starts to introduce defects on the yarn. All other speeds are somehow proportional to the yarn manufacturing speed, but their determination is primarily left to the experience of the operator. Operator experience is highly valuable in setting up the fancy yarn machine described here.

CHAPTER 7

CONCLUSION

7.1 Stages of the Project Development

The purpose of the thesis was to design and construct a new fancy yarn machine which produces slub and snarl yarns. The basic structures of these yarns are given in Chapter 1 of this dissertation. Both of them have complicated structures and can be made perhaps not in a single process but perhaps two successive processes. This of course increases the cost of the yarn.

Making these fancy yarns by using a narrow circular knitting as base or carrier is totally an ingenious idea, which has been put forth some years ago. By doing so, more than one form threads can be made run inside the yarn anyone of which can be plucked out and put into some fancy form. This basic yarn construction has been used without bringing any modifications in this design work and the dissertation reporting the work. Early versions of this yarn had a single form yarn running inside the narrow tubing. This form yarn was made fancy itself and hence providing adequate level of fanciness to the final product, in terms of color, thickness and fancy touches like the inclusion of metallic threads or silk. Later, a two color version came up at early 2000’s. Two different form yarns which can be at two different colors, thicknesses and textures to effect appearance and two different materials to affect the overall material properties have been more beneficial than the single form thread yarn. One example to the machine to produce this yarn was the Sy/48SB model of the Italian company TEMAT Meccatronic, which was actually the only one known to the writer of this dissertation. The technology embedded in this machine is not too much different from the technology of the earlier designs which utilise a single form thread. Only addition to it was a yarn catcher, which catches the second yarn and releases the first and process it.

The amendment first thought on this machine by Jakarsan Ltd. Şti. had been the addition of a third yarn catcher, and increase the number of form threads to three. This of course was an improvement. Three form thread yarn is more preferable than two, just as two form yarn version of the yarn is better than one. Three form threads would facilitate the use of one more color onto the existing yarns, which then would certainly be more attractive and fashionable. When this project was brought to the University of Gaziantep, Mechanical Engineering Department, some new ideas were raised by the university part of the team. That was using the basic colors rather than any other fancy color, which would then facilitate the production of any color and shape motiff or pattern on the fabric or knitting made by this particular yarn. Any color can be obtained by mixing the three basic colors at appropriate proportions. Color proportions on the yarn could be obtained by proportional number of slub or snarl formations, successively generated on the yarn. This was decided, a second step project, and firstly a machine which produces three color yarn should have to be made. So the subject matter of this thesis reported here materialised. As discussions on the design proceeded, one thing was continuously annoying: the production speed of the yarn was very low and so its price was very high. As the yarn and the technology to produce it would be the same, only means of increasing the speed of production was to increase the speed of the operating mechanisms. This is not a simple problem. When the speed of a mechanism is doubled, accelerations and hence inertia forces increase by four-fold. This may load the joints excessively and hence the life span of the machine would be short. Additionally there would be more vibration and noise, which could effect the quality of the yarn and make the machine less friendly. As discussions continued, another innovative idea rose up from the industry part of the team, the inversion of the operating mechanism and the motions they produce. This was perhaps not too much difficult to reach to, as the operating speeds of many textile machines have increased by changing reciprocating motions into continuous circular motions. Rotating hook sewing machines, circular shuttle mesh-bag making machines, circular knitting machines came up with the application of this idea. Wankel mechanism, Tri-Dyne and Bi-Dyne mechanisms to use in making motor vehicle engines are equally innovative applications. “Inversion of the motion” is also a very well-known and useful method to reduce the space required for operation. For example, to observe the behavior of an airplane or motorcar model while moving in air can be easily achieved by keeping the vehicle or vehicle model fixed and blowing air on to it in wind tunnels. Similarly, the behavior of a car body and suspension systems of a car, instead of actually driving it, it could be run on rotating drums.

When the project was enriched by a novel innovation, which is pending for a patent now, it was jointly decided to apply for a technological research grant and carry out a decent project, which would end up with a professional size prototype machine. The project proposal was found eligible by the Ministry of Industry and Trade of the Republic of Turkey and enough cash was granted to carry out the project by Project Number 00342.STZ.2008-2. The design work was carried out by a team, the writer of this thesis being one member. Catia was introduced into the design and the realisations of the inverted mechanism were wholely done by the writer of this dissertation. Many trial runs were done. Design alterations and new test runs proceeded. The controller of the project was called to observe the test runs. Finally a working model was obtained. Then this basic system was transformed into a real, professional size machine, to see the particular problems that does not exist in the single bit, but arise in a larger system. Oncoming problems were solved and the machine was put to display at a national trade fair on textile materials in Istanbul, in 2010

This work has been very fruitful, producing a real prototype machine and all engineering drawings required to construct the machine. Such a practical project could not have been done with the facilities of a university. This project has been terminated successfully. It comprises a good and successful example on the collaboration of the university and the industry. The supporter of the project namely the Ministry of Industry and Trade has been, with this work, have supported a project which is conforming to the development plans of Turkey.

7.1.1 The Main Aim on the Design of the Knitting Head

The main aim of this project has been to increase the operation speed of the machine, because the addition of a third form color even reduces the speed of the existing mechanism and the cost of the yarn increases. To reduce the cost of the yarn, production speed of the machine should be increased. Yarn manufacture operation occurs in two stages; one is the formation of the carrier and the other formation of the snarls and color switching. So, the first solution tried and tested was to increase the running speed of the existing mechanism. Tests carried out on the old design produced excessive vibration and sound when speed increases beyond 800 rpm. Indicator used was the sound levels ate steady state operation, measured by a sound level meter. At some limiting speed, the vibrations and sound of the machine became intolerable. This vibration was due to the unbalanced masses. So, a careful look into the balancing problem was required.

7.1.1.1 Rotating mass balance

Every rotating component in any machine must be balanced to prevent vibration and sound and the fatiguing of components due to cyclic loading. If a particular component is axially symmetric in geometry, it becomes easier to balance. The rotating part of the old design is not axially symmetric. So, unbalanced forces and moments are generated. The rotating components in the old design was balanced dynamically at two planes and hence, up to 800 rpm, operation was smooth, calm and without any vibration and too much noise. But vibration and noise started to occur beyond 800 rpm. Normally a dynamically balanced rotating body should not generate any vibrations. Generated vibrations at elevated speeds were due to the deflection of the rotating components by the bending moments generated. Also deflection is increased by the tension of the driving belt. To get a successful rotating mass balance, the body must be stiff in construction. To increase the stiffness, dimensions should increase. This in turn, increases the masses and mass moments of inertias. In old design total mass of the rotating components was 1850 grams and mass moment of inertia about rotation axis is measured to be 0.00723 kg-m^2. Better success in getting rid of unbalance is achievable by making the rotating body axially symmetric, and mass as small as possible.

To apply this idea, the motion is inverted. The mass of the 12 needle rotating bed is only 338 grams, nearly 1/4 of the old design. Also the needle bed is axially symmetrical. Needles add about 6 grams, but do not change axial symmetry. The bed is rotated by a pulley which is made of aluminum to reduce mass. The pulley weighs 110 grams without a setscrew. The belt is round, made of rubber, and tension it applies is negligibly small. So, total rotating mass here is about 4.13 times less than that of the older design. Mass moment of inertia is measured by bifilar pendulum technique and found to be 0.0000374 kg-m^2, which is about 1/200 of the original design. This enabled an adequate drive with less belt tension.

The mass moment of inertia is measurable experimentally if a prototype component exists. Three methods exist, which are the compound pendulum, torsional pendulum and the filar pendulum. In this work the components whose mass moment of inertias are required are suspended by two strings of equal length, attached to two points at equal distance from the mass center, as shown in Figure 7.1. The bifilar pendulum is made to swing in the horizontal plane and the period of oscillations is measured with a stop-watch. Mass moment of inertia as a function of period is:

$$I_G = \frac{mr^2g}{L}\left(\frac{\tau}{2\pi}\right)^2 \tag{7.1}$$

Where

I_G : the centroidal mass moment of inertia in kg.m^2

m : the mass of the body whose inertia is required in kilograms.

L : Length of the string sin meters.

r : radial distance between the mass center and the points where strings are attached in meters.

G : Gravitational acceleration, 9.81 m/sec^2

τ :   Period of oscillations in seconds.

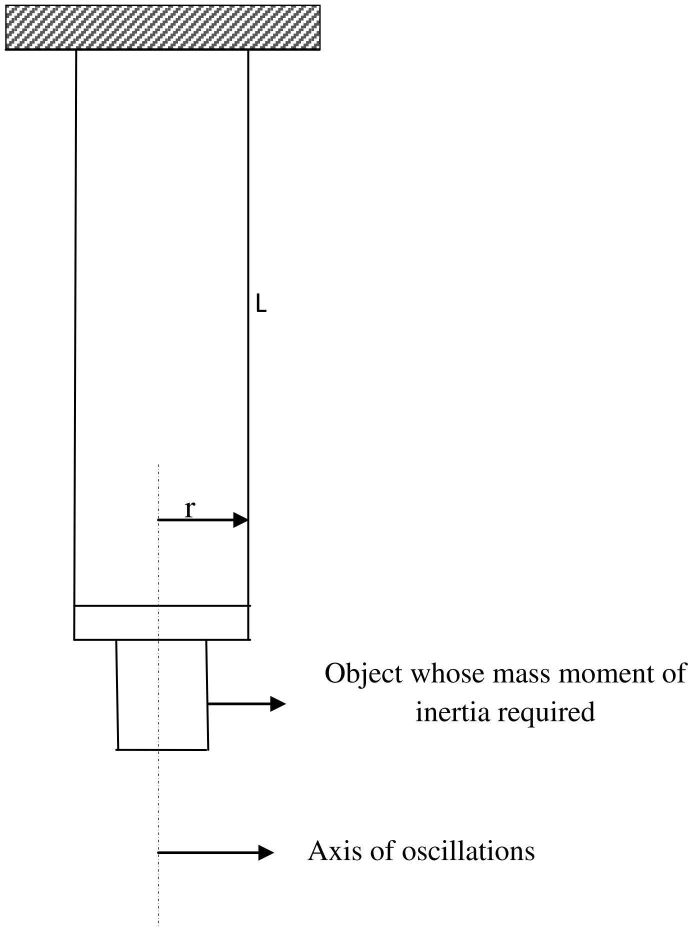


Figure 7.1 Bifilar Pendulum. This technique is the most popular experimental technique to determine the mass moment of inertia of rotating objects.

Performance of the new design is quantified by sound levels. The new design inverted motion has a better performance than the old design. Performance criterion is the operation speed. The speed of operation changes from one yarn to the other but the maximum possible speeds are determined by looking at the sound levels generated. A maximum of 2500 rpm is obtained from the new design whereas the maximum speed of the older design was only 800. At 2500 rpm, the bearings of the knitting head started to heat up, so the maximum speed is determined to be 2000 rpm.

7.1.1.2 Increase of yarn shift process speed

The yarn shift process is actuated pneumatically. To speed up a pneumatic actuation, normally supply pressures must be increased. The valve used is model 4V 210-08 of Ningbo Vogue Pneumatics Industry Co. Ltd. of China. The valve has an effective valve opening of 16 mm^2, and valve flow factor 0.89. The valve is a high response solenoid operated type, which can be operated with a DC bandwidth of 5 hertz. Any signal of greater frequency generates problems in the solenoid. The response time of the spool is 0.05 seconds (Appendix B.5)

The cylinder which drives the yarn shifting pistons has an inside diameter of 9 mm and effective length 51 mm. Within this 51 mm, the piston and the returning springs are placed, hence, the working length is only 42 mm. This leaves a total volume to be filled with pressurized air of 2.672 cm^3.

System pressure is 4 bar gage. The no-load flow of air through this valve is 12.18 liters /sec of free air as calculated. This volume reduces to 2.436 liters when pressurized to 4 bar gauge. The cylinder is filled in 0.00109 seconds without any load, i.e. assuming the mass of the piston and yarn shifter zero. The formula for calculating the flow through a pneumatic valve is given by the Fluids Controls Institute of the USA is:

$$Q = 6.844C_v\sqrt{\Delta P[(P_s + 1) - \Delta P]} \qquad (7.2)$$

Where Q : Air flow in litre / sec f free air at 12.8 ^{o}C

C v : Flow factor for valve, given as 0.89 in manufacturers catalogues.

DP : Pressure drop across the valve in Bar

Ps : Supply pressure in bar gauge

From this analysis, the mechanical part of the yarn shifting operation is just a little over 6 milliseconds. The bottleneck is at the magnetic part of the valve. It permits a maximum speed of 5 Hertz, corresponding to 200 milliseconds between each successive commands. As the actual mechanical movements finish in 6 milliseconds, it is understandable that to speed up the yarn shift, the magnetic process should be speeded up. This is out of context of this dissertation. So, an increase in the supply pressure will not provide any advantage.

Command generation in 5 milliseconds is a difficult task for a PLC. Among several possibilities, PLC selected came up to be the LS-K7M-DR60U of LG.

7.2 Proposal for the Future Work

Next project that should follow this work would be towards increasing the sale of the machine. Projects for textile engineers and textile engineering departments could be:

i) To determine the physical properties of the fancy yarn produced by the machine designed. Yarns made of different materials must be made and tested. There must be numerical data to describe the yarn such that places of application can be determined more easily and more accurately.

ii) To determine the physical characteristics of the knitted and vowen matrices, especially those regarding friction wear and strength. This will enable the producers of fabrics for various applications and producers of knitwear will find numerical data to rely on.

iii) The knitted and vowen matrices can be shown to fashion designers and encourage their use in fashion. The applicability of the yarn in different fields may be searched for.

iv) Different materials can be used for making the yarn. Strong and tough materials may be searched for application, especially metallic ones. Also heat insulating, electromagnetic field proof materials can be searched for.

v) New yarn constructions can be searched for. This project may be a joint work with mechanical engineering researchers. Mechanical engineers may be working to design new machines once a new yarn configuration is found.

Project areas for mechanical engineering can be as follows:

i) The mathematical model describing the dynamics of the operating mechanism and the yarn may be developed and the process may be improved dynamically, such that it can be operated at higher speeds.

ii) The deformation of the yarn during knitting or veawing can be experimentally investigated. The relationship of deformation can be related with machine settings.

iii) Possibility of multi color motiffs may be searched for by using color cameras. Accuracy of color and motiff geometry can be searched for.

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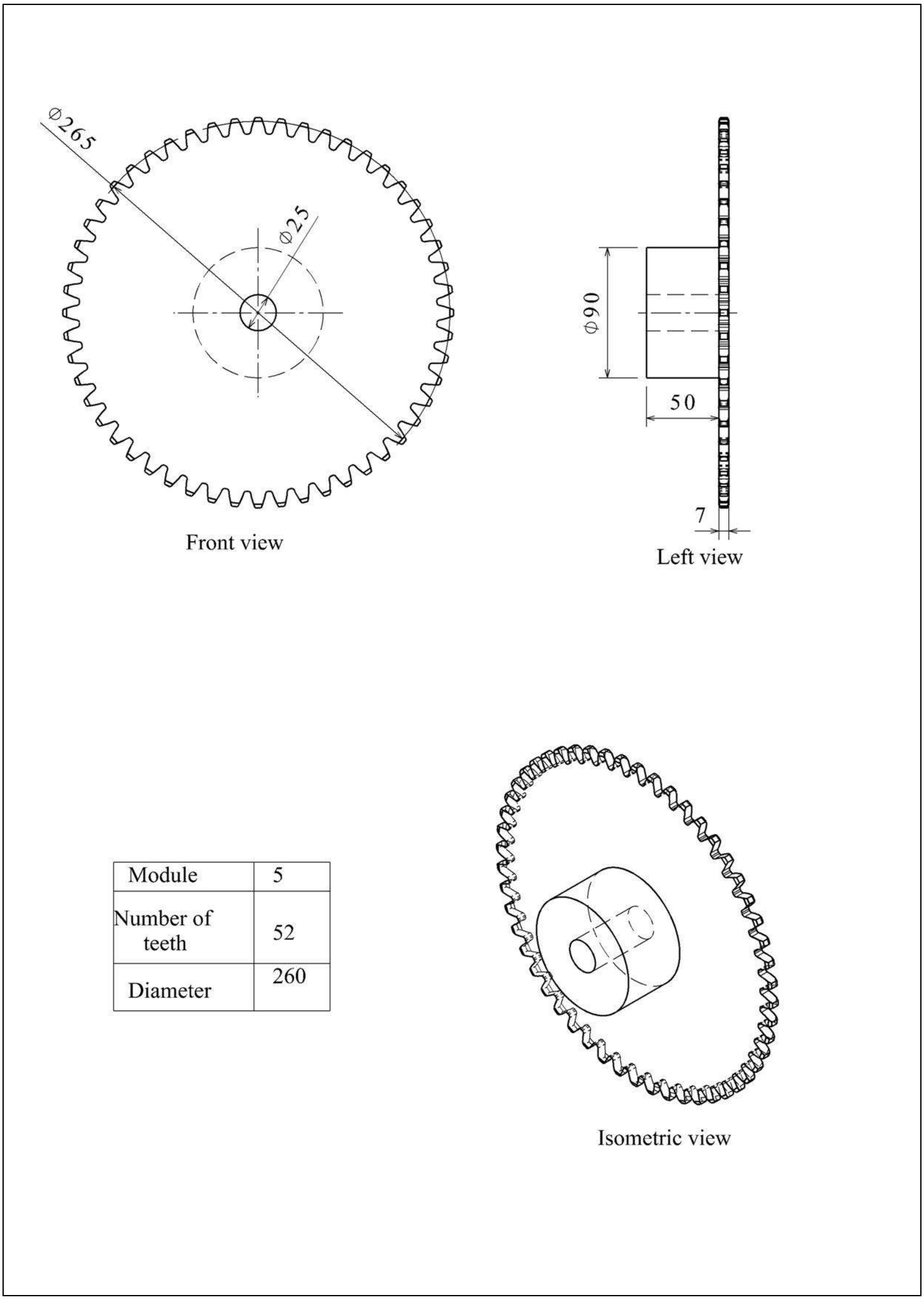
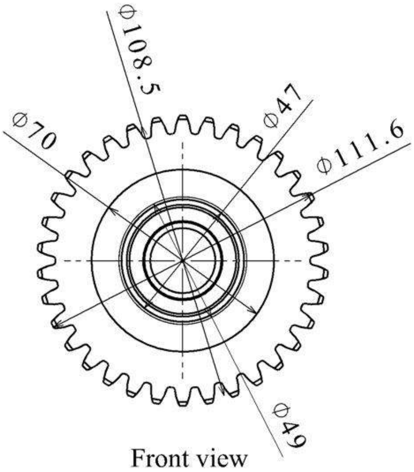
APPENDICES:

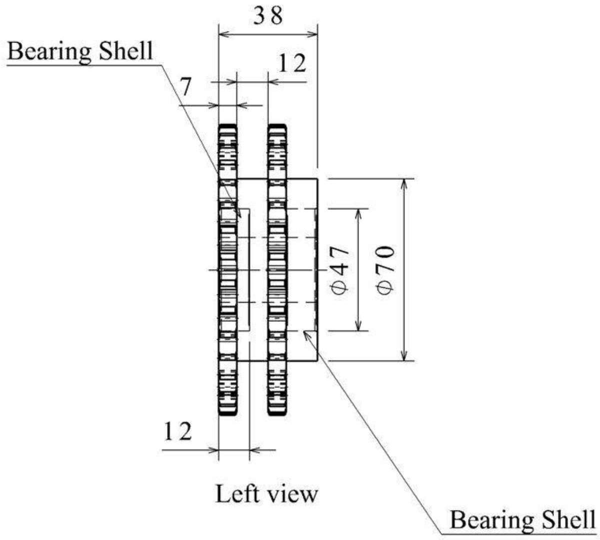


Module	5
Number of teeth	52
Diameter	260

Appendix A.1: Sprocket in the mechanism driving the spin ring frame.

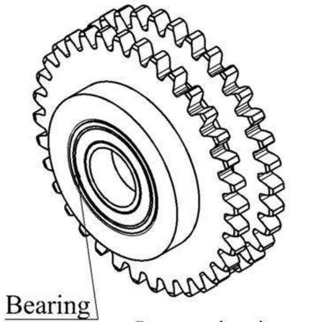


Front view



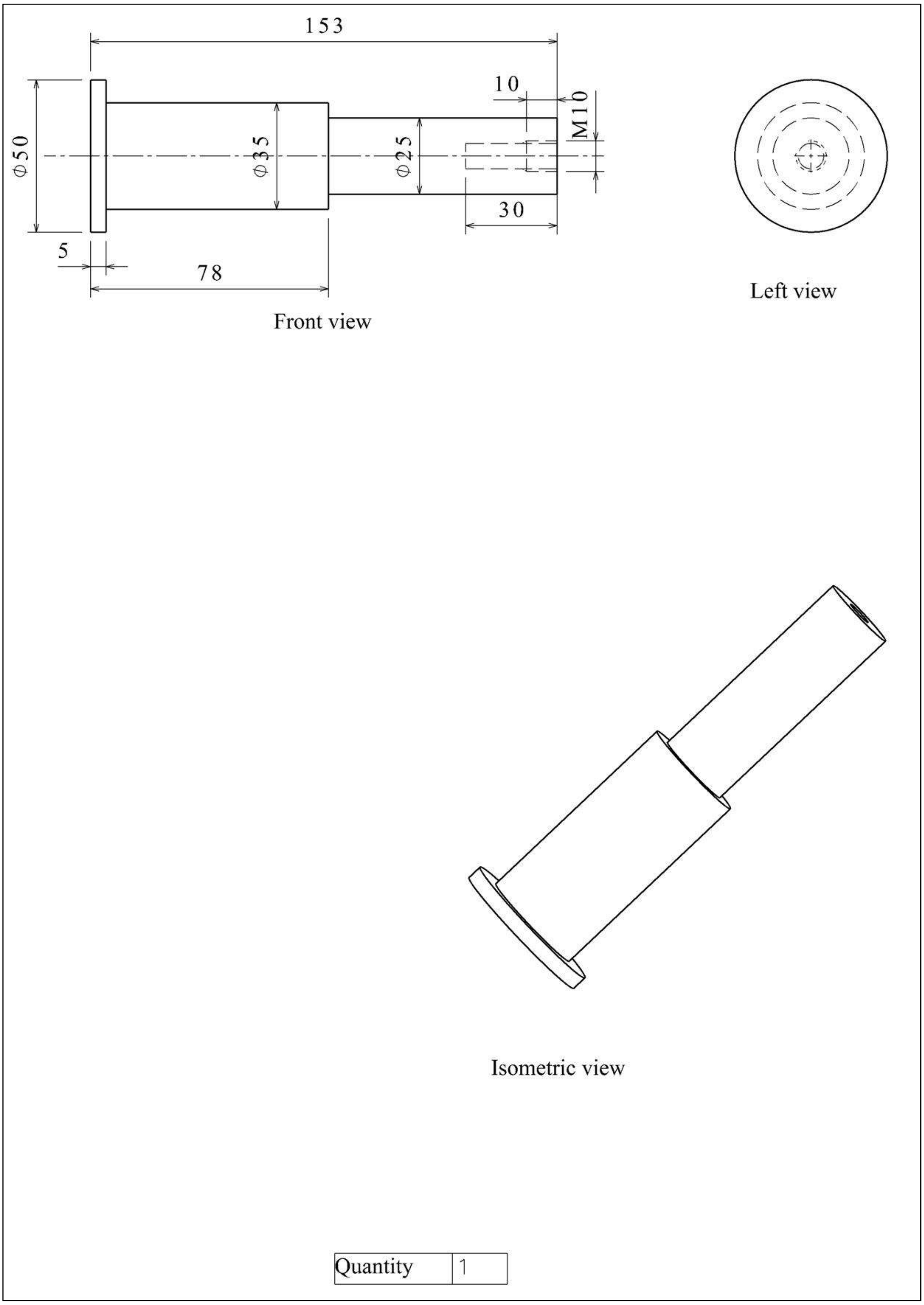
Left view

Module	3.1
Number of teeth	34
Diameter	105.4
Number of Quantity	1

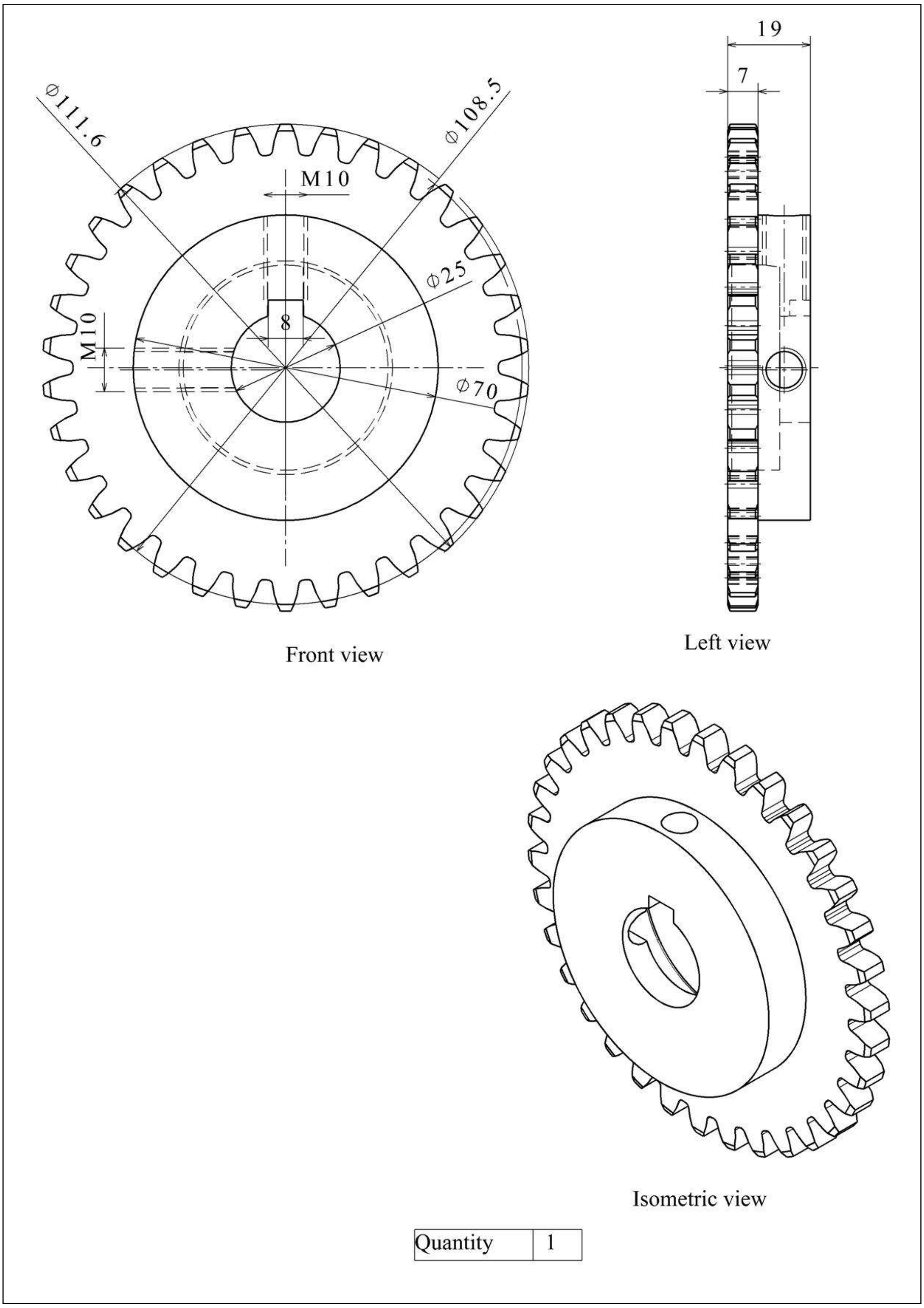


Isometric view

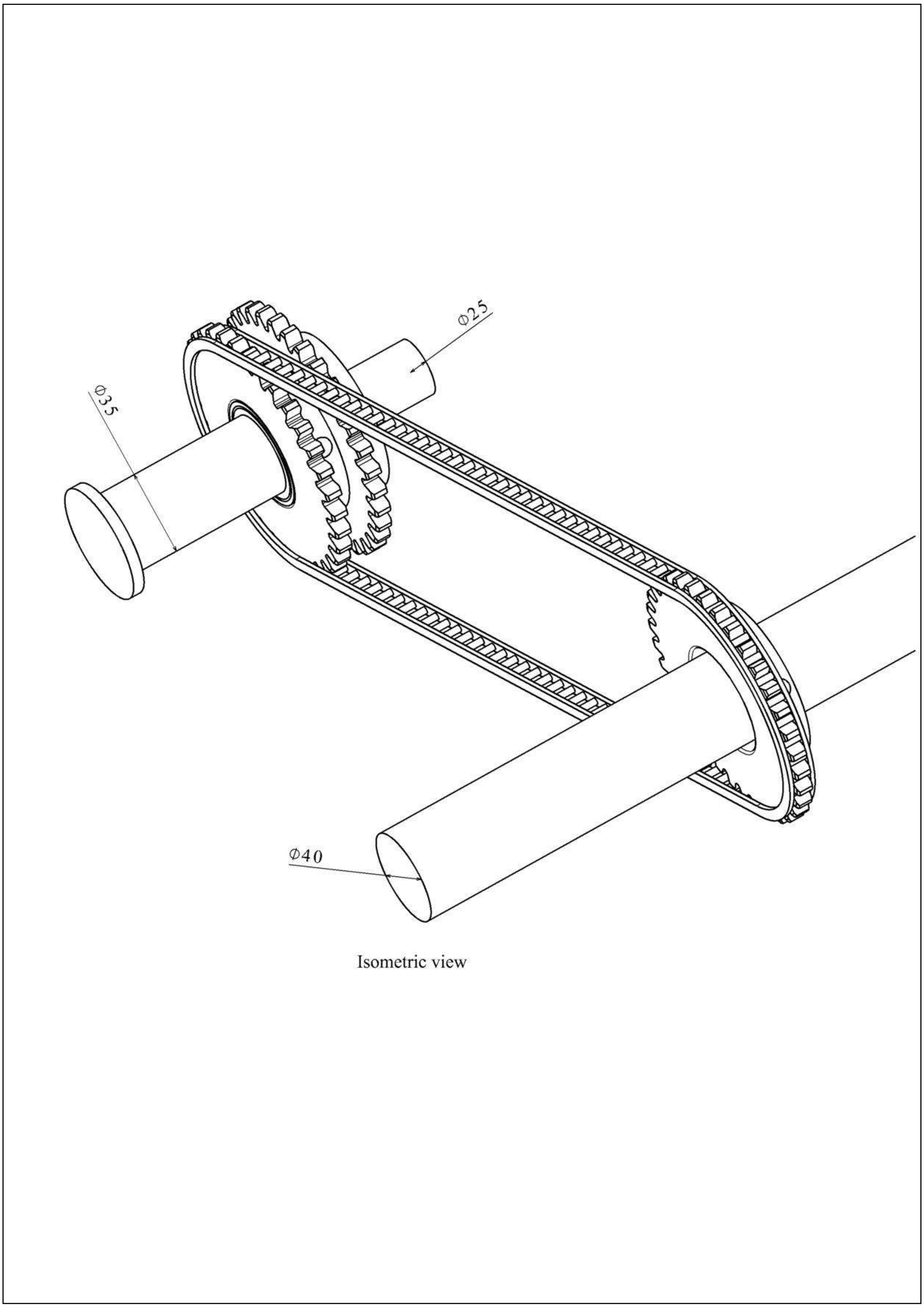
Appendix A.2: Compound sprocket which is used for transmitting power from main shaft to the bobbin shaft



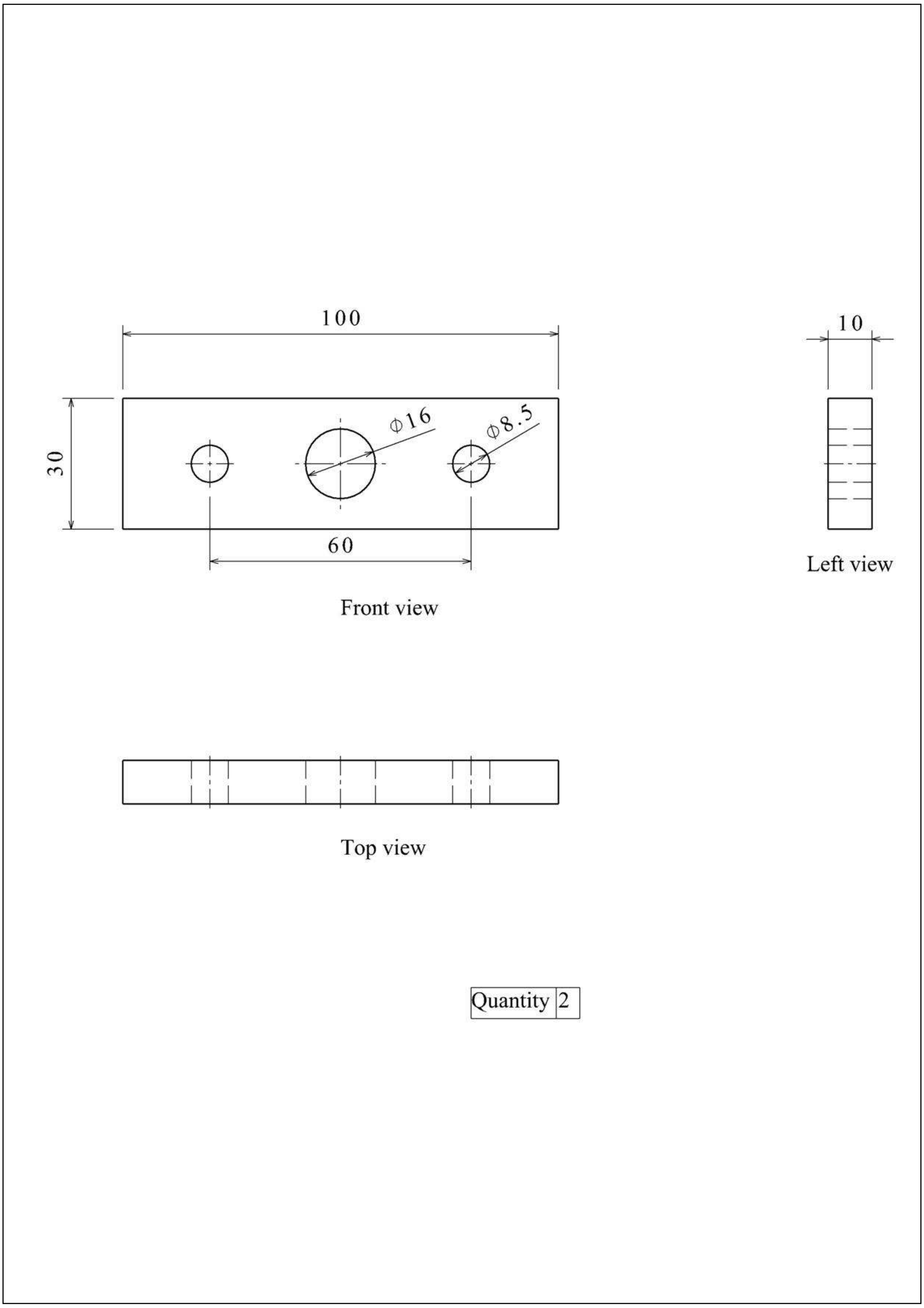
Appendix A.3: Shaft which centers and supports the compound sprocket.



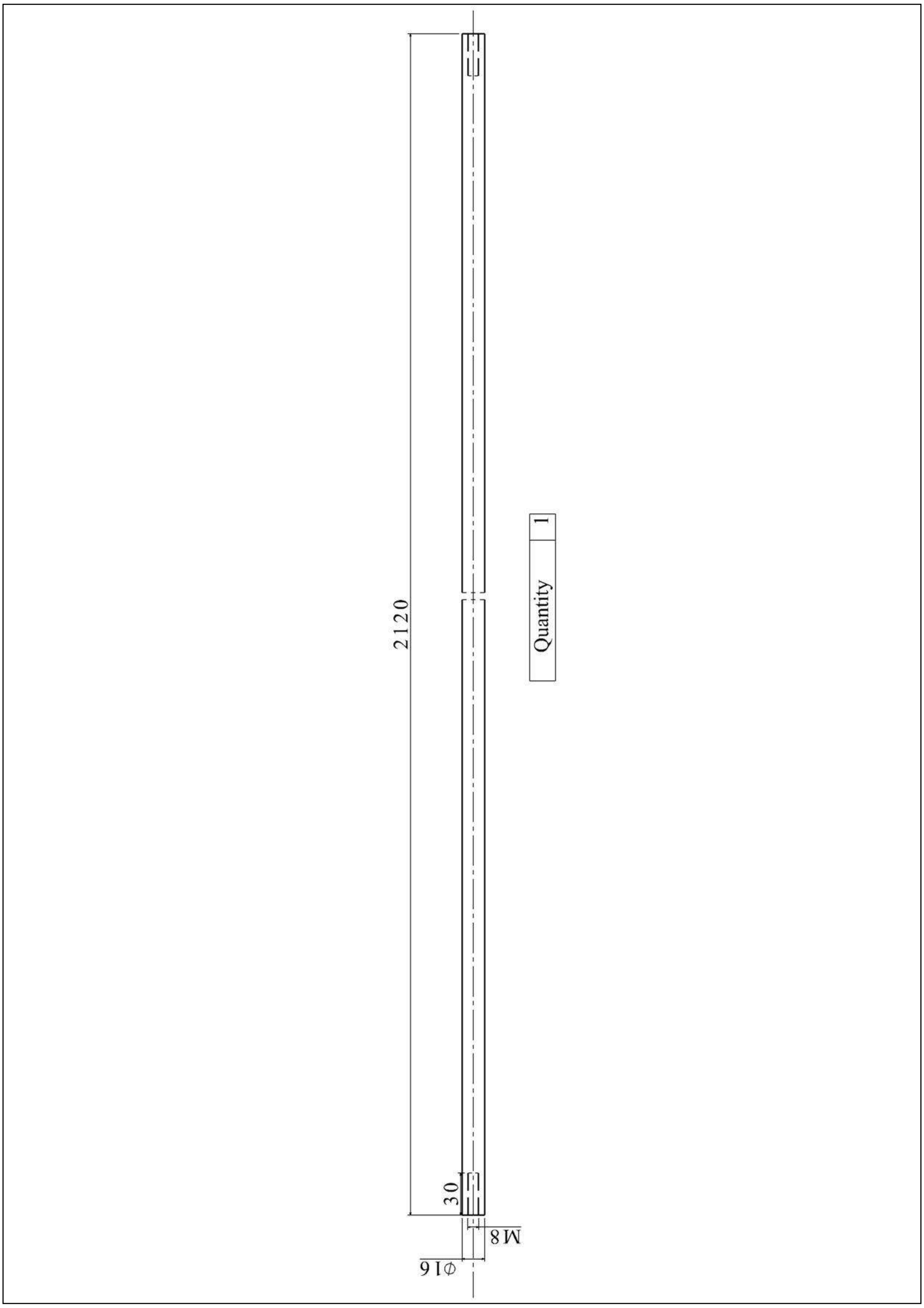
Appendix A.4: Sprocket. This component is used for transmitting power from main shaft to the sprocket in A.2



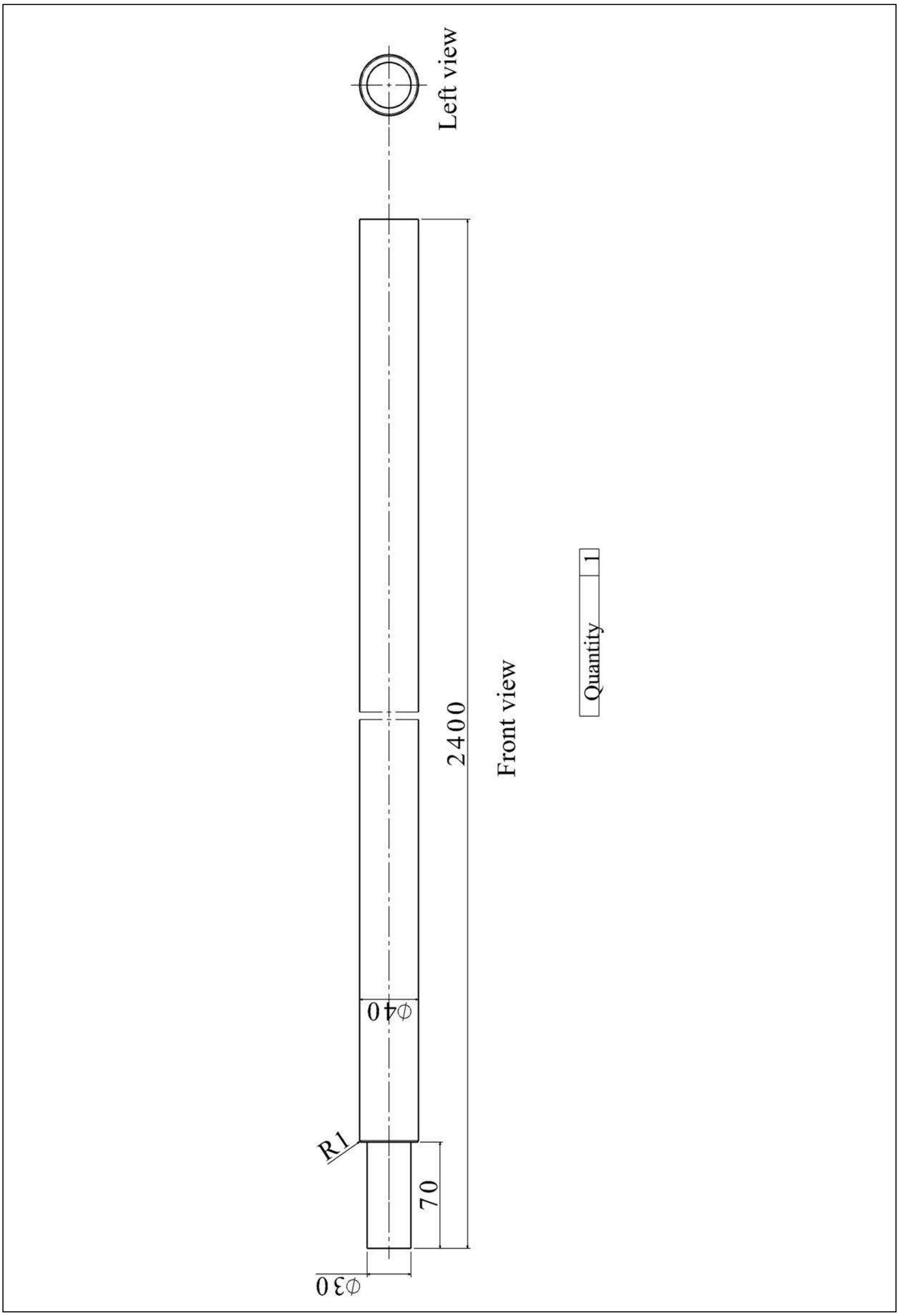
Appendix A.5: Partial assembly drawing for a chain drive.



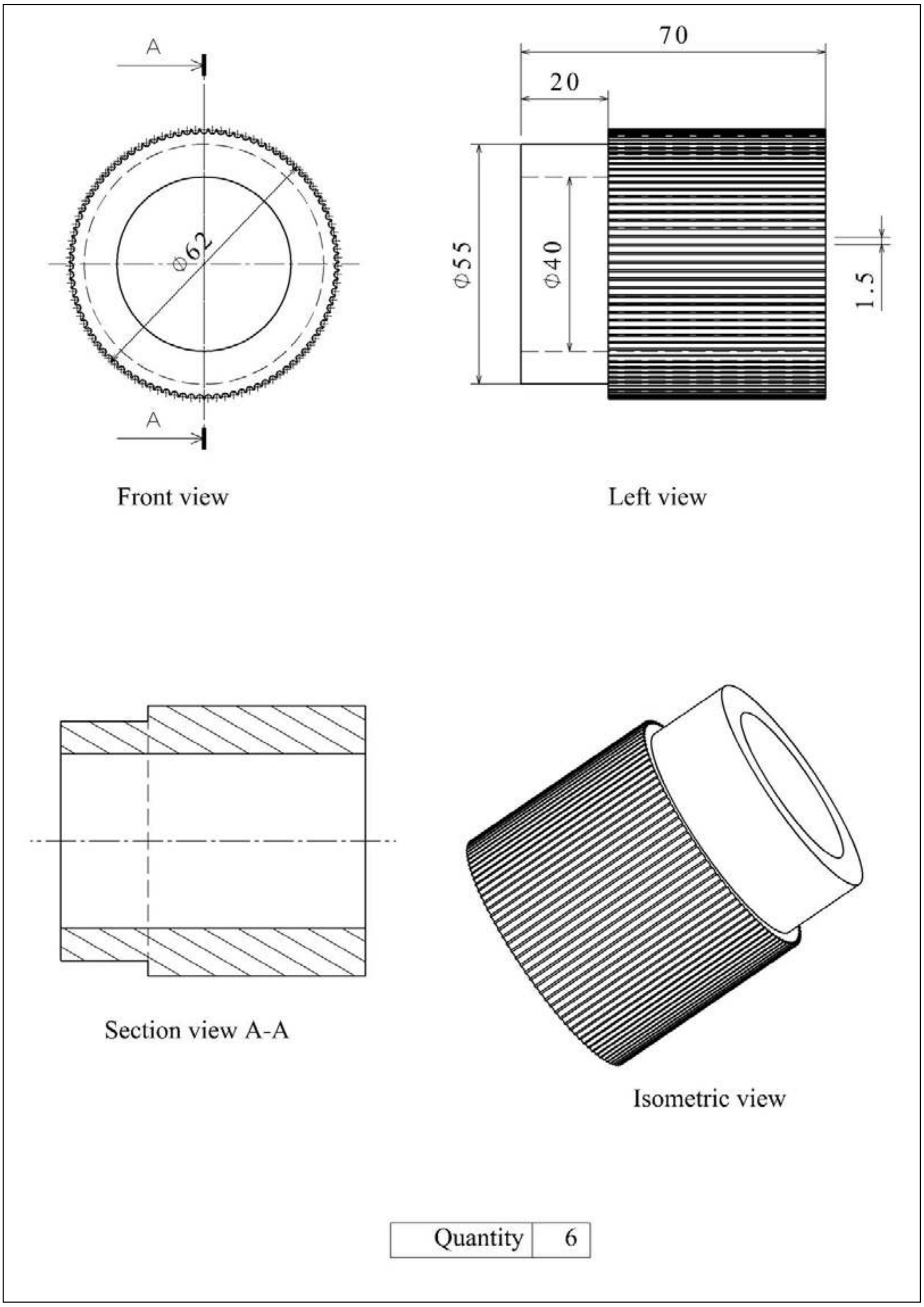
Appendix A.6: Component to support the sheet metal frame to hold the 16 mm diameter shaft



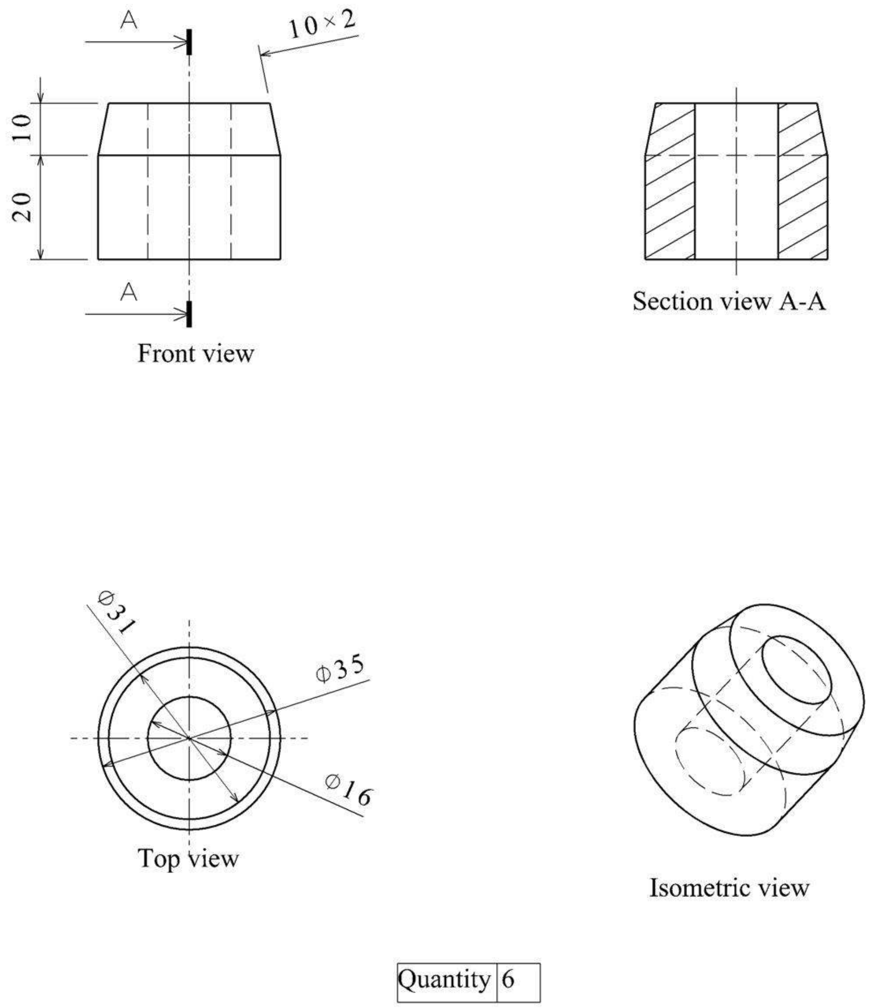
Appendix A.7: 16 mm shaft which holds the compression rockers.



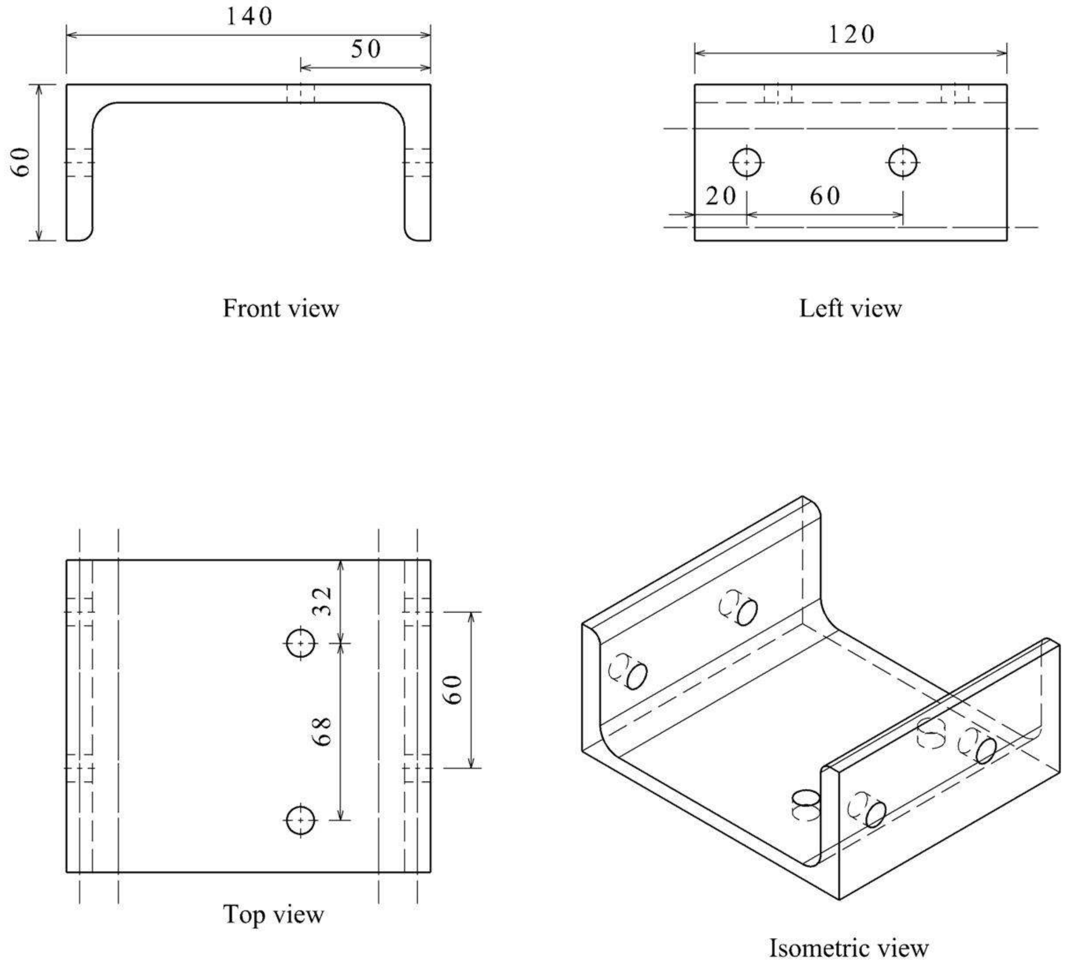
Appendix A.8: Main shaft of the circular knitting machine



Appendix A.9: Friction rollers which advance the finished yarn.

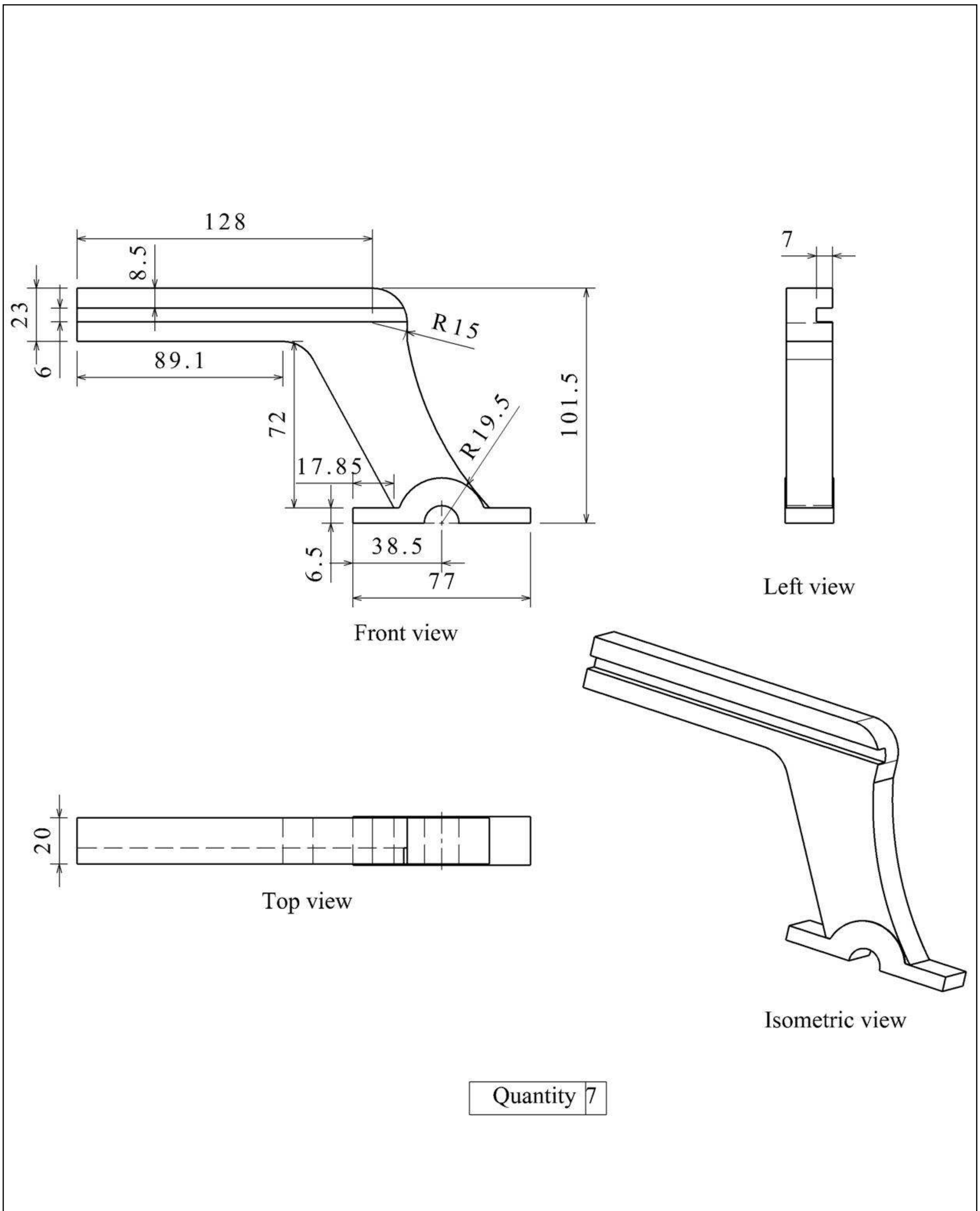


Appendix A.10: Components that constrain the axial movement of rocker arms

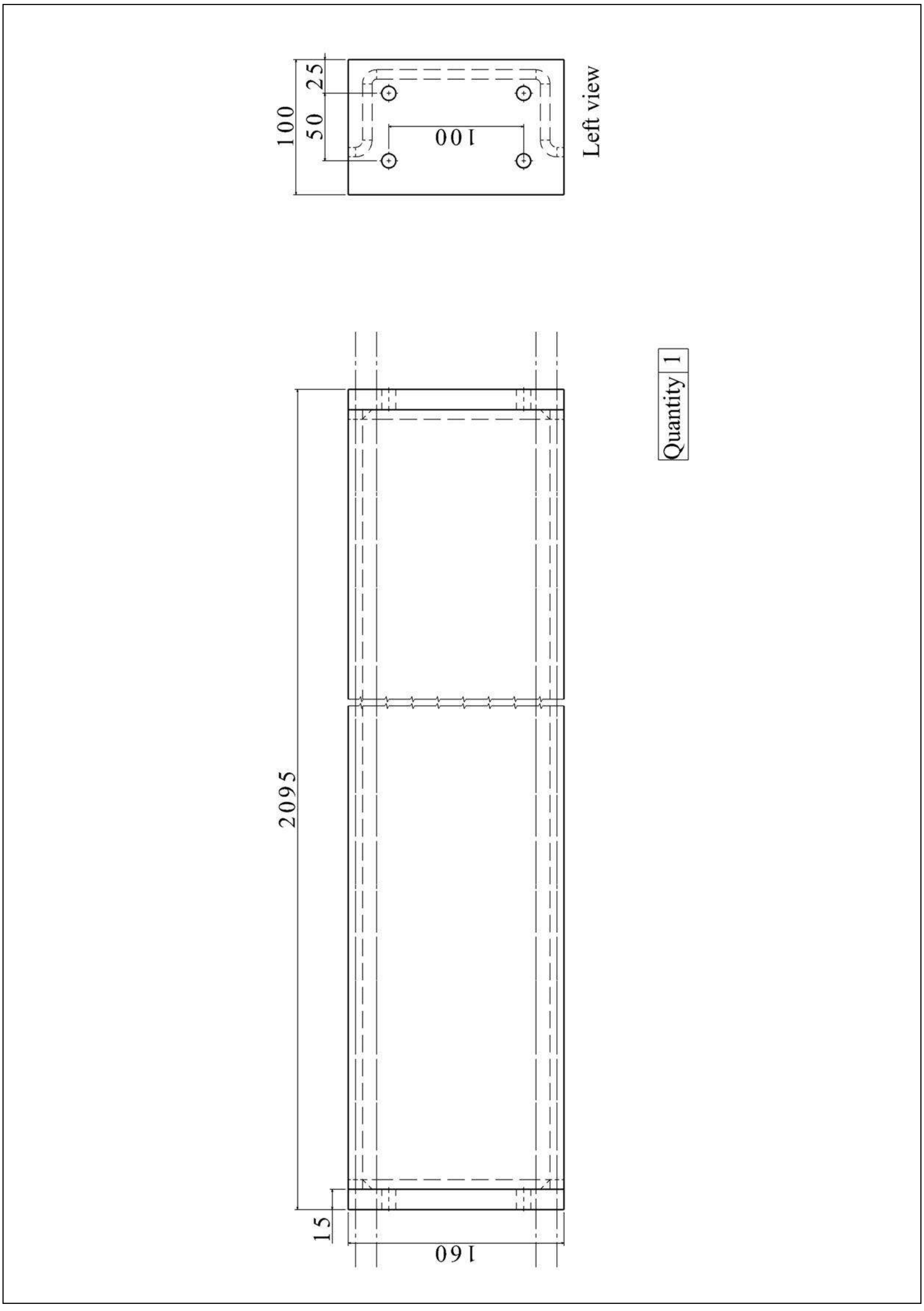


Quantity	6

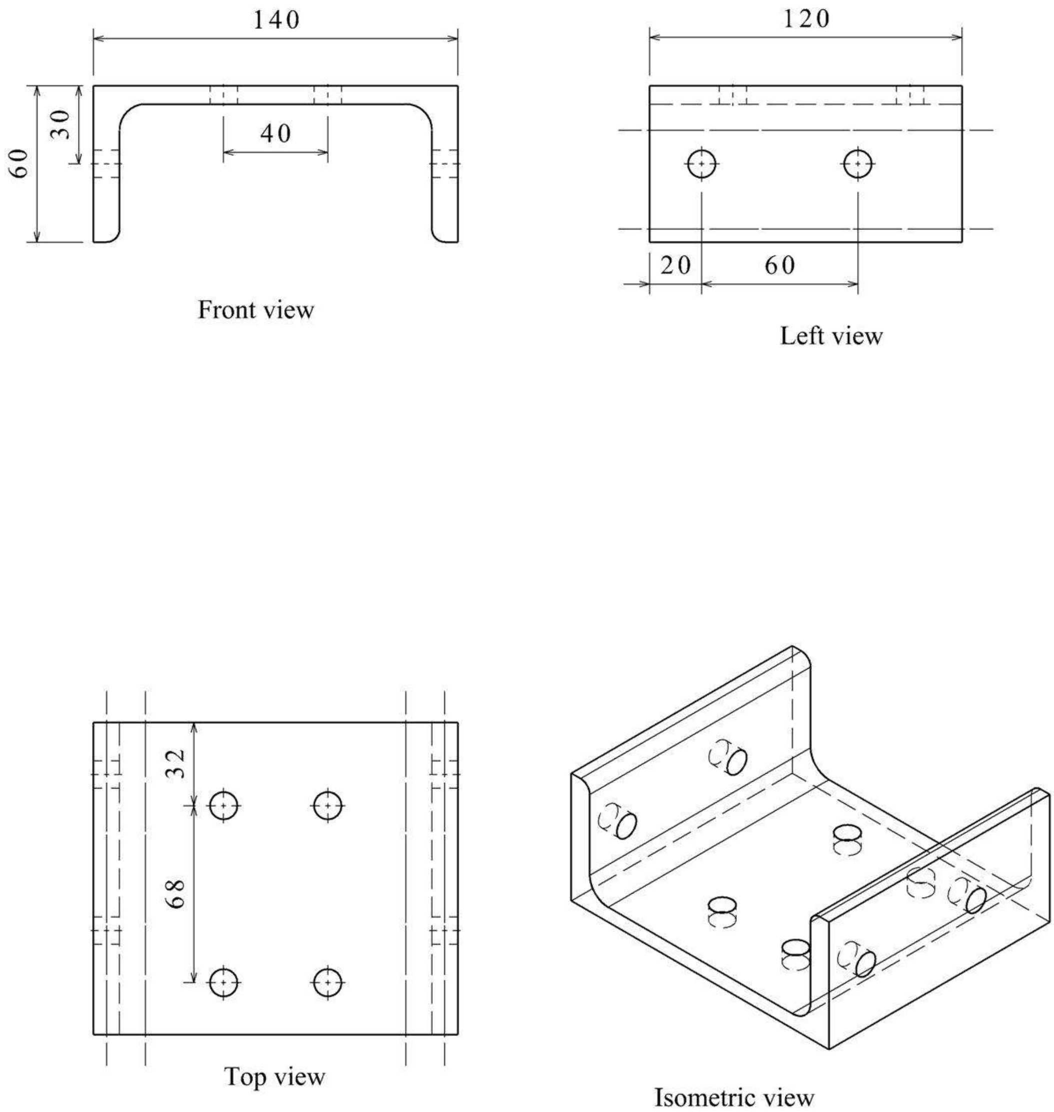
Appendix A.11: UNP profile, part of the machine frame.



Appendix A.12: Bracket used in the yarn winding system.

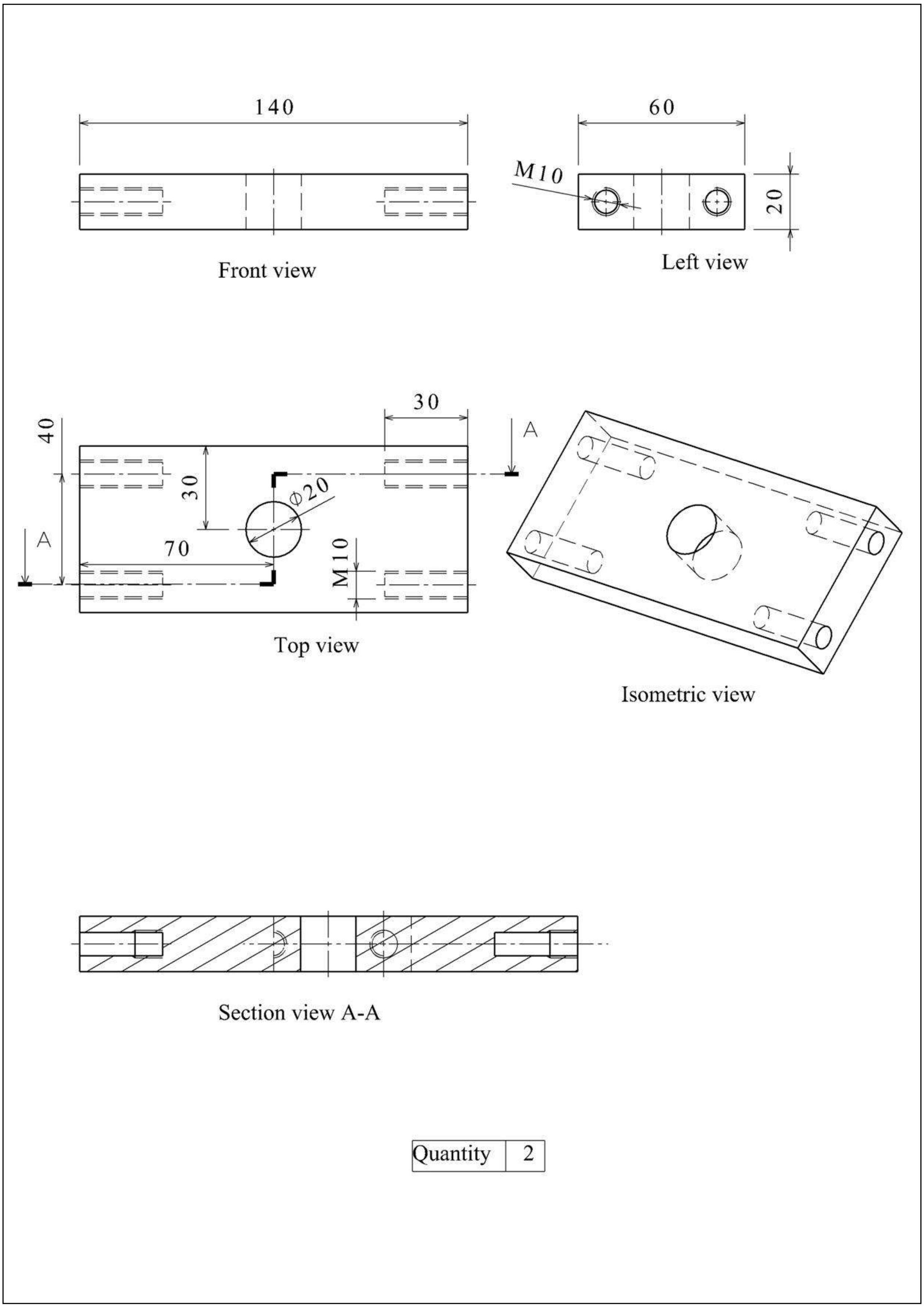


Appendix A.13: UNP profile frame component which holds the motor frames.

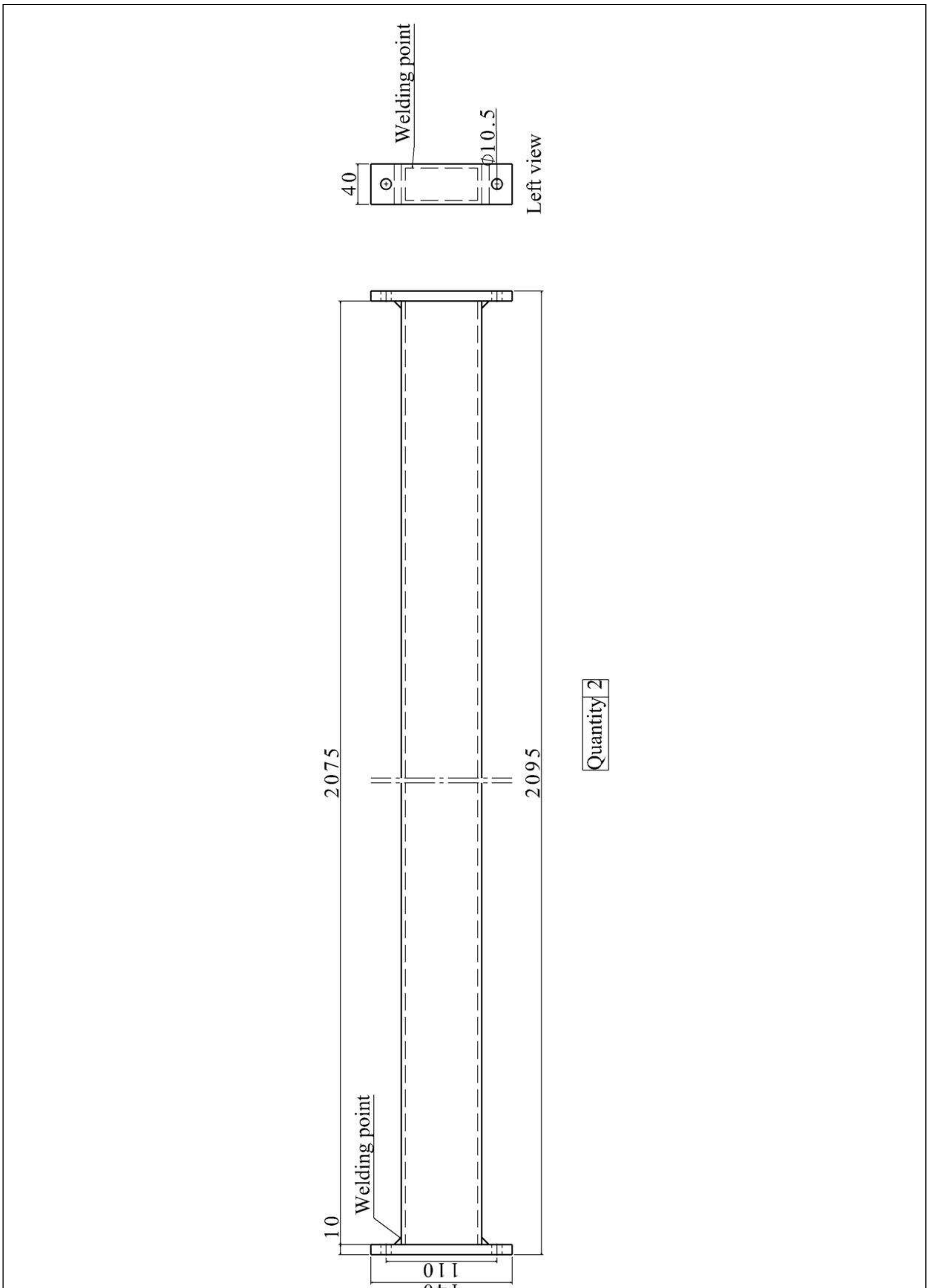


Quantity	1

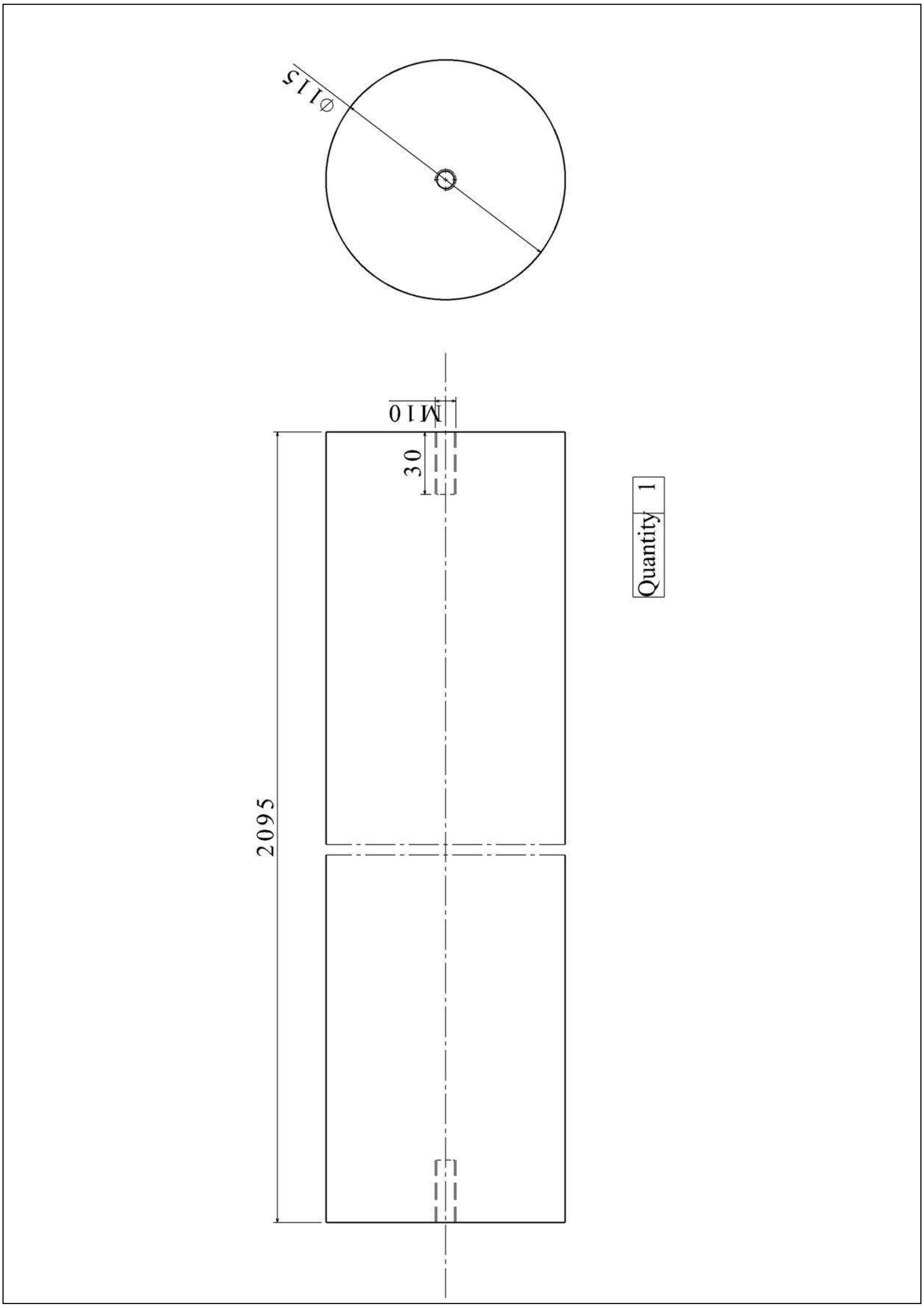
Appendix A.14: UNP profile, part of the machine frame which fixes the vertical slideways to the frame.



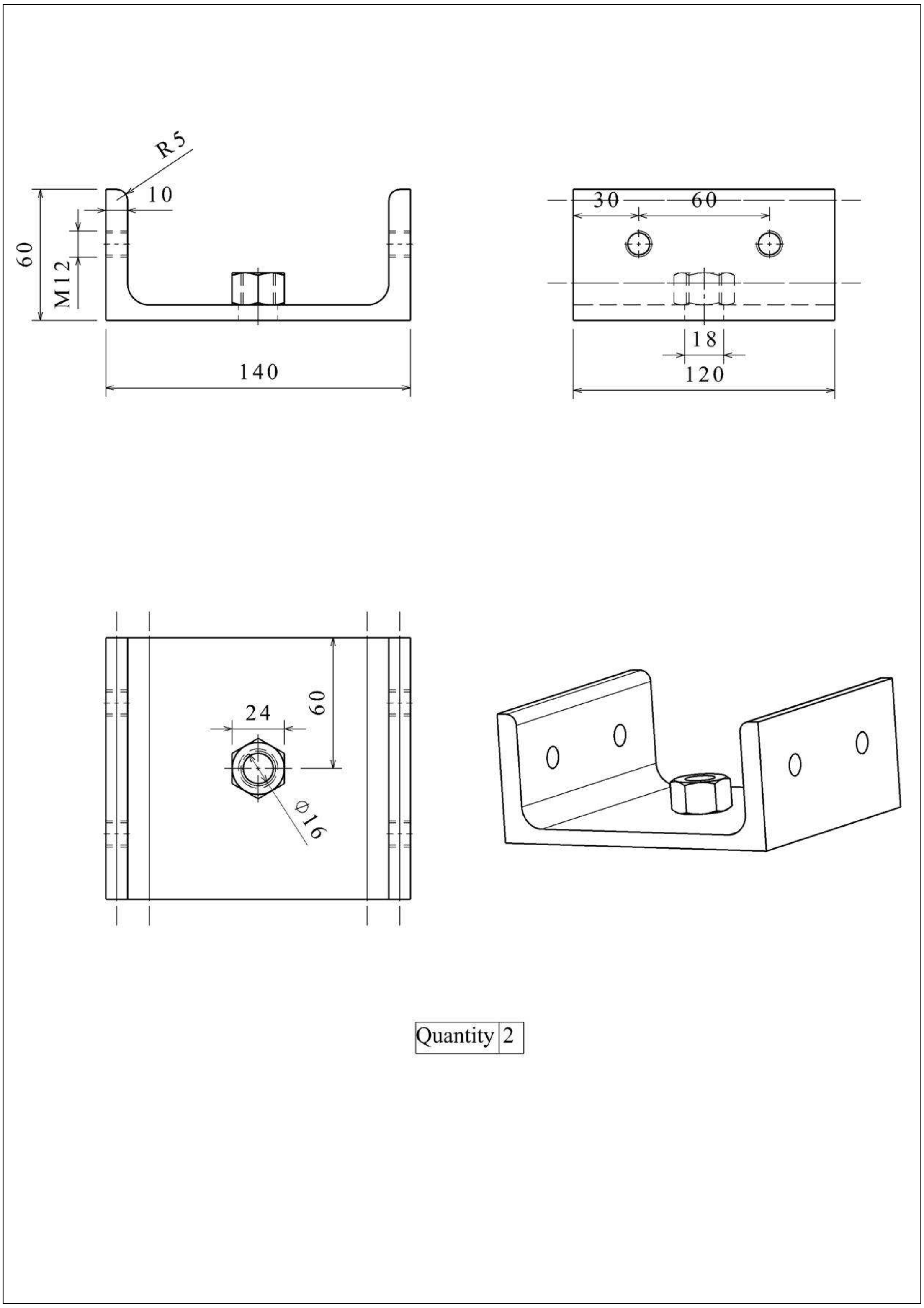
Appendix A.15: Sheet metal fixing part



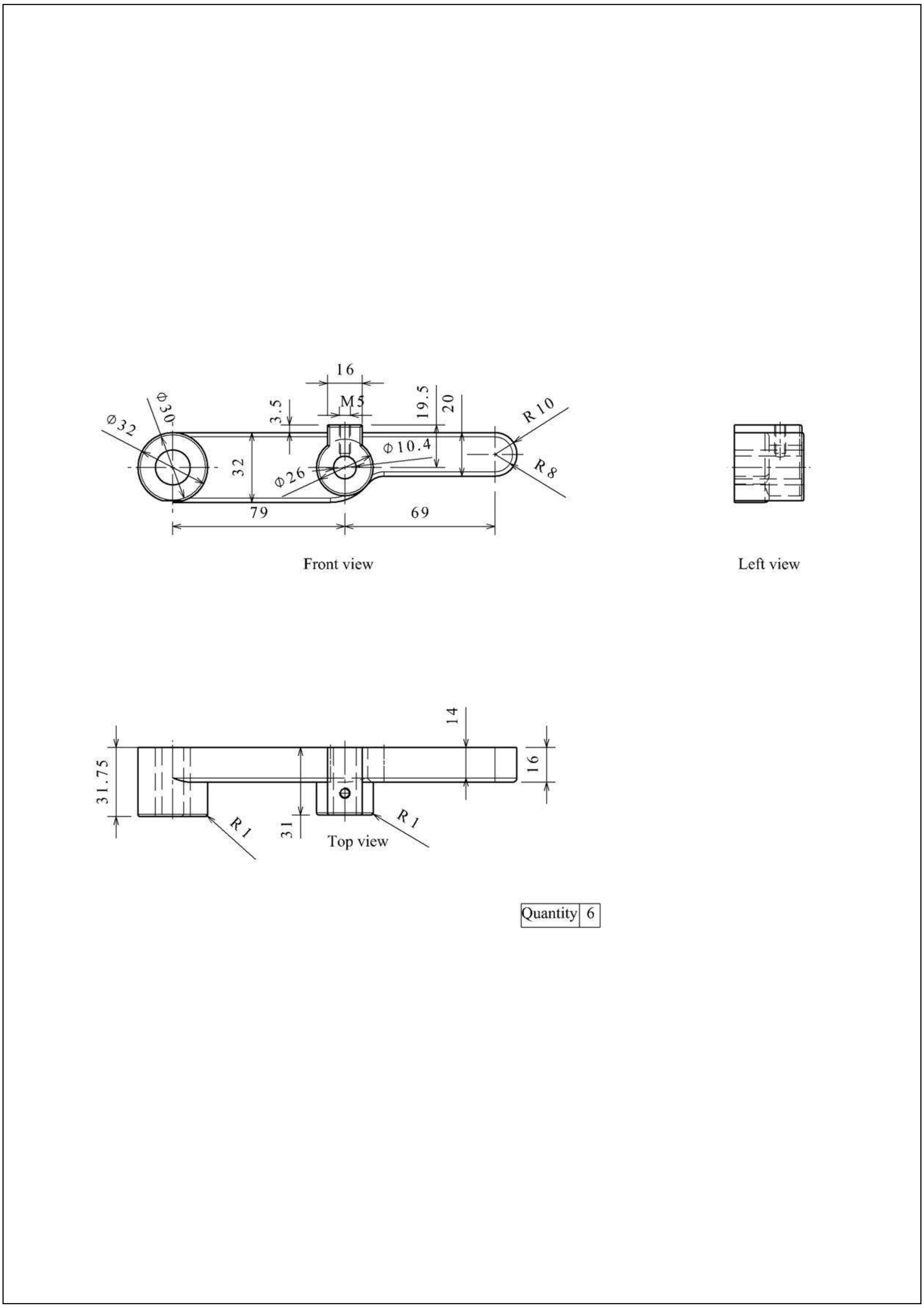
Appendix A.16: Square profile which is used to fix two sheet metal parts of the machine frame.



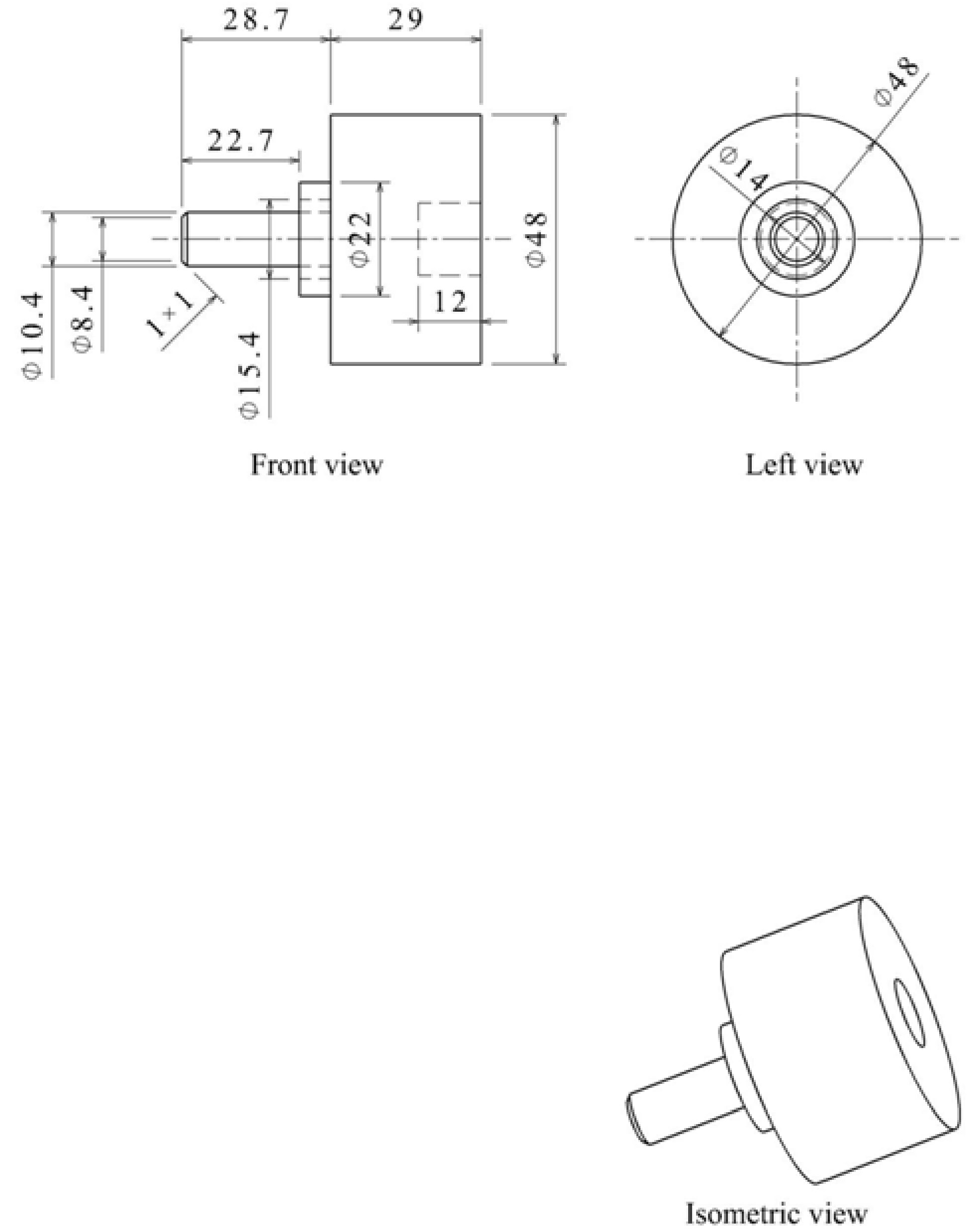
Appendix A.17: Beam made of pipe, which is used for stabilizing the main body.



Appendix A.18 UNP profile, Legs of the machine.

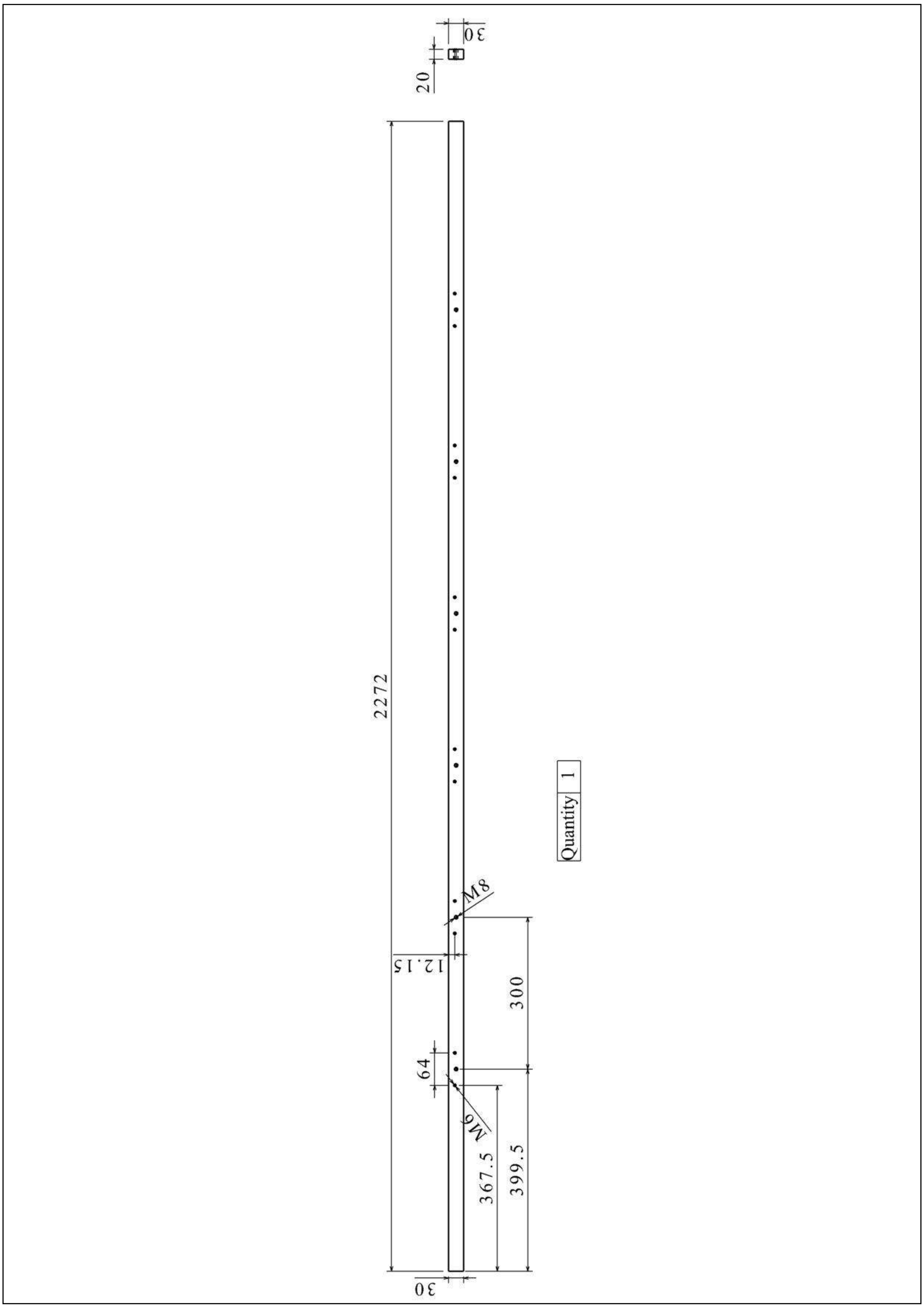


Appendix A.19: Rocker arms for the compression of yarn

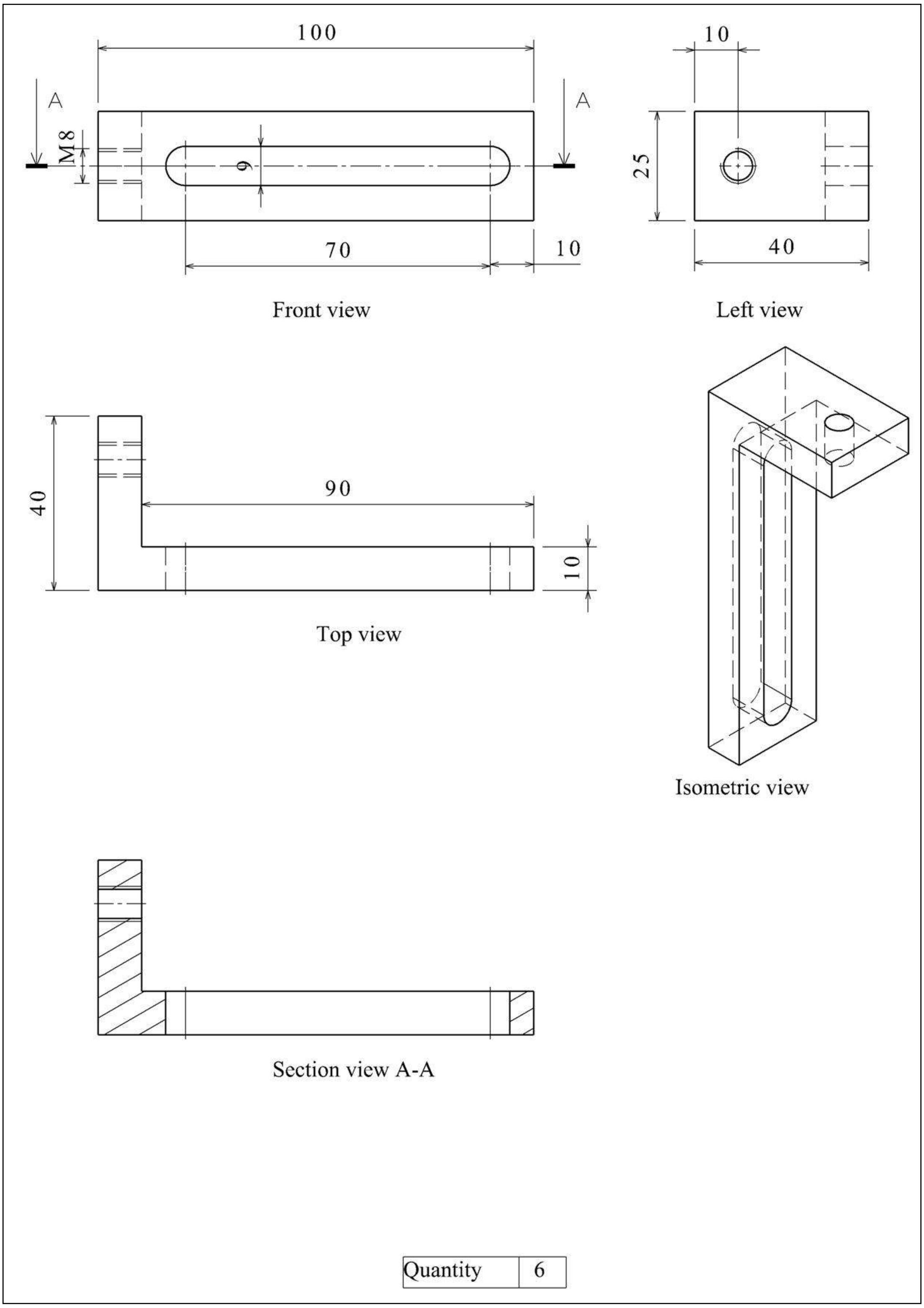


Quantity	6

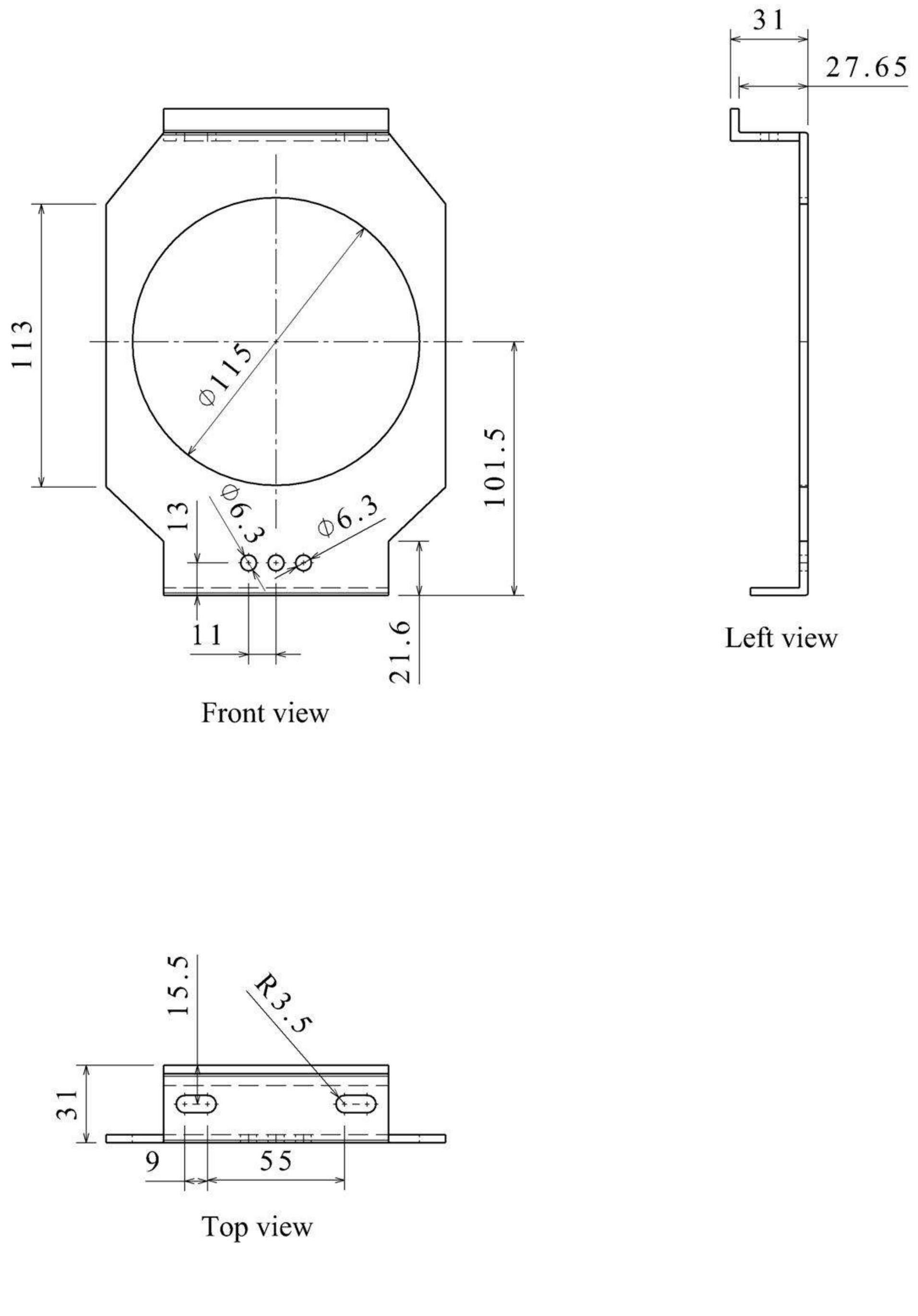
Appendix A.20: Compression rollers



Appendix A.21: Beam, as part of the spin ring frame

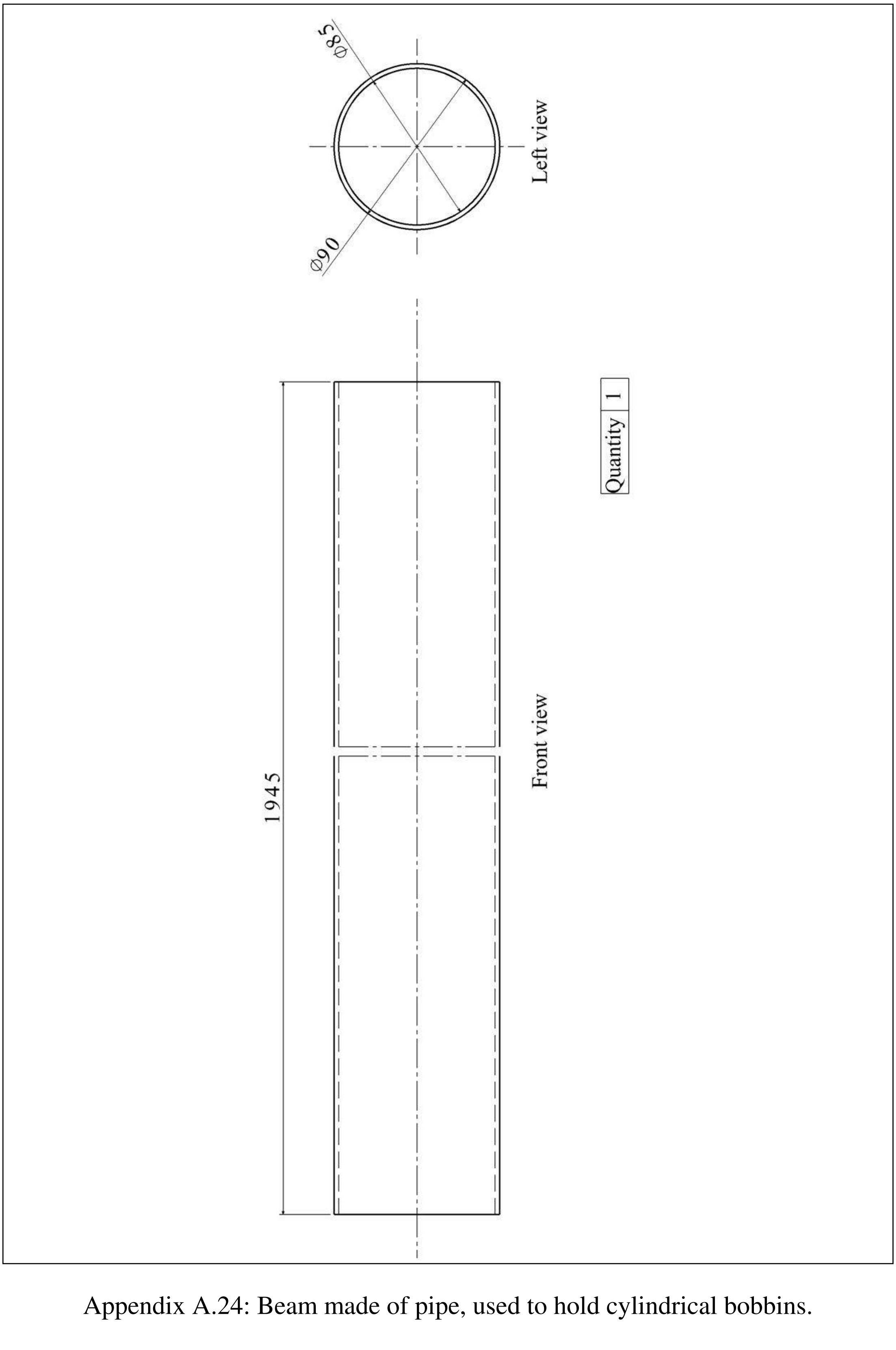


Appendix A.22: Component, part of the spin ring frame.

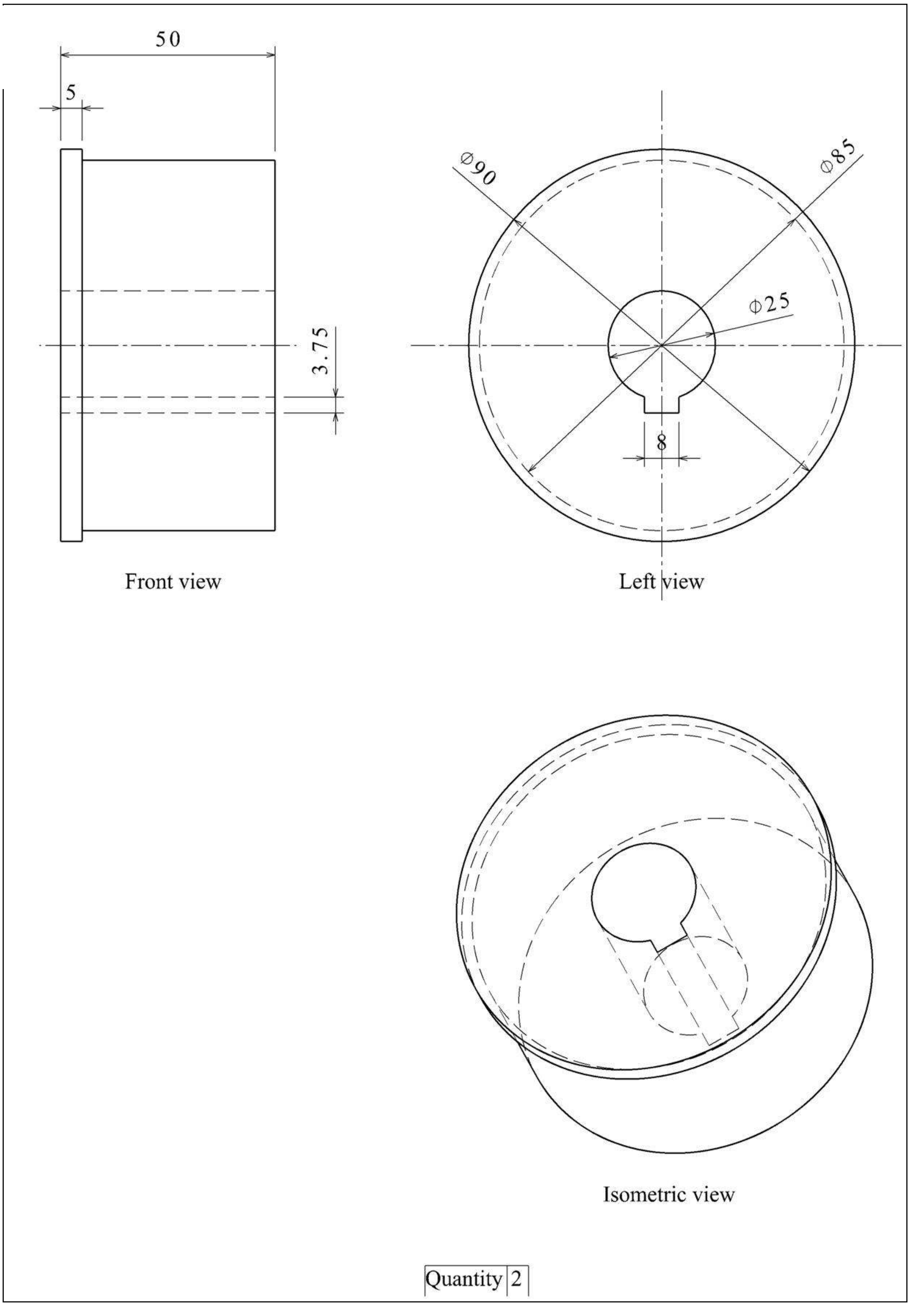


Quantity	6

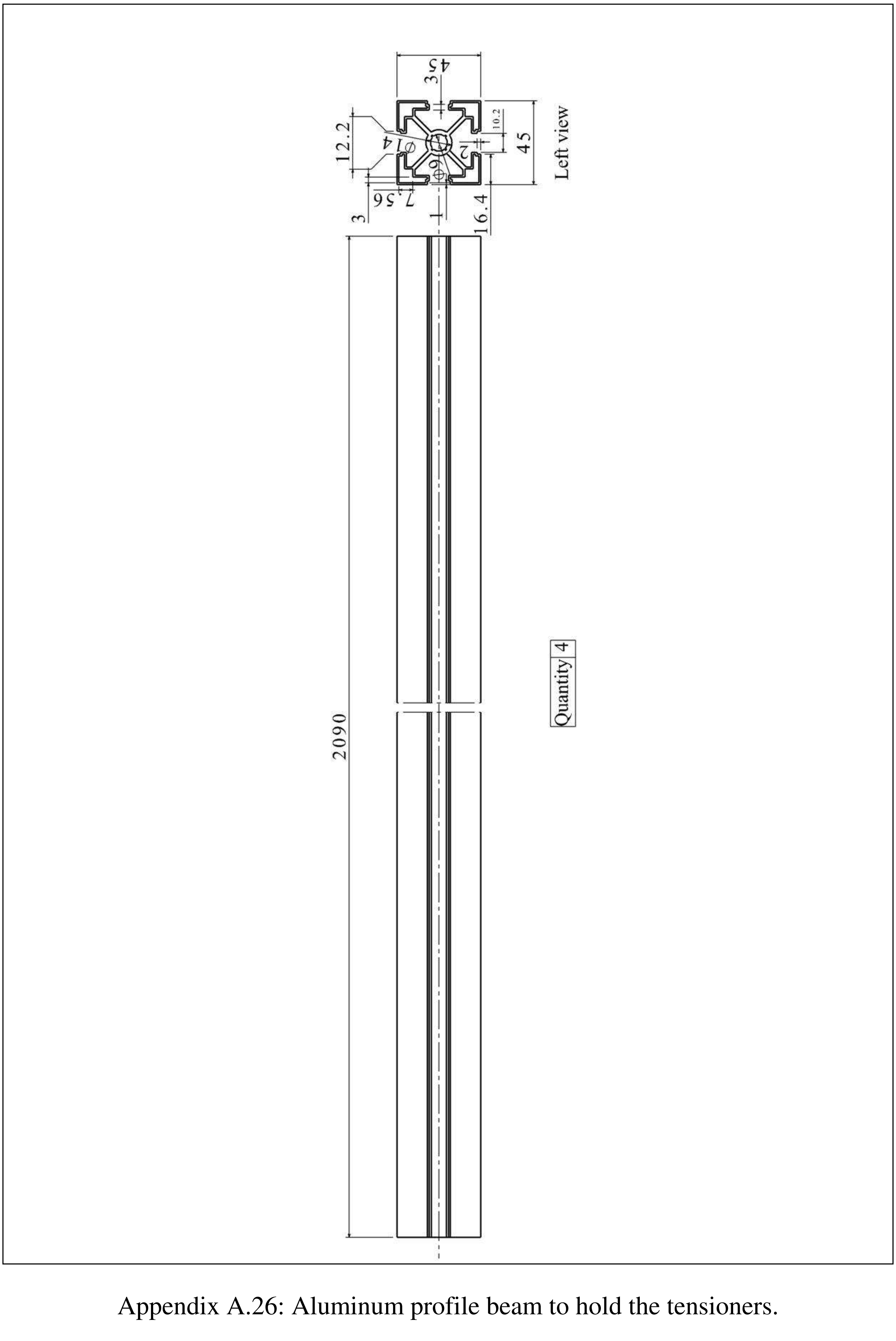
Appendix: A.23: Spin rings



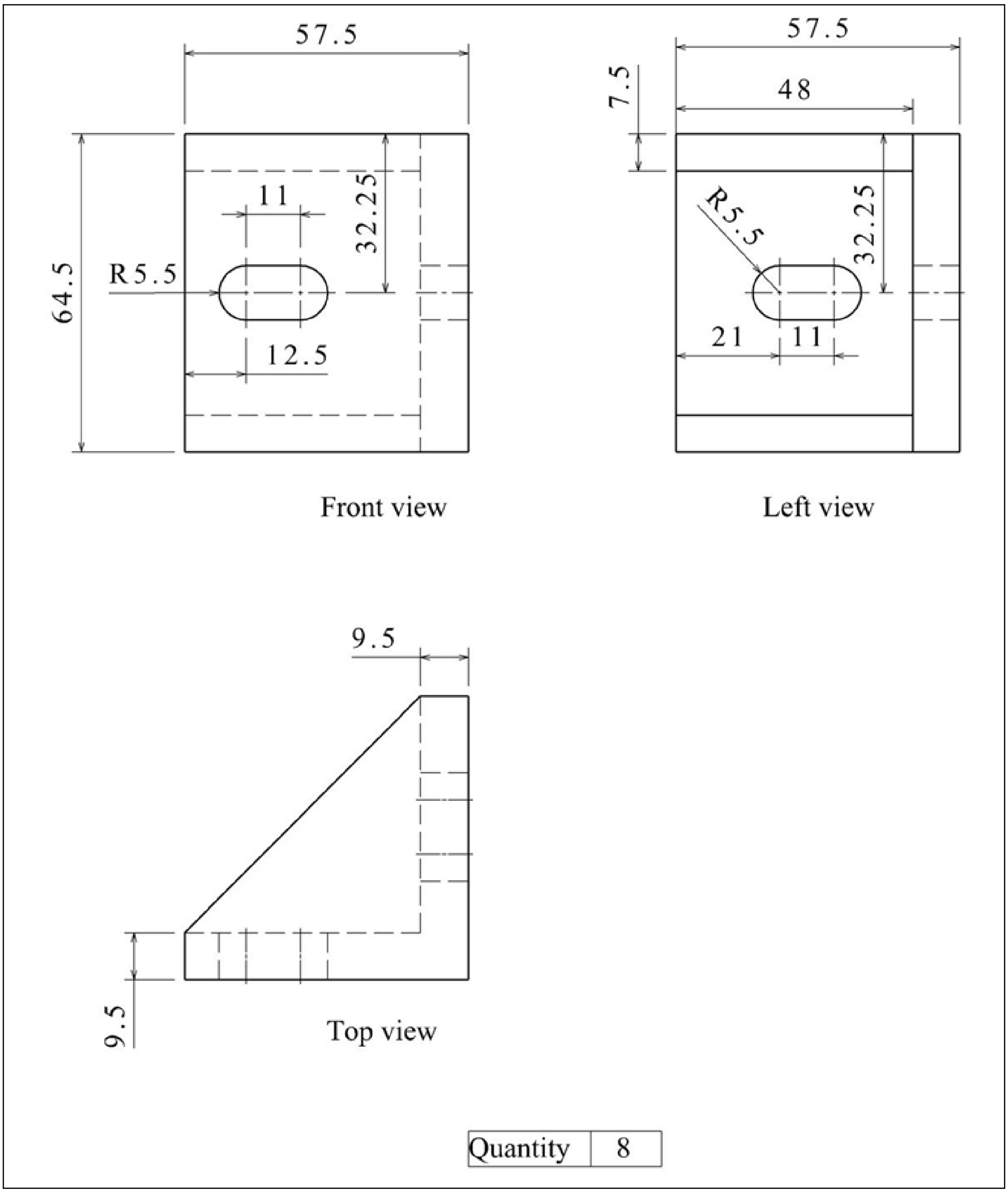
Appendix A.24: Beam made of pipe, used to hold cylindrical bobbins.



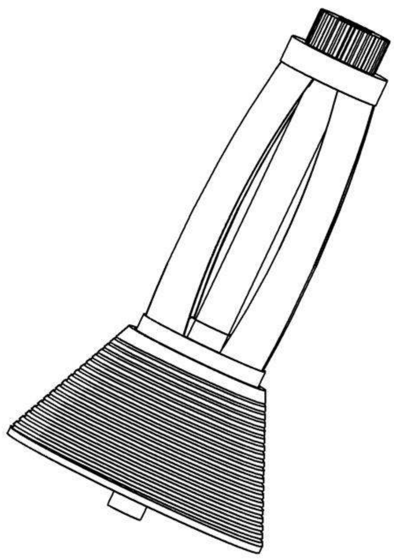
Appendix A.25: End covers of the bobbin holder, made of pipe.



Appendix A.26: Aluminum profile beam to hold the tensioners.

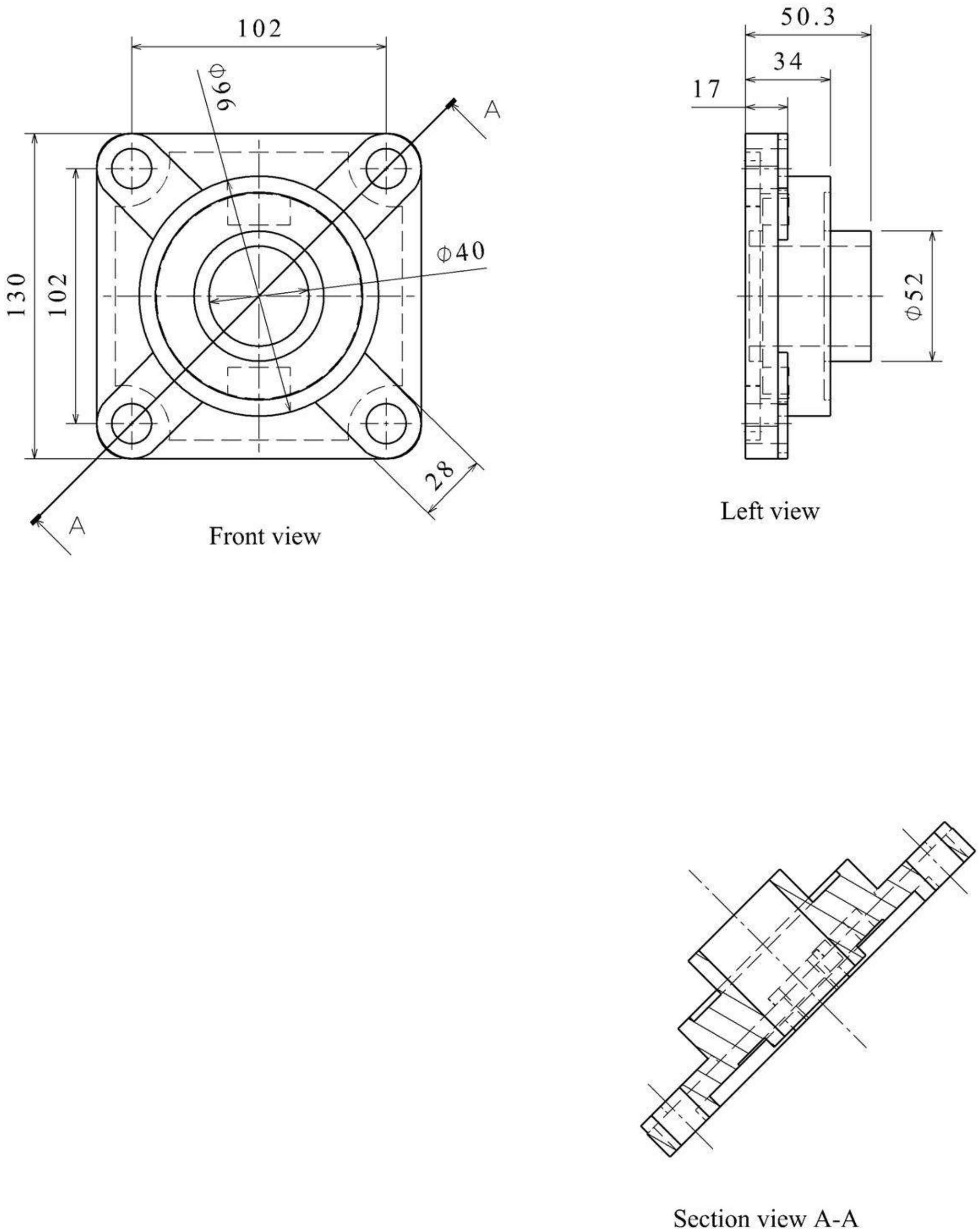


Appendix A.27: Brackets for fixing aluminum beams to the 5 mm sheet metal side plates of the machine frame.



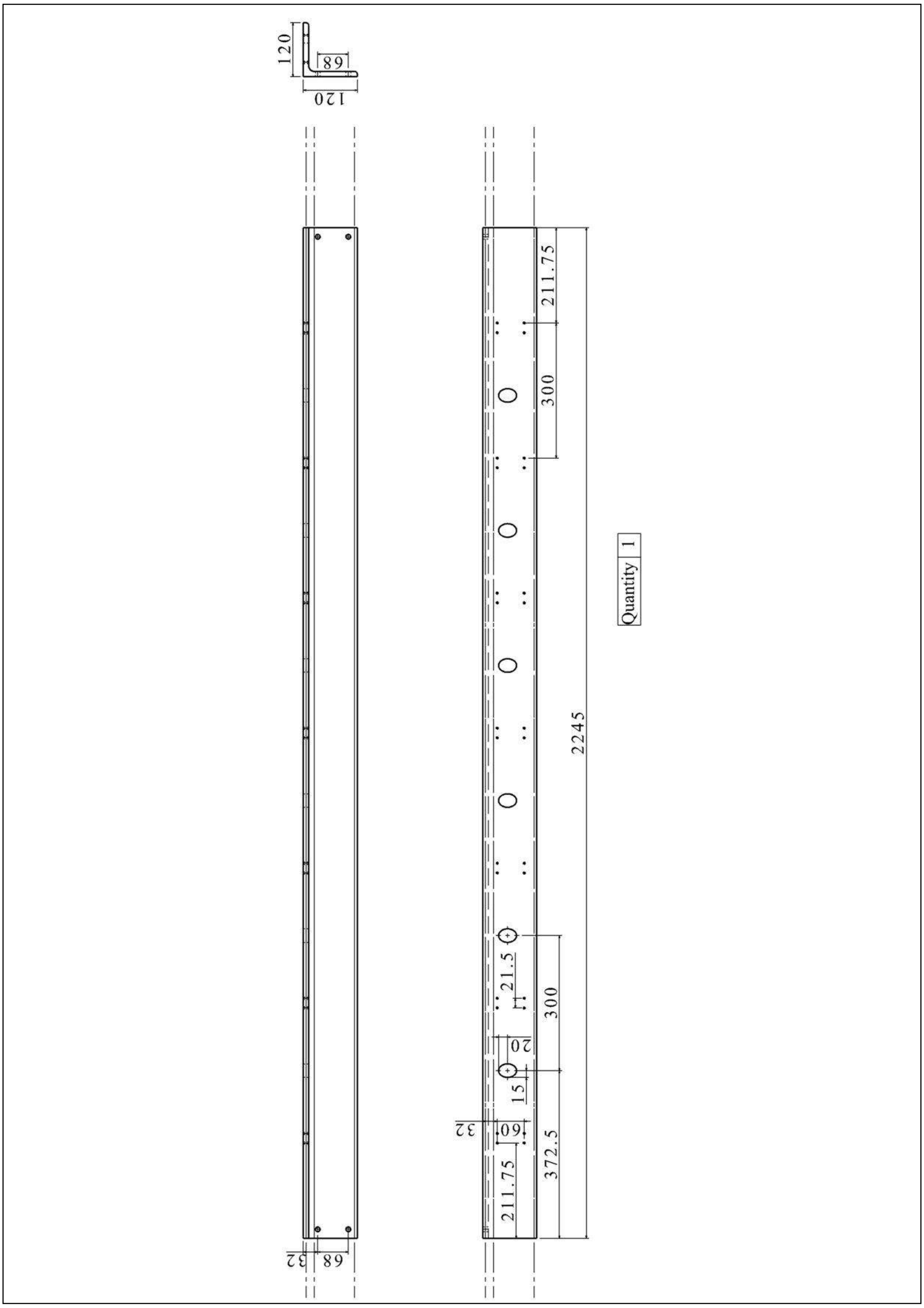
Quantity	24

Appendix A.28: Part of the creel where bobbin is attached

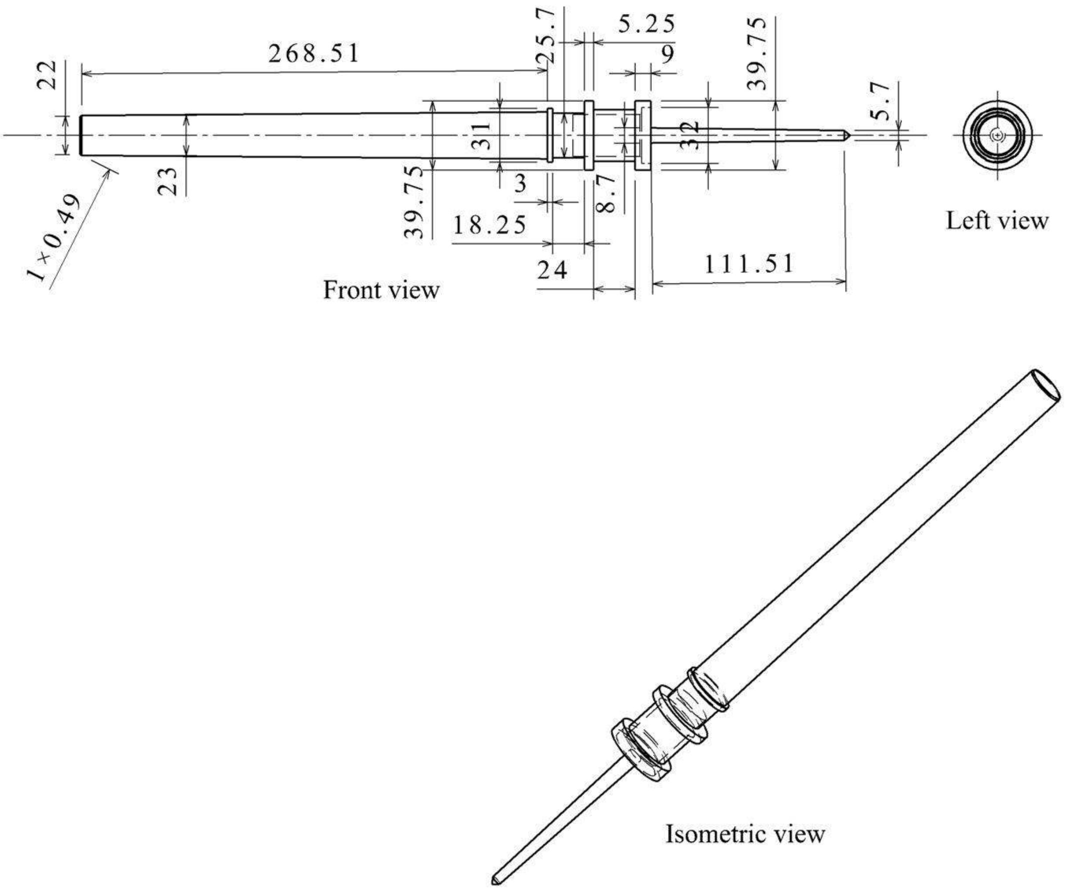


Quantity	2

Appendix A.29: F type bearings to center the 40 mm diameter main shaft.

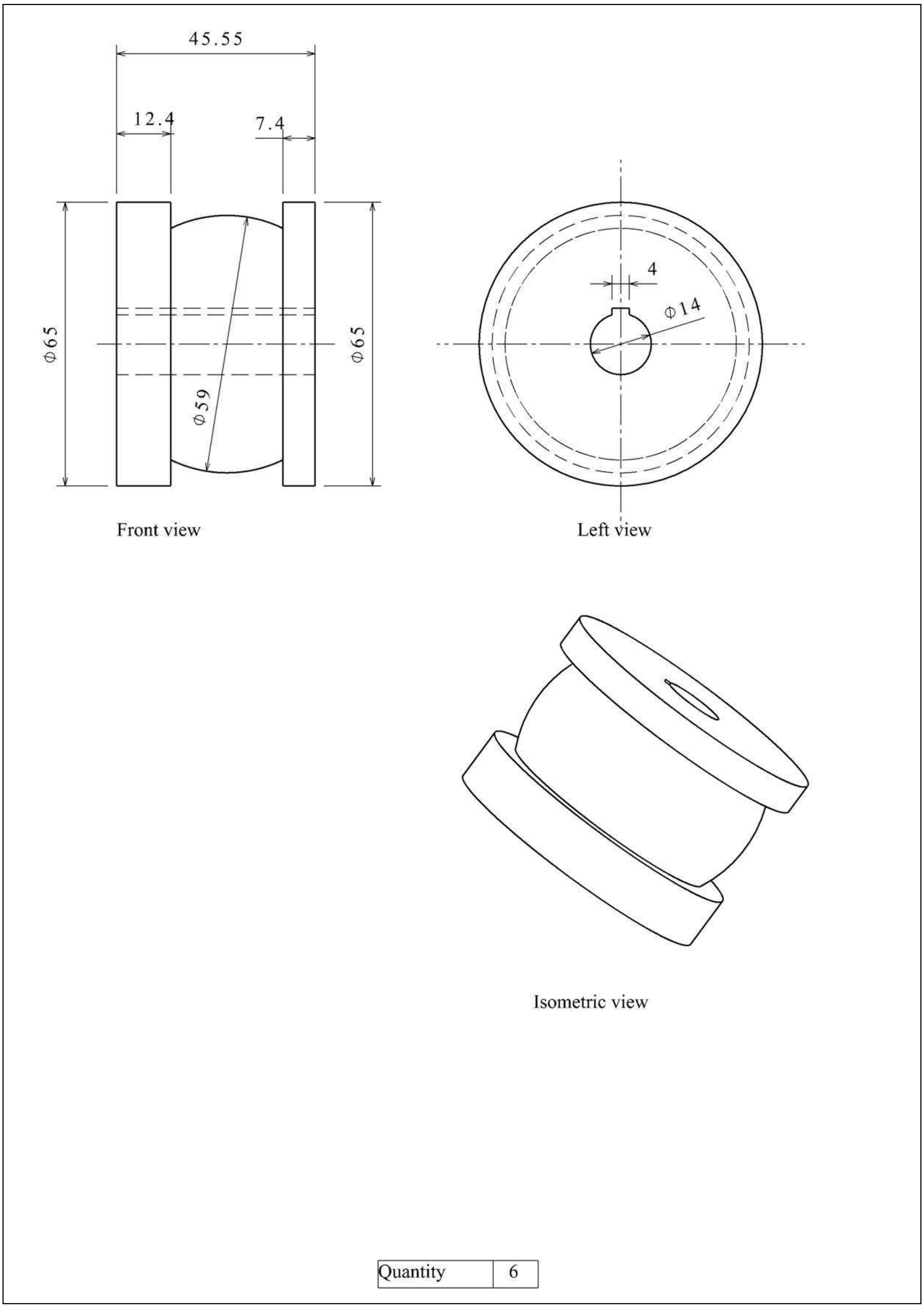


Appendix A.30: Beam made of equal arm angle for holding the spindles and their accessories.

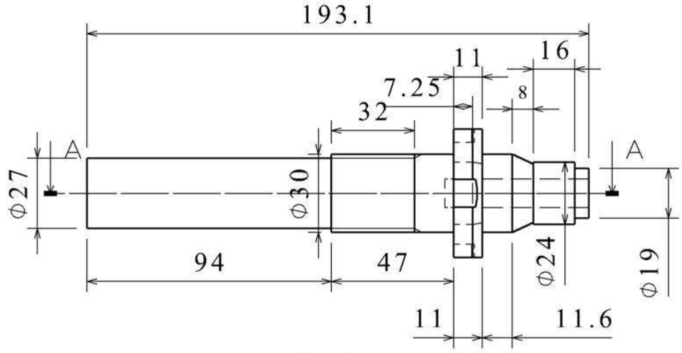


Quantity	6

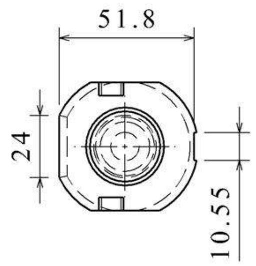
Appendix A.31: Spindle



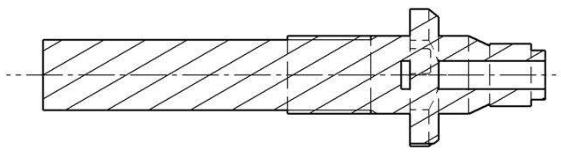
Appendix A.32: Barreling pulley at the tip of motors driving the spindles used for power transmission via flat belt.



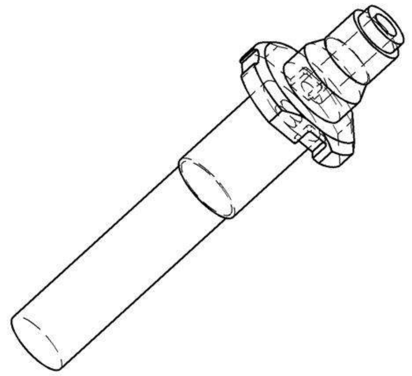
Front view



Left view



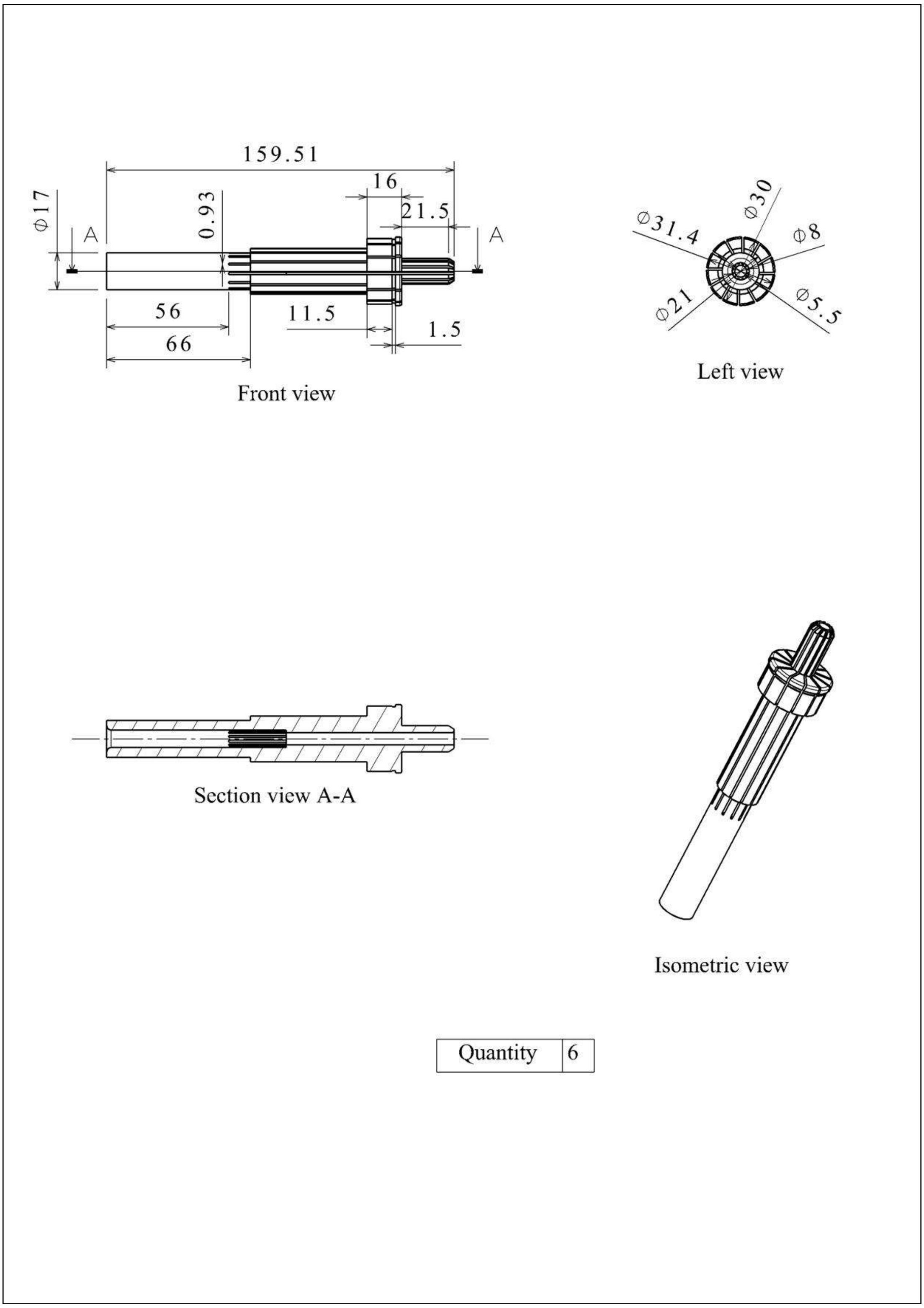
Section view A-A



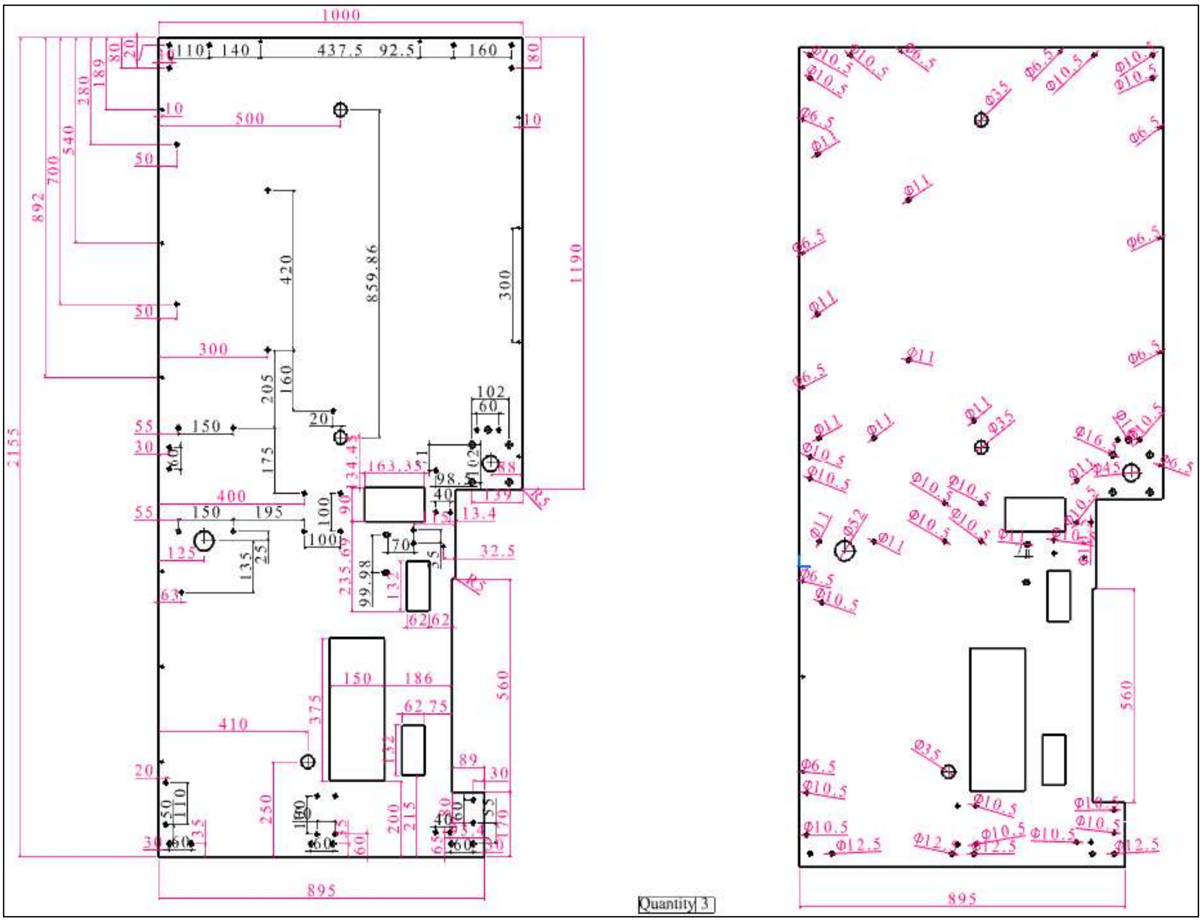
Isometric view

Quantity	6

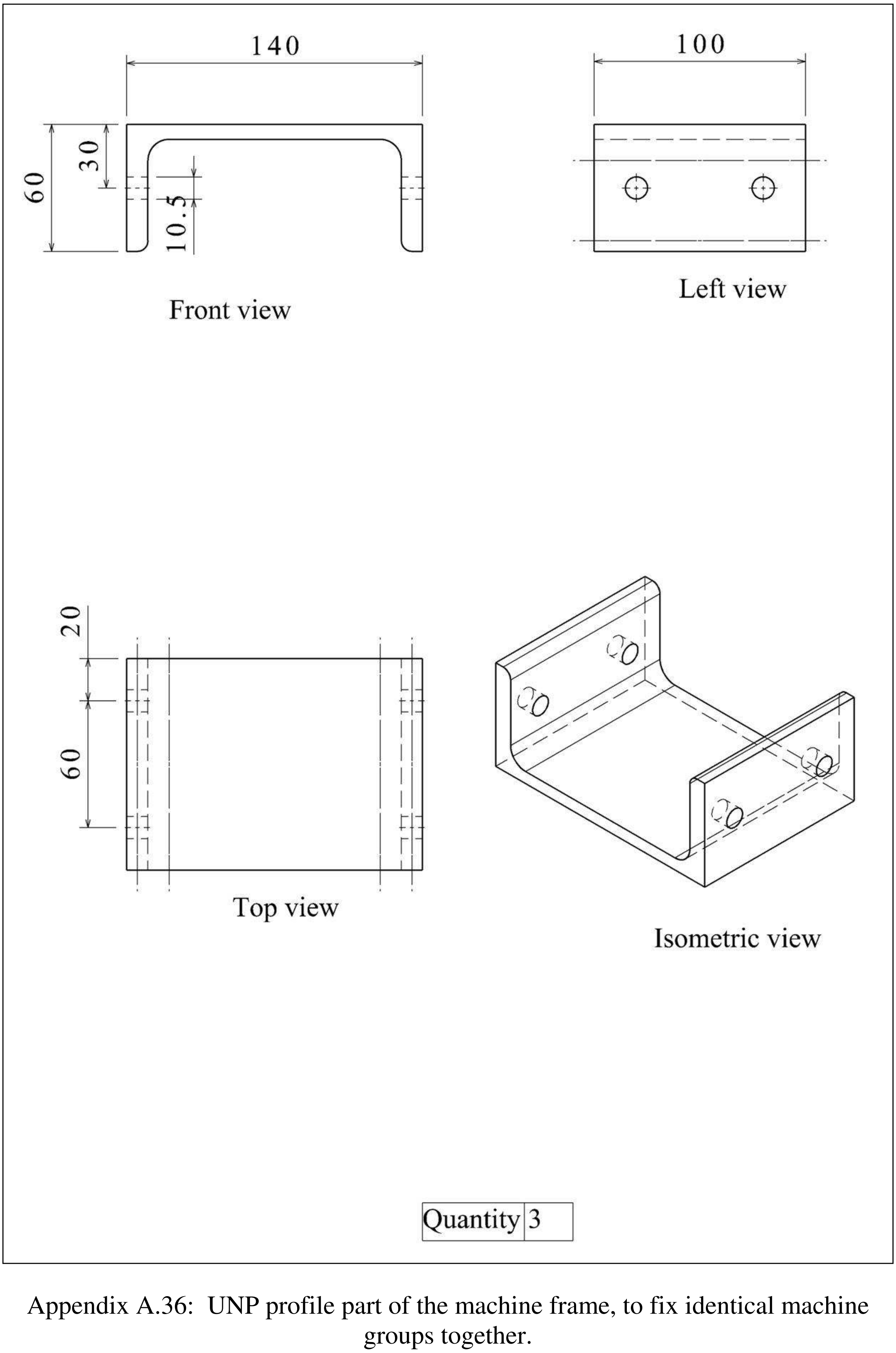
Appendix A.33: Spindle holders.



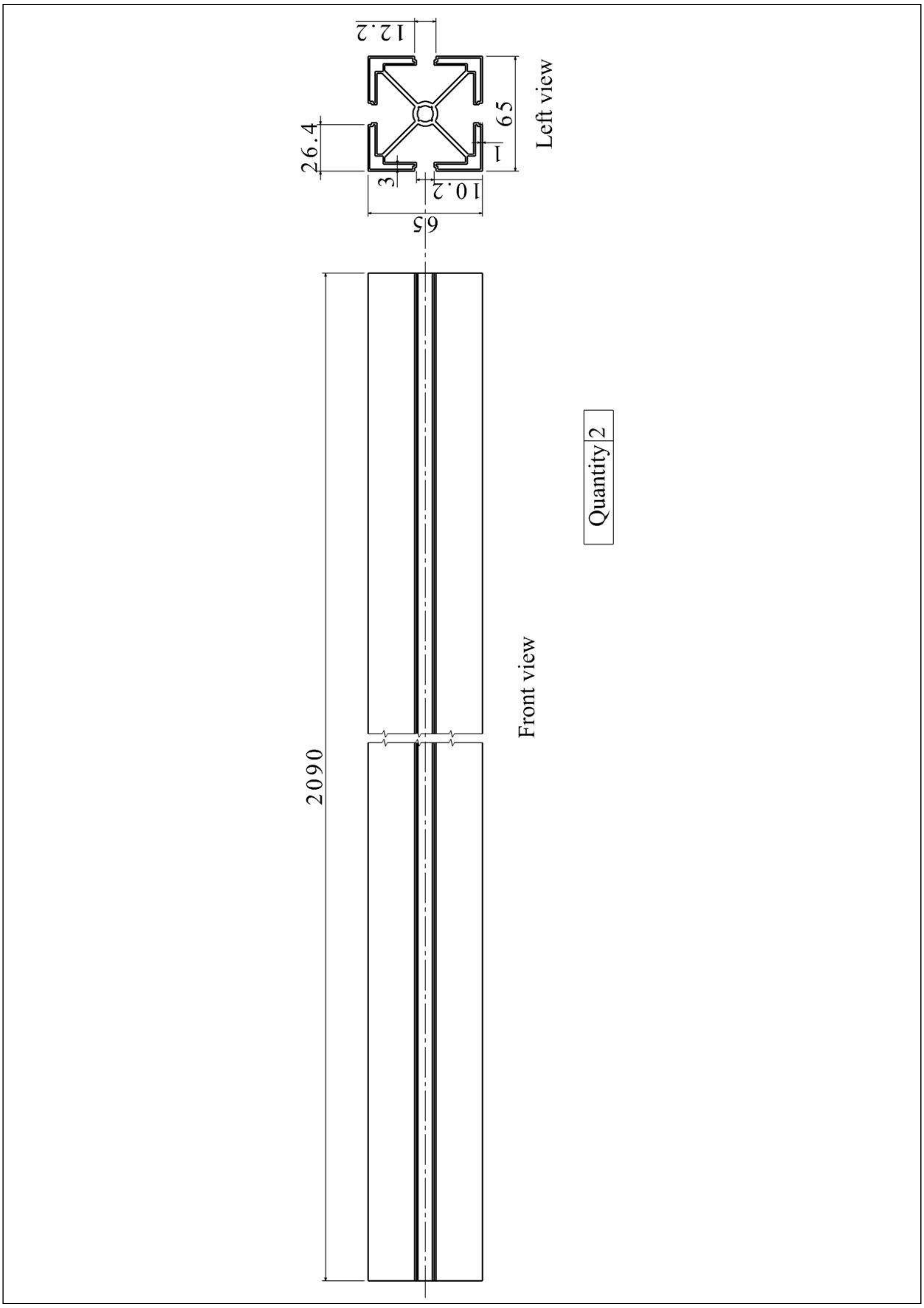
Appendix A.34: Circular needle bed.



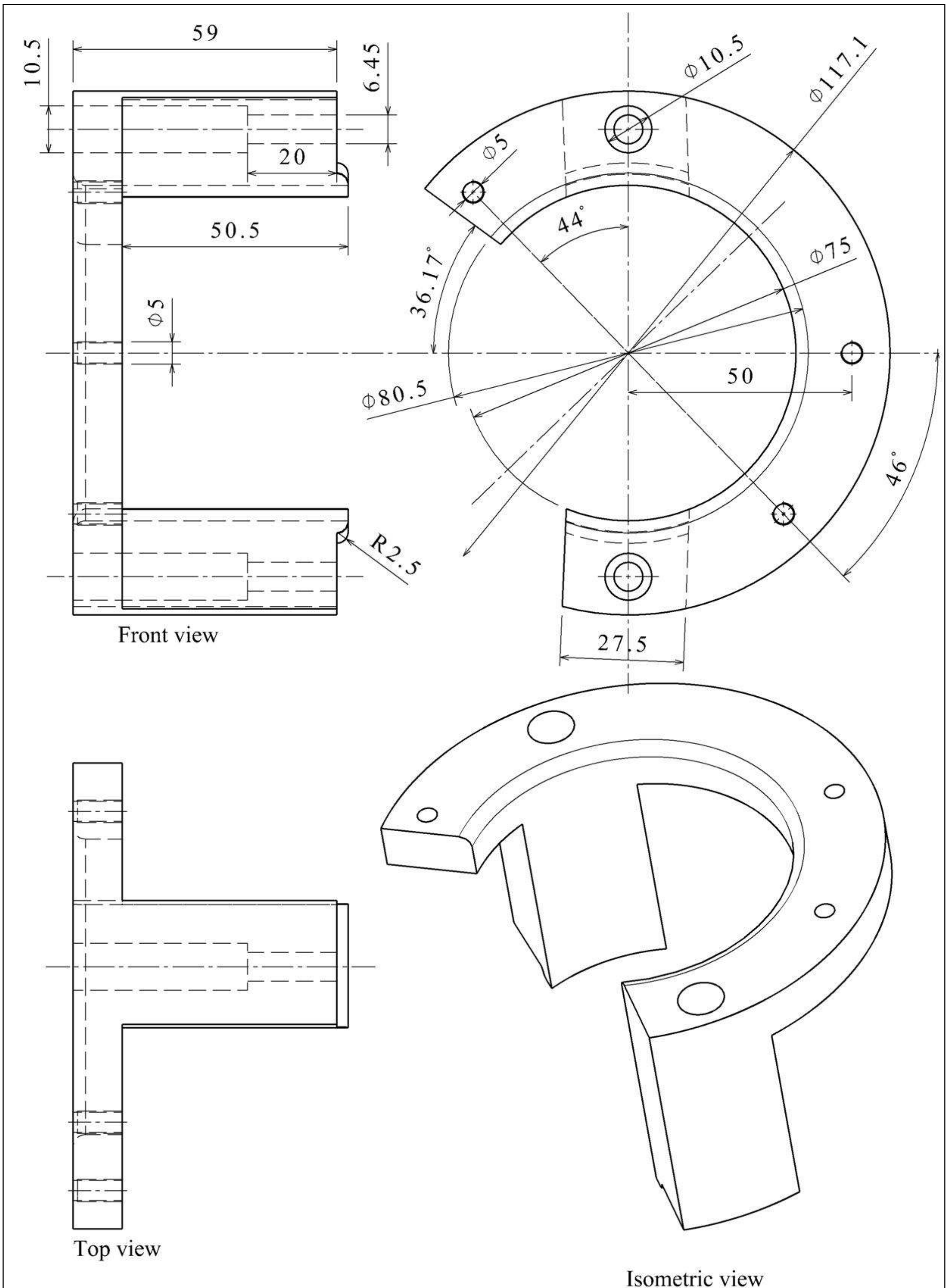
Appendix.35: 5 mm sheet metal side plates of the machine frame.



Appendix A.36: UNP profile part of the machine frame, to fix identical machine groups together.

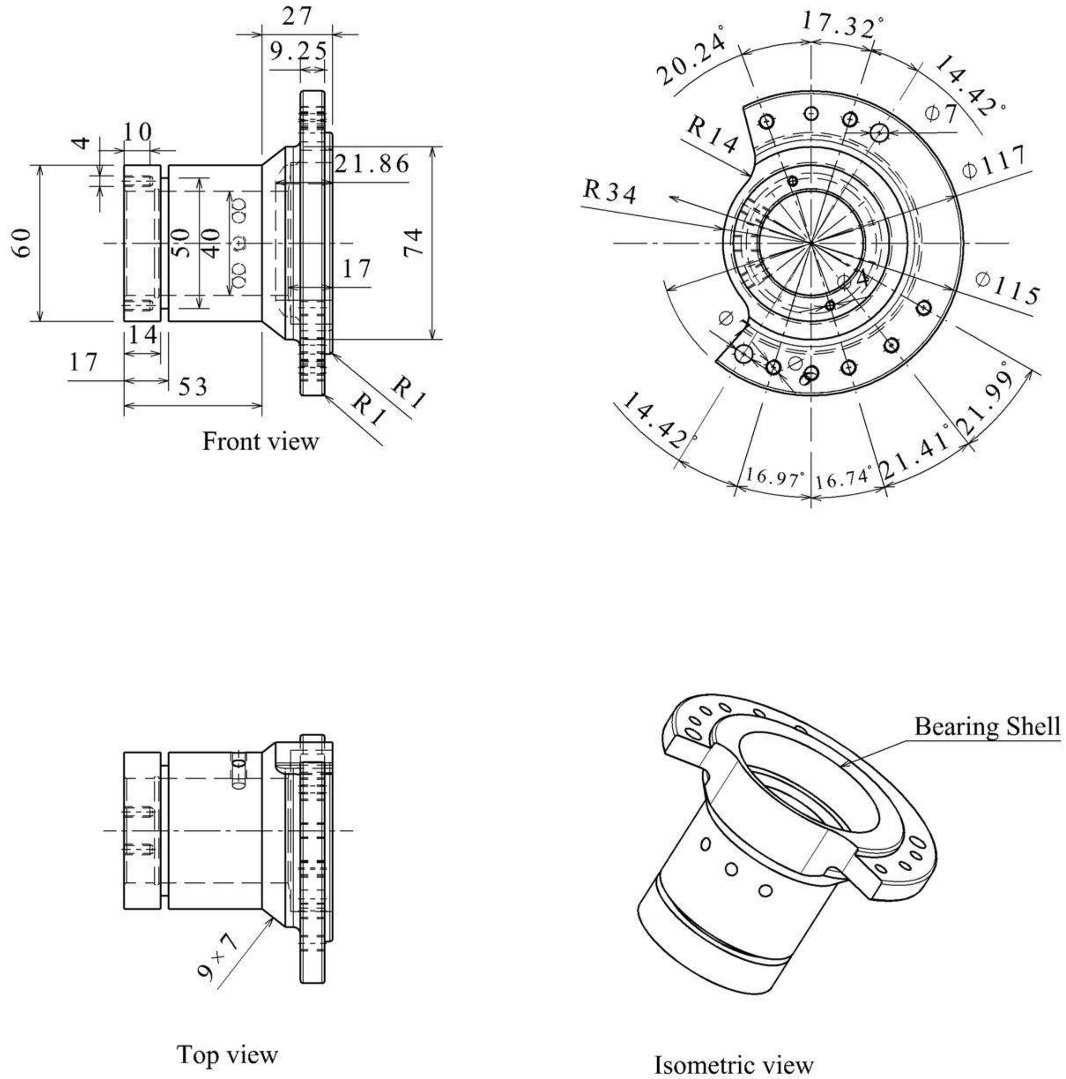


Appendix A.37 Aluminum profile beam used to support components of the knitting heads.



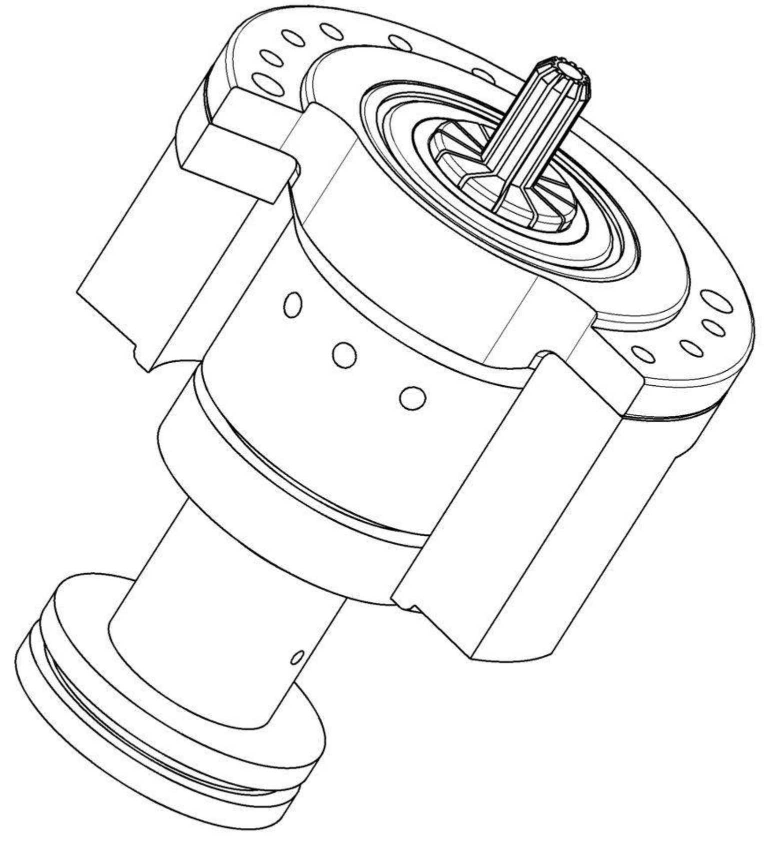
Quantity	6

Appendix A.38: Frame for the knitting head.

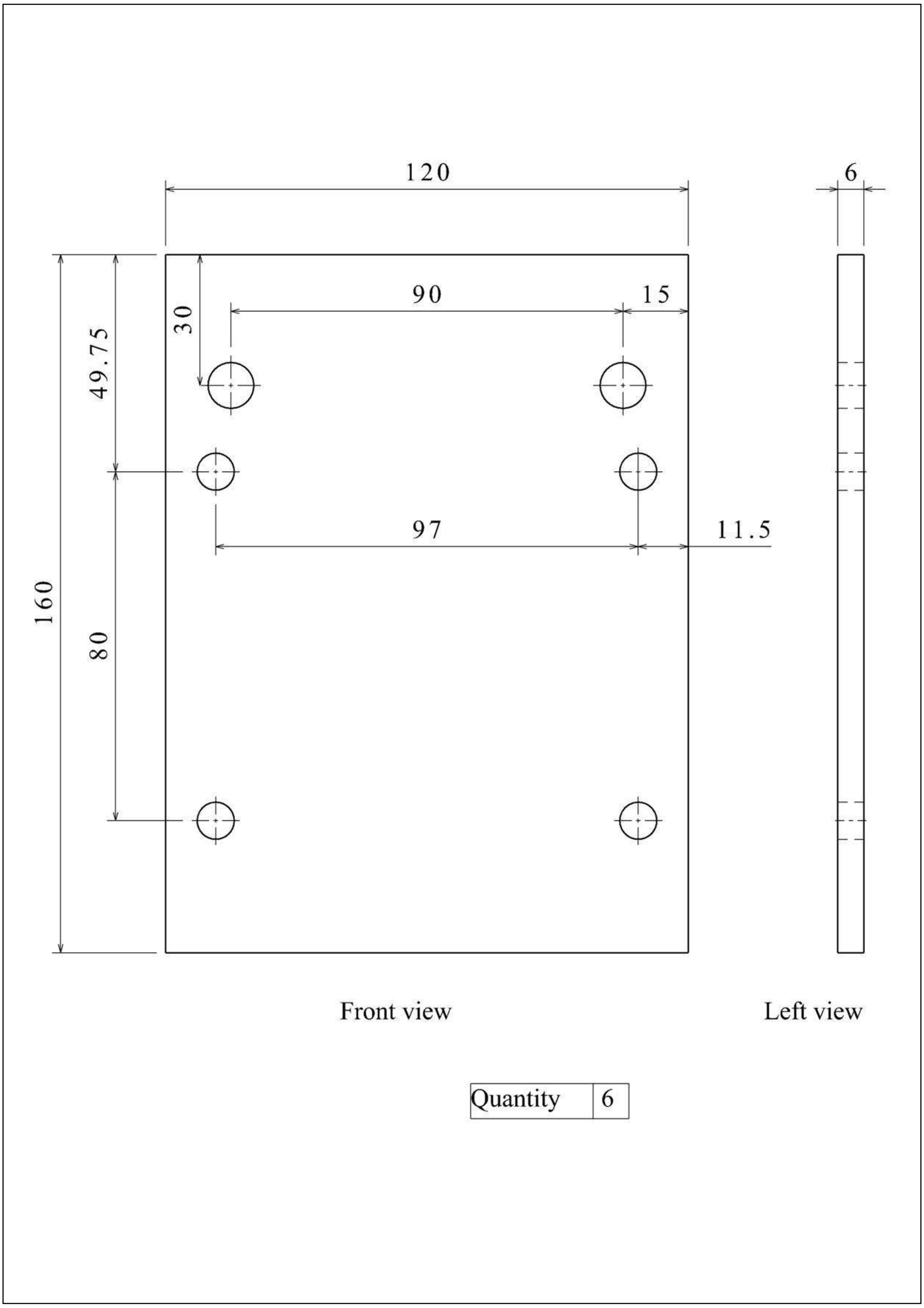


Quantity	6

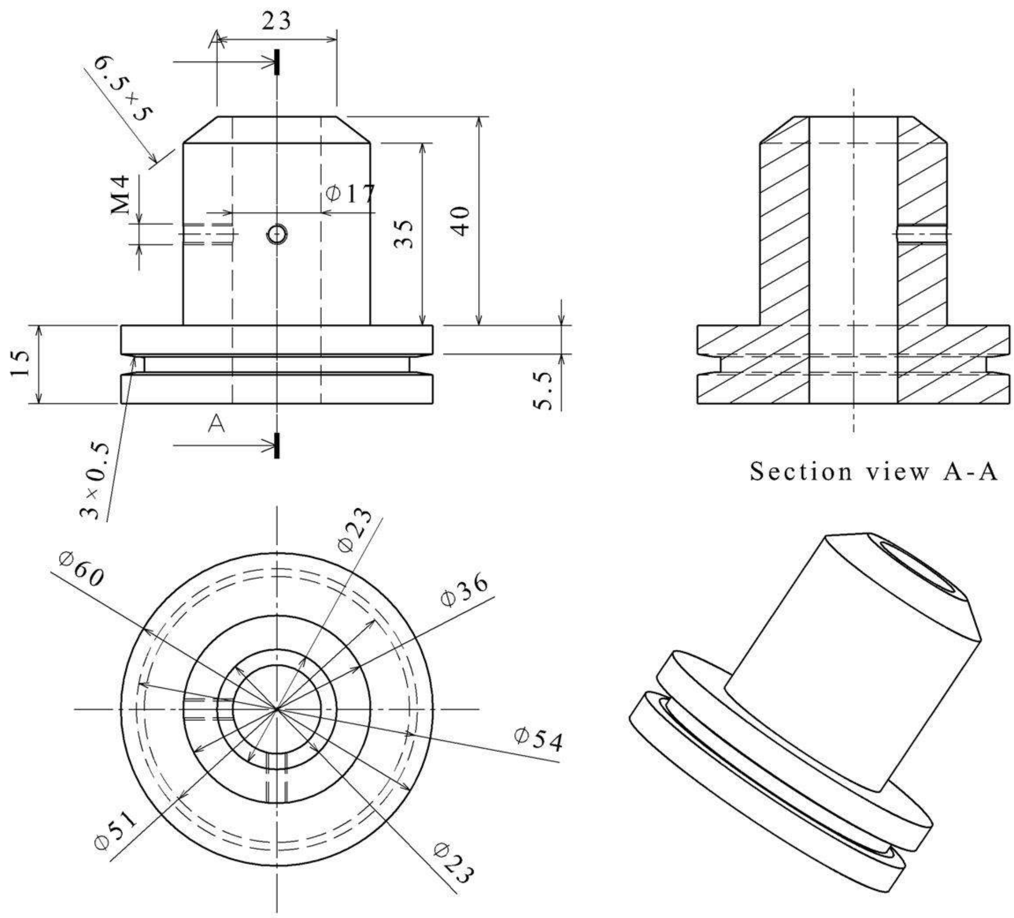
Appendix A.39: Bushing which holds the cam parts together.



Appendix A.40: Assembly drawing for the knitting head.

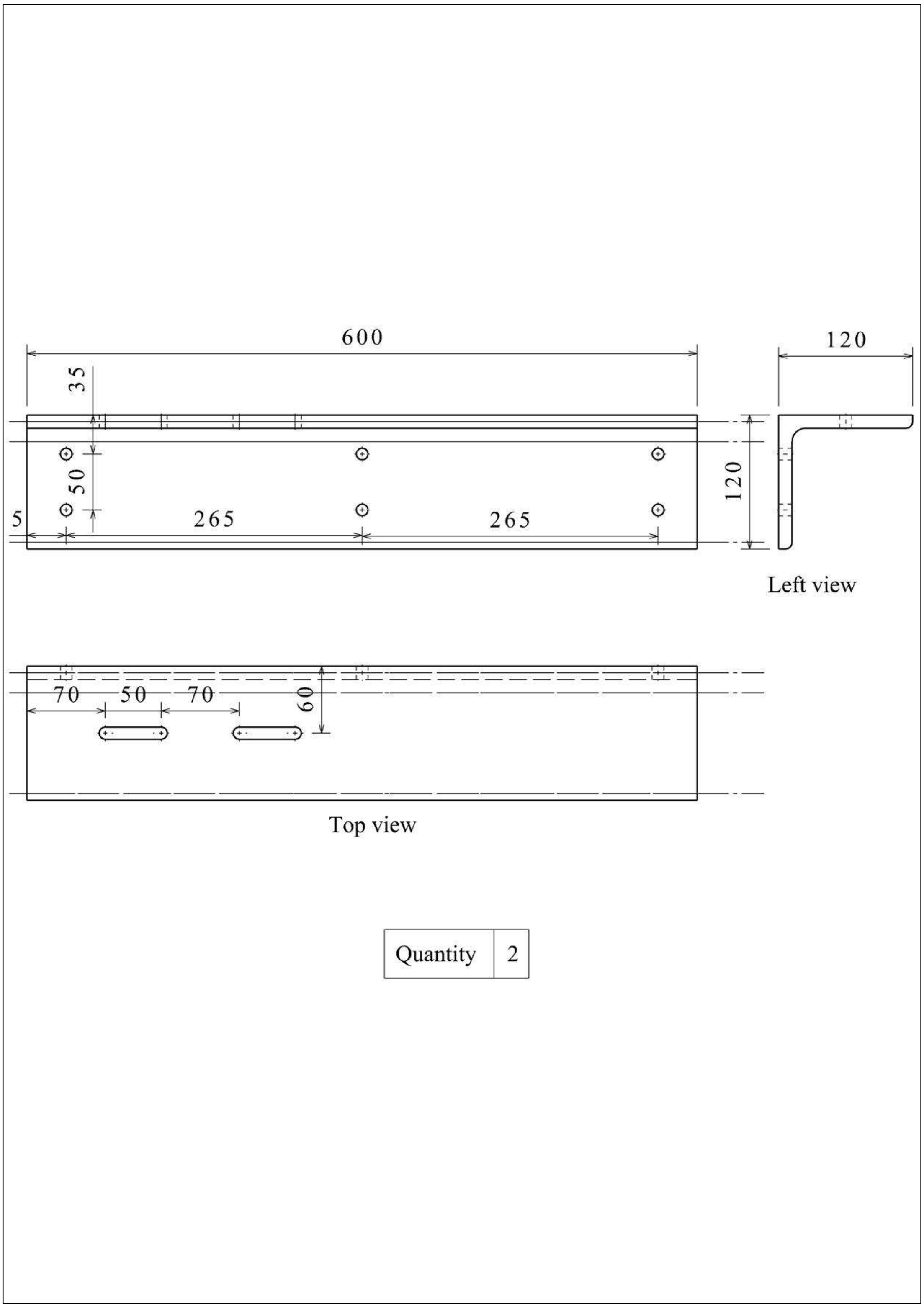


Appendix A.41: 6 mm plates used to fix the knitting head motors to the machine frame.

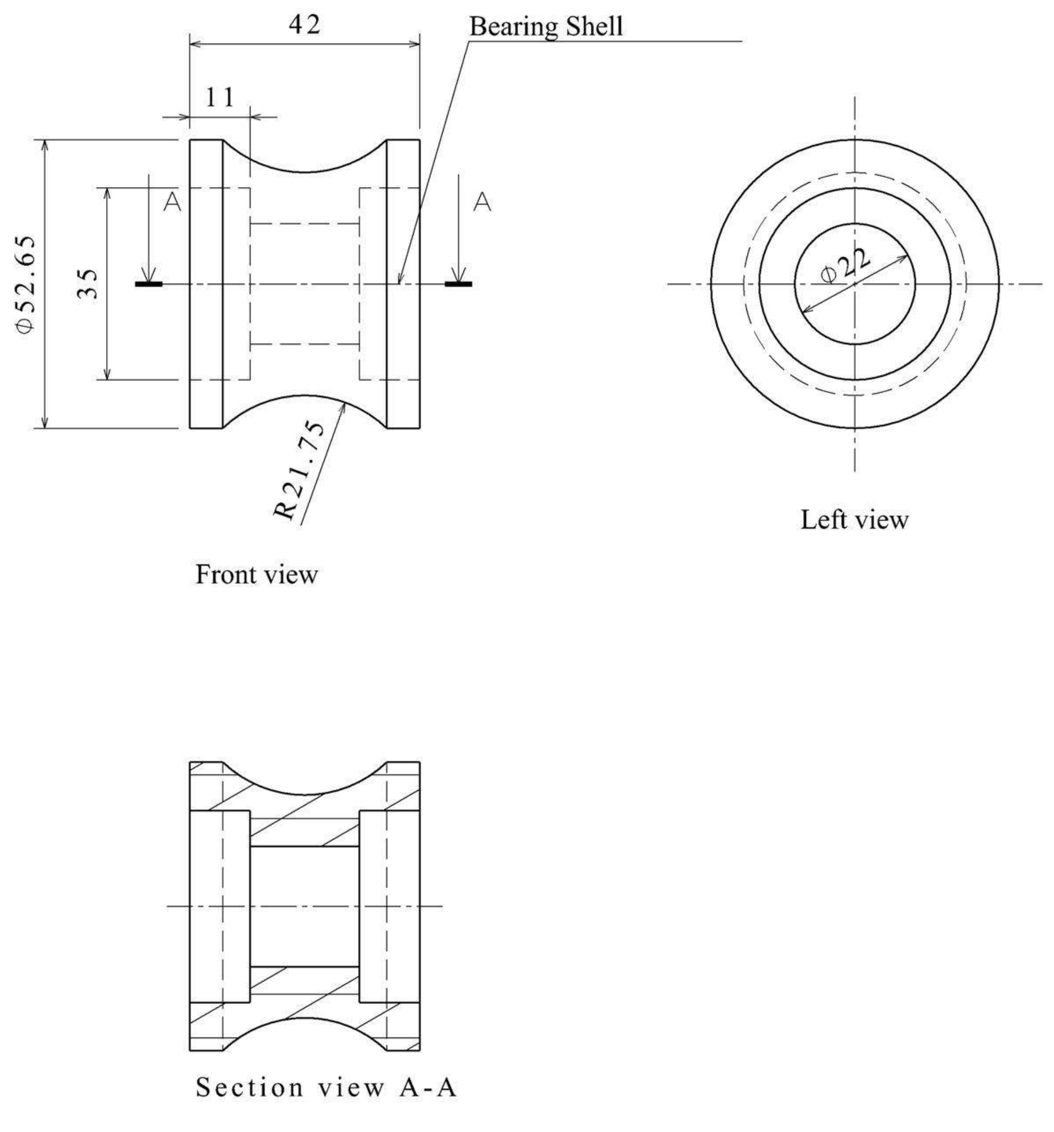


Quantity	6

Appendix A.42: Drive pulleys to be connected to the knitting heads.

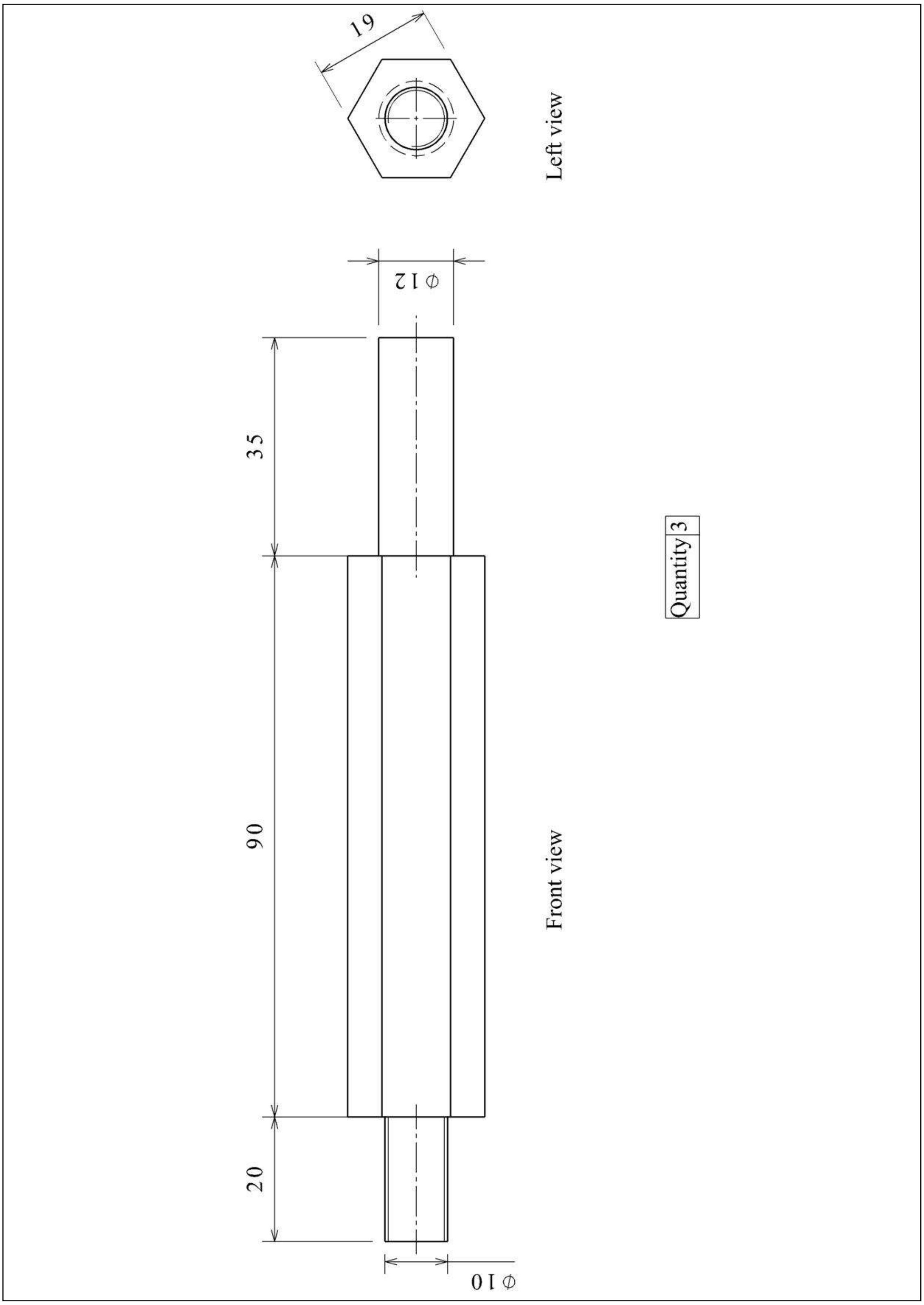


Appendix A.43: Frame component made of equal arm angle.

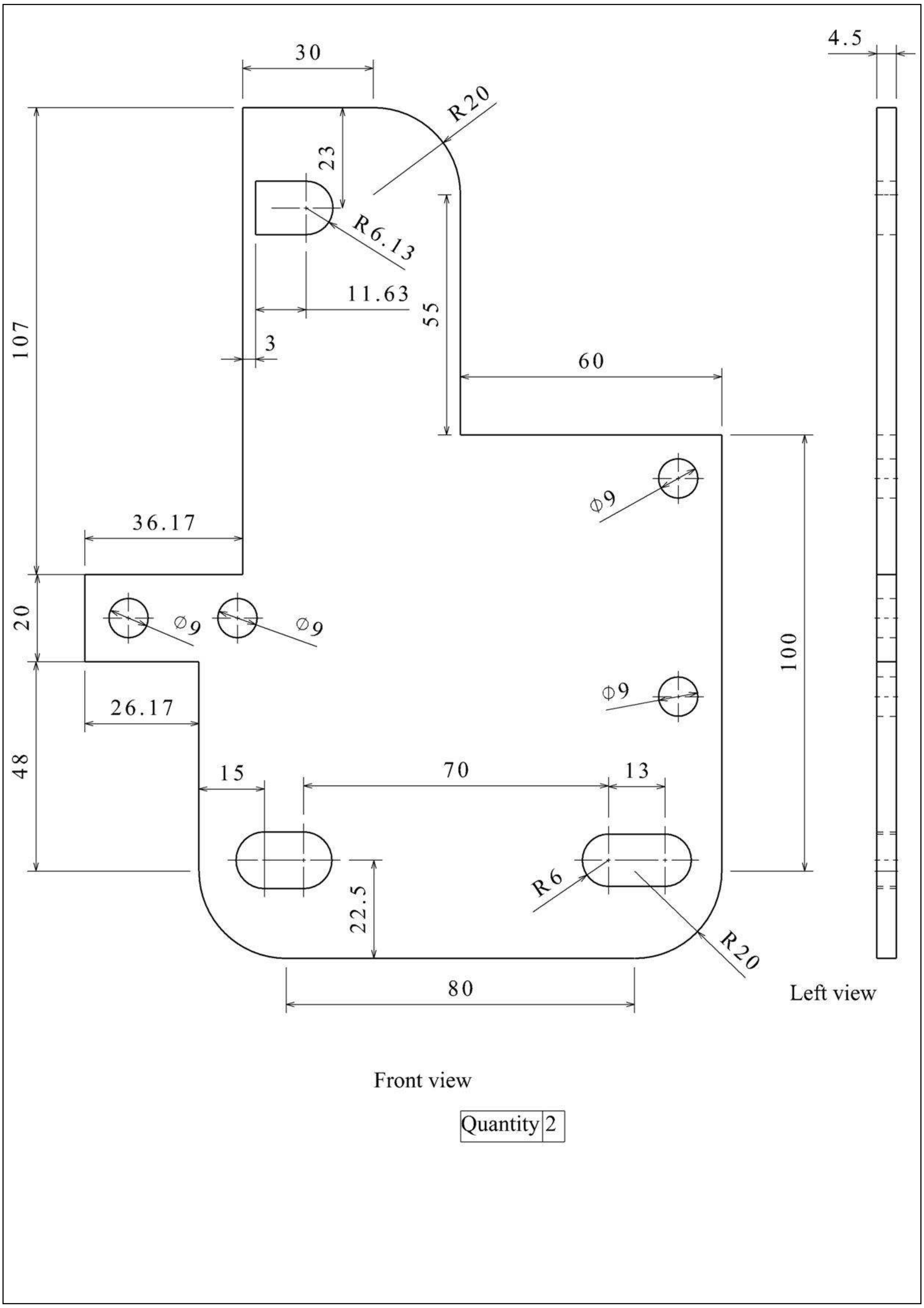


Quantity	3

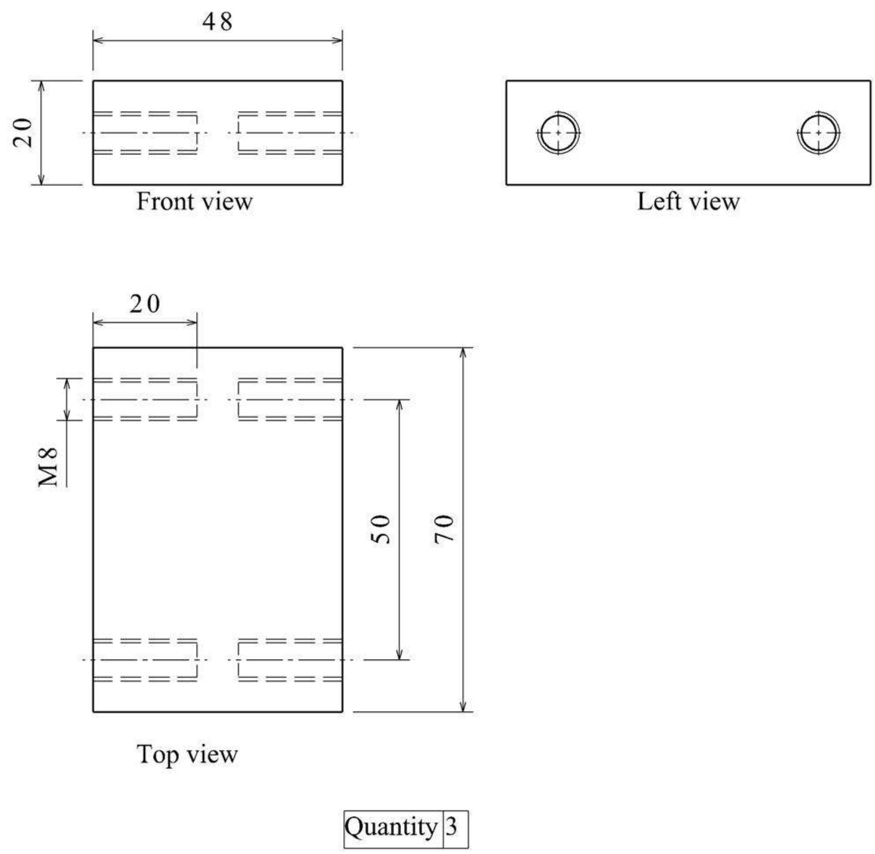
Appendix A.44: Rollers guiding the spin ring frame.



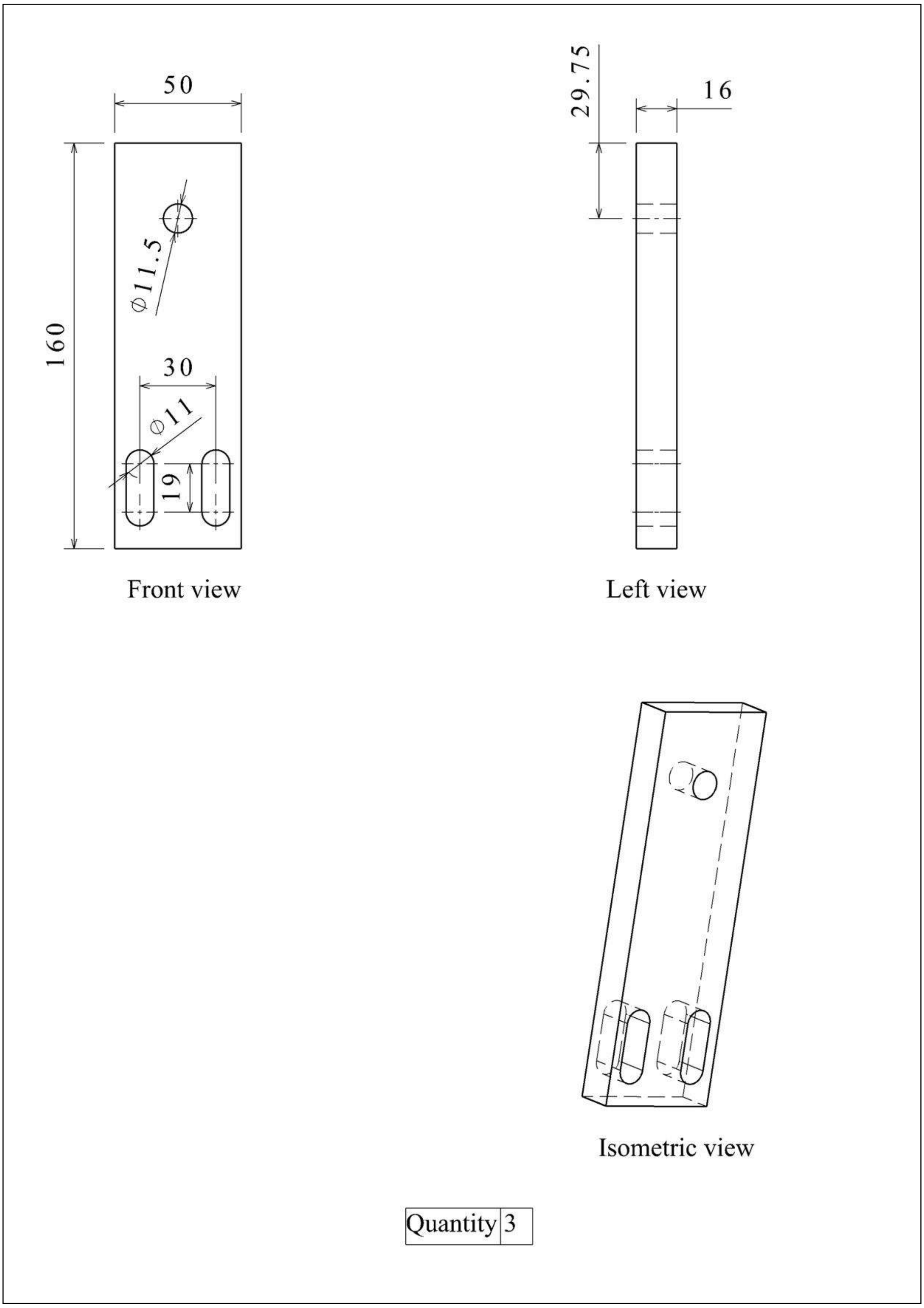
Appendix A.45: Guide pulley shaft.



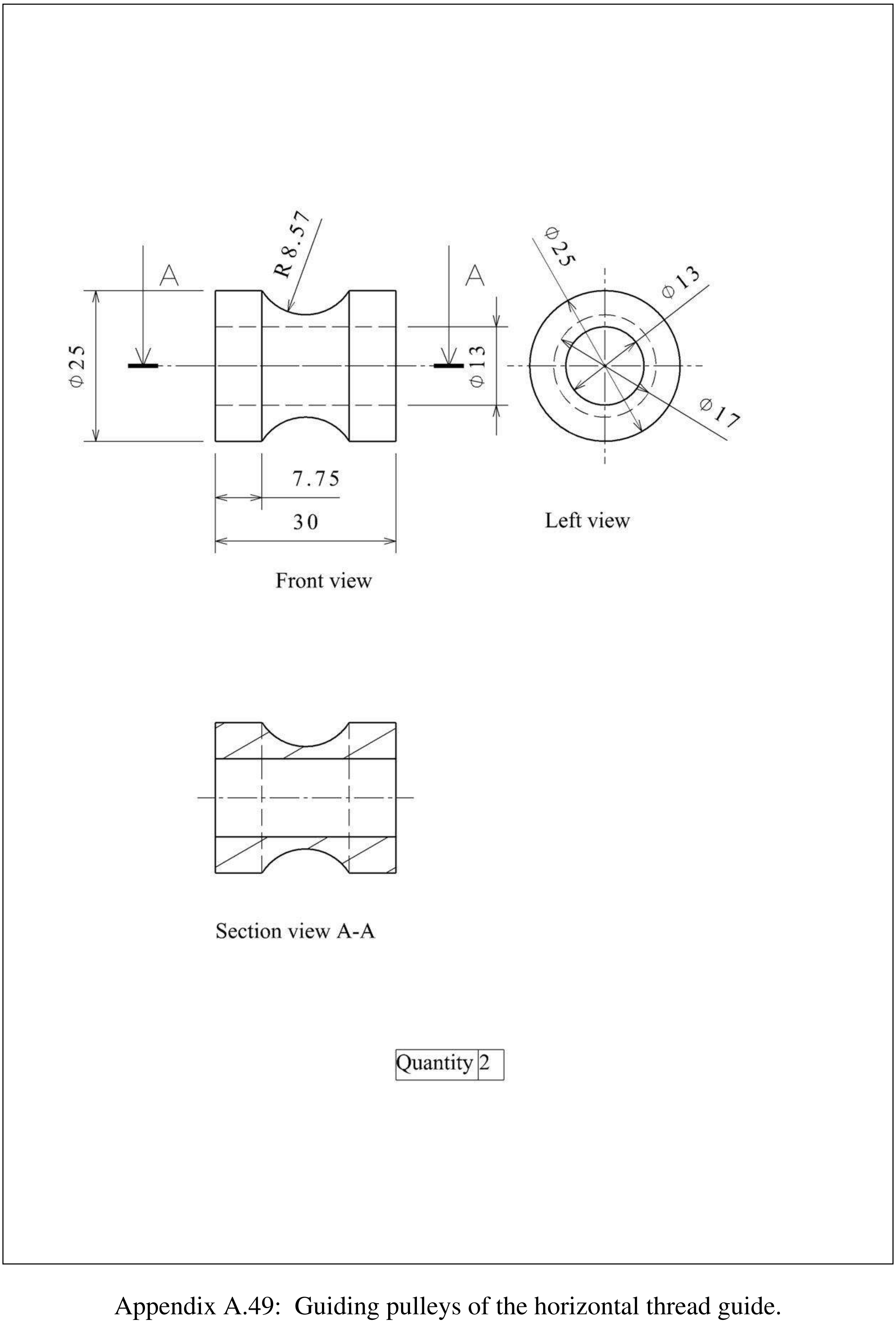
Appendix A.46: Plates which hold the guide pulleys.



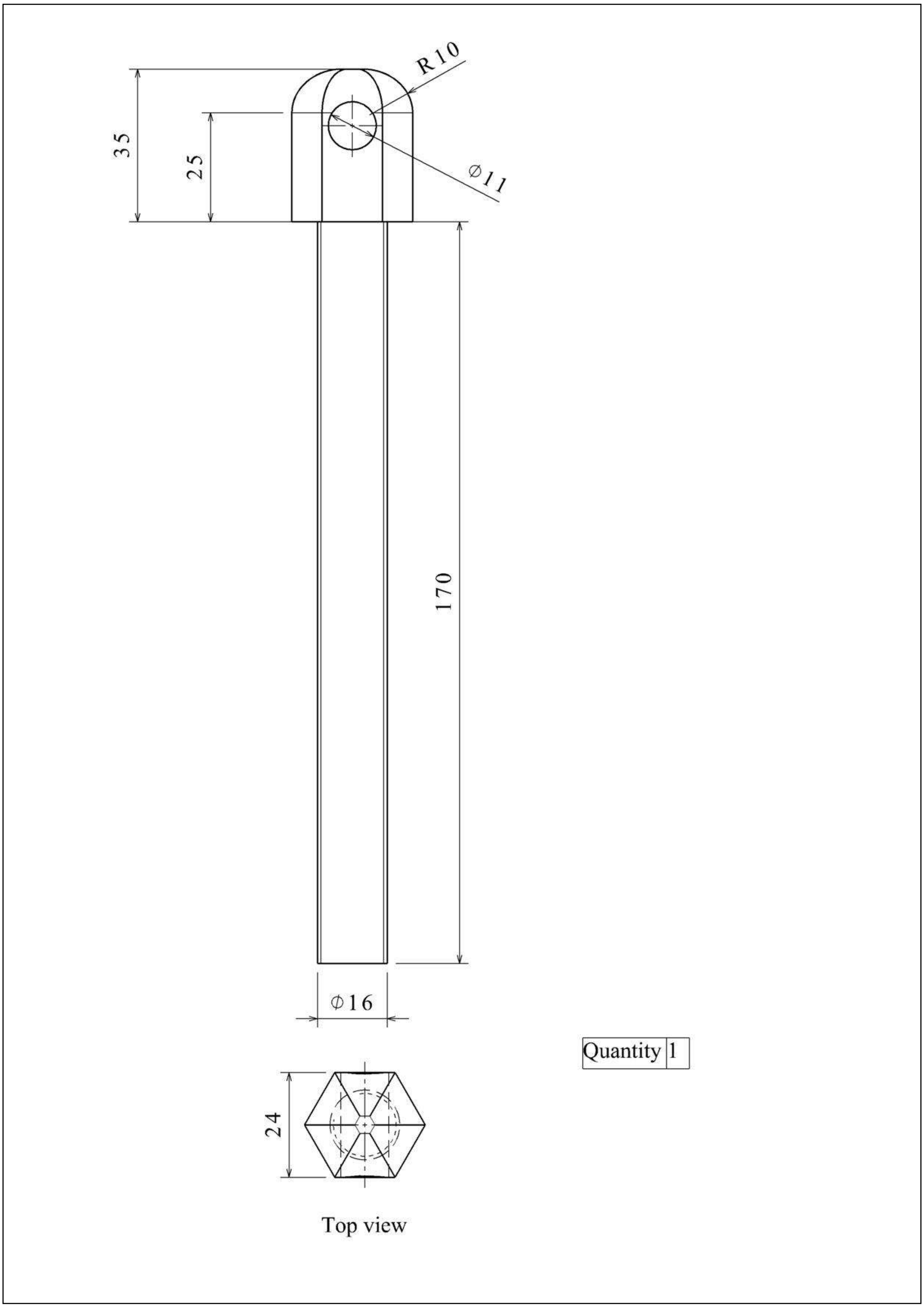
Appendix A.47: Pulley fixtures of the spin ring frame.



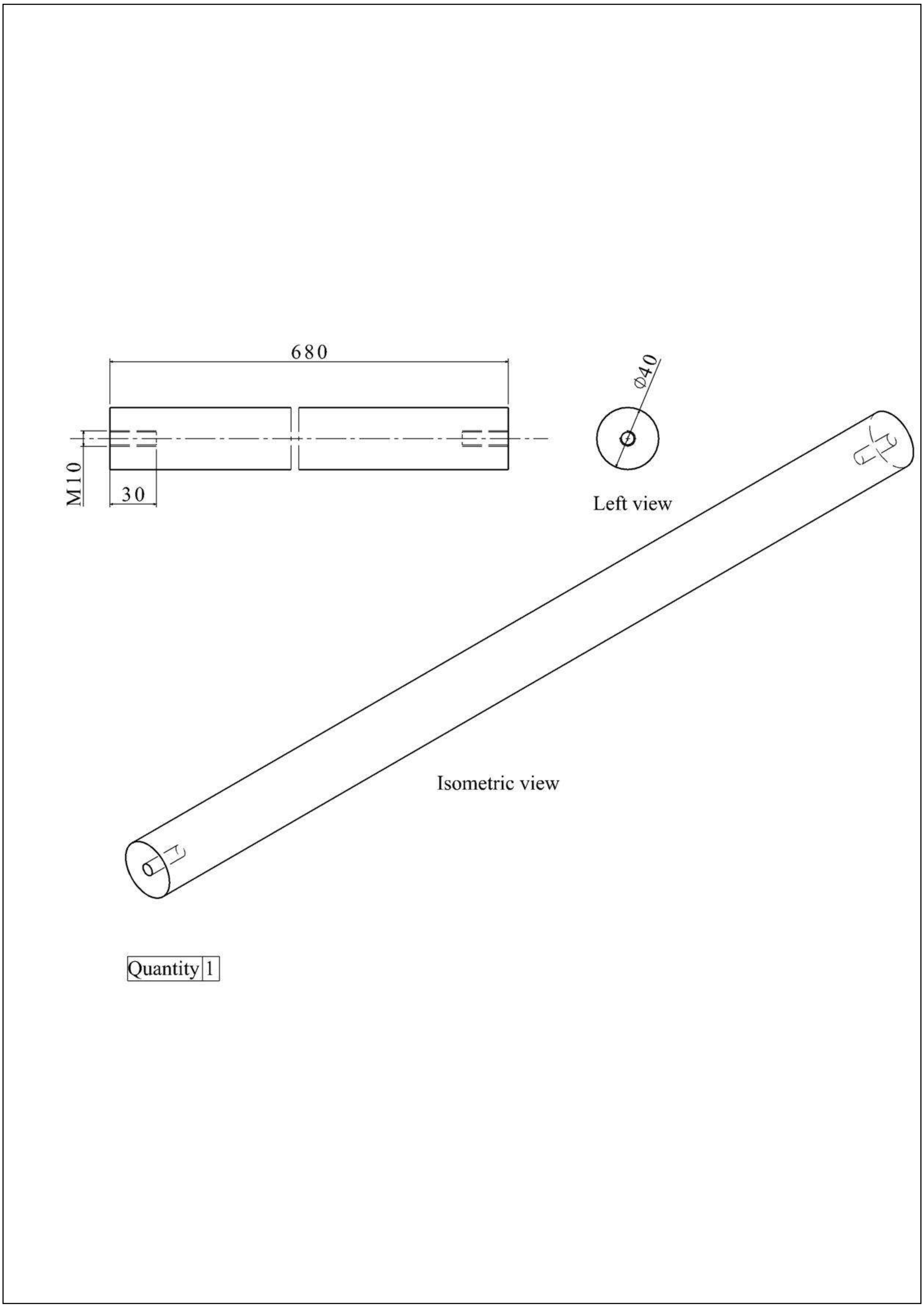
Appendix A.48: Pulley brackets of the horizontal bobbin winder.



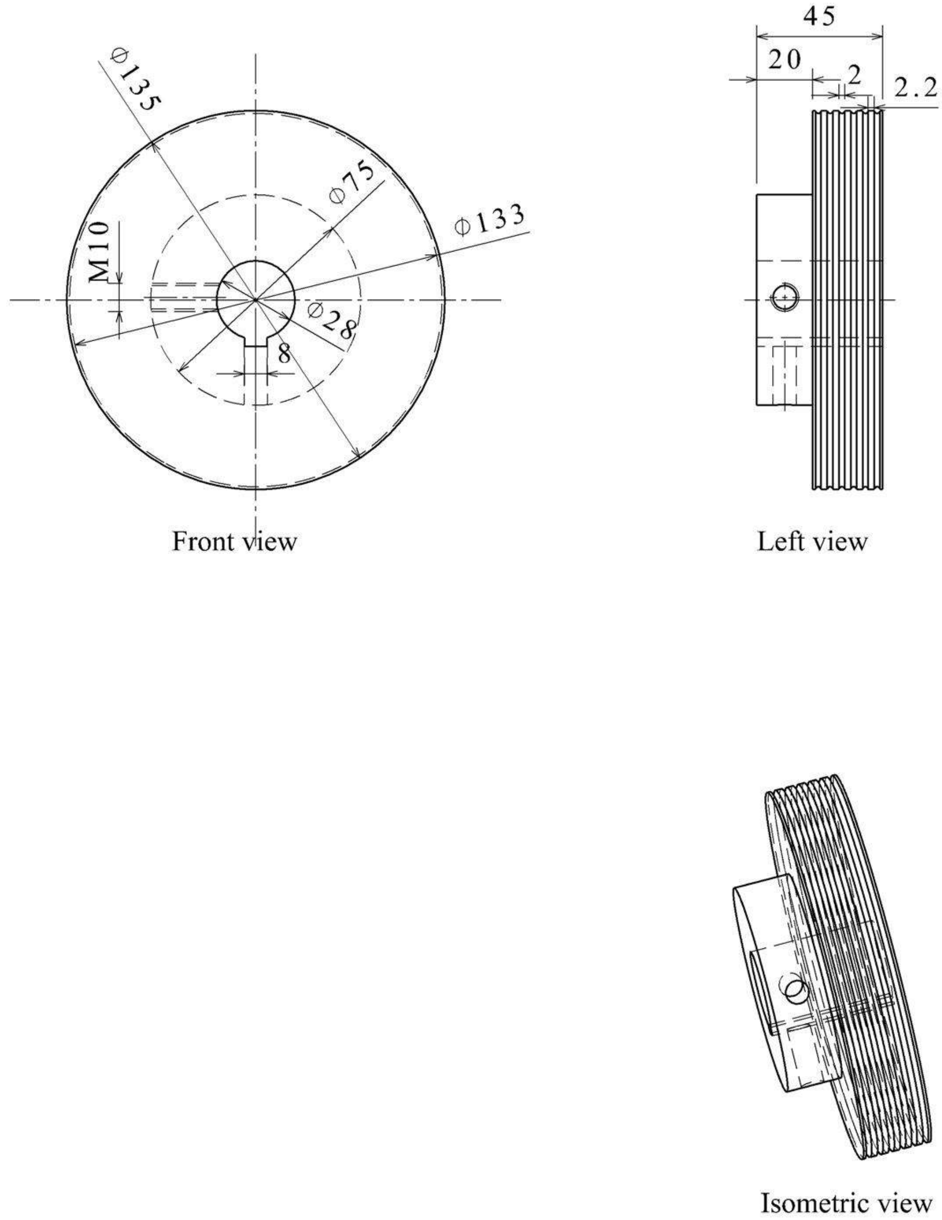
Appendix A.49: Guiding pulleys of the horizontal thread guide.



Appendix A.50 Stretcher bolt of the motor driving the yarn advancing shaft

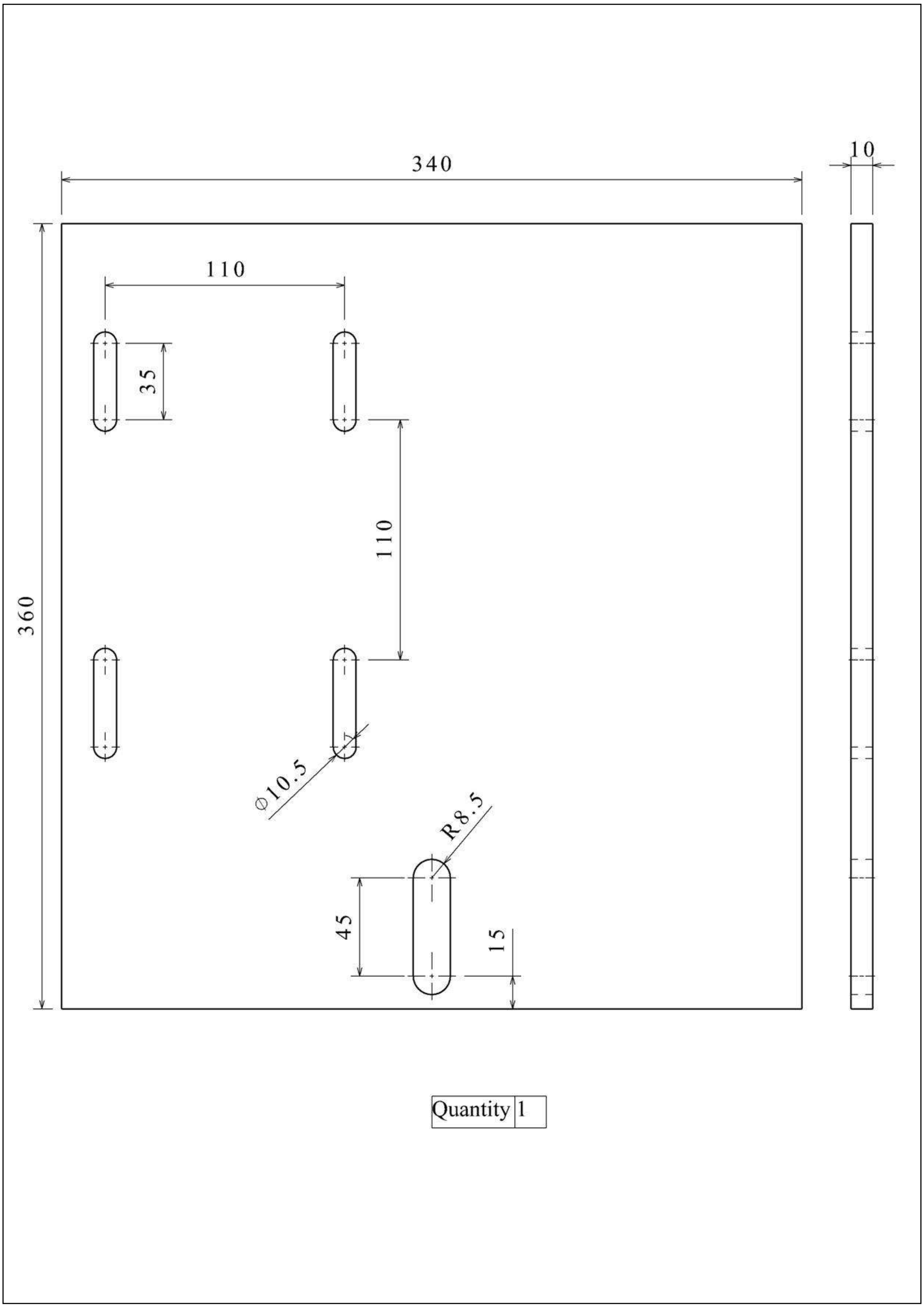


Appendix A.51: Pin connection of the plate holding the yarn advancer motor.

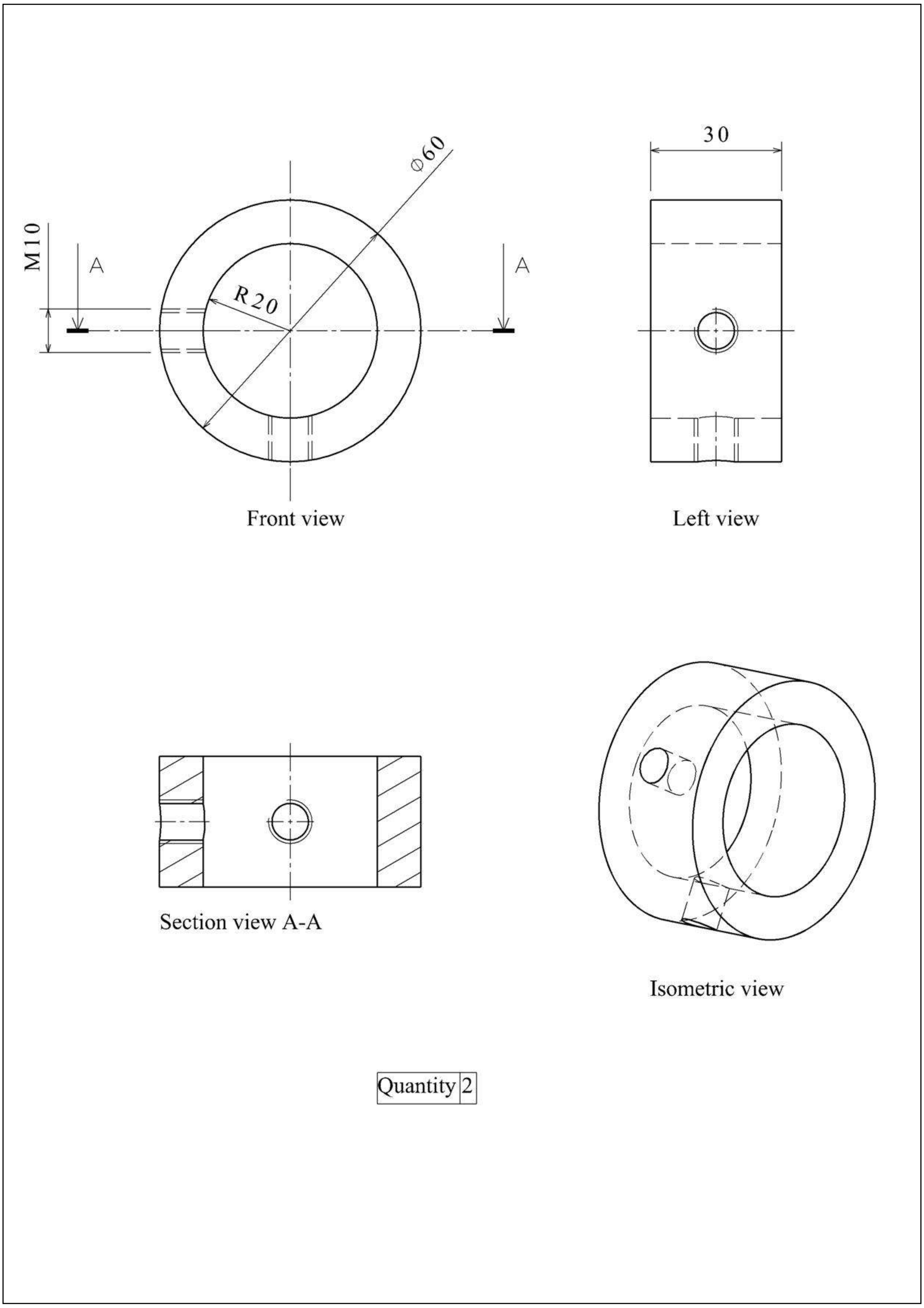


Quantity	1

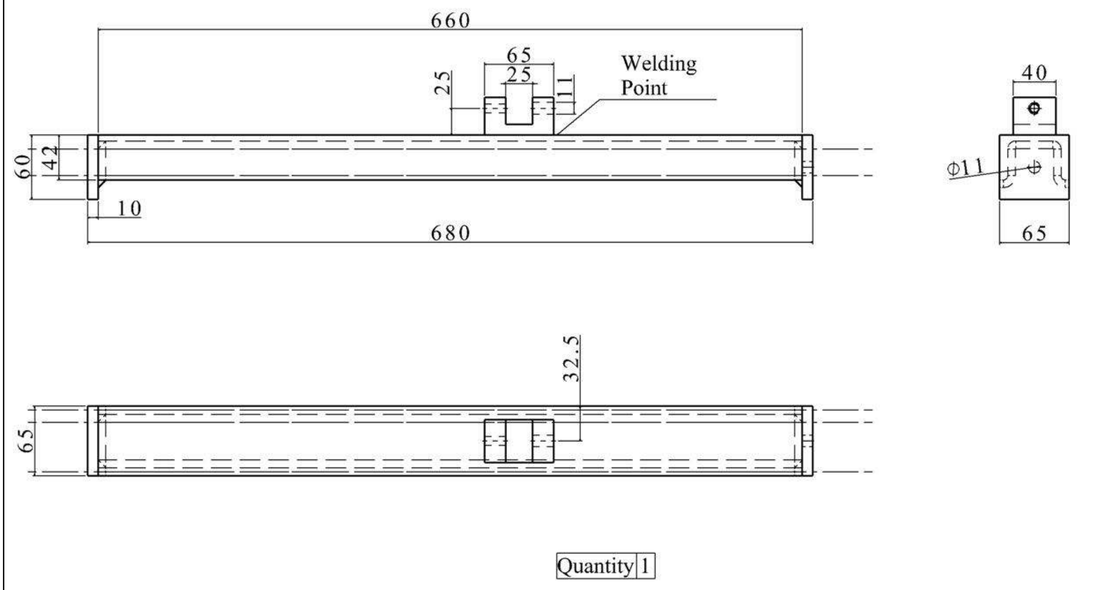
Appendix A.52: Multi groove pulley for the flat belt driving the main shaft of the machine.



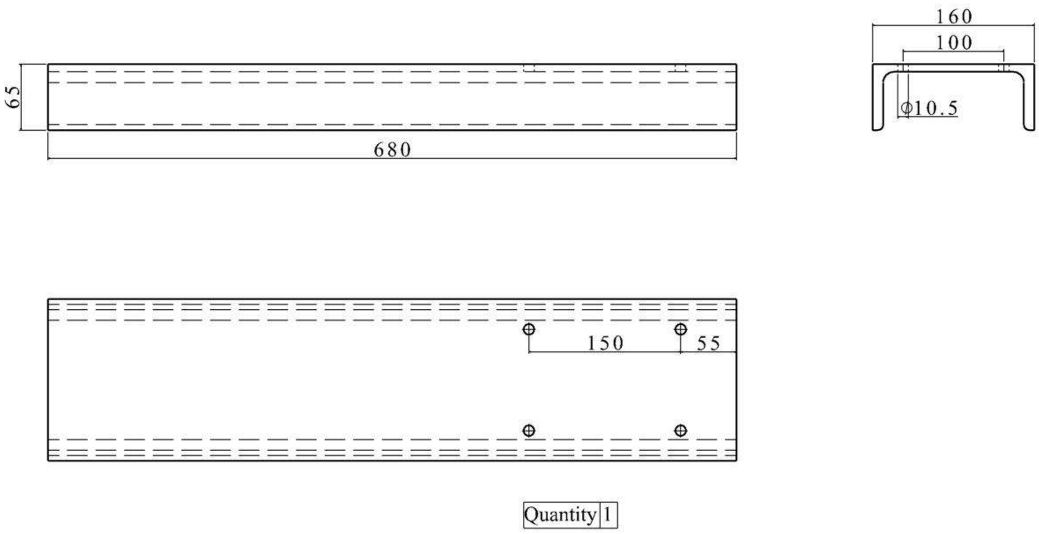
Appendix A.53: Plate holding the motor driving the main shaft of the machine.



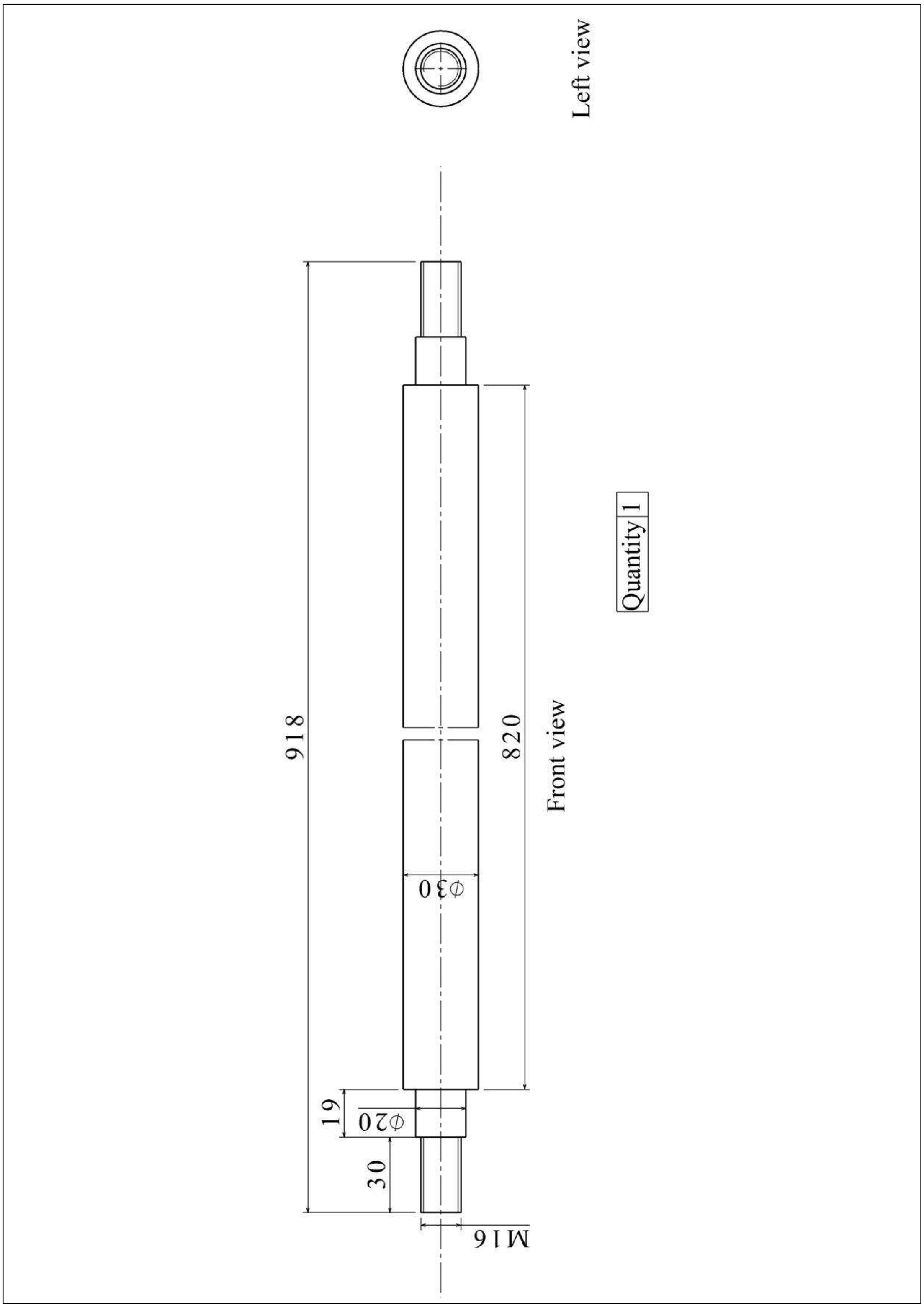
Appendix A.54: Bracket for the pin connection of the plate holding the motor which drives the main shaft of the machine.



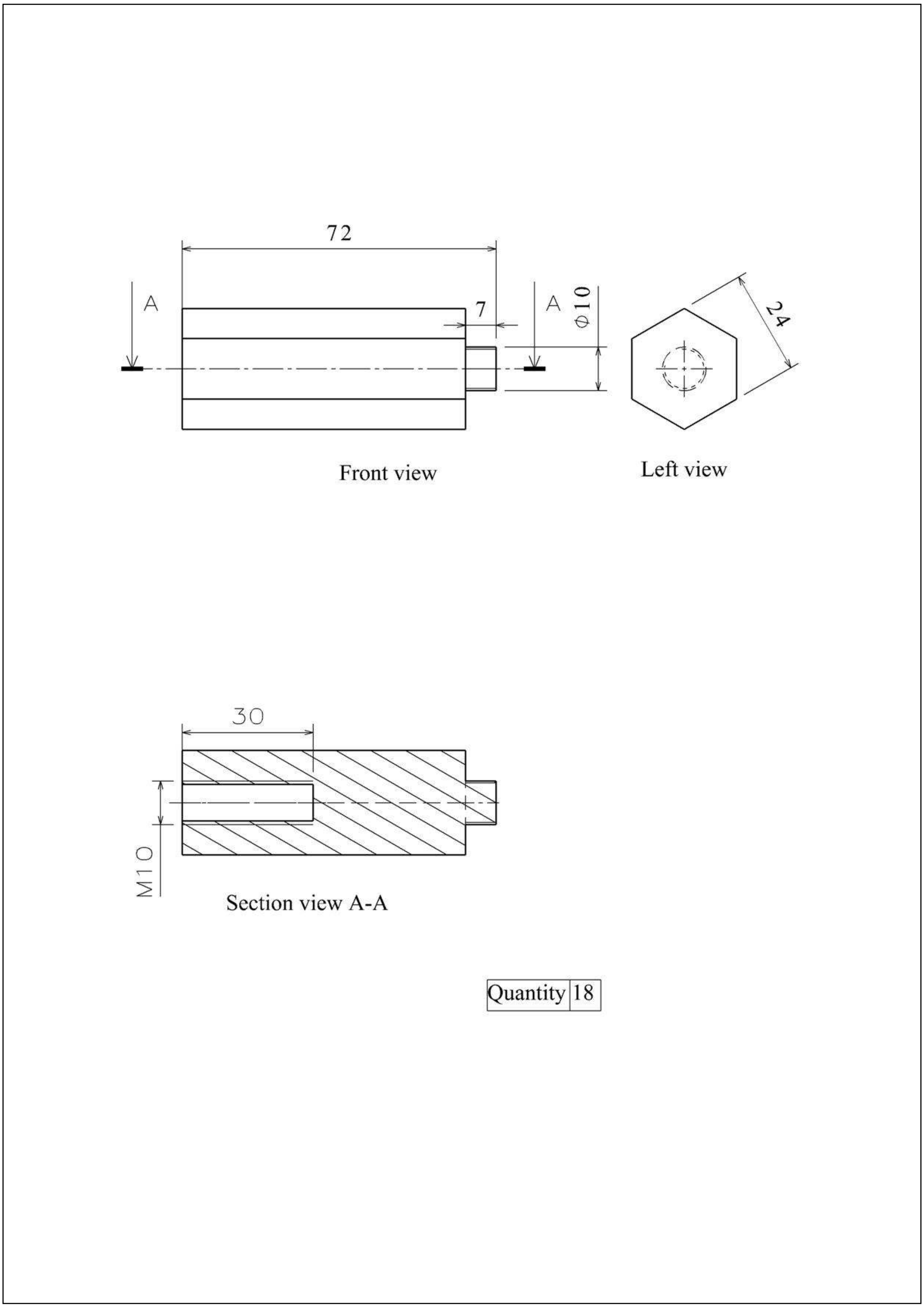
Appendix A.55: UNP profile frame component which is used for holding a motor



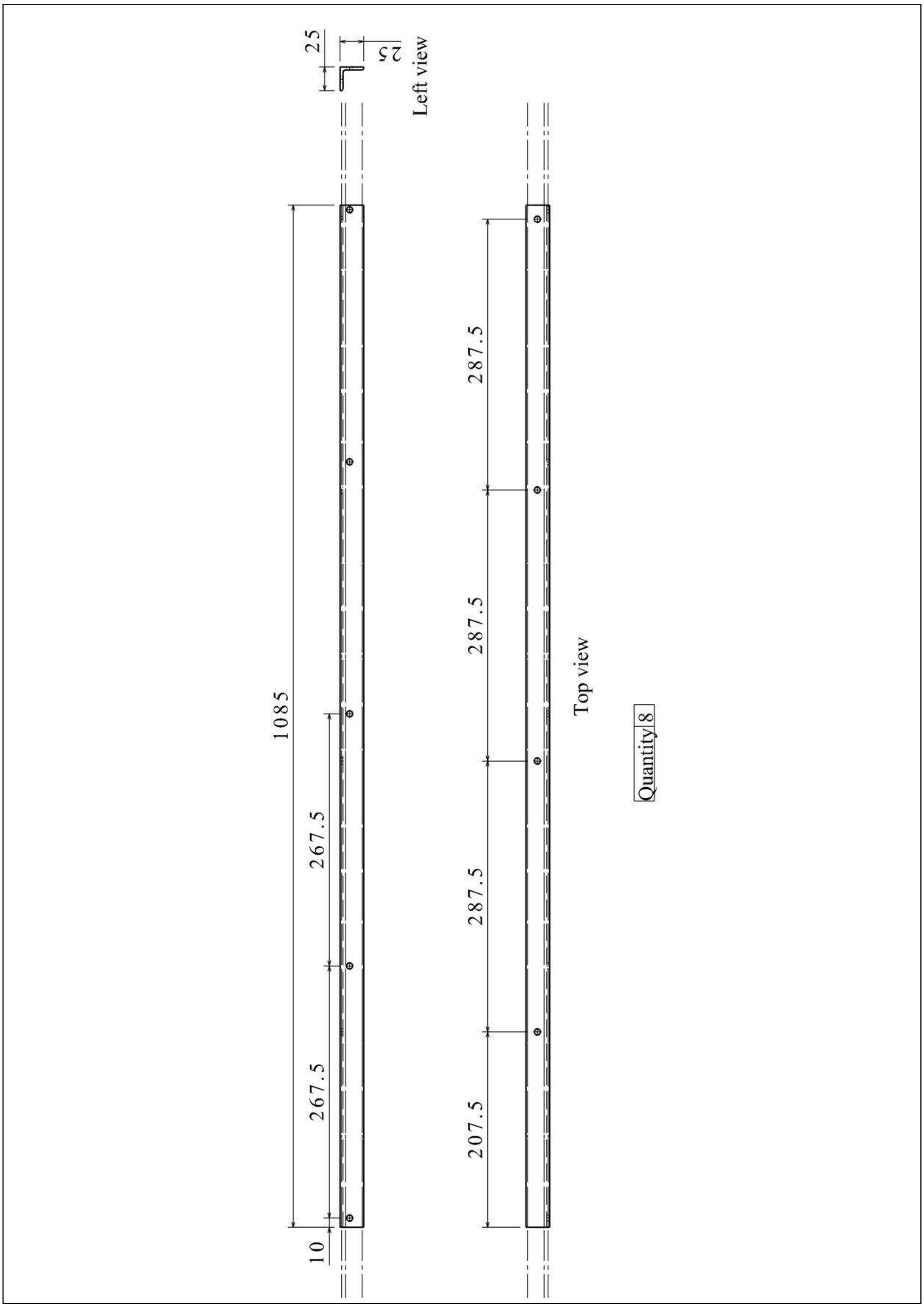
Appendix A.56: UNP profile which is used for fixing the 3 rpm motor to the 5 mm sheet side plates of the machine frame.



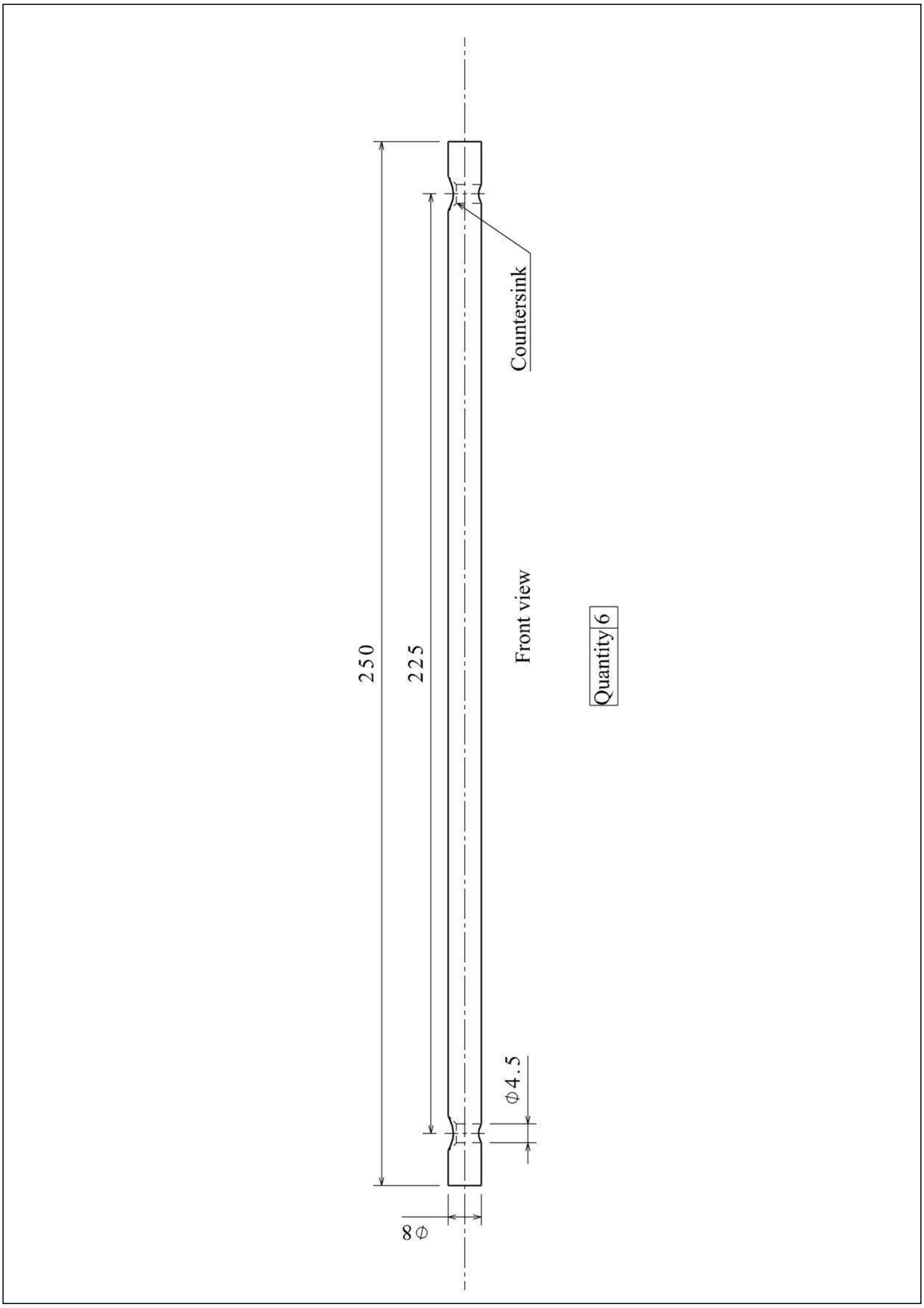
Appendix A.57: Vertical guides of the spin ring frame assembly.



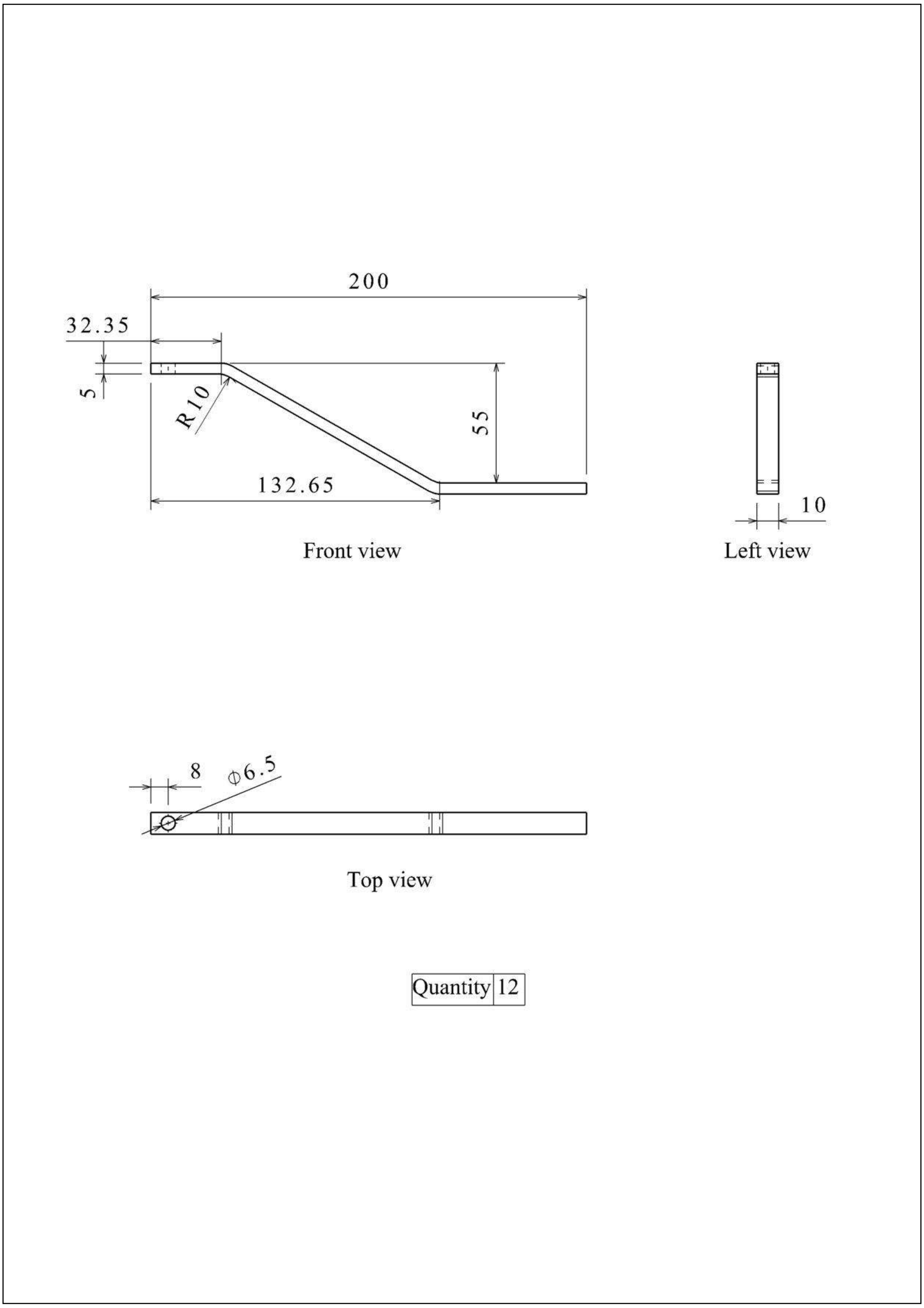
Appendix A.58: Fixture



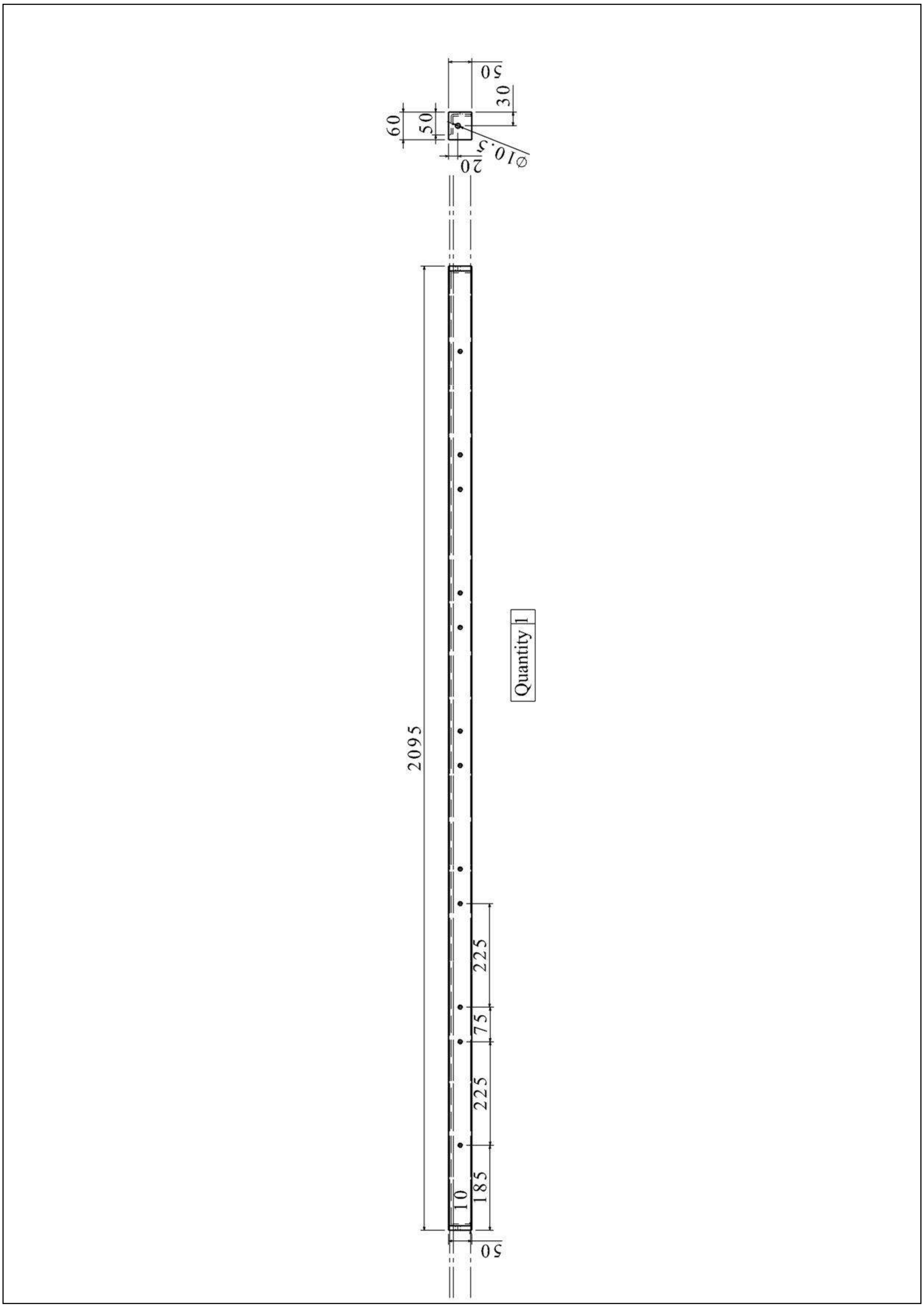
Appendix A.59: Fixture made of equal arm angle.



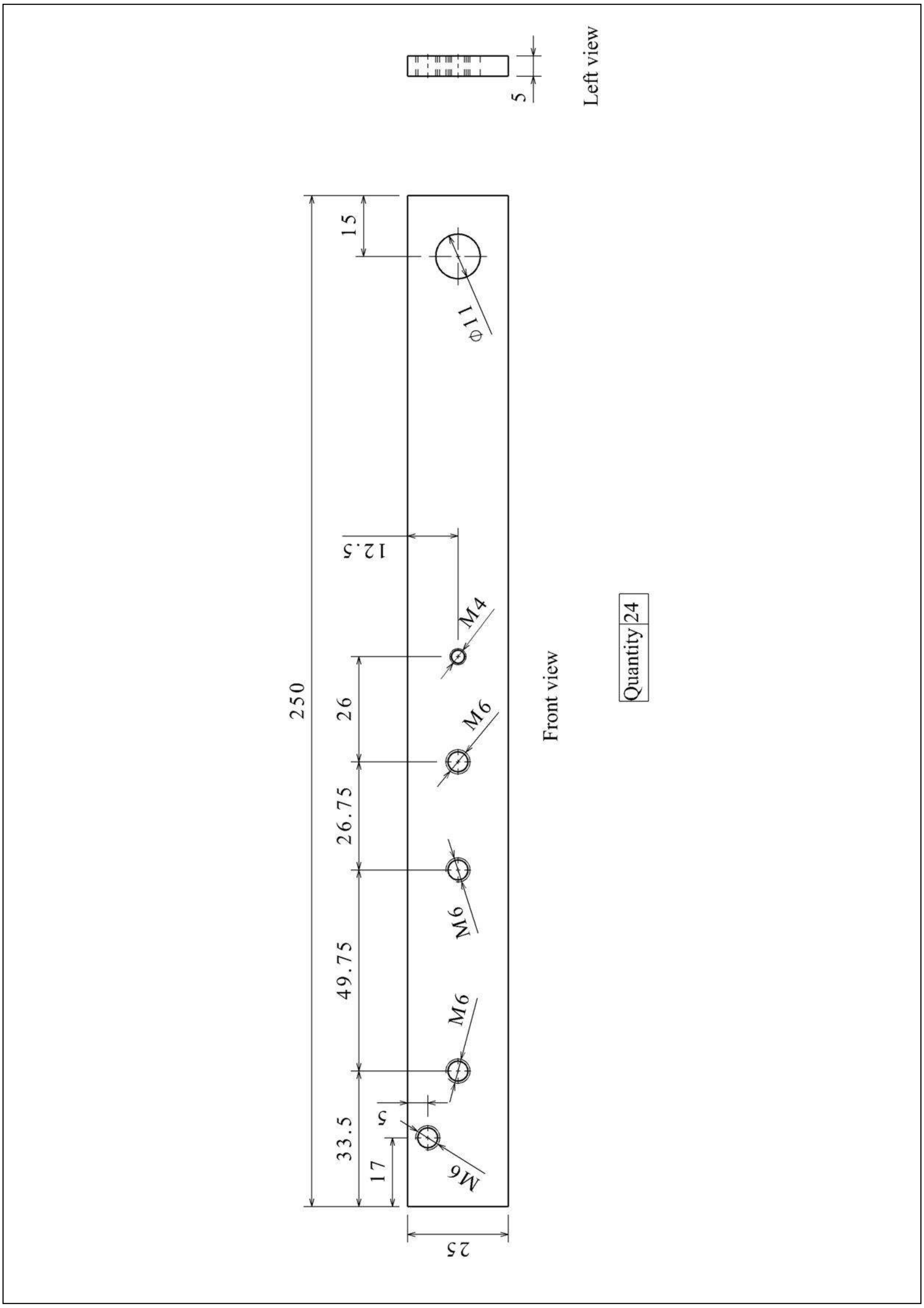
Appendix A.60: Shaft as part of the yarn tensioning device.



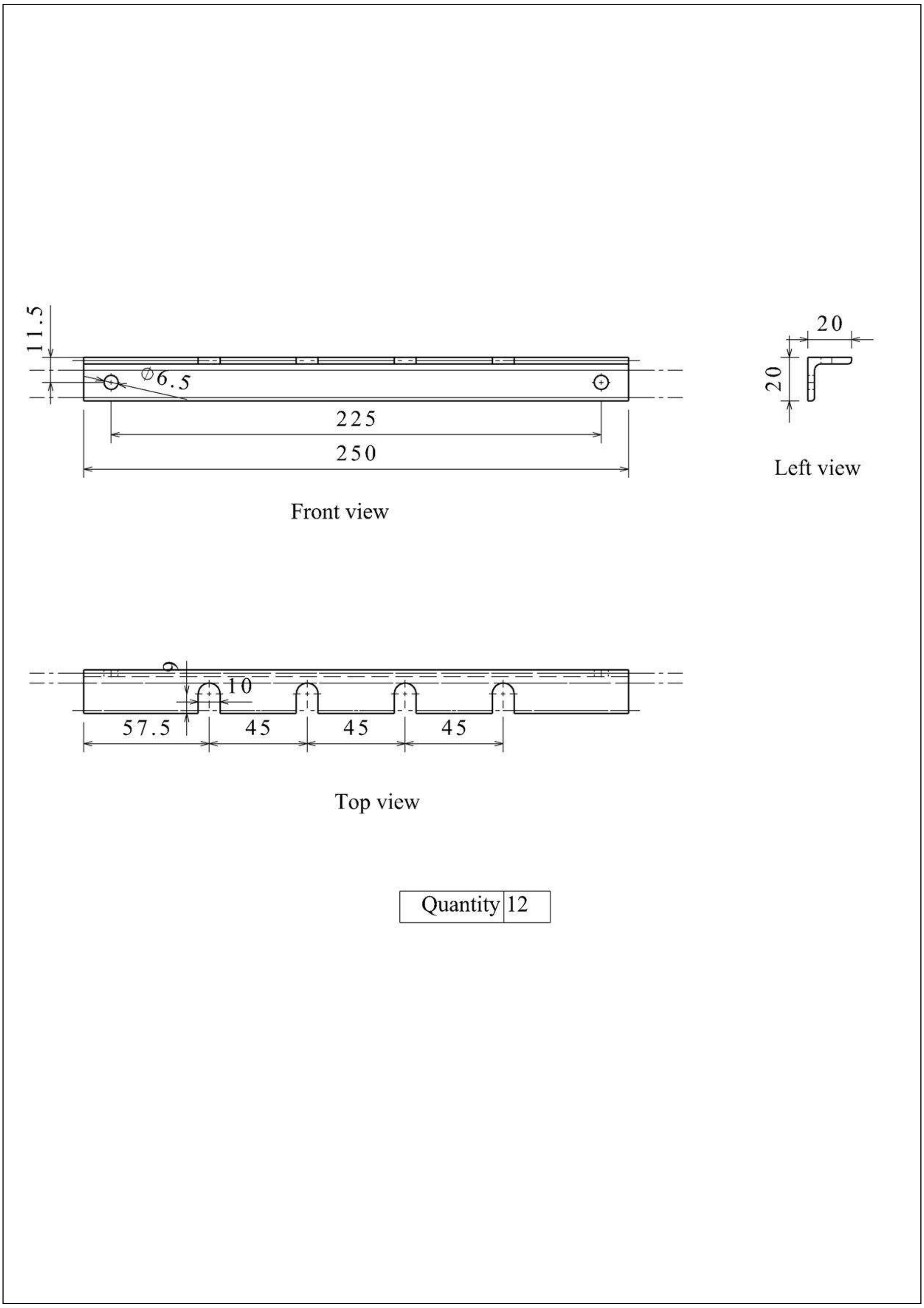
Appendix A.61: Frame on which the tension devices are mounted.



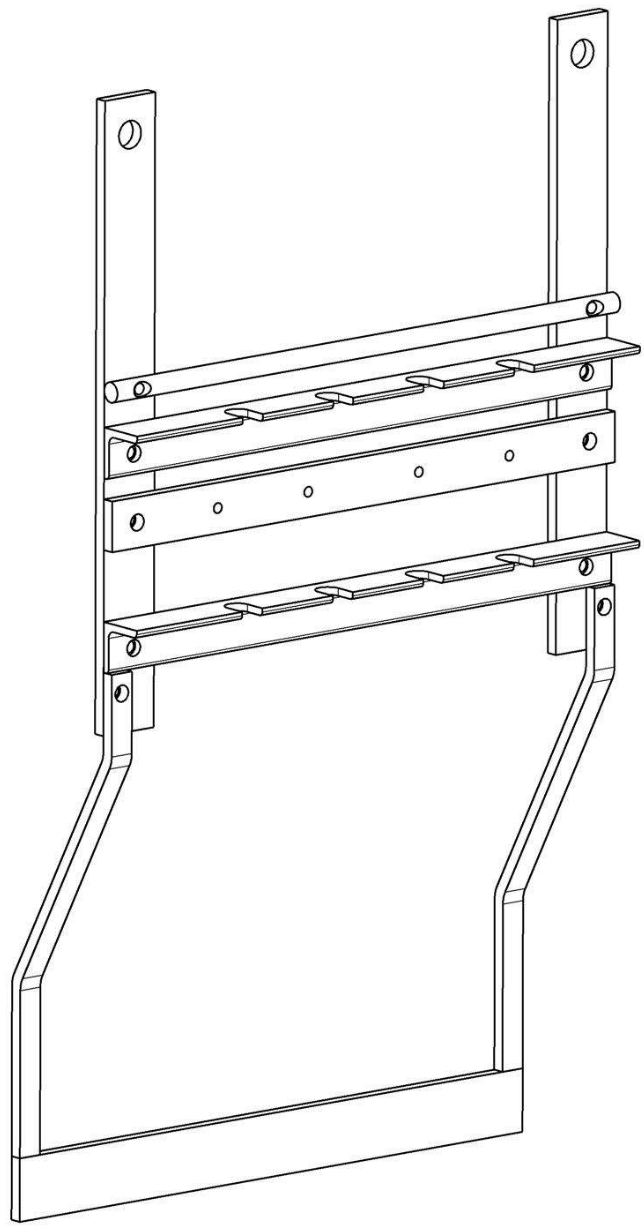
Appendix A.62: Beam made of equal arm angle, on which the yarn rupture detectors are assembled.



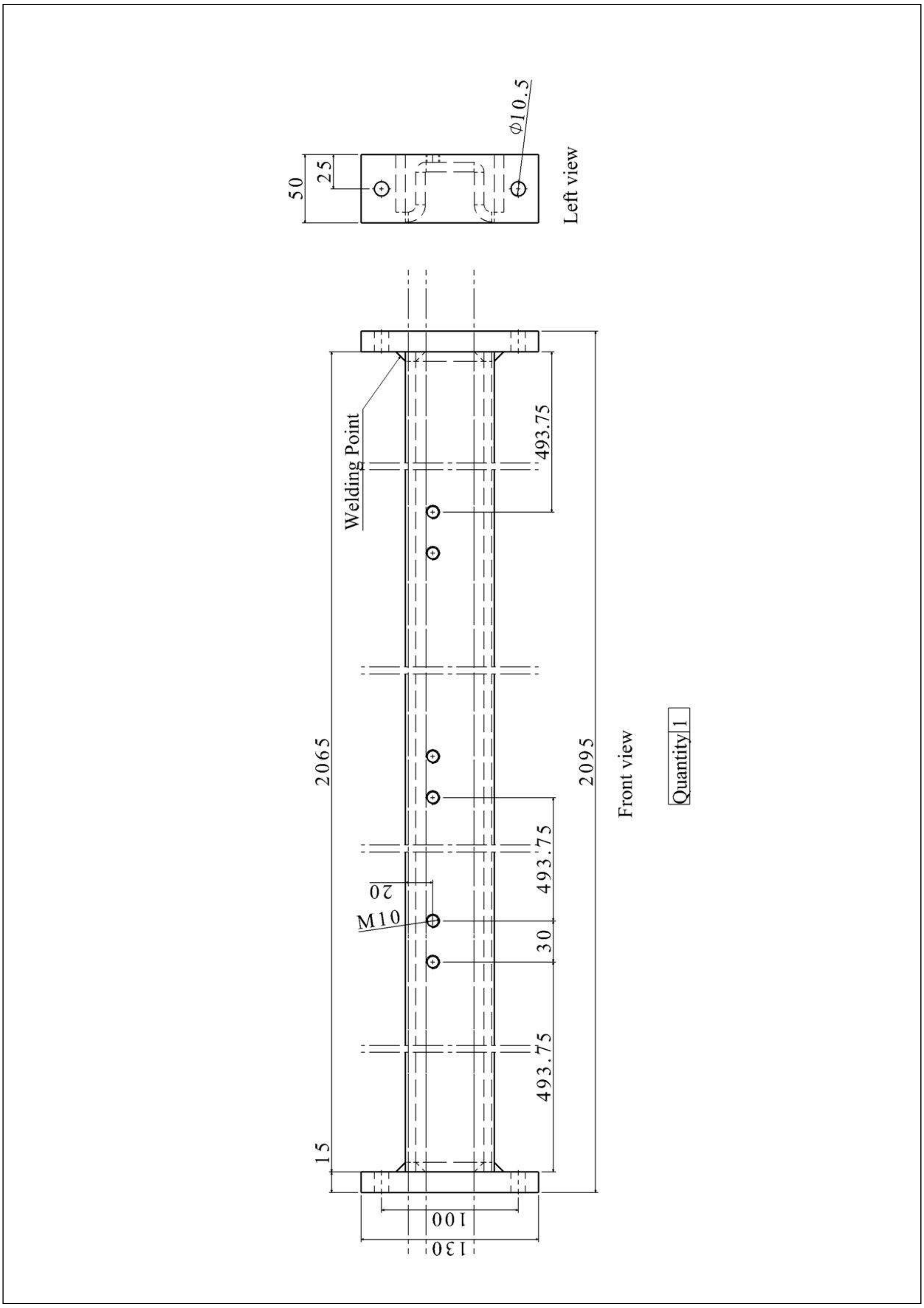
Appendix A.63: Frame for fixing accessories of the tensioning devices.



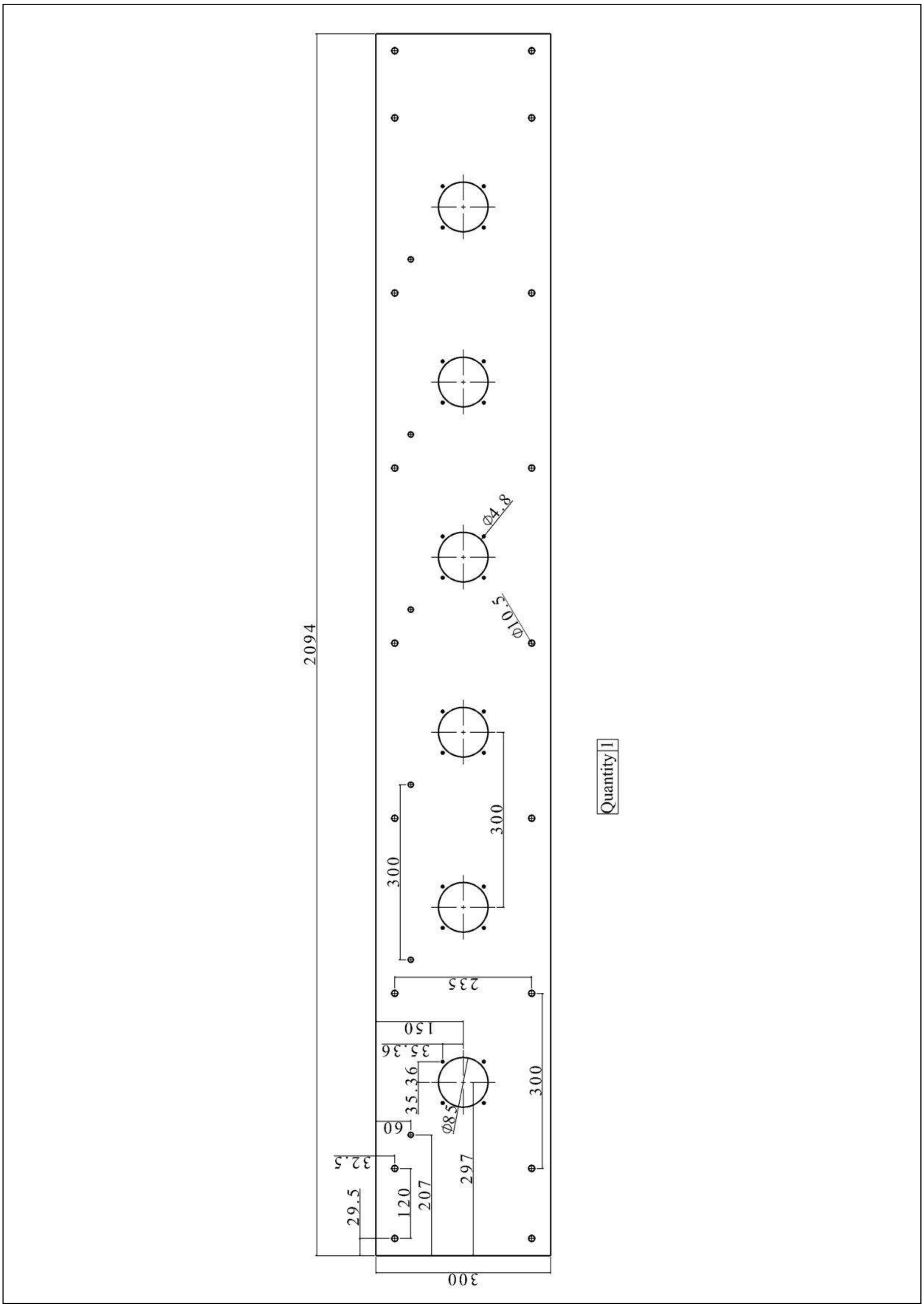
Appendix A.64: Fixture for the tensioning devices made of equal arm angle.



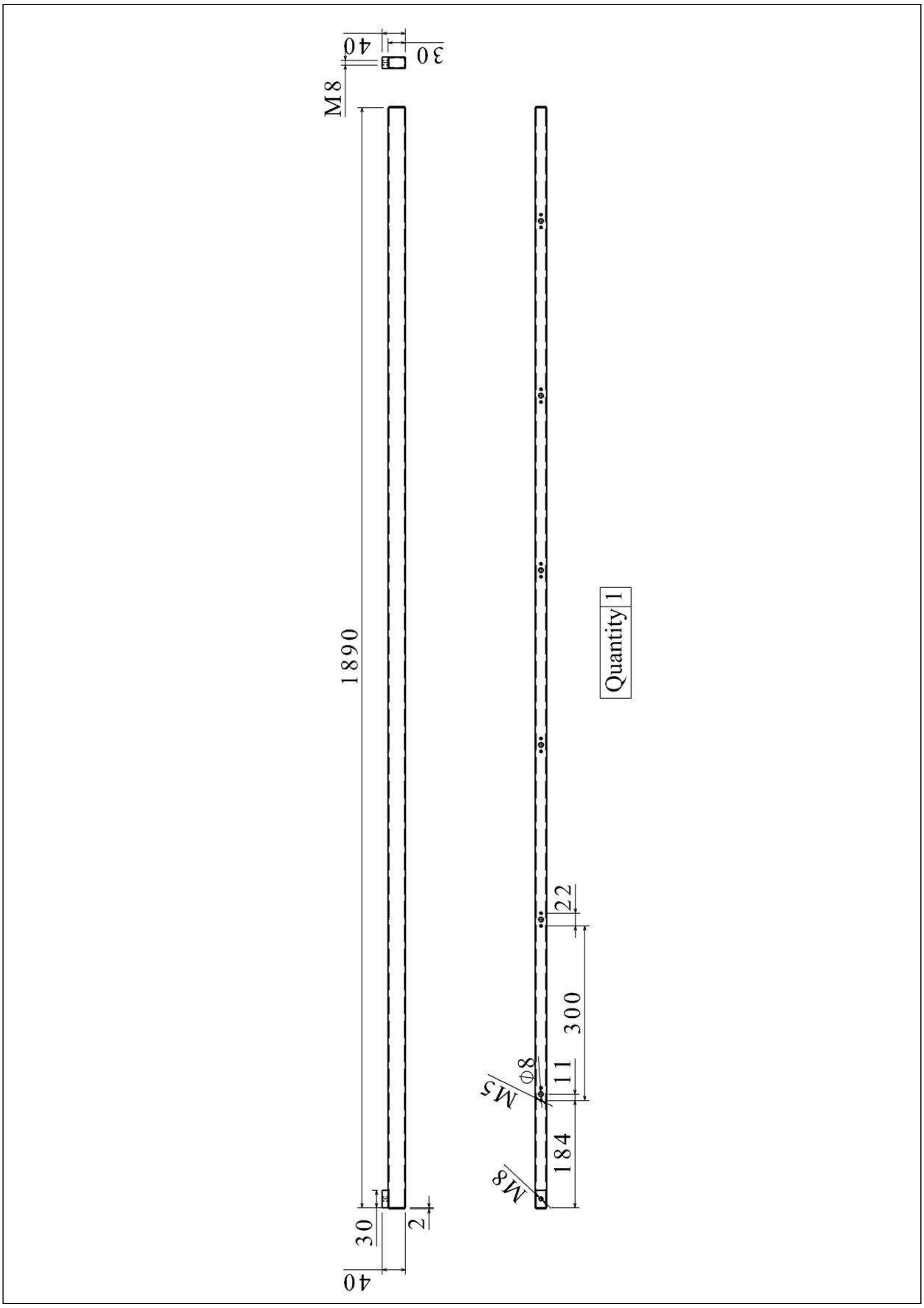
Appendix A.65: Assembly drawing for the frame on which 4 tensionning devices and 4 yarn rupture detectors are mounted on.



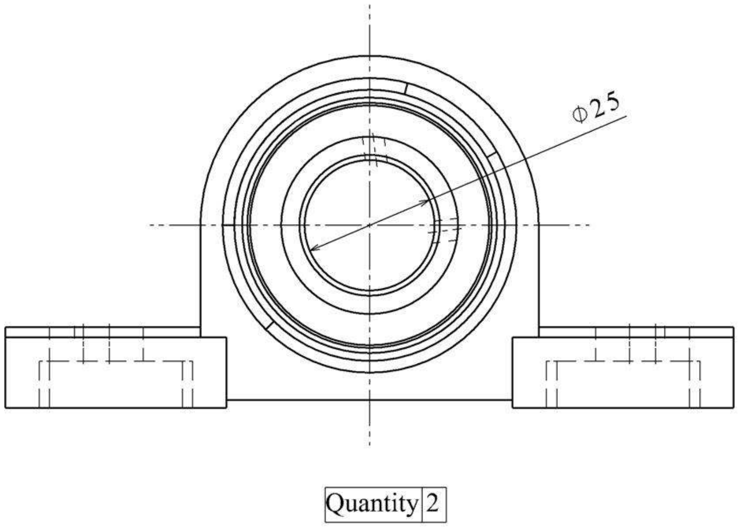
Appendix A.66: UNP profile, part of the main frame of the machine on which guide sprockets are mounted.



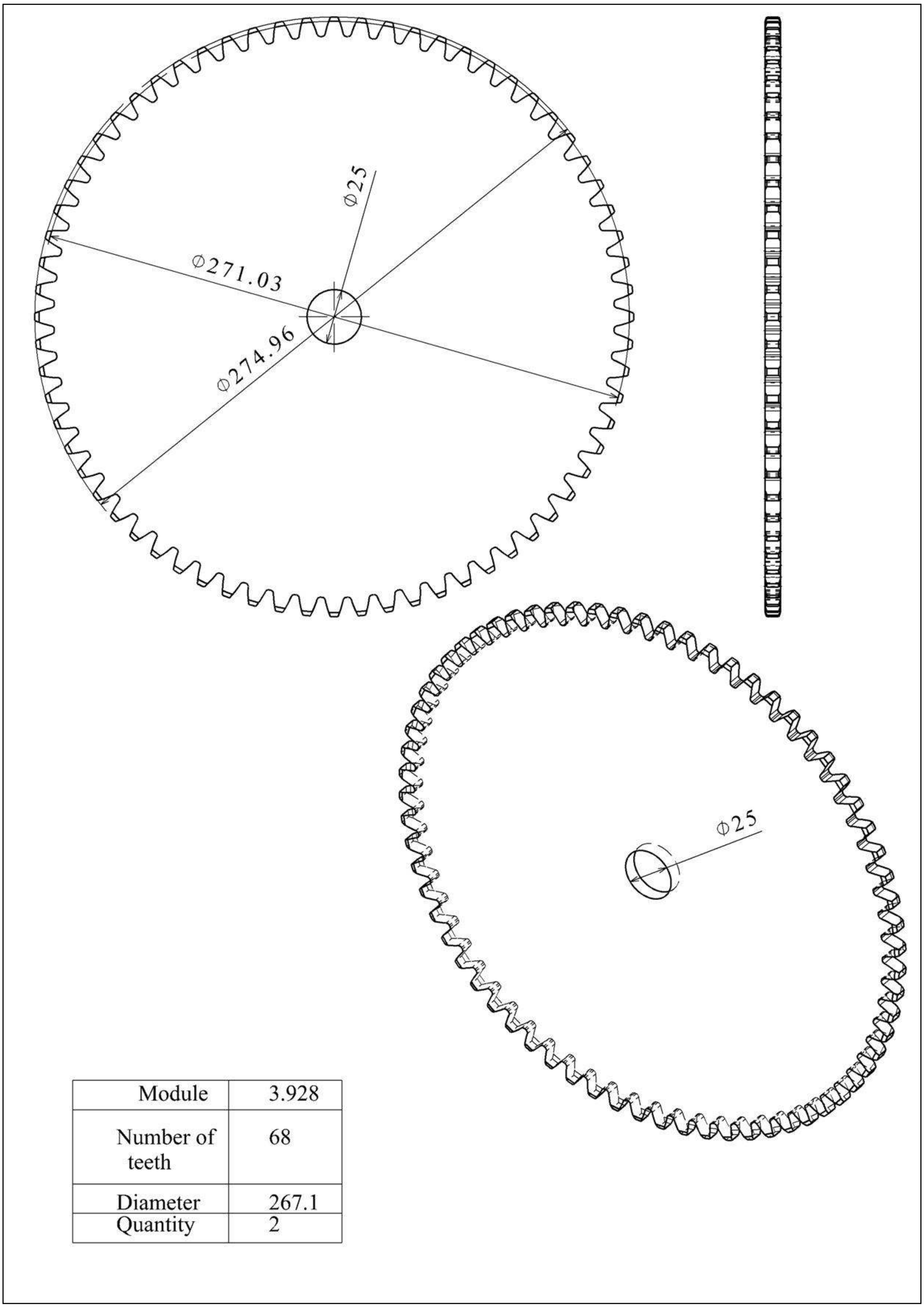
Appendix A.67: 3 mm sheet metal on which knitting heads are assembled.



Appendix A.68: Oiler for the spindle bearings.

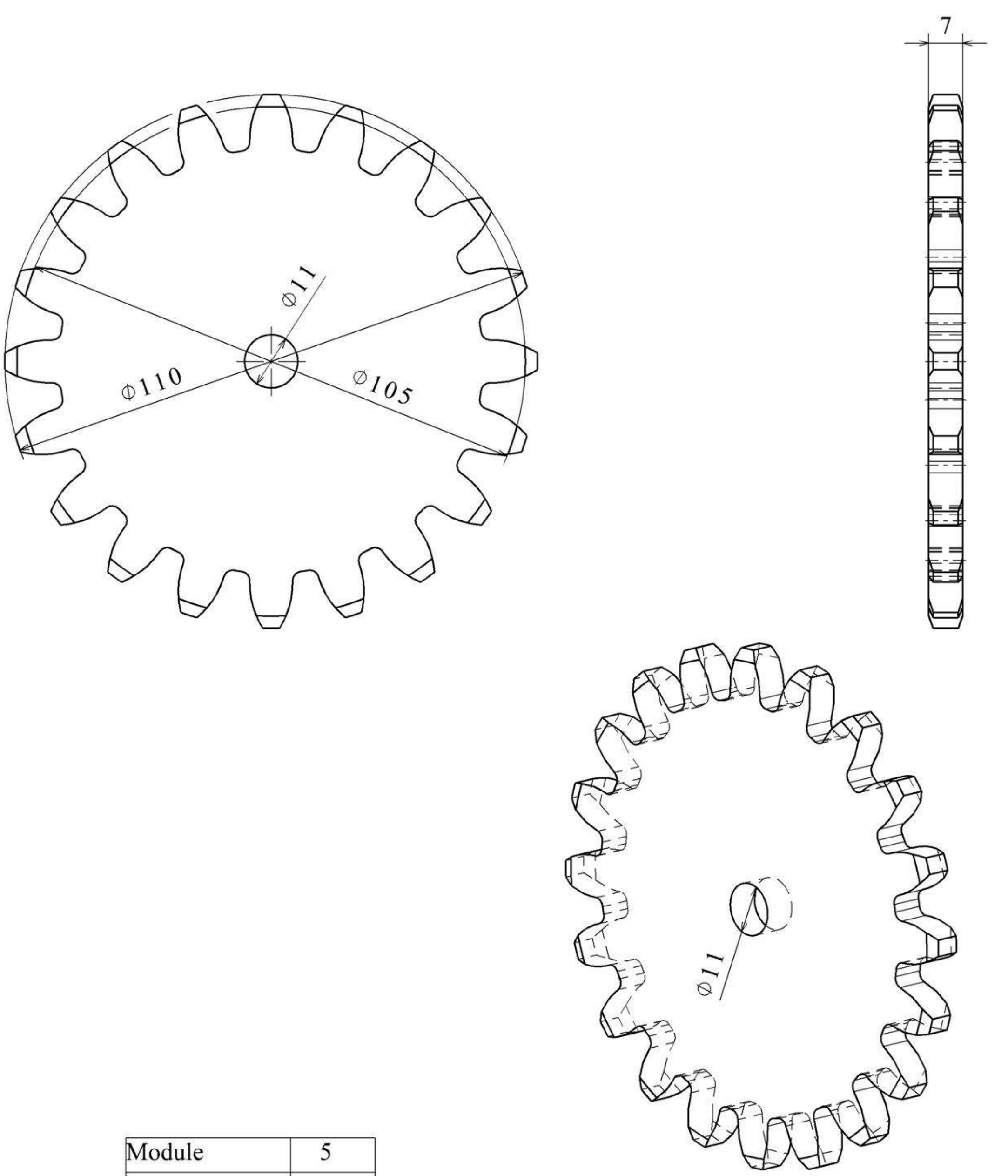


Appendix A.69: Bearings



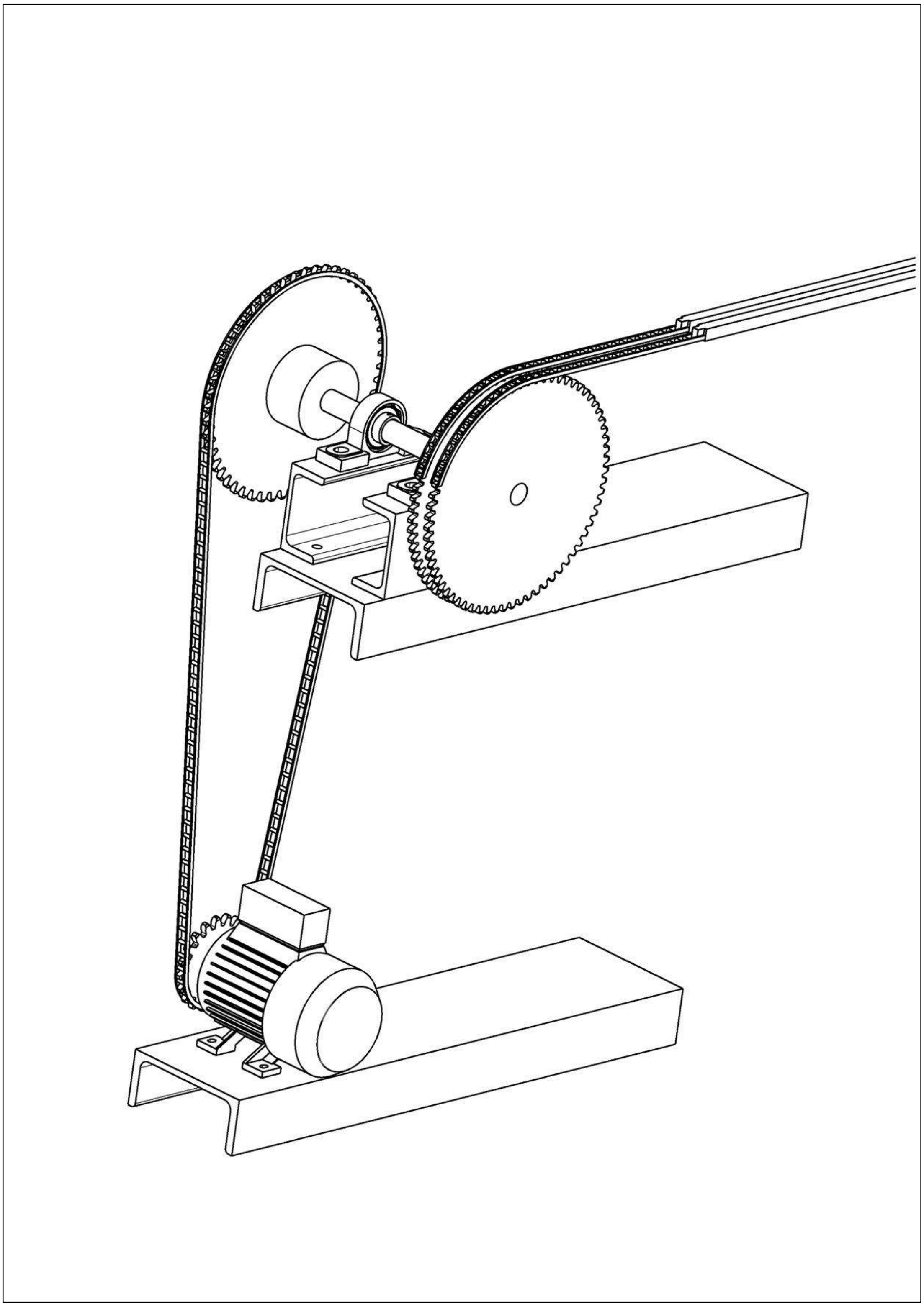
Module	3.928
Number of teeth	68
Diameter	267.1
Quantity	2

Appendix A.70: Sprocket, part of the drive of the spin ring frame.

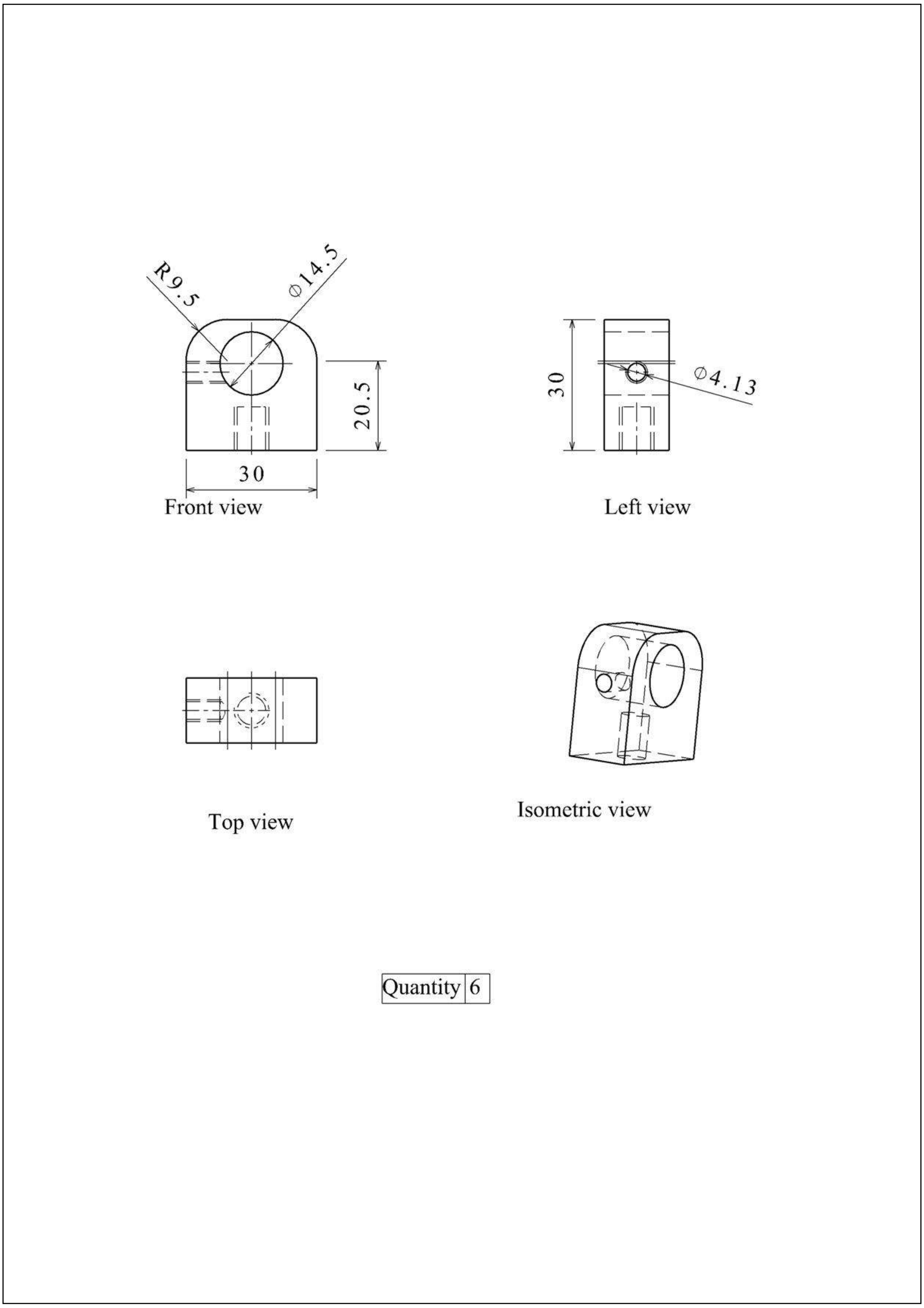


Module	5
Number of teeth	20
Diameter	100
Quantity	1

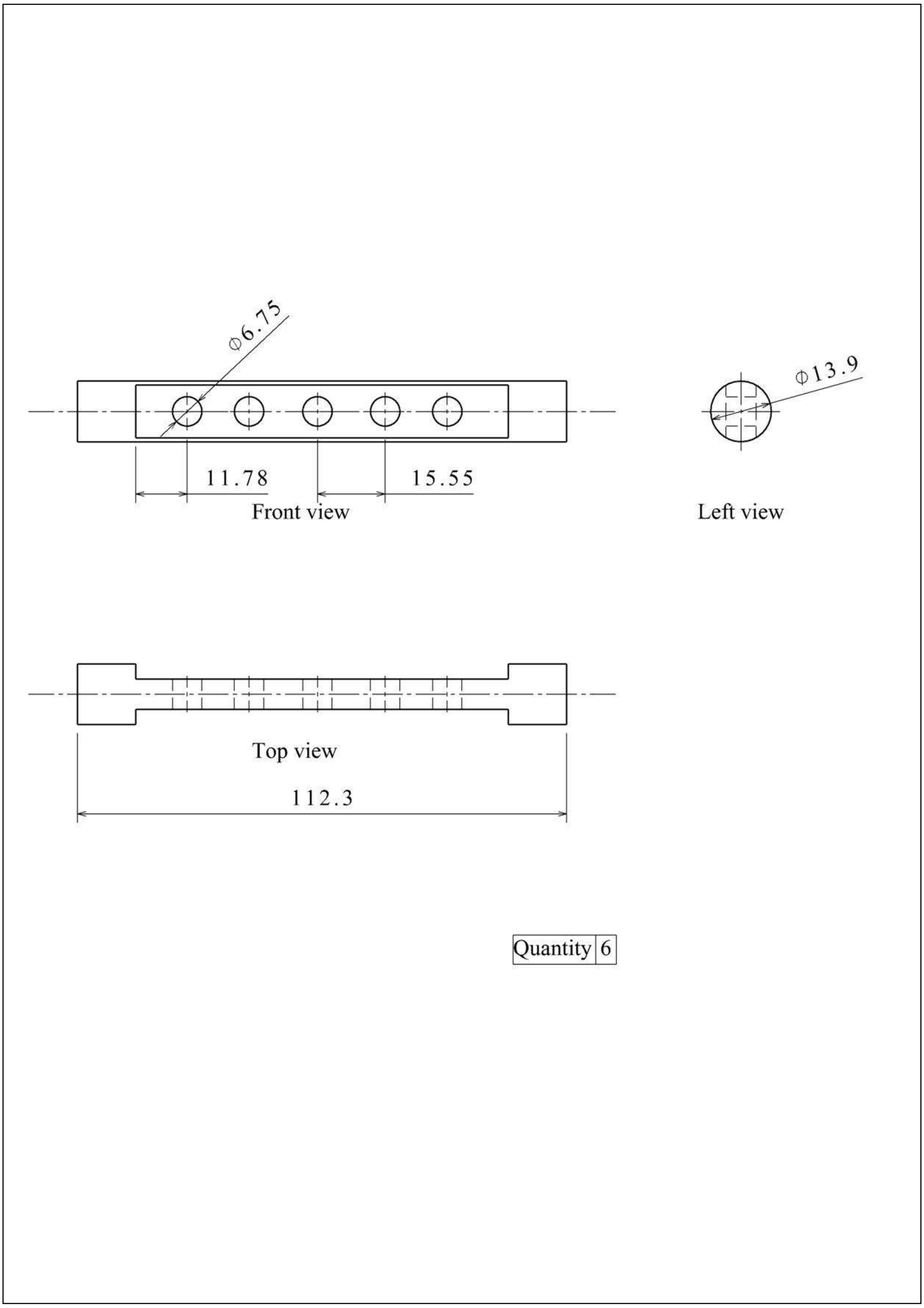
Appendix A.71: Sprocket connected to the output shaft of the 3 rpm motor which drives the spin ring assembly.



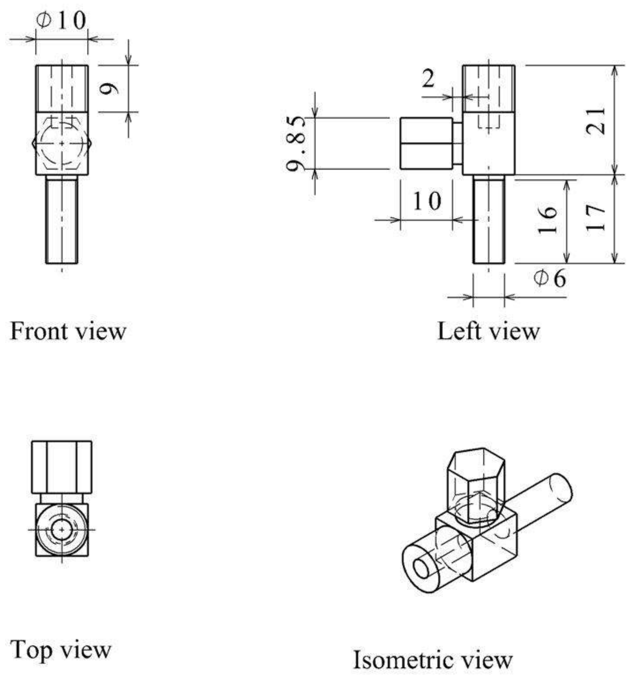
Appendix A.72: Partial assembly drawing of the drive system which powers the spin ring assembly.



Appendix A.73: Brackets to hold the pneumatic cylinders which drive the yarn catchers.

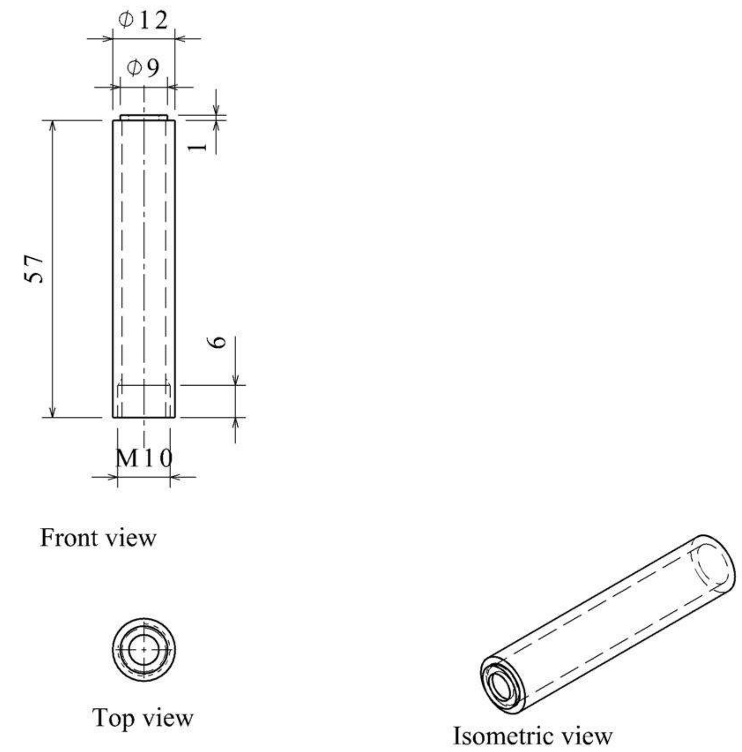


Appendix A.74: Fixtures to fix the brackets holding the pneumatic actuators which drive the yarn catchers.



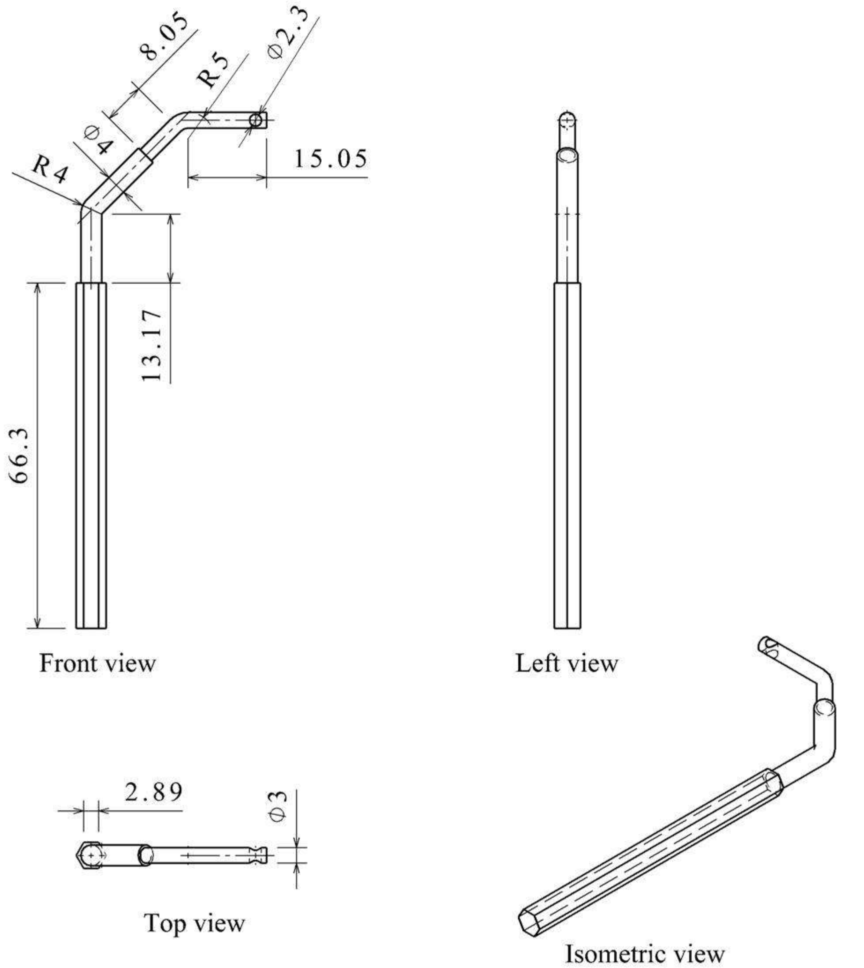
Quantity	18

Appendix A.75: Bottom end plate of the pneumatic cylinder actuating the yarn catchers.



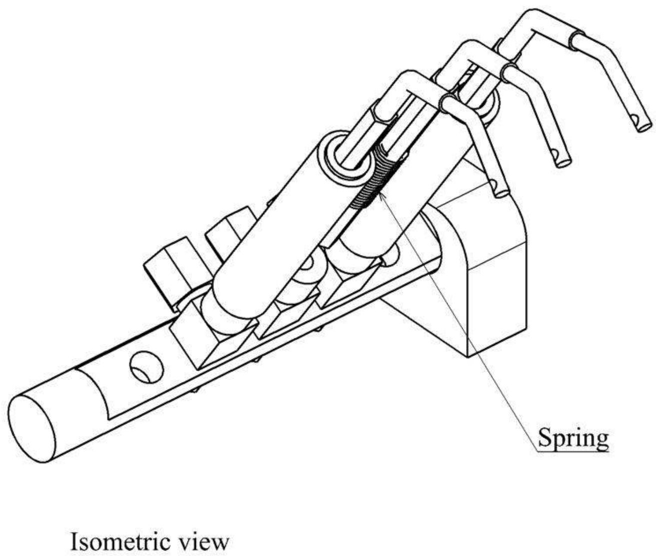
Quantity	18

Appendix A.75: Tubing for the pneumatic actuators.



Quantity	18

Appendix A.76: Yarn catcher.



Appendix A.77: Assembly drawing of the yarn catcher battery.

Product data sheet
Characteristics

ATV12H037M2
variable speed drive ATV12 - 0.37kW - 0.55hp - 200..240V - 1ph - with heat sink

Main

Range of product	Altivar 12
Product or component type	Variable speed drive
Product destination	Asynchronous motors
Product specific application	Simple machine
Assembly style	With heat sink
Component name	ATV12
EMC filter	Integrated
Built-in fan	Without
Network number of phases	Single phase
Power supply voltage	200...240 V - 15...10 %
Motor power kW	0.37 kW
Motor power hp	0.55 hp
Communication port protocol	Modbus
Speed range	1...20
Transient overtorque	150...170 % of nominal motor torque
Asynchronous motor control profile	Sensorless flux vector control with PWM type motor control signal
IP degree of protection	IP20 without blanking plate on upper part

Complementary

Supply frequency	50/60 Hz (+/- 5 %)
Line current	4.9 A , 0...1 kA
Continuous output current	2.4 A at 4 kHz
Maximum transient current	3.6 A for 60 s
Speed drive output frequency	0...400 Hz
Nominal switching frequency	4 kHz
Switching frequency	2...16 kHz adjustable 4...16 kHz with derating factor
Braking torque	Upto 150 % of nominal motor torque with braking resistor at high inertia Upto 70 % of nominal motor torque without braking resistor
Regulation loop	Adjustable Factory-set with the speed loop stability and gain
Motor slip compensation	Adjustable Preset in factory
Prospective line Isc	≤ 1 kA
Output voltage	200...240 V triphase
Electrical connection	L1, L2, L3, U, V, W, PA, PC terminal 3.5 mm² (AWG 12)
Tightening torque	0.8 N.m
Insulation	Electrical between power and control
Supply	Internal supply for logic inputs 24 V DC , voltage limits 20.4...27.6 V 100 mA for overload and short-circuit protection Internal supply for reference potentiometer 5 V DC , voltage limits 4.75...5.25 V 10 mA for overload and short-circuit protection
Analogue input number	1
Analogue input type	AI1 configurable voltage 0...5 V , impedance 30 kOhm AI1 configurable voltage 0...10 V , impedance 30 kOhm AI1 configurable current 0...20 mA , impedance 250 Ohm

Appendix B.1: The data sheet of ATV12H037M2 invertor (Page 1)

Sampling duration	20 ms , tolerance +/- 1 ms for logic input < 10 ms for analogue input
Linearity error	+/- 0.3 ms for analogue input
Discrete input number	4
Discrete input type	LI1...LI4 programmable 24 V , voltage limits 18...30 V
Discrete input logic	Negative by program , ≥ 16 V (state 0), < 10 V (state 1) Positive , 0...< 5 V (state 0), ≥ 11 V (state 1)
Discrete output number	3
Discrete output type	(CLO) transmitter (LO1) open collector (R1A, R1B, R1C) logic relay 1 C/O
Minimum switching current	5 mA at 24 V DC for logic relay
Maximum switching current	2 A at 250 V AC inductive load cos phi = 0.4 , L/R= L/R = 7 ms for logic relay 2 A at 30 V DC inductive load cos phi = 0.4 , L/R= L/R = 7 ms for logic relay 3 A at 250 V AC resistive load cos phi = 1 , L/R= L/R = 0 ms for logic relay 4 A at 30 V DC resistive load cos phi = 1 , L/R= L/R = 0 ms for logic relay
Acceleration and deceleration ramps	S U Linear from 0 to 999.9 s
Braking to standstill	By DC injection , 0.1...30 s
Protection type	Modbus serial link failure Line supply overvoltage Line supply undervoltage Overcurrent between output phases and earth Overheating protection Safety for no network three-phase Short-circuit between motor phases Thermal protection
Insulation resistance	≥ 500 MOhm
Frequency resolution	Analog input converter A/D, 10 bits Display unit 0.1 Hz
Time constant	20 ms , tolerance +/- 1 ms for reference change
Marking	CE
Operating position	Vertical +/- 10 degree
Product weight	0.7 kg

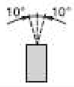
Environment

Electromagnetic compatibility	1.2/50 µs - 8/20 µs surge immunity test (level 3) conforming to EN/IEC 61000-4-5 Electrical fast transient/burst immunity test (level 4) conforming to EN/IEC 61000-4-4 Electrostatic discharge immunity test (level 3) conforming to EN/IEC 61000-4-2 Immunity to conducted disturbances (level 3) conforming to EN/IEC 61000-4-6 Radiated radio-frequency electromagnetic field immunity test (level 3) conforming to EN/IEC 61000-4-3
Standards	EN/IEC 61800-3
Product certifications	C-Tick CSA GOST NOM UL
Vibration resistance	1 gn (f = 13...200 Hz conforming to EN/IEC 60068-2-6 1.5 mm peak to peak (f = 3...13 Hz)drive unmounted on symmetrical DIN rail conforming to EN/IEC 60068-2-6
Shock resistance	15 gn for 11 ms conforming to EN/IEC 60068-2-27
Relative humidity	5...95 % without dripping water conforming to IEC 60068-2-3 5...95 % without condensation conforming to IEC 60068-2-3
Ambient air temperature for storage	-25...70 °C
Ambient air temperature for operation	-10...40 °C with protective cover from the top of the drive removed 40...60 °C with current derating 2.2 % per °C
Operating altitude	1000 m without derating > 1000...2000 m with derating 1 % per 100 m
RoHS EUR conformity date	0915
RoHS EUR status	Compliant

Appendix B.1: The data sheet of ATV12H037M2 invertor (Page 2)

TECHNICAL SPECIFICATIONS

Environment

Degree of protection	• IP20 without protective vent cover, NEMA 1, UL open type • IP21 on wiring terminals • IP31 and IP41 all other areas • UL Type 1 without removal of the protective vent cover from the top of the controller and with the addition of the Conduit Entry Kit.
Resistance to vibration	Conforming to IEC/EN 60068-2-6: 1.5 mm peak to peak from 3 to 13 Hz, 1 gn from 13 to 150 Hz
Resistance to shock	15 g for 11 ms conforming to IEC/EN 60068-2-27
Pollution degree	Pollution degree 2 according to UL 840. Protect the drive against dust, corrosive gas, and falling liquid.
Maximum relative humidity	96% maximum, non-condensing and without dripping (provide heating system if there is condensation) Conforms to IEC 60068-2-3
Maximum ambient temperature	Storage: -13 to +158 °F (-25 to +70 °C) Operation: +14 to +122 °F (-10 to +50 °C) without vent cover removed and without derating; +14 to +140 °F (-10 to +60 °C) with vent cover removed and with derating. Refer to derating curves on page 30.
Altitude	Up to 3,300 ft (1,000 m) without derating; derate by 1% for each additional 330 ft (100 m)
Operating position Maximum permanent angle in relation to the normal vertical mounting position	

Electrical characteristics

Input voltage	ATV31•••M2 (1 phase): 200 V -15% to 240 V +10% ATV31•••M3X (3 phase): 200 V -15% to 240 V +10% ATV31•••N4 (3 phase): 380 V -15% to 460 V +15% ATV31•••S6X (3 phase): 525 V -15% to 575 V +15%
Input frequency	50/60 Hz ±5%
Input phases	ATV31•••M2: 1 ATV31•••M3X: 3 ATV31•••N4: 3 ATV31•••S6X: 3
Output voltage	Maximum voltage equal to input voltage
Output frequency	0 to 500 Hz
Output phases	3
Speed range	1:50
Transient overtorque	170–200% nominal motor torque (typical value)
Maximum transient current	Up to 150% of nominal drive controller current for 60 seconds
Braking torque	With braking resistor: 100% of nominal motor torque continuously and up to 150% for 60 s. Without braking resistor: • Drive controllers ≥ ATV31•U22••: 30% of nominal motor torque • Drive controllers ≤ATV31•U15••: 50% of nominal motor torque • Drive controllers ≤ATV31•075••: 100% of nominal motor torque • Drive controllers ≤ATV31•018M2: 150% of nominal motor torque
Frequency resolution	Display: 0.1 Hz Analog inputs: 0.1 Hz to 100 Hz maximum *[(high speed – low speed)/1024]*
Switching frequency	Adjustable from 2.0 kHz to 16 kHz. Randomly modulated by default, but this can be disabled.
Drive controller protection	Galvanic isolation between power and control (power supplies, inputs, outputs) Protection against short circuits: • within internal power supplies • between output phases • between output phases and ground Protection against input phase loss Thermal protection against overheating and overcurrents Undervoltage and overvoltage faults Overbraking fault
Motor protection	Thermal protection, integrated into the drive controller, by I^2t calculation Protection against motor phase loss

Appendix B.2: The data sheet of Alvitar-31 invertor (Page 1)

Altivar® 31 Adjustable Speed AC Drives
Technical Specifications

Electrical characteristics (continued)

Dielectric strength	**Between ground and power terminals:** ATV31•••M2 and M3X: 2040 Vdc ATV31•••N4: 2410 Vdc ATV31•••S6X: 2550 Vdc **Between control and power terminals:** ATV31•••M2 and M3X: 2880 Vac ATV31•••N4: 3400 Vac ATV31•••S6X: 3600 Vac
Resistance to ground	>500 MΩ (electrical isolation) 500 Vdc for 1 minute
Communication	Modbus and CANopen are integrated into the drive controller and available via an RJ45 connector.
Modbus	RS-485 multidrop serial link characteristics: • Modbus in RTU mode • Services supported: decimal function codes 03, 06, 16, 23, and 43 • Broadcasting • Number of addresses: drive address can be configured via the local keypad display from 1 to 247 • Maximum number of ATV31 drive controllers: 31 (two 470 Ω master pull-down resistors) • Transmission speed: 4800, 9600, or 19200 bps • The following devices can be connected to the RS-485 link: — Remote keypad display — PowerSuite software workstation — PLC — Microprocessor card — PC
CANopen	To connect the ATV31 drive controller to a CANopen network, use the VW3CANTAP2 adapter. The following services are supported: • Implicit exchange of Process Data Object (PDO): — Two predefined PDOs conforming to DSP 402 Velocity Mode — Two configurable PDOs (data and transmission type) — PDOs can be exchanged between slave devices • Explicit exchange of Service Data Object (SDO): — One receive SDO and one transmit SDO • Boot-up messages, emergency messages, node guarding, and producer and consumer heartbeat • Number of addresses: drive controller address can be configured via the integrated terminal from 1 to 127 • Maximum number of drive controllers: 127 • Transmission speed: 10, 20, 50, 125, 250, 500 kbps or 1 Mbps
Codes and standards	• UL Listed per UL 508C as incorporating electronic overload protection: UL File E164874 CCN NMMS • CSA Certified to CSA C22.2 No. 14: CSA File LR96921 Class 3211 06 • CE Marked in accordance with the European low voltage (73/23/EEC and 93/68/EEC) and EMC (89/336/EEC) directives • Conforms to applicable NEMA ICS, IEC, NOM, C-TICK, and ISO 9001 standards
Electromagnetic immunity	ATV31 drives meet IEC and EN requirements, the strictest international standards for electrical industrial control devices. They conform to EN 50178, governing electromagnetic compatibility and conducted and radiated emissions.
Electromagnetic compatibility	• IEC/EN 61000-4-2 level 3 • IEC/EN 61000-4-3 level 3 • IEC/EN 61000-4-4 level 4 • IEC/EN 61000-4-5 level 3 (power access) • IEC/EN 61800-3, environments 1 and 2
Conducted and radiated emissions for drive controllers (Consult page 16 for additional EMC filters)	**All ratings:** IEC/EN 61800-3, environments 2 (industrial network) and 1 (public utility network) in limited distribution. **ATV31H018M2 to CU40N4:** • EN 55011, Class A, Group 1; EN 61800-3 Category C2 with additional EMC filter • EN 55022, Class B, Group 1; EN 61800 **ATV31HU22M2 to HD15N4:** • EN 55011, Class A, Group 2; EN 61800-3 Category C3 with additional EMC filter • EN 55022, Class A, Group 1; EN 61800-3 Category C2 • EN 55022, Class B, Group 1; EN 61800-3 Category C1 **ATV31H018M3X to HD15M3X** with additional EMC filter: • EN 55011, Class A, Group 1; EN 61800-3 Category C2 • EN 55022, Class B, Group 1; EN 61800-3 Category C1
Prospective short-circuit current ICC [1] Refer to "Recommended fuses or Powerpact® circuit breakers" on page 26	**ATV31•••M2** ≤1000 A (ICC at connection point) for single phase power supply **ATV31H018M3X...HU40M3X, ATV31•037N4...•U40N4, ATV31H075S6X...HU40S6X** ≤5000 A (ICC at connection point) for three-phase power supply **ATV31HU55M3X...HD15M3X, ATV31HU55N4...HD15N4, ATV31KU55N4...KD15N4, ATV31HU55S6X...HD15S6X** ≤22000 A (ICC at connection point) for three-phase power supply
Maximum connection capacity and tightening torque of the power supply terminals, motor, braking module, and DC bus	**H018M2, H037M2, H055M2, H075M2, H018M3X, H037M3X, H055M3X, H075M3X, HU11M3X, HU15M3X** 14 AWG (2.5 mm²), 7.08 lb-in (0.8 N•m) **HU11M2, HU15M2, HU22M2, HU22M3X, HU30M3X, HU40M3X, H037N4, H055N4, H075N4, HU11N4,HU15N4, HU22N4, HU30N4, HU40N4, H075S6X, HU15S6X, HU22S6X, HU40S6X** 10 AWG (5 mm²), 10.62 lb-in (1.2 N•m) **HU55M3X, HU75M3X, HU55N4, HU75N4, HU55S6X, HU75S6X** 6 AWG (16 mm²), 19.47 lb-in (2.2 N•m) **HD11M3X, HD15M3X, HD11N4, HD15N4, HD11S6X, HD15S6X** 3 AWG (25 mm²), 35.40 lb-in (4 N•m)
Electrical isolation	Electrical isolation between power and control (inputs, outputs, power supplies)

Appendix B.2: The data sheet of Alvitar-31 invertor (Page 2)

Altivar® 31 Adjustable Speed AC Drives
Technical Specifications

Electrical characteristics (continued)

Internal supplies available	Short-circuit and overload protection: One +10 V (-0 / +8%) supply for setpoint potentiometer (2.2 to 10 kΩ), maximum current 10 mA One +24 V supply (minimum 19 V, maximum 30 V) for logic inputs, maximum current 100 mA
Configurable analog inputs Three configurable analog inputs AI1, AI2, AI3.	**AI1:** Analog input 0 to +10 V (maximum safe voltage is 30 V) • Impedance: 30 kΩ • Resolution: 0.01 V, 10-bit converter • Precision: ± 4.3% of maximum value • Linearity: ± 0.2% of maximum value • Sampling time: 8 ms • Shielded cable length: 100 m (328 ft) maximum **AI2:** Analog input 0 to +10 V (maximum safe voltage is 30 V) Bipolar analog input 0 to ±10 V (maximum safe voltage is ±30 V) *The + or - polarity of the voltage on AI2 affects the direction of the setpoint and therefore the direction of rotation.* • Impedance: 30 kΩ • Resolution: 0.01 V, 10-bit + sign converter • Precision: ± 4.3% of maximum value • Linearity: ± 0.2% of maximum value • Sampling time: 8 ms • Shielded cable length: 100 m (328 ft) maximum **AI3:** Analog input X–Y mA; X and Y programmable from 0–20 mA • Impedance: 250 Ω • Resolution: 0.02 mA, 10-bit converter • Precision: ± 4.3% of maximum value • Linearity: ± 0.2% of maximum value • Sampling time: 8 ms
Analog output configurable for voltage, current, or logic output Analog voltage output AOV or Analog current output AOC or Logic voltage output on AOC *Can assign either AOV or AOC, but not both.*	Analog output 0 to 10 V, minimum load impedance 470 Ω or Analog output X to Y mA; X and Y programmable from 0–20 mA, maximum load impedance 800 Ω: • Resolution: 8 bits • Precision: ± 1% • Linearity: ± 0.2% • Sampling time: 8 ms or AOC can be configured as a 24 V logic output with a minimum load impedance of 1.2 kΩ.
Configurable relay outputs **R1A** is a N.O. contact. **R1B** is a N.C. contact. **R1C** is the common. R1 is programmable—factory set as a fault relay (R1A is closed and R1B is open when the controller is powered with no fault) **R2A, R2C** N.O. contact of programmable relay R2	• Minimum switching capacity: 10 mA for 5 Vdc • Maximum switching capacity on a resistive load (power factor = 1 and L/R time constant = 0 ms): 5 A for 250 Vac and 30 Vdc • Maximum switching capacity on an inductive load (power factor = 0.4 and L/R time constant = 7 ms): 1.5 A for 250 Vac and 30 Vdc • Sampling time: 8 ms • Service life: 100,000 operations at maximum switching power; 1,000,000 operations at minimum switching power
Logic inputs LI LI1, LI2, LI3, LI4, LI5, LI6	Programmable logic inputs • +24 V power supply (maximum 30 V) • Impedance: 3.5 kΩ • State 0 if the difference between LIx and CLI is < 5 V, State 1 if the difference between LIx and CLI is > 11 V • Sampling time: 4 ms
Maximum I/O connection capacity and tightening torque	14 AWG (2.5 mm^2) 0.6 N•m (5.31 lb-in)
Acceleration and deceleration ramps	Ramp profiles: • linear, can be adjusted separately from 0.1 to 999.9 s • S, U, or customized Automatic adaptation of deceleration ramp time if braking capacities are exceeded, possible inhibition of this adaptation (use of braking resistor).
DC injection braking	DC injection braking can be initiated: • By a signal on a programmable logic input • Automatically as soon as the estimated output frequency drops to < 0.5 Hz, period adjustable from 0 to 30 s or continuous, current adjustable from 0 to 1.2 In
Signaling on the drive local keypad display	• One red LED indicating the presence of drive voltage • Four 7-segment displays • Two CANopen status LEDs (RUN and ERR)
Scan time for reference change	5 ms

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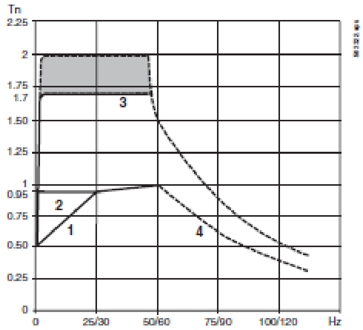
Appendix B.2: The data sheet of Alvitar-31 invertor (Page 3)

Torque characteristics (typical curves)

The torque characteristics curves below define the available continuous torque and transient overtorque for both force-cooled and self-cooled motors. The only difference is in the ability of the motor to provide a high continuous torque at less than half the nominal speed.



1. Self-cooled motor: continuous useful torque
2. Force-cooled motor: continuous useful torque
3. Transient overtorque 1.7 to 2 Tn
4. Torque in overspeed at constant power[1]

Special uses

Using a motor with a different rating than the drive

The drive can supply any motor with a power rating lower than that for which it is designed.
For motors rated slightly higher than the drive, ensure that the load does not exceed the continuous output current of the drive.

Testing on a low power motor or without a motor

In a testing or maintenance environment, the drive can be run without switching to a motor with the same rating as the drive (particularly useful in the case of high power drives). This requires deactivation of motor phase loss detection.

Connecting motors in parallel

The rating of the drive must be greater than or equal to the sum of the currents of the motors connected to the drive.
External thermal protection must be provided for each motor.
If connecting three or more motors in parallel, we recommend installing an output filter between the drive and the motors.

1. The nominal frequency of the motor and the maximum output frequency are adjustable between 40 and 500 Hz.
NOTE: Check the mechanical overspeed characteristics of the selected motor with the manufacturer.

Appendix B.2: The data sheet of Alvitar-31 invertor (Page 4)

Servo Motor Charactercistics

Servo Motor (APM-)	SAR3A	SAR5A	SA01A	SB01A	SB02A	SB04A
Servo Drive (APD-)	VN01				VN02	VN04
Rated Power (KW)	0,03	0,05	0,1	0,1	0,2	0,4
Torque [N/m] Rated	0,095	0,159	0,318	0,318	0,637	1,274
Torque [N/m] Max	0,97	1,62	3,25	3,25	6,50	13,0
Inertia $[kg \cdot m^2 \times 10^{-4}]$	0,011	0,021	0,045	0,144	0,182	0,321
Allowable Load Inertia Ratio	30 times of motor inertia				20 times	
Speed [r/min] Rated	3000					
Speed [r/min] Max	5000					
Encoder	Standard : Incremental 3000P/R, Option :Serial 17(bit)					
Operating environment	Vibration : Less than 49[m/s²](5G), Operating Temp : 0~40[℃], Storage Temp : -20~-80[℃]					

Servo Motor (APM-)	SBN01A	SBN02A	SBN04A	SBN04A-BK	SC04A	SC06A
Servo Drive (APD-)	VN01	VN02	VN04			VN04
Rated Power (KW)	0,1	0,2	0,4	0,4	0,6	0,4
Torque [N/m] Rated	0,318	0,637	1,273	1,273	1,27	1,91
Torque [N/m] Max	0,955	1,910	3,82	3,82	3,82	5,34
Inertia $[kg \cdot m^2 \times 10^{-4}]$	0,014	0,182	0,322	0,254	0,674	1,092
Allowable Load Inertia Ratio	20 times of motor inertia				15 times	
Speed [r/min] Rated	3000					
Speed [r/min] Max	5000					
Encoder	Standard : Incremental 3000P/R, Option :Serial 17(bit)					
Operating environment	Vibration : Less than 49[m/s²](5G), Operating Temp : 0~+40[℃], Storage Temp : -20~-80[℃]					

Servo Motor (APM-)	SC08A	SC10A	SC03D	SC05D	SC06D	SC07D
Servo Drive (APD-)	VN07	VN10	VN04		VN07	
Rated Power (KW)	0,8	1,0	0,3	0,45	0,55	0,65
Torque [N/m] Rated	2,55	3,19	1,43	2,15	2,63	3,09
Torque [N/m] Max	6,88	9,56	4,29	6,44	7,88	9,29
Inertia $[kg \cdot m^2 \times 10^{-4}]$	1,509	1,927	0,674	1,092	1,509	1,927
Allowable Load Inertia Ratio	15 times of motor inertia					
Speed [r/min] Rated	3000		2000			
Speed [r/min] Max	5000		3000			
Encoder	Standard : Incremental 3000P/R, Option :Serial 17(bit)					
Operating environment	Vibration : Less than 49[m/s²](5G), Operating Temp : 0~+40[℃], Storage Temp : -20~-80[℃]					

Servo Motor (APM-)	SE09A	SE15A	SE22A	SE30A	SE06D	SE11D
Servo Drive (APD-)	VN10	VN15	VN20	VN35	VN07	VN10
Rated Power (KW)	0,9	1,5	2,2	3,0	0,6	1,1
Torque [N/m] Rated	2,86	4,77	7,0	9,55	2,86	5,25
Torque [N/m] Max	8,59	14,32	21,01	28,65	8,59	15,75
Inertia $[kg \cdot m^2 \times 10^{-4}]$	6,659	11,999	17,339	22,679	6,659	11,999
Allowable Load Inertia Ratio	10 times of motor inertia					
Speed [r/min] Rated	3000				2000	
Speed [r/min] Max	5000				3000	
Encoder	Standard : Incremental 3000P/R, Option :Serial 17(bit)					
Operating environment	Vibration : Less than 49[m/s²](5G), Operating Temp : 0~+40[℃], Storage Temp : -20~-80[℃]					

Appendix B.3: The data sheet of motor and servo drive (Page 1)

Servo Motor Charactercistics

Servo Motor (APM-)		SE16D	SE22D	SE03M	SE06M	SE09M	SE12M
Servo Drive (APD-)		VN15	VN20	VN04	VN07	VN10	VN15
Rated Power (KW)		1,6	2,2	0,3	0,6	0,9	1,2
Torque [N.m]	Rated	7,63	10,5	2,86	5,72	8,59	11,46
	Max	22,92	31,51	8,59	17,18	25,77	34,22
Inertia $[kg \cdot m^2 \times 10^{-4}]$		17,339	22,679	6,659	11,999	17,339	22,679
Allowable Load Inertia Ratio		10 times of motor inertia					
Speed [r/min]	Rated	2000		1000			
	Max	3000		2000			
Encoder		Standard : Incremental 3000P/R, Option :Serial 17(bit)					
Operating environment		Vibration : Less than 49[m/s²](5G), Operating Temp : 0~40[℃], Storage Temp : -20~-80[℃]					

Servo Motor (APM-)		SF30A	SF22D	SF35D	SF12M	SF20M	SF30M
Servo Drive (APD-)		VN30	VN20	VN35	VN15	VN20	VN30
Rated Power (KW)		3,0	2,2	3,5	1,2	2,0	3,0
Torque [N.m]	Rated	9,55	10,5	16,7	11,46	19,09	28,64
	Max	28,64	31,5	50,12	34,38	57,29	85,94
Inertia $[kg \cdot m^2 \times 10^{-4}]$		30,74	30,74	52,13	30,74	52,13	83,60
Allowable Load Inertia Ratio		모터 이너셔의 5배					
Speed [r/min]	Rated	3000	2,000		1,000		
	Max	5000	3,000		2,000		
Encoder		Standard : Incremental 3000P/R, Option :Serial 17(bit)					
Operating environment		Vibration : Less than 49[m/s²](5G), Operating Temp : 0~40[℃], Storage Temp : -20~-80[℃]					

Servo Motor (APM-)		SE05G	SE09G	SE13G	SE17G	SF20G	SF30G
Servo Drive (APD-)		VN07	VN10	VN15	VN20		VN30
Rated Power (KW)		0,45	0,85	1,3	1,7	1,8	2,9
Torque [N.m]	Rated	2,86	5,41	8,27	10,82	11,45	18,46
	Max	8,59	16,23	24,82	32,46	34,37	55,38
Inertia $[kg \cdot m^2 \times 10^{-4}]$		6,659	11,999	17,339	22,679	30,74	52,13
Allowable Load Inertia Ratio		모터 이너셔의 10배				모터 이너셔의 5배	
Speed [r/min]	Rated	1,500					
	Max	3,000					
Encoder		Standard : Incremental 3000P/R, Option :Serial 17(bit)					
Operating environment		Vibration : Less than 49[m/s²](5G), Operating Temp : 0~+40[℃], Storage Temp : -20~-80[℃]					

Servo Motor (APM-)		SG22D	SG35D	SG20G	SG30G	SG12M	SG20M
Servo Drive (APD-)		VN20	VN35	VN20	VN30	VN15	VN20
Rated Power (KW)		2,2	3,5	1,8	2,9	1,2	2,0
Torque [N.m]	Rated	10,5	16,7	11,5	18,5	11,5	19,1
	Max	31,5	50,1	34,4	55,4	34,4	57,3
Inertia $[kg \cdot m^2 \times 10^{-4}]$		51,42	80,35	51,42	80,35	51,42	80,35
Allowable Load Inertia Ratio		5 times of motor inertia					
Speed [r/min]	Rated	2000		1500		1000	
	Max	3000		3000		2000	
Encoder		Standard : Incremental 3000P/R, Option :Serial 17(bit)					
Operating environment		Vibration : Less than 49[m/s²](5G), Operating Temp : 0~+40[℃], Storage Temp : -20~-80[℃]					

Appendix B.3: The data sheet of motor and servo drive (Page 2)

Servo Motor Charactercistics

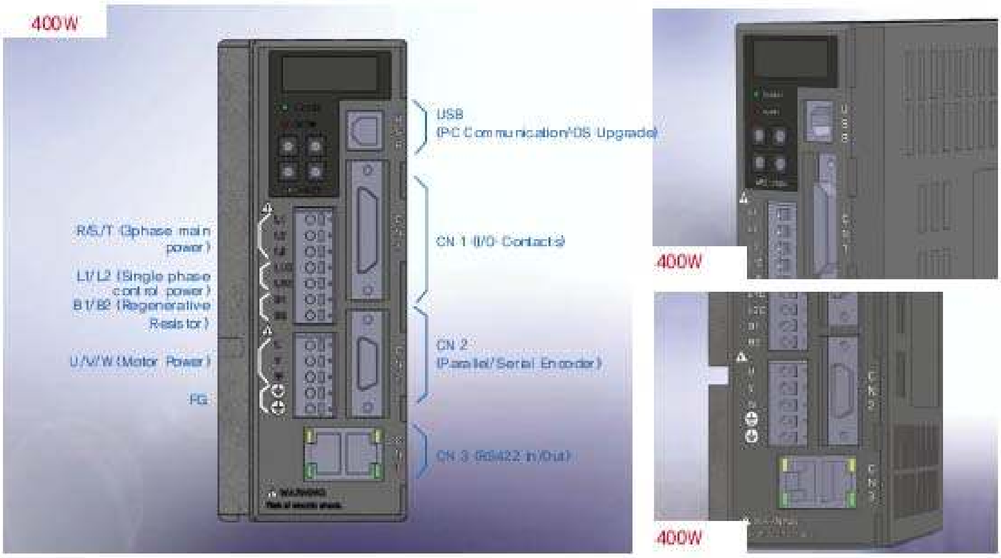
Servo Motor (APM-)		SG30M	HB01A	HB02A	HB04A	HB09A	HE15A
Servo Drive (AFD-)		VN30	VN01	VN02	VN04	VN10	VN15
Rated Power (kW)		3,0	0,1	0,2	0,4	0,9	1,5
Torque [N,m]	Rated	28,6	0,318	0,637	1,274	2,86	4,77
	Max	85,9	0,955	1,912	3,822	8,59	14,32
Inertia $[kg.m^2 \times 10^{-4}]$		0,014	0,182	0,322	0,254	0,674	1,092
Allowable Load Inertia Ratio		5 times	20 times of motor inertia			10 times	
Speed [r/min]	Rated	1000	3000				
	Max	2000	5000				
Encoder		Standard : Incremental 3000P/R, Option :Serial 17(bit)					
Operating environment		Vibration : Less than $49[m/s^2]$(5G), Operating Temp : 0~+40[℃], Storage Temp : -20~-80[℃]					

VN Servo Drive Spec

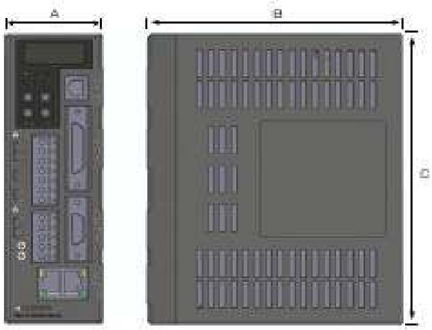
		VN01	VN02	VN04	VN07	VN10	VN15	VN20	VN35
Power Supply		3 phase AC 200~230V +10[%] -- 15[%], 50/60[Hz]							
Applicable motor	Voltage type	3 phase sine wave PWM driven AC Servo Motor							
	Rated Current[A]	1,4	1,65	3,0	4,3	6,0	10	16	21
	Max Current[A]	4,2	4,95	9,0	12,9	18,0	30	48	63
Detector Type		Standard : Incremental line drive 2000 ~ 10000P/R Option : Serial 17(bit)							
Speed Control Mode	Speed control range	Max 1:5000							
	Frequency response	600[Hz] (For using Serial Encoder)							
	Speed command	DC -10[V] ~ +10[V](-voltage : Reverse Rotation), 3 digital speed commands							
	Acceleration/Deceleration time	Linear 0~10,000[ms], S type acceleration/deceleration							
	Speed Variation ratio	± 0,01[%] or less [load variation 0~100%], ±0,1[%] or less [Temperature 25 ±10℃]							
Position Control Mode	Input frequency	Line drive : 500[kbps] Open collector : 400[kbps]							
	Input pulse	A+B phase, forward + reverse pulse, direction + pulse(Line driver, Open Collector)							
	Electronic gear ratio	Digital 4 speed, Available detail adjust							
Torque Control Mode	Torque command	DC -10[V] ~ +10[V] (- voltage : reverse)							
	Torque linearity	Less than 2[%]							
	Speed limit	DC 0[V] ~ +10[V], 3 digital speed commands							
Embedded Function	Generative Brake	Standard embedded [Operating on Servo ON or Servo OFF]							
	Regenerative Brake	Option		Standard				Embedded	
	Loader	Embedded 7 segments [6 digits], CHARGE & ALARM Lamp							
	Monitor output	DC -5[V] ~ +5[V], 2Channels [Speed, Torque, Position etc]							
	Protective function	For the error and mistake of Input/UVW wiring, Encoder pulse setting, Overheat of power module, Over current, Over load and Over speed etc							
Ambient Environment	Temperature	0 ~ 50 [℃]							
	Humidity	Less than 90[%] (Avoid condensation)							
	Environment	Indoor, No corrosive gas, inflammable gas and Oil mist etc							

Appendix B.3: The data sheet of motor and servo drive (Page 3)

VN Series Designation



VN Series Dimension



Drive	A(mm)	B(mm)	C(mm)	Weight(kg)
APD-VN01N	52	132	150	0,8
APD-VN02N	52	132	150	0,8
APD-VN04N	61	132	150	1,0
APD-VN07N	90	190	160	1,9
APD-VN10N	90	190	160	2,0
APD-VN15N	110	190	160	2,7

Appendix B.3: The data sheet of motor and servo drive (Page 4)

Merit of VN Series

Compact
- Reduced 40% of size compare with VS series (400W)
- Improve space flexibility of control panel with minature design

Low Cost
- Reduced 7~10% of production cost from VS series (400W)

Serial Encoder Support
- 17 ~ 19 Bit serial encoder is available (From 2009)

Excellent Speed Response
- Fast response speed compare with VS series (When serial encoder is used)

Various Alarm Function
- For the error and mistake of Input/UVW wiring, Encoder pulse setting, Overheat of power module, Over current, Over load and Over speed etc

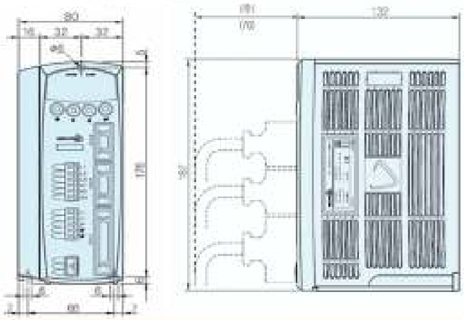
USB Communication
- O/S download, PC communication (From 2009)

RS-422 Communication
- From 2009

VS / VN Drive Comparison • Dimensions

VS Drive

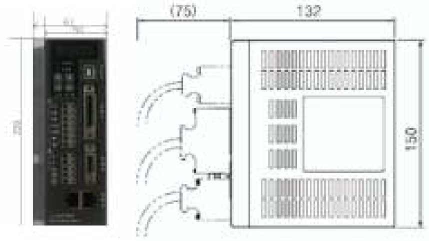
Mecapion VS Drive



[400W] WxLxH : 80X176X132 [mm]

VN Drive

Mecapion VN Drive



[400W] WxLxH : 61X150X132 [mm]

Appendix B.3: The data sheet of motor and servo drive (Page 5)

VS / VN Comparison

• Based on 400W drives

Article / Drive		APD-VS04N	APD-VN04N
Pictures			
Power Supply		3 phase AC 200~230V +10[%] ~ -15[%], 50/60[Hz]	
Applicable motor	Voltage type	3 phase sine wave PWM driven AC Servo Motor	
	Rated Current	3.2	3
	Max Current	9.6	9
Detector Type		Standard : Incremental Line Drive 2000~10000P/R	Standard : Incremental Line Drive 2000~10000P/R Option : Serial 17bit
Speed Control Mode	Speed control range	Max 1 : 10,000	1 : 5,000
	Frequency response	Max 400[Hz]	Incremental : 400Hz, Serial : Over than 600Hz
	Speed command	7 digital speed commands	3 digital speed commands
	Acceleration/Deceleration time	Linear 0~10,000[ms], S type acceleration/deceleration	
	Speed Variation ratio	±0.01[%] or less [load variation 0~100%], ±0.1[%] or less [Temperature 25±10℃]	
Position Control Mode	Input frequency	Line Drive : 500[kbps] Open Collector : 400[kbps]	
	Input pulse	A+B phase, forward + reverse pulse, direction + pulse(Line driver, Open Collector)	
	Electronic gear ratio	Digital 4 speed, Precise adjustment function	
Torque Control Mode	Torque command	DC -10[V] ~ +10[V] (- voltage : reverse)	
	Torque linearity	Less than 2[%]	
	Speed limit	DC 0[V] ~ +10[V], 3 digital speed commands	
Ambient Environment	I/O Contact	Input: 14, Output: 6, Analogue Input: 2 Pulse line: 2, Monitor: 2	Input: 9, Output: 3, Analogue Input: 2, Pulse line: 2, Monitor: 2
	Feedback encoder from controller	1/1 ~ 1/16: 16 Steps divided output	Arbitrary divided output
	PC-Communication	RS232	USB
	EXT. Communication	RS485	RS422

Appendix B.3: The data sheet of motor and servo drive (Page 6)

DATA SHEET

LG Programmable Logic Controller

MASTER-K80S Series

K7M-DR20/30/40/60S

LG Industrial Systems

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  LG Industrial Systems
  Elevator Co., Ltd.
  T : +86-10-6462-3256
  F : +86-10-6462-3255
- **Bogota Branch**
  LG Industrial Systems de
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  T : +57-1-310-6077
  F : +57-1-310-5631
- **Dalian Branch**
  Dalian LG Industrial Systems
  Co., Ltd.
  T : +86-411-281-2579
  F : +86-411-281-2578
- **Hong Kong Branch**
  LG Industrial Systems (HK) Ltd.
  T : +852-2598-6615
  F : +852-2598-7105
- **Singapore Branch**
  LG Industrial Systems Co., Ltd.
  T : +65-323-7361
  F : +65-323-7362
- **Tokyo Branch**
  LG Industrial Systems Co., Ltd. Tokyo Office
  T : +81-3-3589-6362
  F : +81-3-3588-1810
- **Bangkok Branch**
  LG Industrial Systems (Thailand)
  Co., Ltd
  T : +66-2-381-8443
  F : +66-2-381-8445
- **Chicago Branch**
  LG Industrial Systems Co., Ltd.
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  T : +1-708-692-4500
  F : +1-708-692-4501
- **Hanoi Branch**
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  T : +84-4-821-0388
  F : +84-4-821-0399
- **Shanghai Branch**
  Shanghai LG Industrial Systems Co., Ltd.
  T : +86-21-6248-2710
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- **Head Office**
  LG Twin Towers 20, Yoido-dong, Yongdungpo-gu, Seoul 150-721, Korea
  Tel : +82-2-3777-4641~7 Fax : +82-2-3777-4648
  Home page : http:www.lgis.lg.co.kr/fa

702008002

Before handling the product

Read this data sheet carefully prior to any operation, mounting, installation or start-up of the product.

Materials for MASTER-K

Name	Code
KGLWIN (Programming software)	702005036
MASTER-K (Instruction & programming)	702006539
MASTER-K80S User's manual	702006391

❑ Safety Precautions

Be sure to read carefully the safety precautions given in data sheet and user's manual before operating the module and follow them.

The precautions explained here only apply to the K80S CPU module. For safety precautions on the PLC system, see the K80S User's manual.

A precaution is given with a hazard alert triangular symbol to call your attention, and precautions are represented as follows according to the degree of hazard.

⚠ Warning	If not provided with proper prevention, it can cause death, fatal injury or considerable loss of property
⚠ Caution	If not properly observed, it can cause a hazard situation to result in severe or slight injury or a loss of property.

⚠ However, a precaution followed with 'Caution' can also result in serious conditions. Both of two symbols indicate that an important content is mentioned, therefore, be sure to observe it. Keep this manual handy for your quick reference in necessary.

❑ Design Precautions

⚠ Caution

- Don not run I/O signal lines near to high voltage line or power line. Separate them as 100mm or more as possible. Otherwise, noise can cause module malfunction.

❑ Installation Precautions

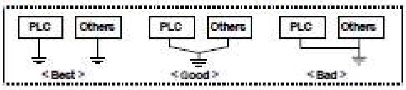
⚠ Caution

- Operate the PLC in the environment conditions given in the general specifications.
- If operated in other environment not specified in the general specifications, it can cause an electric shock, a fire, malfunction or damage or degradation of the module.
- Make sure the module fixing projections is inserted into the module fixing hole and fixed.
- Improper installation of the module can cause malfunction, disorder or falling.

❑ Wiring Precautions

⚠ Caution

- Make sure that FG the terminal is grounded with class 3 grounding which is dedicated to the PLC. Otherwise, it can cause disorder or malfunction of PLC.

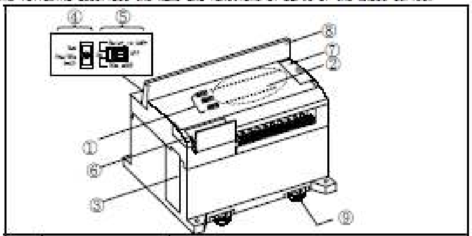


- Before the PLC wiring, be sure to check the rated voltage and terminal arrangement for the module and observe them correctly. If a different power, not of the rated voltage, is applied or wrong wiring is provided, it can cause a fire or disorder of the module.
- Drive the terminal screws firmly to the defined torque. If loosely driven, it can cause short circuit, a fire or malfunction.
- Be careful that any foreign matter like wire scraps should not enter into the module. It can cause a fire, disorder or malfunction.

Appendix B.4: The technical details of the PLC and operator's console (Page 1)

5. Parts Name and Descriptions

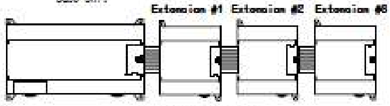
The following describes the name and functions of parts of the MK80S Series.



No.	Name		Function
①	CPU Status LED	PWR LED	Indicates of the power status. • On : normal state • Off : abnormal state or off
		RUN LED	Indicates the operation status of the CPU. • On : When the CPU operates with the mode setting switch in the local or remote RUN • Off : When the followings occur ▶ the voltage is not normally supplied to the CPU ▶ the mode setting switch is in the stop or pause ▶ An error which makes operation stop is detected
		ERR LED	Indicates the operation status of the CPU. • Flicker : An error is detected by self diagnostic during operation • Off : When the CPU is normal state
②	Input/Output LED		Indicates the input/output status
③	Battery holder		Battery holder
④	The mode setting switch		Sets the operation mode of the CPU. • RUN : Program operation is executed • STOP : Program operation is stopped • PAU / REM ▶ PAUSE : Program operation is temporarily stopped ▶ REMOTE Used for the remote operation
⑤	Memory setting dip switch		For detailed direction for use, refer to the MK80S user's manual 6 chapter
⑥	RS-232C Connector		• 9 pin connector for KGLWIN and Cnet
⑦	For Extension connector cover		• the connector which mounted extension unit cover
⑧	Terminal block cover		• the protection cover for external wiring
⑨	The hook for DIN rail		• The hook for DIN rail

6. I/O No. Allocation Method

1) I/O No. Allocation is granting address to unit & module for output/input data



Mounting Module	Maximum No. of module can be mounted	Remark
Extension I/O module	2	
A/D conversion module	2	
Analog timer module	3	
Communication module	1	

3) The following is method I/O number allocation.

Item	Specification	Area	Remark
Base Unit	Input	P000 ~ P03F	64 Points Fixed
	Output	P040 ~ P07F	64 Points Fixed
Extension #1	Input	P080 ~ P08F	16 Points Fixed
	Output	P090 ~ P09F	16 Points Fixed
Extension #2	Input	P100 ~ P10F	16 Points Fixed
	Output	P110 ~ P11F	16 Points Fixed
Extension #3	Special	None	No more points
Special		None	A/D,A/T, etc

-. Basically I/O allocation is fixed-point method and special module is not allocated

(The area which is not used can be used internal relay)

7. Internal High Speed Function

1) Summary

The high-speed counting can count high speed pulse which can not be process with The CPU counting instructions. It can be counting pulse witch occurs encoder or pulse generator.

Function	Description
Counter function	- 1 pulse operation Mode(Up/down count by program) 1 pulse operation Mode(Up/down count by phase B pulse input) 2 pulse operation Mode(Up/down count by difference of phase)
Multiplication	The multiplication factor for the input pulse may be set to 1,2 or 4(selected by special data register D4999)
Data comparison function	F170 is on when the current value reaches to the setting value
Preset operation	Sequence program or external preset input

2) Performance specifications

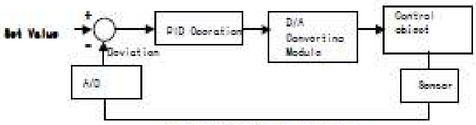
Item		Specification
Input signal	signal	A Phase , B Phase , Preset
	Signal level	DC24V
	Signal type	Voltage input
Counting range		0~16,777,215(binary 24bits)
Max. counting speed		1Phase 16 kHz or 2Phase 8 kHz
Up/Down selection	1 Phase	Program or B-Phase input
	2 Phase	Auto-select by phase difference of A and B Phase
Multiplication		1,2 or 4
Preset input		Program or external input

8. PID Control Function

This chapter describes information about the built-in PID function of MK80S Series.(Max. 8 loops)

1) The characteristics of PID function of MK80S series as following

① The PID function is integrated into the CPU module. Therefore, all PID control action can be performed with instructions and parameter without any separated PID module.
② Forward/reverse operations are available.
③ P operation, PI operation, PID operation and On/Off operation can be selected easily.
④ The manual output (the user-defined forced output) is available.
⑤ By proper parameter setting, It can be stable operation regardless of external disturbance.
⑥ The operation scan time (the internal that PID controller gets a sampling data from actuator) is changeable for optimizing to the system characteristics.



PID Control system block diagram

2) Instruction for PID control

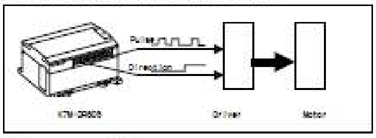
For the PID Operation of MK80S, there are two instructions, as follow.

No.	Instruction	Function
1	PID8	Perform the PID operation
2	PID8AT	Perform the auto tuning operation

9. Pulse Output

1) Introduction

In the transistor output type of MK80S, the pulse output function – maximum 2kpps – is internalised. By using this function with stepping motor or servo motor driver, MK80S is applicable to a positioning system.



2) Performance specification

Item	Specification
No. of output	1Point
Output type	Pulse
Output velocity	Max. 2Kpps, Min. 50pps
Output pulse	0 ~ 4294967295
Execution type of the increasing/decreasing velocity	Designation of acceleration
Type of the direction	Right/opposite direction pulse output
Load power supply	DC 12V/24V

Appendix B.4: The technical details of the PLC and operator's console (Page 2)

☐ Test RUN and maintenance precautions

⚠ Warning

- Do not contact the terminals while the power is applied. It can cause malfunction.
- When cleaning or driving a terminal screw, perform them after the power has been turned off.

⚠ Caution

- Do not separate the module from the printed circuit board, or do not remodel the module. They can cause disorder, malfunction, damage of the module or a fire. When mounting or dismounting the module, perform them after the power has been turned off.
- Do not change battery while power is off. It can cause loss of data.

☐ Waste Disposal Precaution

⚠ Caution

- When disposing the module, do it as an industrial waste.

1. Introduction

This data sheet provides brief information about characteristics, configuration, and usage of MASTER-K Series.

2. General Specifications

No	Item	Specifications					Standard
1	Operating temperature	0 ~ 55℃ (32 ~ 131°F)					
2	Storage temperature	-25 ~ 70℃ (-13 ~ 158°F)					
3	Operating Humidity	5 ~ 95%RH, non-condensing					
4	Storage humidity	5 ~ 95%RH, non-condensing					
5	Vibration	Occasional vibration					IEC61131-2
		Frequency	Acceleration	Amplitude	Sweep count		
		10≤ f﹤57 Hz	-	0.075 mm	10 times in each direction for X, Y, Z		
		57 ≤ f≤ 150 Hz	9.8 ㎨ {1G}	-			
		Continuos vibration					
		Frequency	Acceleration	Amplitude			
		10≤ f﹤57 Hz	-	0.035 mm			
		57≤ f≤ 150 Hz	4.9 ㎨{0.5G}	-			
6	Shocks	*Maximum shock acceleration: 147 ㎨ {15G} *Duration time :11 ms *Pulse wave: half sine wave pulse (3 times in each of X, Y and Z directions)					IEC61131-2
7	Noise immunity	Square wave impulse noise	± 1,500 V				
		Electrostatic discharge	Voltage :4kV(contact discharge)				IEC61131-2 IEC1000-4-2
		Radiated electromagnetic field	27 ~ 500 MHz, 10 V/m				IEC61131-2 IEC1000-4-3
		Fast transient & Burst noise	Severity Level	All power modules	Digital I/Os (Ue ≥ 24 V)	Digital I/Os (Ue < 24 V) Analog I/Os communication I/Os	IEC61131-2 IEC1000-4-4
			Voltage	2 kV	1 kV	0.25 kV	
8	Atmosphere	Free from corrosive gases and excessive dust					
9	Altitude for use	Up to 2,000m					
10	Pollution degree	2 or lower					
11	Cooling method	Self-cooling					

3. Performance Specifications

Item			KTM-DR20S	KTM-DR30S	KTM-DR40S	KTM-DR60S	Remark
Operation method			Cyclic operation of stored program Interrupt task operation				
I/O Control method			Scan synchronized batch processing method (Refresh method) Direct method by instruction				
Program language			Ladder Diagram, Instruction List				
Number of Instruction	Basic		30				
	Application		218				
Processing Time			Basic Instruction : 0.5 ㎲/Step				
Program memory Cap.			7K Step				
I/O Points			20	30	40	60	
Data Area	P		P000 ~ P15F				I/O Relay
	M		M000 ~ M191F				Internal Relay
	K		K000 ~ K31F				Keep Relay
	L		L000 ~ L63F				Link Relay
	F		F000 ~F63F				Special Relay
	T		100ms : T000 ~ T191(192 Point) 10ms : T192 ~ T255(64Point) Adjustable boundary area by parameter setting				Timer
	C		C000 ~ C255				Counter
	S		S00.00 ~ S99.99				Step Relay
	D		D0000 ~ D4999				Data Register
Operating Mode			RUN, STOP, PAUSE, DEBUG				
Self-diagnostic functions			Watch dog timer, memory error detection, I/O error Detection, Battery error detection, Power error Detection, etc				
Memory backup at power down			Latch area setting by basic parameter				
Number of maximum extension			3				
Weight(g)			480	560	670	845	
Internal function	PID Control function		Auto tuning by instruction, control by forward and reverse actions 8 PID control loops				
	Cnet I/F function		MASTER-K Dedicated protocol support MODBUS protocol support User defined protocol support RS-232C 1 port				Share a port With KGL-WIN
	High Speed Counter	speed	1 Phase 16 kHz , 2 Phase 8 kHz 1Channel				
		Function	- 1 pulse operation Mode(Increment/decrement count by program) 1 pulse operation Mode(Increment/decrement count by phase B pulse input) 2 pulse operation Mode(Increment/decrement count by difference of phase)				
		Multiplication	The multiplication factor for the input pulse may Be set to 1,2 or 4				Selected by Special data Register D4999
	Pulse catch		Pulse width : 0.2 ms ,8 points				
	Pulse output		2 kHz ,1 point				Transistor output only
	External Interrupt		8 Points : 0.4ms				
	Input Filter		0 ~ 15 ms				

4. Operation Processing Method

1) Cyclic operation

A PLC program is sequentially executed from the first step to the last step, which is called scan. This sequential processing is called cyclic operation. Cyclic operation of the PLC continues as long as conditions do not change for interrupt processing during program execution.

2) Time driven interrupts operation method

In time driven interrupt operation method, operations are processed not repeatedly but at every preset interval. In the K80S CPU module, interval can be set to between 0.01 ~ 6 second. This operation is used to process operation with a constant cycle

3) Event driven interrupts operation method

If a situation occurs which is requested to be urgently processed during execution of a PLC program, this operation method processes immediately the operation which corresponds to interrupt program. The signal, which informs those urgent conditions to the CPU module, is called interrupt signal. The K80S CPU module has two kind of interrupt operation methods, which are internal and external interrupt signal methods.

Appendix B.4: The technical details of the PLC and operator's console (Page 3)

10. Internal communication function

10.1 Dedicated communication

MK80S series has built-in Cnet communication function, and it is possibles that communicate with various external devices without separated Cnet I/F module. By using LGIS's dedicated protocol, user can read, write, and monitor memory devices of K80S module.

Built-in Cnet of K80S supports the following functions;

- Read single/continuous device
- Write single/continuous device
- Read the CPU status
- Register monitoring device
- Execute monitoring
- 1:1 connection between LG PLCs

10.2 User defined communication

User can define an user-defined protocol to communicate with other manufacturer's devices. By supporting user-defined protocol, K80S series can communicate with various devices have their own protocol.

10.3 Modbus protocol

K80S series includes Modbus protocol, and it is easy to connect with Modbus devices. (You don't need to write Modbus protocol as user-defined protocol)

REMARK

1)Please refer the chapter 8 of K80S user's manual for details of built-in Cnet I/F function of K80S series.

11. Other Internal Functions

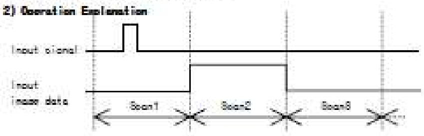
11.1 Pulse Catch Function

In the base unit, 8 points of pulse catch input contact points(P000~P007) are internalized. Through using this contact point short pulse signal, short as 0.2ms, can be taken which can not be executed by general digital input..

1) Usage

When narrow width of pulse signal is input, a trouble occurs which can not be executed by general digital input, so the operation does not perform as user's intention. But in this case through pulse catch function even narrow interval of pulse signal as 0.2ms min can be executed..

2) Operation Explanation



Step	Execution contents
Scan1	CPU senses input when pulse signal, min. 0.2ms, is input, then saves the status.
Scan2	Used to turn on the region of input image.
Scan3	Used to turn off the region of input image

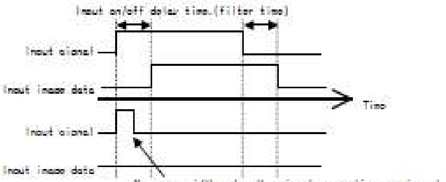
11.2 Input Filter Function

External input of MK80S selects input on/off delay time. From the range of 0-15ms. Credibility secured system may be established by adjustment of input correction no. through using environment.

1) Usage

Input signal status affects to the credibility of system in where noise occurs frequently or pulse width of input signal affects as a crucial factor. In this case the user sets up the proper input on/off delay time, then the trouble by miss operation of input signal may be prevented because the signal which is shorter than set up value is not adopted

2) Operation Explanation

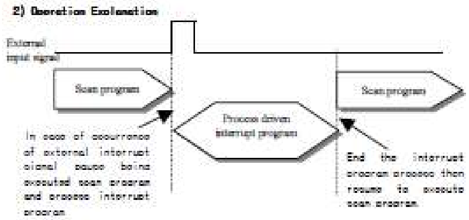


In MK80S Series can perform max 8 points of external contact task by using input of base unit without special interrupt module.

1) Usage

This function is useful to execute a task program has been set to an external input signal.

2) Operation Explanation



3) Function

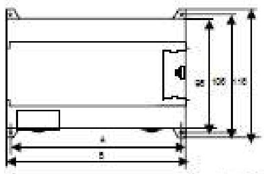
- Maximum 8 points can be used to external interrupt input within P000 ~ P007
- Inputting 8points of base unit are set functions like following.

	00	01	02	03	04	05	06	07
High speed counter	A Phase	B Phase	Preset	●	●	●	●	●
Process driven interrupt	●	●	●	●	●	●	●	●
Time driven interrupt	-	-	-	-	-	-	-	-
Can be used 8 points totally								

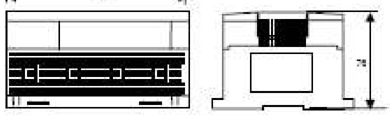
- Max. 8points of external contact point task are available to use. But the no. of them is decreased by using other task.

12. Dimension (mm)

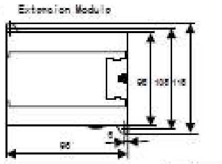
1) Base Unit

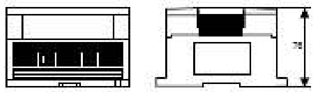


	A	B
20 Points	85	95
30 Points	135	145
40 Points	165	175
60 Points	215	225

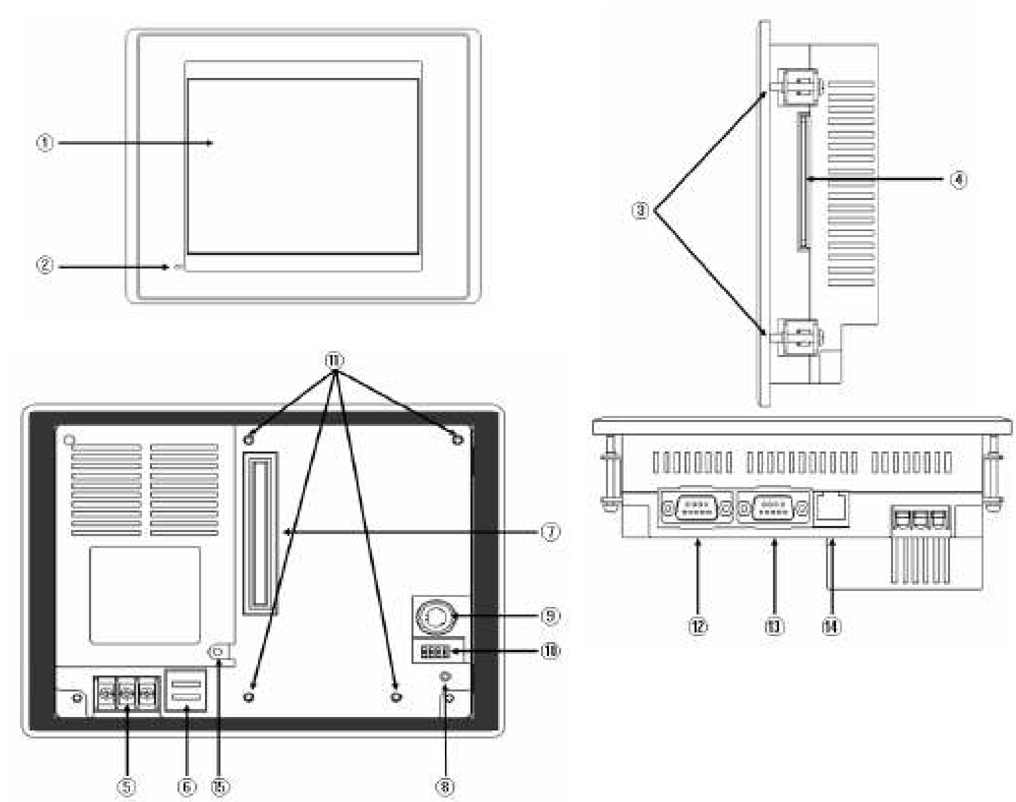


2) Extension Module



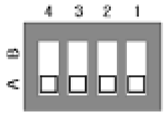


Appendix B.4: The technical details of the PLC and operator's console (Page 4)



Number	Name	Description	
①	Front side	1) Analog touch panel: User touch input 2) LCD: screen indication	
②	LED Status	Indicates operation status of device	
		Green	Normal RUN status (monitoring, downloading the project data) Initializing the status when booting (HMI does not operate)
		Red	Error occurs (communication error, project data error)
③	Panel fixed part	XGT Panel is fixed at panel by bracket.	

Appendix B.4: The technical details of the PLC and operator's console (Page 5)

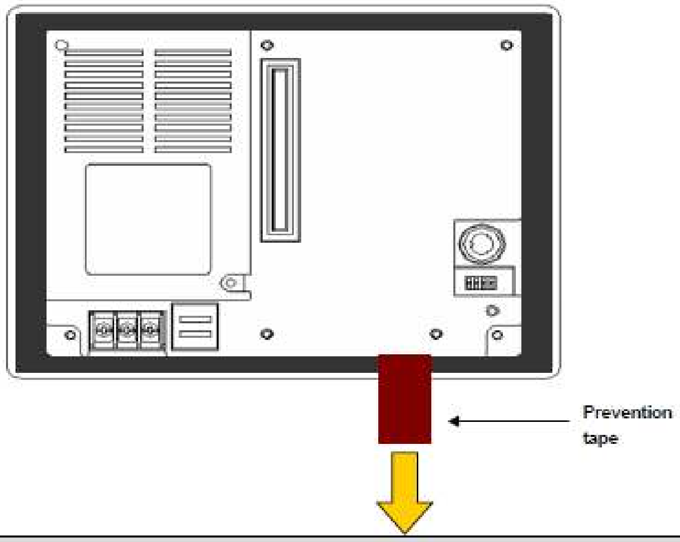
Number	Name	Description		
④	CF card interface	1) Logging/recipe/screen data backup 2) Upgrade of windows CE is available.		
⑤	Power connection terminal	It consists of power input and FG terminal.		
⑥	USB interface	It consists of 2 ports. 1) USB memory connection: logging/recipe/screen data backup 2) USB memory connection: project data transmission/backup 3) User interface connection: use of mouse/keyboard 4) Printer connection: printing is available		
⑦	Extension port	Extension module installation		
⑧	Reset switch	Hardware reset switch		
⑨	TOOL interface	RS-232C interface 1) project data transmission 2) logging/recipe/alarm/screen data backup 3) machine software upgrade		
⑩	Setting switch 	Device setting switch		
		No.1	No use	
		No.2	A setting	Normal operation (basic setting)
			B setting	When upgrading Windows CE
		No.3	A setting	Use of Watchdog (basic setting)
			B setting	No use of Watchdog
		No.4	A setting	RS-422/485 terminal resistor setting (120Ω)
			B setting	No use of RS-422/485 terminal resistor
⑪	Extension module fixation hall	Extension module fixation hall		
⑫	RS-422/485 connector	RS-422/485: PLC/control machine communication		
⑬	RS-232C connector	RS-232C: PLC/control machine communication		
⑭	Ethernet terminal	Ethernet: 10/100 BASE-T 1) Project data transmission 2) logging/recipe/alarm/screen data backup 3) machine software upgrade 4) PLC/control machine communication		
⑮	FG terminal	FG terminal hole for extension module		

Remark

(1) For details about communication connection, please refer to the communication user manual.
(2) For details about installation, please refer to the Chapter 9. Installation and Wiring.

Appendix B.4: The technical details of the PLC and operator's console (Page 6)

When you use the XGT Panel, the prevention tape is installed to prevent battery discharge.
If you remove this prevention tape, backup is available.
In order to remove tape, pull tape downward like the following figure.



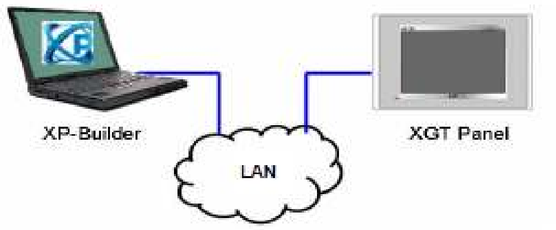
2.2 System Configuration

In order to use XGT Panel, write project data at the XP-Builder and transmit it to the XGT Panel.

XGT Panel can be basically connected through RS-232C.
Maximum communication speed is 115,200 [bps].

RS-232C communication speed is not fast so it takes long time to transmit project data into XGT Panel.

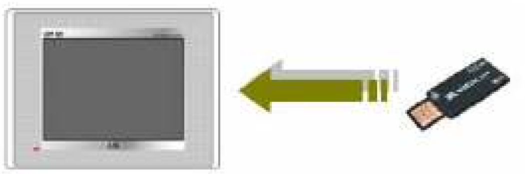
Project data can be quickly transmitted through Ethernet.
When LAN system is configured like the following figure, you can use it easily and effectively.



Appendix B.4: The technical details of the PLC and operator's console (Page 7)

In case that LAN system is not configured, it provides 1:1 connection. (LAN cable should be cross cable.)

When communication is not available to transmit project data, USB storage device is available
For details, please refer to the Chapter.7 and XP-Builder user manual.



Remark

1) We recommend Ethernet more than RS-232C.
2) For the Ethernet cable manufacture, please refer to the communication manual.
3) For the project transmission method, please refer to the XP-Builder manual.

Appendix B.4: The technical details of the PLC and operator’s console (Page 8)

3.1 General Standards

XGT Panel's general standard is as follows.

<table>
<tr><th>No.</th><th>Category</th><th colspan="6">Standard</th><th>Related standard</th></tr>
<tr><td>1</td><td>Ambient operating temperature</td><td colspan="6">0℃~+50℃</td><td></td></tr>
<tr><td>2</td><td>Storage temperature</td><td colspan="6">-20℃~+60℃</td><td></td></tr>
<tr><td>3</td><td>Operating humidity</td><td colspan="6">10~85%RH, non-condensing.</td><td></td></tr>
<tr><td>4</td><td>Storage humidity</td><td colspan="6">10~85%RH, non-condensing.</td><td></td></tr>
<tr><td rowspan="8">5</td><td rowspan="8">Vibration resistance</td><td colspan="5">Occasional vibration</td><td>count</td><td></td></tr>
<tr><td colspan="2">Frequency</td><td>Acceleration</td><td colspan="2">Amplitude</td><td rowspan="7">10 times for each X, Y, Z axis</td><td rowspan="7">IEC 61131-2</td></tr>
<tr><td colspan="2">5≤f<9Hz</td><td>-</td><td colspan="2">3.5 mm</td></tr>
<tr><td colspan="2">9≤f≤150Hz</td><td>9.8m/s^2</td><td colspan="2">-</td></tr>
<tr><td colspan="5">Continuous vibration</td></tr>
<tr><td colspan="2">Frequency</td><td>Acceleration</td><td colspan="2">Amplitude</td></tr>
<tr><td colspan="2">5≤f<9Hz</td><td>-</td><td colspan="2">1.75 mm</td></tr>
<tr><td colspan="2">9≤f≤150Hz</td><td>4.9m/s^2</td><td colspan="2">-</td></tr>
<tr><td>6</td><td>Shock endurance</td><td colspan="6">* Maximum shock acceleration: 147m/s^2 (15g)
* Duration time: 11ms
* Pulse wave: half sine pulse (3 shocks per axis, on X, Y, Z axis)</td><td>IEC 61131-2</td></tr>
<tr><td rowspan="5">7</td><td rowspan="5">Noise Immunity</td><td>Square wave Impulse noise</td><td colspan="5">AC: ±1,500V
DC: ±1,000V</td><td>LSIS' Standard</td></tr>
<tr><td>Electrostatic discharge Immunity</td><td colspan="5">Voltage: 6 kV (Discharge by contact)</td><td>IEC 61131-2
IEC 61000-4-2</td></tr>
<tr><td>Radiated electromagnetic field noise</td><td colspan="5">27 ~ 500 MHz, 10 V/m</td><td>IEC 61131-2
IEC 61000-4-3</td></tr>
<tr><td rowspan="2">Fast transient & Burst noise</td><td>Category</td><td colspan="2">Power module</td><td colspan="2">Communication interface</td><td rowspan="2">IEC 61131-2
IEC 61000-4-4</td></tr>
<tr><td>Voltage</td><td colspan="2">2 kV</td><td colspan="2">1 kV</td></tr>
<tr><td>8</td><td>Atmosphere</td><td colspan="6">Free from corrosive gases and excessive dust</td><td></td></tr>
<tr><td>9</td><td>Altitude</td><td colspan="6">Less than 2,000m (6,562 ft)</td><td></td></tr>
<tr><td>10</td><td>Pollution degree</td><td colspan="6">Less than 2</td><td></td></tr>
<tr><td>11</td><td>Cooling method</td><td colspan="6">Air-cooling</td><td></td></tr>
</table>

Appendix B.4: The technical details of the PLC and operator's console (Page 9)

Ordering code

4V 1 10 - 06 B - AC220V - W

Specification
4V:5/2(3) way solenoid valve
4A:5/2(3) way pneumatic control valve
3V:3/2 way solenoid valve
3A:3/2 way pneumatic control valve

Series
100 series

Coil and places
10:Single-head double-position
20:Double-head double-position
30C:Double-head three-position close centre
30E:Double-head three-position exhaust centre
30P:Double-head three-position Pressure centre

Port size
M5: M5×0.8
06: 1/8"

Joint pipe form and initial state
Blank:Pipe connection type
B:5/2 way plate connection type
5/3 way plate connection type
NC:3/2 way normal close type
NO:3/2 way normal open type

Coil voltage
DC12V
DC24V
AC24V 50Hz/60Hz
AC110V 50Hz/60Hz
AC220V 50Hz/60Hz
AC380V 50Hz/60Hz

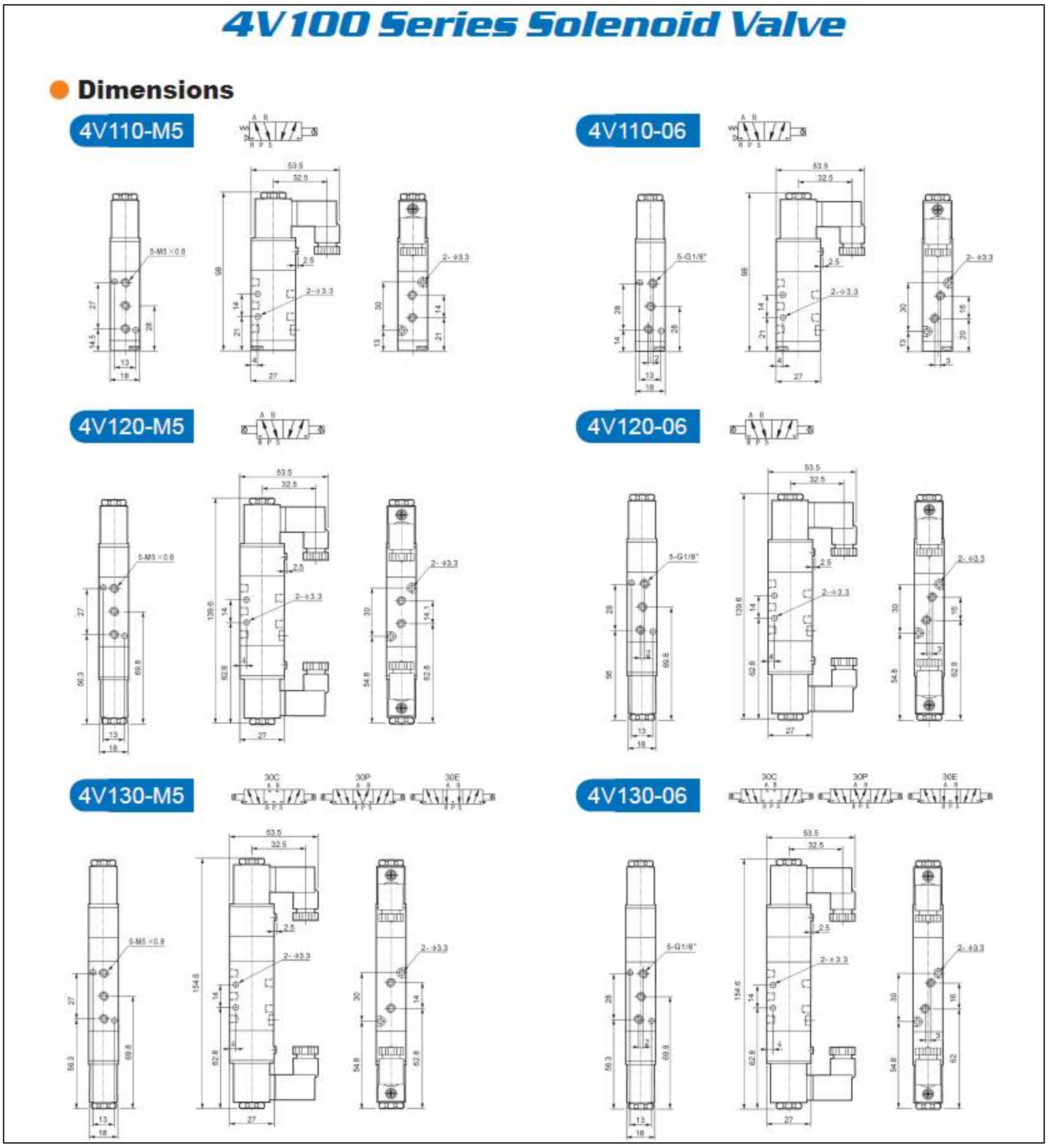
Electrical entry
Blank:Standard connector
LD:Brown connector with light
LD:White connector with light
W: Lead wire type

Specifications

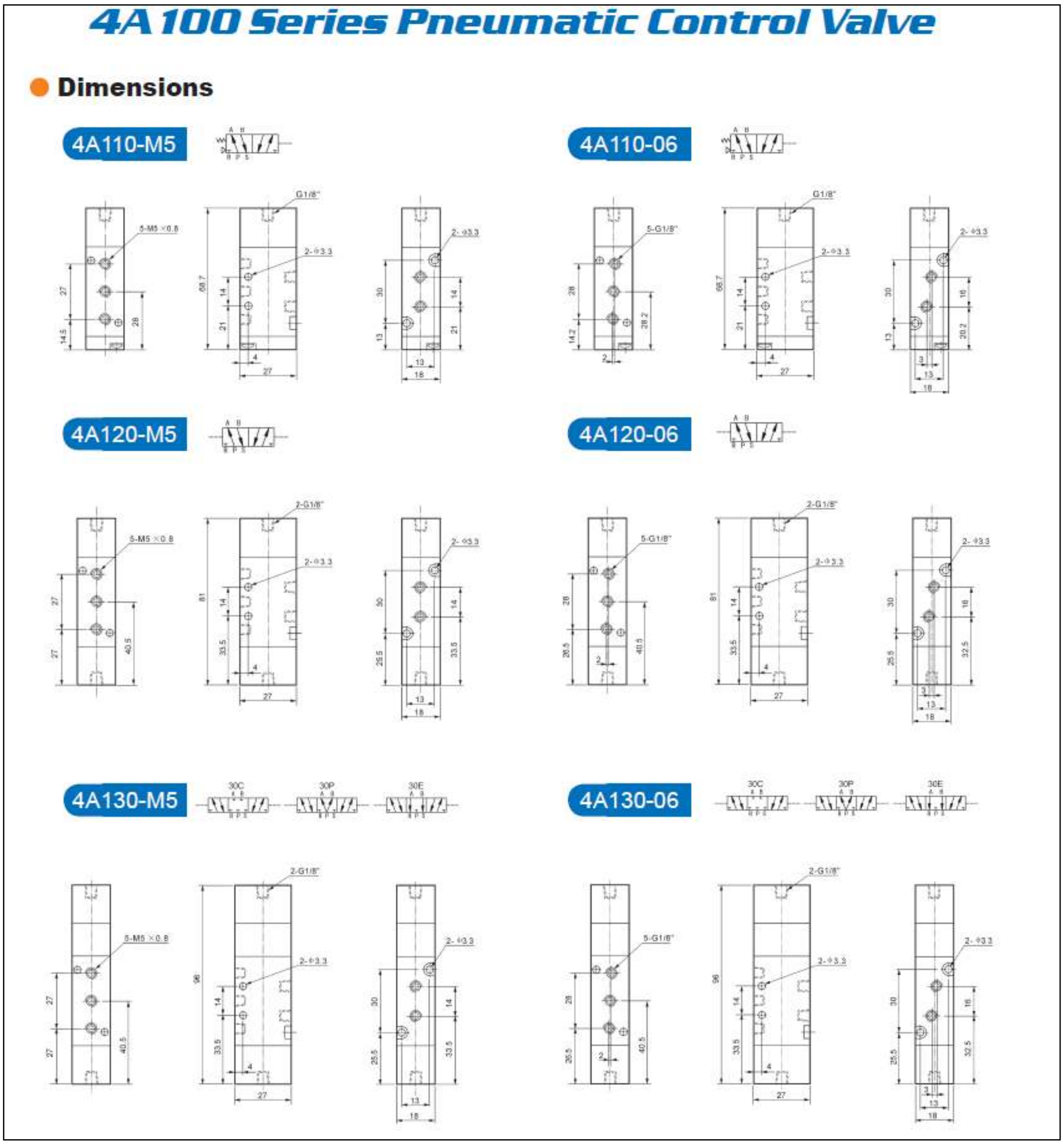
Model	4V110-M5	4V120-M5	4V130C-M5	4V130E-M5	4V130P-M5	4V110-06	4V120-06	4V130C-06	4V130E-06	4V130P-06
	4A110-M5	4A120-M5	4A130C-M5	4A130E-M5	4A130P-M5	4A110-06	4A120-06	4A130C-06	4A130E-06	4A130P-06
Position and way NO.	5/2 way		5/3 way			5/2 way		5/3 way		
Effective area	10mm^2(CV=0.56)		7mm^2(CV=0.40)			12mm^2(CV=0.67)		9mm^2(CV=0.5)		

Model	3V110-M5	3V120-M5	3A110-M5	3A120-M5	3V110-06	3V120-06	3A110-06	3A120-06
Position and way NO.	3/2 way				3/2 way			
Effective area	10mm^2(CV=0.56)				12mm^2(CV=0.67)			
Port size	Air inlet=Air outlet=Exhaust=M5×0.8				Air inlet=Air outlet=Exhaust=G1/8"			
Fluid	40 micron filtered air							
Operation	Inside pilot type							
Operating pressure	0.15~0.8MPa							
Max. proof pressure	1.2MPa							
Temperature	5~50℃							
Allowable voltage	±10% of rated voltage							
Power consumption	AC: 2.5VA DC: 2.5W							
Coil insulation & protection grade	Class F. IP65							
Electrical entry	Lead wire or connector							
Highest action frequency	5 cycle / second							
Shortest excitation time	0.05 second							

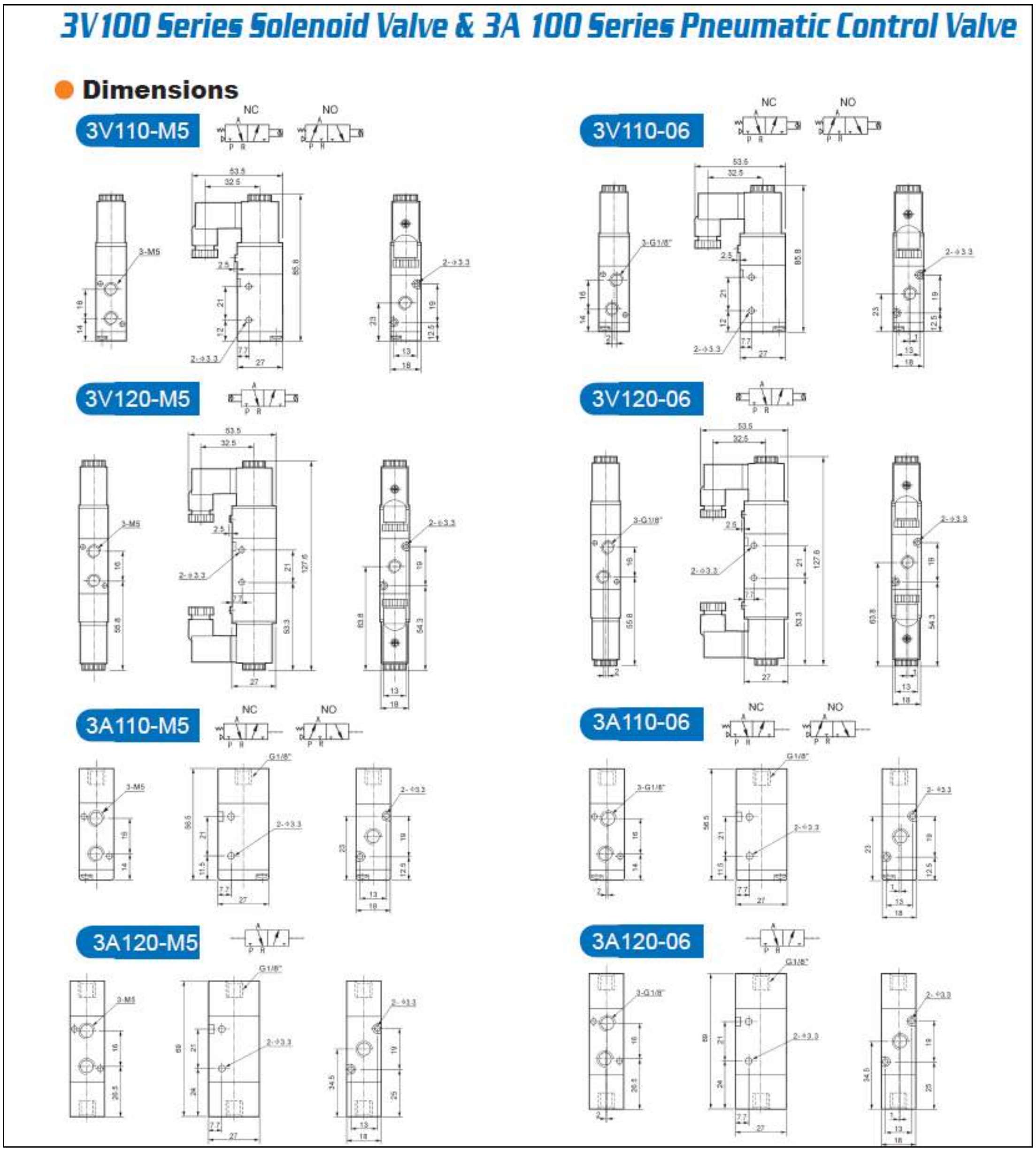
Appendix B.5: The technical details of the pneumatic valve (Page 1)



Appendix B.5: The technical details of the pneumatic valve (Page 2)



Appendix B.5: The technical details of the pneumatic valve (Page 3)



Appendix B.5: The technical details of the pneumatic valve (Page 4)

Ordering code

4V 2 10 - 08 B - AC220V - W

Specification
4V:5/2(3) way solenoid valve
4A:5/2(3) way pneumatic control valve
3V:3/2 way solenoid valve
3A:3/2 way pneumatic control valve

Series
200 series

Coil and places
10:Single-head double-position
20:Double-head double-position
30C:Double-head three-position close centre
30E:Double-head three-position exhaust centre
30P:Double-head three-position Pressure centre

Port size
06: 1/8"
08: 1/4"

Joint pipe form and initial state
Blank:Pipe connection type
B:5/2 way plate connection type
5/3 way plate connection type
NC:3/2 way normal close type
NO:3/2 way normal open type

Coil voltage
DC12V
DC24V
AC24V 50Hz/60Hz
AC110V 50Hz/60Hz
AC220V 50Hz/60Hz
AC380V 50Hz/60Hz

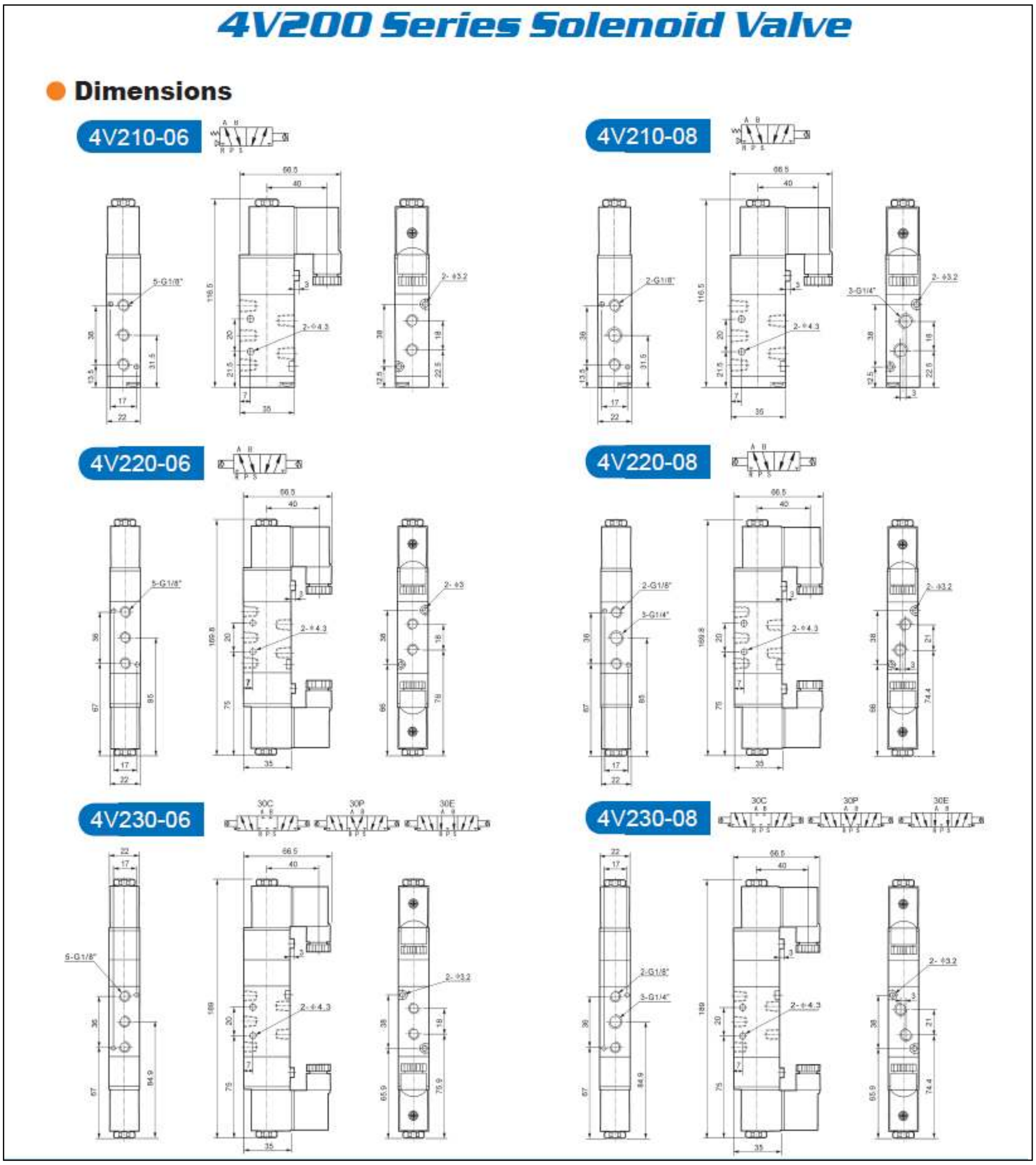
Electrical entry
Blank:Standard connector
LD:Brown connector with light
LD[1]:White connector with light
W: Lead wire type

Specifications

Model	4V210-06	4V220-06	4V230C-06	4V230E-06	4V230P-06	4V210-08	4V220-08	4V230C-08	4V230E-08	4V230P-08
	4A210-06	4A220-06	4A230C-06	4A230E-06	4A230P-06	4A210-08	4A220-08	4A230C-08	4A230E-08	4A230P-08
Position and way NO.	5/2 way		5/3Five-way			5/2 way		5/3 way		
Effective area	14mm²(CV=0.78)		12mm²(CV=0.67)			16mm²(CV=0.89)		12mm²(CV=0.67)		

Model	3V210-06	3V220-06	3A210-06	3A220-06	3V210-08	3V220-08	3A210-08	3A220-08
Position and way NO.	3/2 way				3/2 way			
Effective area	14mm²(CV=0.78)				16mm²(CV=0.89)			
Port size	Air inlet=Air outlet=Exhaust=G1/8"				Air inlet=Air outlet=G1/4" Exhaust=G1/8"			
Fluid	40 micron filtered air							
Operation	Inside pilot type							
Operating pressure	0.15~0.8MPa							
Max. proof pressure	1.2MPa							
Temperature	5~50℃							
Allowable voltage	±10% of rated voltage							
Power consumption	AC: 4.5VA DC: 3W							
Coil insulation & protection grade	Class F. IP65							
Electrical entry	Lead wire or connector							
Highest action frequency	5 cycle / second							
Shortest excitation time	0.05 second							

Appendix B.5: The technical details of the pneumatic valve (Page 5)



Appendix B.5: The technical details of the pneumatic valve (Page 6)