

DOKUZ EYLÜL UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

**MECHATRONIC DESIGN OF 70 KG END POINT
LOAD CAPACITY PRESS FEEDING ROBOT**



by
Ecenur GÖRER

May, 2022
İZMİR

MECHATRONIC DESIGN OF 70 KG END POINT LOAD CAPACITY PRESS FEEDING ROBOT

**A Thesis Submitted to the
Graduate School of Natural and Applied Sciences of Dokuz Eylül University
In Partial Fulfillment of the Requirements for Degree of Master of
Philosophy in Mechanical Engineering,
Machine Theory and Dynamics Department**

**by
Ecenur GÖRER**

May, 2022

İZMİR

M.Sc THESIS EXAMINATION RESULT FORM

We have read the thesis entitled “**MECHATRONIC DESIGN OF 70 KG END POINT LOAD CAPACITY PRESS FEEDING ROBOT**” completed by **ECENUR GÖRER** under supervision of **ASSIST. PROF. DR. MURAT AKDAĞ** and we certify that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science.

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Ecenur GÖRER

70 KG UÇ NOKTA YÜK KAPASİTELİ PRES BESLEME ROBOTUNUN MEKATRONİK TASARIMI

ÖZ

Bu çalışmada, çalıştığım firmada 70 kg ağırlığındaki disk hammadde ürünlerinin tekrar tekrar istiflenmesini gerektiren yuvarlama presine manuel yükleme yerine insan gücünden tasarruf etmek, verimliliği ve ergonomiyi artırmak için kartezyen robotik bir sistem tasarlanmıştır.

Sistem; iki eksenli hareket kontrollü robot kolları, özel amaçlı bir tutucu ve bir ürün merkezleme platformu olmak üzere üç bölümden oluşmaktadır. Çalışma kapsamında mekanik ve kontrol sistem tasarımları tamamlanmıştır. Tasarım aşamasında, etkili faktörlerin belirlenmesi için Minitab istatistiksel veri analiz programı kullanılarak deney tasarımı yapılmıştır. Mekanik tasarım sürecinde bilgisayar destekli tasarım için Autodesk Inventor, Nastran CAD programları ve mühendislik araçları kullanılmıştır. Ayrıca firma atölyesinde üretim denemeleri yapılarak statik analizler test edilmiştir. Tasarlanan sistem aynı zamanda bir boşaltma sistemi olarak da uyarlanabilmektedir. Bunun sonucunda işçilik maliyetlerinde ve iş kazalarında azalma, üretim sayılarında ise artış olacaktır. Yükleme boşaltma sisteminin maliyetleri ve faktörlerin kazanç getirileri hesaplandığında yatırım 1 yıl içinde amorti edilebilmektedir. Yıllık potansiyel kazanç getirisi ortalama 250.000 USD olacaktır.

Çalışmanın amacı, teori ve mühendislik bilgilerini pratiğe dönüştürmek, çalıştığım şirkette bazı sorunlara çözüm bulmak ve bilimsel çalışmalara katkıda bulunmaktır.

Anahtar kelimeler: Kartezyen robot, mekanik modelleme, maliyet kazançları

MECHATRONIC DESIGN OF 70 KG END POINT LOAD CAPACITY PRESS FEEDING ROBOT

ABSTRACT

In this study, a cartesian robotic system was designed to save manpower and increase efficiency and ergonomics, instead of manually loading to the rounding press, which require repetitive stacking the disc raw material products weighing 70 kg, in my working company.

The system consists of three parts: two-axis motion-controlled robot arms, a special purpose gripper and a product centering platform. Within the scope of the study, mechanical and control system designs were completed. In the design phase, an experiment was designed by using the Minitab statistical data analysis program for determining the effective factors. Autodesk Inventor, Nastran CAD programs and engineering tools were used for computer aided design in the mechanical design process. In addition, the static analyzes were tested by making production trials in the company workshop. The designed system can also be adapted as an unloading system. As a result, there will be a decrease in labor costs and the number of work accidents, and an increase in production numbers. When the costs of the loading and unloading system and the earnings returns of the factors are calculated, the investment can be amortized within 1 year. Annual potential earnings return will be an average of 250.000 USD.

The aim of the study, transforming theory and engineering knowledge into practice, finding solutions for some problems in my working company and contributing scientific studies.

Keywords: Cartesian robots, mechanical modeling, cost gains

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CHAPTER 1

INTRODUCTION

1.1 History of the Industrial Robots

Industrial robots have become an integral part of the manufacturing world. While robots have seen a rapid incline in their use in more recent years, they have actually been on production lines for several decades.

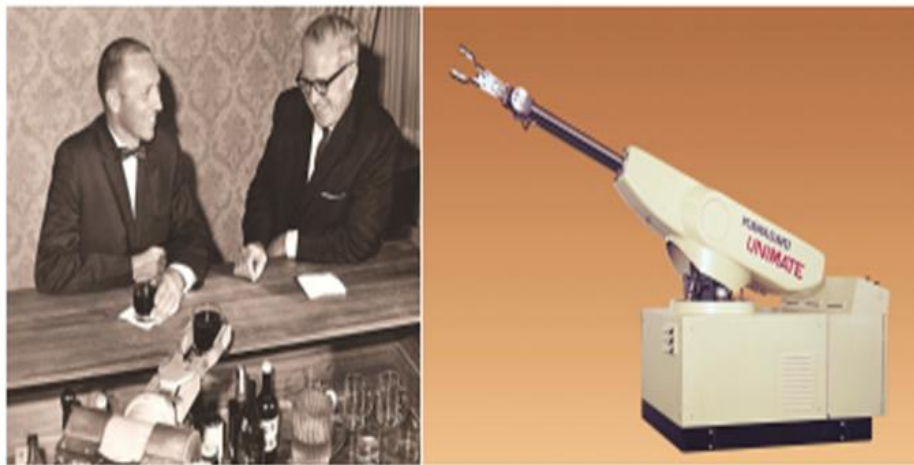


Figure 1.1 Joseph Engelberger and George Devol(left); The Ultimate robot(right)

In 1954; the first industrial robotics patent was placed by George Devol, who would become known as the “Father of Robotics.”

In 1962; Unimation started the robotic automation of the automotive industry with the release of their UNIMATE robot. UNIMATE was the first industrial robot to be installed by a large automotive manufacturer.



Figure 1.2 Stanford arm

In 1969; Victor Scheinman invented the Stanford Arm at Stanford University. The Stanford Arm was the first 6-axis all electric robot designed as a robot arm solution.

In 1975, another European company jumped into the robotics market when ASEA introduced their IRB 6.

In 1978, Unimation along with GM developed the PUMA robot arm (Programmable Universal Machine for Assembly).



Figure 1.3 Puma robot



Figure 1.4 The "legendary" ABB IRB robot

Additional robotic milestones took place towards the late 1970s.



Figure 1.5 One of the first prototypes of Scara robot, designed by Hiroshi M.



Figure 1.6 Examples of adept one Scara robots

In the 1980s; the growth of industrial robots began to skyrocket with new robots being introduced almost monthly.

In 1981, the first robots with motors installed in their arm joints was developed by Takeo Kanade.



Figure 1.7 Delta robots in the Demarex work cells for the packaging of pretzels



Figure 1.8 The ABB Flex-Pitcher robot

In the 2000s; robotic companies began to further expand the application of robots with the introduction of cobots.

The industrial robotics is still developing in the current days. Innovation and hardware, some new programming techniques connected with Artificial Intelligence.

1.2 Previous Studies

With the development of technology, studies in the field of robotics and automation are increased day by day. Flexible and high-quality production by robotic systems is provided great advantages to companies in today's competitive environment. Accordingly, the increasing in robots needs for different areas of production is led to an increasing in robot development studies.

As a result of the researches, it is determined that robot development and classification studies are carried out depending on the factors of usage areas, coordinate systems, coordinate types, drive mechanisms, load capacities. The development history of robots is explained in the introduction part by the details.

In this study, a cartesian robotic system was designed to save manpower and increase efficiency and ergonomics instead of manually loading to the rounding press which require repetitive stacking the disc raw material products weighing 70 kg, in my working company. During this study, examined some of the studies are presented below.

A cartesian coordinated welding robot was designed and implemented at Yıldız Technical University. In the system, two stepper motors were used. With the help of a special program written in visual basic to control the robot with a PC, the control signals were sent to the control card via the PC parallel port. The signals were transmitted to the stepper motor driver cards and the circuit that triggers welding torch by the control card. As a result, the robot was able to weld at the desired parameters. With this study, it has been determined that the application examples and their results are more successful than the optimum welding speed in manual gas arc welding (Eğilmez, 2005).

In another master's project, a cartesian robot with an open structure was designed. The mechanical part of the robot was consisted of arms that move independently of each other and arms. The speed and direction control of the system was done by driving over the parallel port. Necessary arm movements were performed with stepper motors. The route information to be followed has been transmitted to the system in DXF file format. By using intermediate programs, this road information was translated into arm movements. The motion sensibility of the robot arms was determined 0.006250 and 0.003125 in full and half step, respectively. It has been tested as a plotter by attaching a pen to the carrier platform and as a computer-controlled cutting machine by attaching an oxy-gas apparatus. In the test results, the desired values were achieved in motion and dimension sensibility (Özyalçın, 2006).

In a published article, methods related to a fast pick and place prototype robot design and control was mentioned. This article focused on a newly built research platform using its vision system. It could identify round objects that were randomly scattered on a table. Then, using its gripper they were picked and placed inside a basket. The control system was tuned such that, the succession of operations runs fast and safe. In this study, they have been gone from concepts to design, validation in simulation and eventually experimental validation (A. Steinhausser, J. Swevers, 2016).

In a master thesis At Sakarya University, a cartesian robot with three sliding joints was designed, which could store objects by recognizing objects using the image processing method in the C++ programming language. The purpose of this study was to ensure that businesses deliver the right amount, to the right place, at the right time.

In addition, it was aimed to reduce the cost and increase the quality. When the reference studies were examined, it has been calculated that the error obtained in the algorithms used in the image processing program was below the percentage of three. This study wouldn't be sensitive in practice compared to the theory. So, its applicability has been decided (Akpınar, 2008).

In an article, the study about the mechanical design of a cartesian manipulator for warehouse pick and place was published robotic manipulation and grasping, in cluttered and unstructured environments were a current challenge for robotics. Enabling robots to operate in these challenging environments had direct applications from automating warehouses to harvesting fruit in agriculture. One of the main challenges associated with these difficult robotic manipulation tasks were the motion planning and control problem for multi-DOF. (Degree of freedom) manipulators. This study is presented the design and performance evaluation of a novel low cost cartesian manipulator, Cartman who took first place in the Amazon Robotics Challenge in 2017. It could perform pick and place tasks of household items in a cluttered environment. The robot was capable of linear speeds of 1 m/sec. and angular speeds of 1.5 rad./sec. capable of submillimeter static accuracy and safe payload capacity of 2 kg (P. Corke, C. Lehrert, 2017).

At Uppsala University, the design of a gripper tool for robotic picking and placing study was completed. The final design of the gripper tool was used in the robot cell simulation program ABB Robot Studio for choosing a proper cell design. The gripper tool was designed in light weight material aluminum and used electromagnets for picking and releasing the different notched part. The gripper tool was assembled on an industrial robot from ABB IRB 7600 with a handling capacity of 150 kg and 3.5 m. reach (Mohammed, 2010).

1.3 The Purpose of the Thesis

In this study, a cartesian robotic system was designed to save manpower and increase efficiency and ergonomics, instead of manually loading to the rounding press which is required repetitive stacking the disc raw material products weighing 70 kg, in my working company.

The project, which move in two axes 70 kg end carrying capacity cartesian robot is included force power and motor calculations, finite element analysis, control system and methods, statical data analysis and cost calculations.

Our aim is reduced risk analysis, REBA analysis, accident frequency rate, cycle time, labor costs and increasing the number of products while keeping OEE and EE data constantly.

1.4 The Content of The Thesis

The content of the thesis work is given below.

In chapter one; industrial robots and its history, previous thesis, doctorate, article studies and examples about this subject, the purpose of the thesis were explained.

In chapter two; definition of industrial robots, types, features, usage areas, cartesian robots, gripper types, robot mathematics and robot programming methods were explained.

In chapter three; the design and detailed model of the cartesian robot with a tip carrying capacity of 70 kg has been completed. Accordingly, the most appropriate design has been determined and its justifications have been explained. Statical data analysis, 3D drawings and mechanical design, electrical control design are completed.

In chapter four; risk analysis, REBA analysis, accident frequency rate, cycle time and effects on the number of products, which were determined as indicators of the study, were compared before and after the study. It was explained how the indicator's detail calculations were completed. And, the cost gains due to these improvements have been determined.

In chapter five; it was included conclusions, discussions and recommendations related to the study.

CHAPTER 2

CONCEPT OF ROBOT

2.1 Definition of Robots

Many different definitions have been made about robots until today. The definitions made by the relevant robot organizations on industrial robots are even more different. In Webster's dictionary, robots are defined as "automated tools that perform functions that humans usually perform". However, according to this definition, a washing machine can also be considered a robot.

The definition of robot by the Robotics Institute of America is "a multifunctional and programmable manipulator designed to move materials, parts and tools, or a special tool that can perform variable programmed movements to perform different tasks."

The most comprehensive definition and classification of industrial robots is specified by the TS EN ISO 8373 standard. The definition is expressed as follows under the heading "Manipulating industrial robots-Robot". A fixed or mobile, automatically controlled, reprogrammable, multi-purpose programmable manipulator in three or more axes for use in industrial automation applications (TS EN ISO, 1999). The definition of the manipulator is stated in the relevant standard as follows: "The mechanism consists of a series of parts that are generally compatible with each other or added; A machine used to hold and/or move objects (parts or assemblies), usually within a few degrees of freedom (TS EN ISO, 1999).

The detailed explanations of the terms (requirements) used in the robot definition are as follows:

- Reprogram ability, changeability of programmed movements or auxiliary functions without physical changes (TS EN ISO, 1999). As an example, we can say that a spot-welding robot in a work line in a car factory can put different model 3 vehicles with just a program change.
- Versatility, the ability to adapt to different applications by making physical changes (TS EN ISO, 1999).

The use of a robot used in spot welding in a work line in a car factory, by removing the spot-welding apparatus (tooling) attached to the end part (gripper), connecting the assembly apparatus and using it in assembly can be an example that fits this definition.

- Axis is the term used to describe the motion of the robot in linear or circular mode.

A robot basically consists of five parts. The parts given below are the basic element that make up the robot. The functioning and classification of the robot is done according to these five stages.

- * Mechanical part: Forms the chassis part of the robot.

- * End effector: Real work is done by it. It is the most extreme point of the robot. It is actively used in the application.

- * Engines: It is used to move the joints and handle. Servo and hydraulic are the most used type.

- * Controls: It is processed the inputs.

- * Sensors: It is depended the controls. The output and input data are provided for it.

2.1.1 Description of Pick and Place Robots

With the development of technology, improvement and development studies on robots continued. Pick and place robots are preferred especially in places where repetitive movements are made, ergonomic conditions are not suitable, and time losses are frequent. They are important robots because of their cost-effectiveness and increased efficiency. While making robot selections, it is necessary to examine the area and working conditions. Pick and place robots are designed to prevent repetitive movements and create safe work areas.

2.1.1.1 Usage Areas of Pick and Place Robots

Pick and place robots are well developed mechanically and software. They can adapt quickly to changes. Their information storage performance is strong. They are preferred in areas that require high performance and fast adaptation. The usage areas of pick and place robots are very wide. There are many different types depending on this. The important thing is to choose the right robot for the right place.

2.1.1.2 Types of Pick and Place Robots

Different types of pick and place robots have been developed considering working conditions and working areas. Six different types of pick and place robots are described below.

Delta Robots: They can operate at high speeds. There is a great variety of configurations. The design uses three light arms to facilitate movement. Optical technology is applied to recognize details such as color and shape. They generally work in four axes.

Palletizing Robots: As the name suggests, it is a type of robot developed for palletizing works. Placing and palletizing the produced materials after they are completed is a waste of time. These robots are preferred in order to prevent this and increase efficiency. Besides, they are advantageous because they take up less space.

Robotic Arm: They are used for standard applications. They are five-axis robot types. They are used to move objects in a plane. They are preferred for simple tasks.

Cobot (Collaborative) Robots: They are called collaborative robots. increase efficiency and productivity. The optimizations are strong. They are advanced robot types in position selection and orientation.

Cartesian Robots: They can work in more than one plane. They can move in x-y-z axes. They are more preferred in places where position sensitivity is present. Different types of drive mechanisms are used in their design.

Fast Pick and Place Robots: It is preferred for processes where speed is important. It has the fastest cycle up to 150 times per minute. It is frequently preferred in packaging lines.

2.1.1.3 Choosing the Appropriate Pick and Place Robot

It is an important factor to choose the most suitable one for the working area among these robot types, where there is a great variety. In this case, the choice should be made according to some important factors. The most important of these factors are; number of axes, payload, working area and reach, speed and repeatability.

Factor of reach

The robot must be able to meet the maximum working range required for the working area. Details such as vertical and horizontal movement distances, the distance between the material to be transported and the location centers to be transported are important.

Factor of repeatability

That refers to the pick and place ability of the robot. This feature is an important selection factor in areas where the same operations are carried out in stacking areas.

Factor of carrying capacity

Preferences are made according to maximum and minimum loads. In designs, max. carrying capacity is taken into account.

Factor of number of axes

It is an indicator of the flexibility of movement of the robot. There are varieties of 4-5 and 6 axes. Preference is made according to the location of the place to be used.

Factor of speed

Speed is an important factor in many fields of work. It is a preferred factor in priorities such as increasing productivity and number of products.

2.2 Motion Axes of Robots

Movement axes should be determined and detailed in the most appropriate way for the usage area. For that, the work and the working area of the robot must be defined very well. This is a factor that affects the operation and controls of the robot significantly. They have different movements defined as its own axis or degrees of freedom. If a manipulator rotates around its axis, this robot is called a "single axis robot". If the manipulator moves up and down, this robot is called a "biaxial robot". Rotating around its own axis and moving up and down, the manipulator can also move back and forth on the horizontal axis. This robot is called a "three-axis robot". Industrial robots have at least three axes. These movements are its rotation around its own axis, its ability to move up-down and forward-backward.

2.3 Working Area of Robots

In the general meaning, the total area that the robot arm can reach is called the working area. In robot selection, first of all, the robot working area should be determined correctly. An unsuitable choice of study area will also mislead in the determination of other conditions. For this reason, after determining the work area, a design should be made or a robot should be purchased depending on the features explained in detail in other chapters. The area of the press loading system to be made in this thesis is shown in figure 2.2. Accordingly, other condition choices were made depending on this field.



Figure 2.1 Current disc rounding press

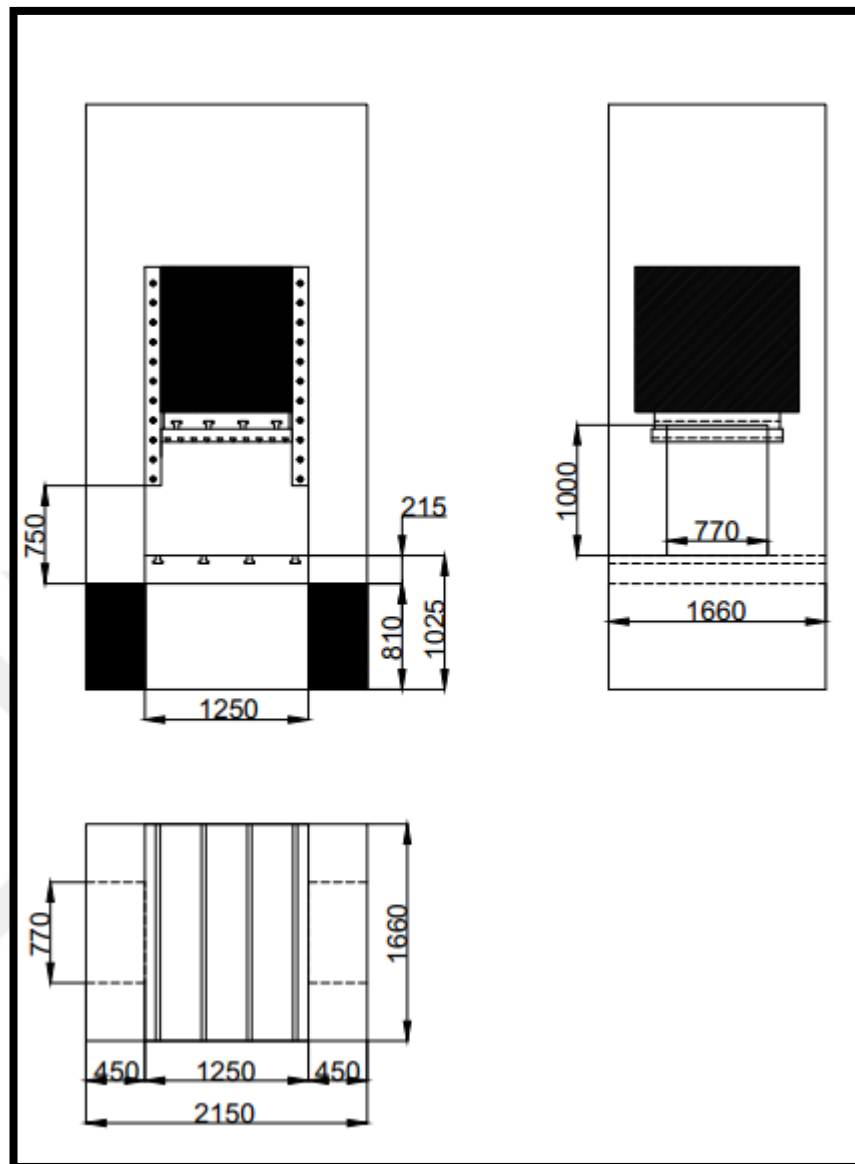


Figure 2. 2 Press detail dimensions

2.4 Classifications of Robots

Industrial robots can be classified into many different categories. Below are their classifications in 5 different categories. According to; usage areas, coordinate systems, control types, drive mechanisms and load capacities are categorized.

2.4.1 According to Usage Areas

- Welding robot
- Assembly robot
- Casting robot
- Material handling robot
- Palletizer, packaging robot
- Machining robot
- Surface coating robot
- Grinding, polishing robot
- Experimental, research robots
- Robots used in medicine
- Scientific robots (in space and oceans)
- Robots for stage, movie purposes
- Defense and weapon robots

2.4.2 According to Coordinate System

2.4.2.1 Cartesian Robot

Robot with three sliding articulated arms whose axes match Cartesian coordinate systems (TSEN ISO 8373, 1999). The structure of the robot is shown in Figure 2.1. As a Cartesian robot application, we can count examples such as spot welding and packaging.

Also, cartesian robots are one of the most preferred robot types in terms of product loading, unloading and stacking. In particular, cartesian robots were developed with medium-weight loads that require repeated stacking, increase productivity by saving manpower and reducing damage caused by improper stacking.

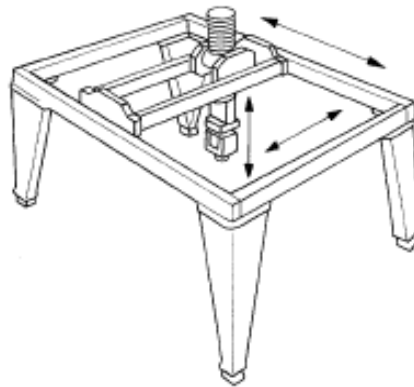


Figure 2.3 Structure of a cartesian coordinate robot (TS EN ISO 8973,1999)

2.4.2.2 Cylindrical Robot

Robot whose arm consists of at least one rotating joint and at least one sliding joint, and whose axes are in the form of a cylindrical coordinate system (TS EN ISO 8373, 1999). The structure of the robot is shown in Figure 2.2. As an application of this robot type, we can say material transfer between work lines.

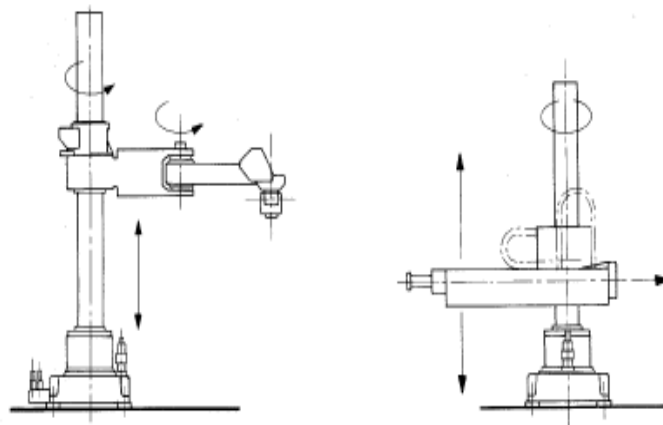


Figure 2.4 Structure of a cylindrical coordinate robot (TS EN ISO 8373, 1999)

2.4.2.3 Spherical Robot

Robot whose arm consists of at least two rotating joints and at least one sliding joint, with axes in the form of a polar coordinate system (TS EN ISO 8373, 1999).

The structure of the robot is shown in Figure 2.3. This type of robot is used most are the stage and movies. They are used to hold the camera at different angles, constantly moving and without vibration.

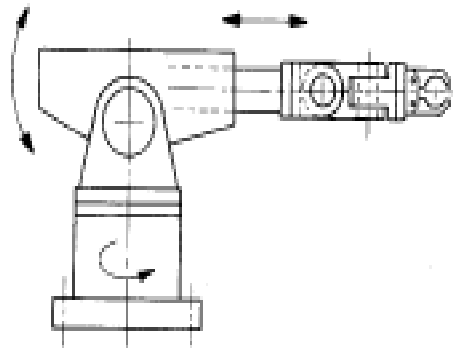


Figure 2.5 Structure of a spherical coordinate robot (TS EN ISO 8373,1999)

2.4.2.4 Scara Robot

Robot with two parallel rotating joints to achieve alignment in a selected plane. The term SCARA is an abbreviation of the sentence “Selectively Complaint Arm for Robotic Assembly” (TS EN ISO 8373, 1999). The structure of the robot is shown in Figure 2.4.

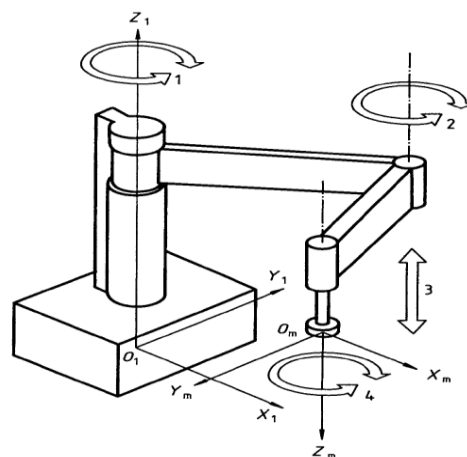


Figure 2.6 Structure of a scara robot (TS EN ISO 8373,1999)

2.4.2.5 Pendulum Robot

Universal jointed spherical robot whose mechanical structure enables hinge rotation (TS EN ISO 8373, 1999). The structure of the robot is shown in Figure 2.5. This type of robots is used in machining jobs.

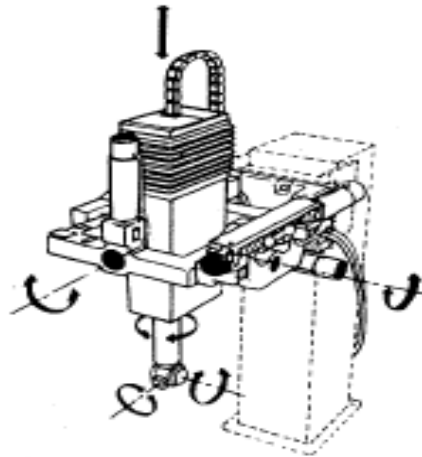


Figure 2.7 Structure of a pendulum robot (TS EN ISO 8373, 1999)

2.4.2.6 Articulated Robot

Robot whose arm consists of three rotating joints (TS EN ISO 8373, 1999). The structure of the robot is shown in Figure 2.6. Articulated robots are the most used robots in the industry. They can be adapted to any application.

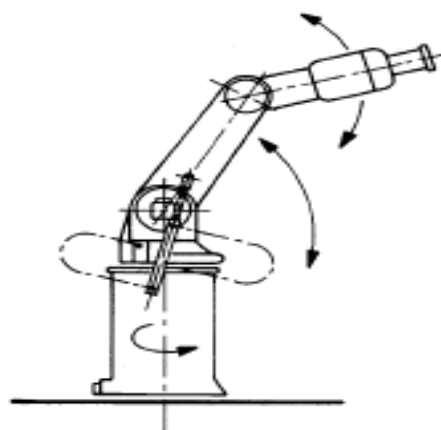


Figure 2.8 Structure of an articulated robot (TS EN ISO 8373,1999)

2.4.2.7 Parallel Robot

Robot consisting of three sliding joints whose arms (primary axes) work synchronously. This type of robots is generally used for material transportation in work lines.

2.4.2.8 Vertebrated Robot

A robot whose arm consists of two or more ball joints. These types of robots are not used in industry.

2.4.3 According to Control Types

2.4.3.1 Sequentially Controlled Robot

A command operation that can only be dictated to the robot by the user, by passing the robot through its programmed poses (positions) without a fixed path to follow between poses (TS EN ISO 8373, 1999). The robot's control system ensures that the machine movements are in a sequential order. When one move ends, the next begins. Here the movement of the robot is binary, like on/off, start/stop. All subjects and motion sequences of the robot can be programmed with the aid of a simple programming tool. Typical applications of cascading robots are point-to-point (PTP, point-to-point) and repetitive (playback) applications.

2.4.3.2 Orbit Controlled Robot

It is a control system in which the robot can only dictate the path that the robot will follow between the programmed poses at a programmed speed to the robot (TS EN ISO 8373, 1999). It is a type of robot that allows 3 or more controllable axes to move together depending on the commands that determine the time-based trajectory required to reach the next position from its current position (this motion is normally provided by interpolation). Robots of this type are often described as iterative, CNC, or continuous trajectory robots.

2.4.3.3 Adaptive Controlled Robot

They are robots with sensor control, adaptive control or learning control. Planning and scheduling jobs or tasks based on information from sensors and past experience, learning as a result of iterative behavior are examples of such functions.

Position it with the help of image processing while collecting the parts. A straightening robot or a welding robot equipped with functions that provide continuous seam tracking are typical examples of adaptive robots. Some terms in this definition are defined in the ISO 8373 standard as follows.

* Sensor control: Control system in which the robot's movement or force adjusted according to the external sensor outputs (TS EN ISO 8373, 1999).

* Adaptive (Adaptive) control: It is the control system in which the parameters of the control system are adjusted according to the conditions detected during the operation (TS EN ISO 8373, 1999).

* Learning control: It is a control system in which the experience gained during previous cycles is used automatically in changing control parameters and/or algorithms (TS EN ISO 8373, 1999).

* Teleoperated robot: A type of robot that is remotely controlled by an operator. The function of this robot carries the sensor-motor functions of the human to long distances and the reactions of the machine according to the behavior of the operator are programmable. Systems known as remote-controlled robots or computer-assisted teleoperators fall into this category. Such robots have a simple or complex control structure, they are controlled by physical (cable, cable channel, pipe) or non-physical (wireless) channels. Those controlled only by mechanical connections are excluded from this definition.

2.4.4 According to Drive Mechanisms

2.4.4.1 Electrically Driven Robot

Electrical propulsion is the most commonly applied drive type in robotic systems. In addition to its advantages such as control, speed and precision superiority, cheapness, easy applicability and cleaning, it also has disadvantages such as low sensitivity and low power/weight ratio due to the gap in gear systems. Due to the sparking in the engine, it is inconvenient to use in flammable environments. However, with the developing technology, it has been ensured that the external environment is not affected by the spark.

Until recently, only DC motors were understood when electrical propulsion was mentioned, but nowadays AC motors are used more frequently due to their brushless and torque characteristics. In addition, if the position accuracy expected from the robot is not very important and an open loop control system is used, stepper motors can be used. Electrical drive is generally applied in robots as direct drive.

2.4.4.2 Hydraulic Driven Robot

The main reason for the use of hydraulic drive is the requirement of large forces. The incompressibility of the hydraulic fluid gives the system an excellent position accuracy. The system is self-locking. Valves are closed in any power failure and keeps the system in its final state. In addition to these advantages of hydraulic systems, there are also important disadvantages such as providing oil tightness, pollution, slowness and high initial investment cost.

2.4.4.3 Pneumatic Driven Robot

It is the cheapest among the propulsion systems. It can be moved very quickly, but there is a position problem due to the air being compressed. It is generally used in stroke movements. One of the great advantages of the system is its cleanliness. Since the system uses air, it does not pollute the environment much. Although the pneumatic drive seems cheap, the energy consumed by the compressor required for propulsion and the decrease in air pressure increase the cost of the system when we carry the compressed air away with pipes.

2.4.5 According to Their Load Carrying Capacity

2.4.5.1 Low Load Carrying Capacity Robot

These are robots with a maximum load of 3-16kg. These types of robots can be used in small scale jobs. Examples of these are part tests (continuous on-off, durability test, etc.), assembly of small parts, grinding, polishing, bonding applications.

2.4.5.2 Medium Load Carrying Capacity Robot

These are robots with a maximum load of 30-60kg. These robots can be used in many applications from simple to complex jobs.

Examples include arc welding, plating, grinding polishing, bonding, laser welding/cutting, plasma cutting, waterjet cutting, assembly, palletizing (small scale), transport (small scale) and measuring applications.

2.4.5.3 High Load Carrying Capacity Robot

They are robots with a maximum load of 100-240kg. This type of robot is suitable for all kinds of applications. They also enable spot welding with their high load capacities. Also, high load capabilities make robots advantageous in palletizing and handling operations.

2.4.5.4 Very High Load Carrying Capacity Robot

Robots with a maximum load of 360-570kg. This type of robot is used where very high loads have to be carried. Application examples of these robots can be counted as palletizing, handling and packaging.

2.5 Robot Grippers

Grippers, which are the end elements in robot applications, are used very comfortably in the transport of parts, assembly processes, welding processes, painting processes. However, when it is considered that the same gripper can do more than one job or carry parts with different properties in an assembly line, it has functional difficulties. In this case, different purpose grippers were needed. There are some actuators based on various technologies that generate the power required for the movement of robot joints. The most commonly used actuator technologies are electric motors, hydraulic actuators and pneumatic actuators.

2.5.1 Mechanical Gripper

They are holders that can be designed according to the shape of the part. There are different types such as parallel, three-fingered, angled, radial, bellows, rotary holders. They are used in many fields and are functional. Material selections and actuator selections are extremely important in mechanical grippers designed according to the intended use. Each differs from the other through these features.



Figure 2.9 Mechanical gripper

2.5.2 Vacuum Gripper

Vacuum grippers are used to interact with their environment and perform tasks, light robots, like all industrial robots, depend on vehicles. They form the interface of the workpiece and they are a decisive part of the overall system. With their help, robots can pick, transport, position, process, sort, stack and store a wide variety of goods and components. Vacuum gripping systems allow for a particularly gentle handling of workpieces, a compact and space-saving system design and gripping from above. The vacuum can be positioned side-to-side from the top without any gaps, as it is not necessary to fully grasp the object.



Figure 2.10 Vacuum gripper

2.5.3 Magnetic Gripper

Magnetic grippers are two types. They are natural magnetics or electro magnetics. These grippers are manufactured after they are designed according to the diameter and the load capacity. They are more preferred to be used on dirty, oily, rough surfaces compared to vacuum grippers. They are the grippers which are frequently used in production areas.

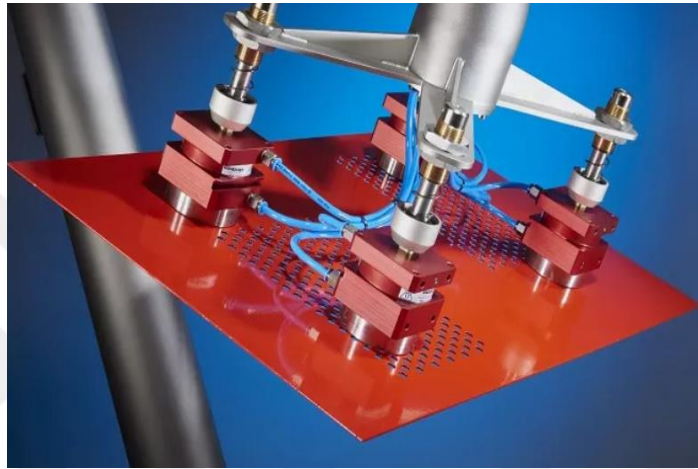


Figure 2.11 Magnetic gripper

2.6 Programming of Robot Details

Two methods are used for programming robots. They are programmed with a teaching method and an interface program. The programming of simple robots is done with the interface program. On the other hand, the teaching method that can be applied in advanced robots provides great convenience to the programmer.

2.6.1 Method of Teachings

By means of the teaching box, the robot can be moved to the desired point and these positions can be memorized. teaching box details are shown in figure 2.10. In addition, by using the menus on the teaching box, control can be provided on computers without robot programming. It provides great convenience especially in the process of determining the positions. It directly memorizes the part positions and coordinates. It facilitates control by providing communication between the robot and the user.

2.6.2 Method of the Interface Programming

With the robot's own interface program, the operation performing for the robot is programmed by the computer and loaded into the robot. There is an interface program developed by each company. The commands are used in these programs differently, for each brand of robot. The robot's movement type, speed and position determination in the working area can be performed from the interface program. The general flowchart is shown in Figure 2.10 which is for the robot programming.

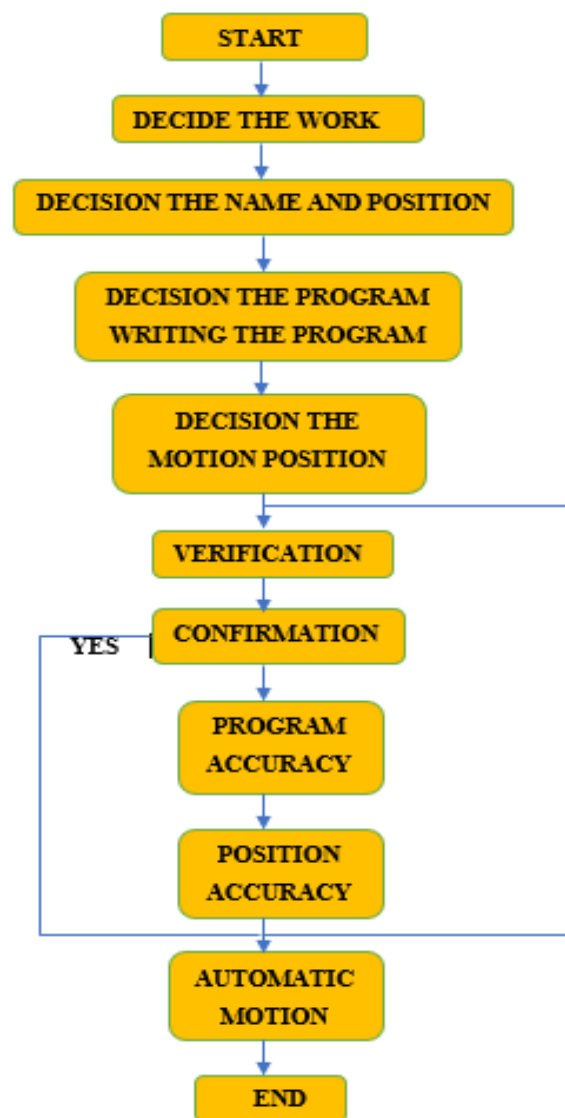


Figure 2.12 Robot programming flow chart

CHAPTER 3

CARTESIAN ROBOT DESIGN

3.1 Statistical Data Analysis Using Minitab Program

The MiniTAB program is a useful statistical program used in process development and process improvements. It is frequently used especially in 6 sigma techniques and projects and facilitates the work. It is included different analysis methods that can be evaluated in many ways. Its availability has continued to increase since 1970 and its usage has become widespread in companies.

It is provided approaches from different perspectives in production projects and operation analysis. Accordingly, it offers a wide variety of solutions. It is provided importance in root cause determination by simplifying complex data. It is an important feature to have a comprehensive analysis content tools and methods such as a variety of graphs and charts.

It is made complex data related to operation, such as 6 sigma projects, quickly decipherable. Reliable results are obtained from the analyzes made with this program. Visuality is at the forefront to make the data more understandable. It is included many visual tools such as histograms, box plots, and scatter charts. It also provides different possibilities for computation of data.

The program supports different types of windows that can run through windows.

They are determined as these:

- Worksheet window: It is provided all the graphical visual characters.
- Report window: It is showed statistical data results.
- Worksheet window: It is designed particularly data input works.
- Session window: It is showed the details of statical data.

Companies can then use the analyzed data to affect real change within their organizations and see improved results.

That program offers many advantages compared with similar products like Microsoft Excel. However, in the context of statistical analysis and specific mathematical functions, Minitab is far more advanced and powerful. Its visualization capabilities alone provide an invaluable service for users who need a genuine understanding of what their data means and what trends it illustrates. As long as you input clean data, all you need to do is click your mouse a few times to generate elegant, informative charts you can start using to improve your processes right away. Essentially, Minitab acts as a tool for applying Six Sigma principles and methodology. Six Sigma professionals must often accomplish the following objectives:

- Determine the pain points in established processes.
- Usage of tools and data to improve the effective solutions.
- The developed strategies.
- Monitor the resulting changes and adjust if necessary.

Minitab assists with all these tasks. It simplifies the data input for statistical analysis so users can get to identifying their pain points quickly.

This program has many applications in terms of quality control, improvement and productivity. Solution examples are mentioned below to improve the production process by performing data analysis.

- Increasing the quality and control standards:

By using this program and analysis methods, quality deficiencies can be determined and improvements can be made accordingly. For example, an art supplies company identified the root cause of adhesion problems on crayon labels with this analysis. Finding that the adhesives were not sticking properly, the company set up retaliation machines near the facility's labeling machines to ensure more durable crayon packaging and to detect appropriate humidity levels. this work has been a 6-sigma project that has saved the company \$1.5 million.

- Increasing efficiency by reducing downtime:

Effective data analysis facilitates the detection of problems and ensures smoother operations. Decreased breakdowns will positively affect production efficiency. Many companies have made significant profits with this method.

- Increasing the analytical data usage:

It is an important factor for setting realistic company growth targets. Determined targets are improved processes. Improved processes are increased the efficiency of operations.

In order to make this determination, the total company occupational accident data for the last 3 years were obtained from the occupational health and safety department in detail. Depending on the data, statistical data analysis based on lines was made using the Minitab program.

As a result of this analysis, the region with the highest occupational accidents were determined the cutting line rate of percentage of % 12. A statistical data analysis was made again depending on all the machines in the cutting line. As a result of this analysis, it was determined that the disk rounding presses were the most dangerous machine with the highest accident rate by percentage of % 60.

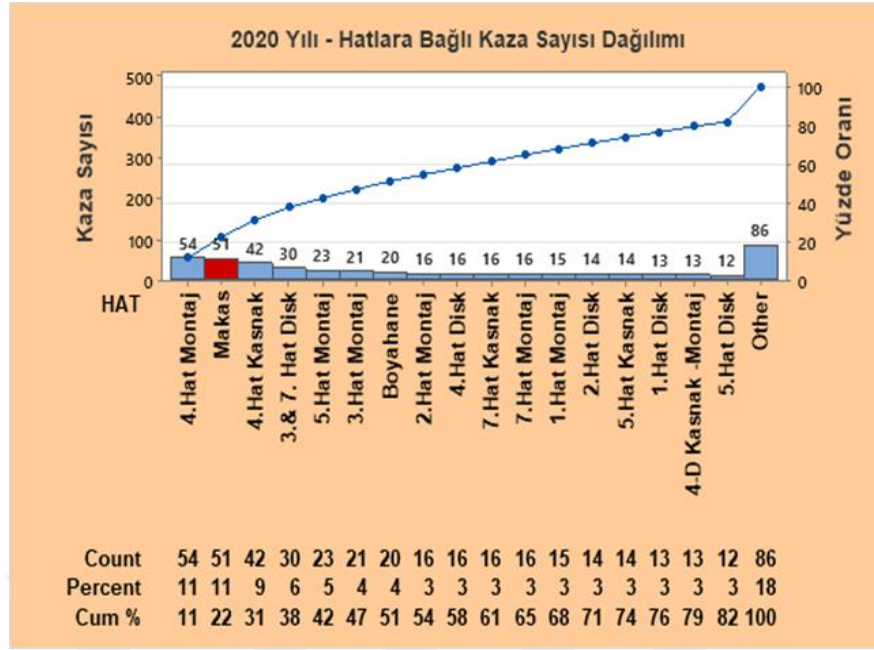


Figure 3.1 In 2020, Number of accidents related to lines

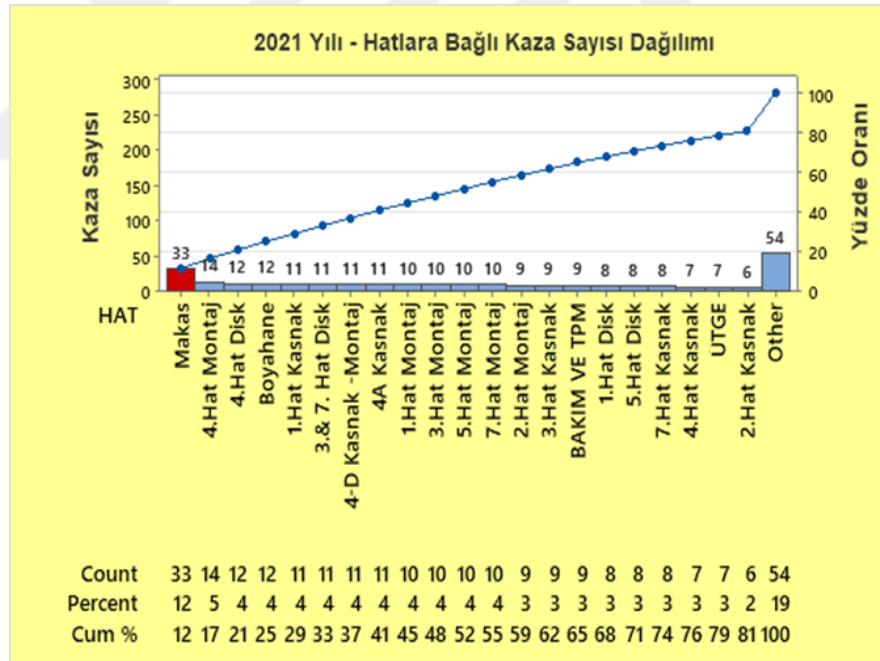


Figure 3.2 In 2021, Number of accidents related to lines

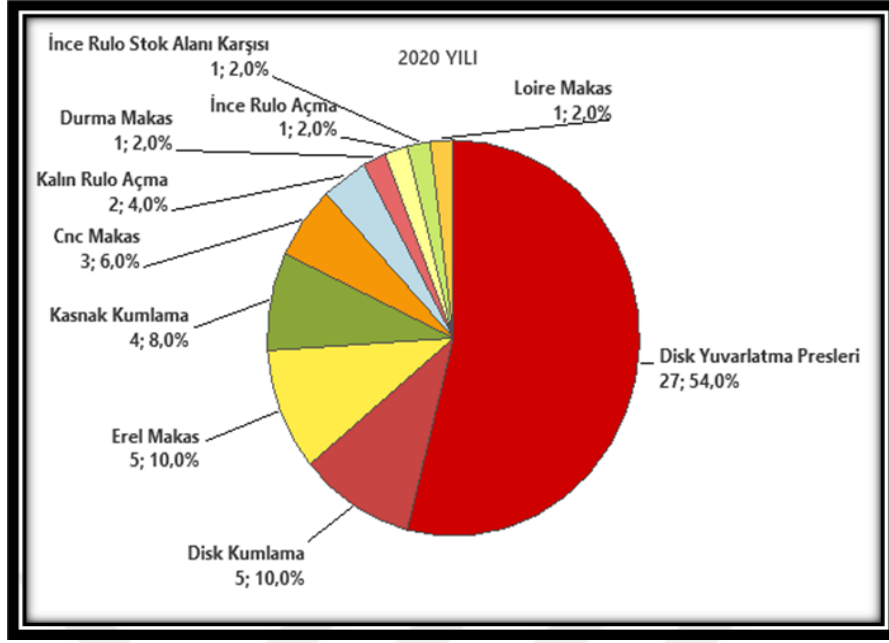


Figure 3.3 In 2020, Number of accidents related to cutting lines

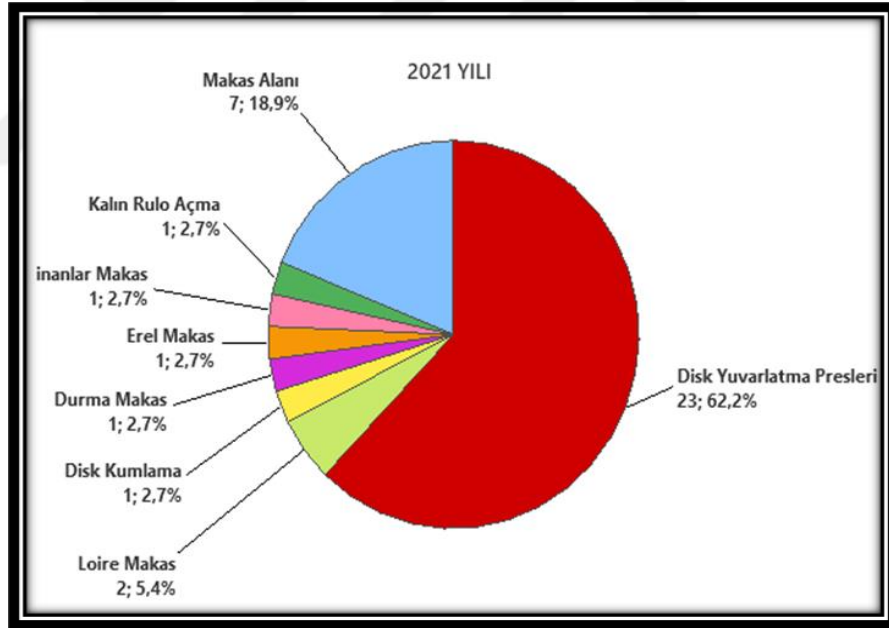


Figure 3.4 In 2021, Number of accidents related to cutting lines

3.2 Mechanical Design

3.2.1 Mechanical Working and Design Details of the System

Mechanical operation and design steps are explained below with all details.

- The detail measurements of the disc rounding press for which the system design will be made have been taken.
- The dimensions of the study area have been determined.
- Press working range and max. course sizes are determined.
- Press cycle times were taken for different shifts and the average time was determined.
- The design draft was created by taking the dimensions and thicknesses of the material to be processed in the press.
- Depending on these data, the types of robots that I have explained in detail in chapter two have been examined. The most suitable cartesian robot type for this area has been determined and the design process has begun.
- In the first stage, centering platform design for material stacking and loading is designed. Materials to be processed in the press max. stack height of 300 mm will be loaded on the centering platform. Disc centering platform max. will be carried 2000 kg of weight. A centering platform with wheels and fixed in a certain position has been designed. So, that the forklift operator can load properly and the working operator can work according to ergonomic conditions. Construction design and wheel selection were made according to these numerical values.
- In the second stage, a system that provides up and down movement depending on the decrease in the materials taken from the stack is determined. This system will be pneumatic or hydraulic. Although our primary preference is the pneumatic system, a hydraulic system may also be preferred depending on the production conditions. Two system trials are planned during the manufacturing process. At this point, cylinder stroke selections centering platform – material stack height and press max. made by taking the ram height into account.

In addition, attention was paid to the selection of material for the system in the up down movement. Bronze material was preferred as the shaft bearing material and induction chrome shaft were preferred as the shaft material. These materials are preferred because they are resistant to abrasion.

- In the third stage, the details required for the robot gripper, which enables material to be held and transported, are determined. According to the received data, max. diameter: 525 mm, max. thickness 15 mm and max. sheet material dimensions are 525x525x15 mm. The magnet selection was made by taking these dimensions into account. Electromagnet is preferred because the material surface is oily and rough. For the gripper chassis magnet connections made lightly. The chassis has been reinforced with ribs to prevent bending.
- At the last stage, the system that provides the movement between the disc centering platform and the press center has been created. The total distance between the two centers is 1450 mm. This motion transmission will be with linear guide system and ball screw-nut system. The reason why these systems are preferred is that they are suitable for positioning accuracy.
- The electrical software details are described in detail in section 3.3.
- In the following process, the same design will be made in the press unloading system. Only the design of the gripper will be changed due to the change in the shape of the product. In this regard, the necessary improvement will be achieved by designing a gripper consisting of a pneumatic system and electromagnets.

3.2.2 Definition of the Mechanical Materials

Table 3.1 Mechanical material list

MATERIAL	COUNT
KUVE 30 B-L / Bearing carriage	4
KUVE 30 - Guideway	2
LTRM 3006 RH - Ball screw nut	1
M30, L=2000 mm - Ball screw	1
Fixed end bearing	2
Ø: 90mm, L: 60mm - Electromagnet	3
HC02-P 100-70 h:400 mm / (if necessary)	1
Steel material kg/USD	300 kg
Bronze material kg/USD	6 kg
Profile construction	3 lengths
Hydraulic system (Block, lock direction control valve, pressure reducer) / (if necessary)	1
Pneumatic cylinder PNC-Ø100 mm, L=400 mm	1
Fixed carrying rollers / M391-551-150 If necessary, M360-551-150 Movable carrying rollers	4
6005 - Bearings	2
Coupling / GS24 SJC55GRD Inner diameter – max: 28 mm, min: 12 mm	1

3.2.3 Purpose of the Usage Mechanical Materials

- **Linear bearings and guideway (4 and 2 pieces)**

It is a machine element that provides rigid, durable and precise movement along a linear axis. It is preferred because of its lubricating feature, short supply time and suitability for the working area.

- **Ball screw and nuts (1 piece)**

Screw shafts are machine elements that convert circular motion to linear motion. There are two types, with ball and without ball.

Ball screw shafts; It is exposed to less friction force thanks to the balls that are seated in the space between the nut and the shaft.

Without ball screw shafts; There is no transfer ball in the gap between the nut and the shaft. Therefore, friction is more. This will cause rapid wear of the nut. Also, at certain points, there may be a problem in the motion system without a braked motor.

- **Ball screw bearings (2 pieces)**

It is used to make bedding according to the diameters of the screw shaft used in the system. It is connected to the screw shaft-motor side and provides the transfer of loads on the system to the body. In addition, the bearings provide resistance up to high revolutions.

- **Electromagnets (3 pieces)**

Grippers, which are the end elements in robot applications, are used transport of parts. There are two types of electromagnets. They are chosen with respect to using areas and product's dimensions.

- **Coupling (1 piece)**

Coupling is one of the most basic machine elements that provide power transmission. It ensures that the power transmission is safe. It transmits the rotary motion from the motor to the shaft. It reduces the load of the shaft by tolerating the slip rate in the shafts to a certain extent.

- **Hydraulic Cylinder (1 piece) / (if necessary)**

It is a circuit element that converts hydraulic energy to mechanical energy in the hydraulic circuit and obtains linear motion and force. Speed adjustments are made very precisely in the engine and cylinders. They are protected against overload. Having oil leaks and high cost are their disadvantages.

- **Pneumatic Cylinder (1 piece)**

Pneumatic cylinders are used to obtain linear and angular movements. They convert pneumatic energy into mechanical energy. Compared to hydraulic cylinders, it has a wide variety. There is a wide variety of cylinder types, standard and non-standard. Cylinders produced for general applications can withstand operating pressures of up to 10 bar. Specially produced pneumatic cylinders are used for higher pressures.

- **Fixed & Movable Carrying Rollers (4 pieces)**

They are moving parts with bearings used to provide displacement in long and straight distances. It is preferred to use two fixed and two movable types to avoid movement restrictions.

- **Fixed Ball Bearings (2 pieces)**

Deep groove ball bearings are versatile self-retaining bearings with solid outer rings, inner rings, and ball and cage assemblies. Simple in design, high resistance and low maintenance, these bearings are available in single-row and two-row, and open and capped designs.

3.2.4 Definition of the System Parts

Design is defined in four parts:

- Two axis motion-controlled robot arms
- Special purpose gripper
- Product carrying & centering platform
- Special purpose stacking carrier

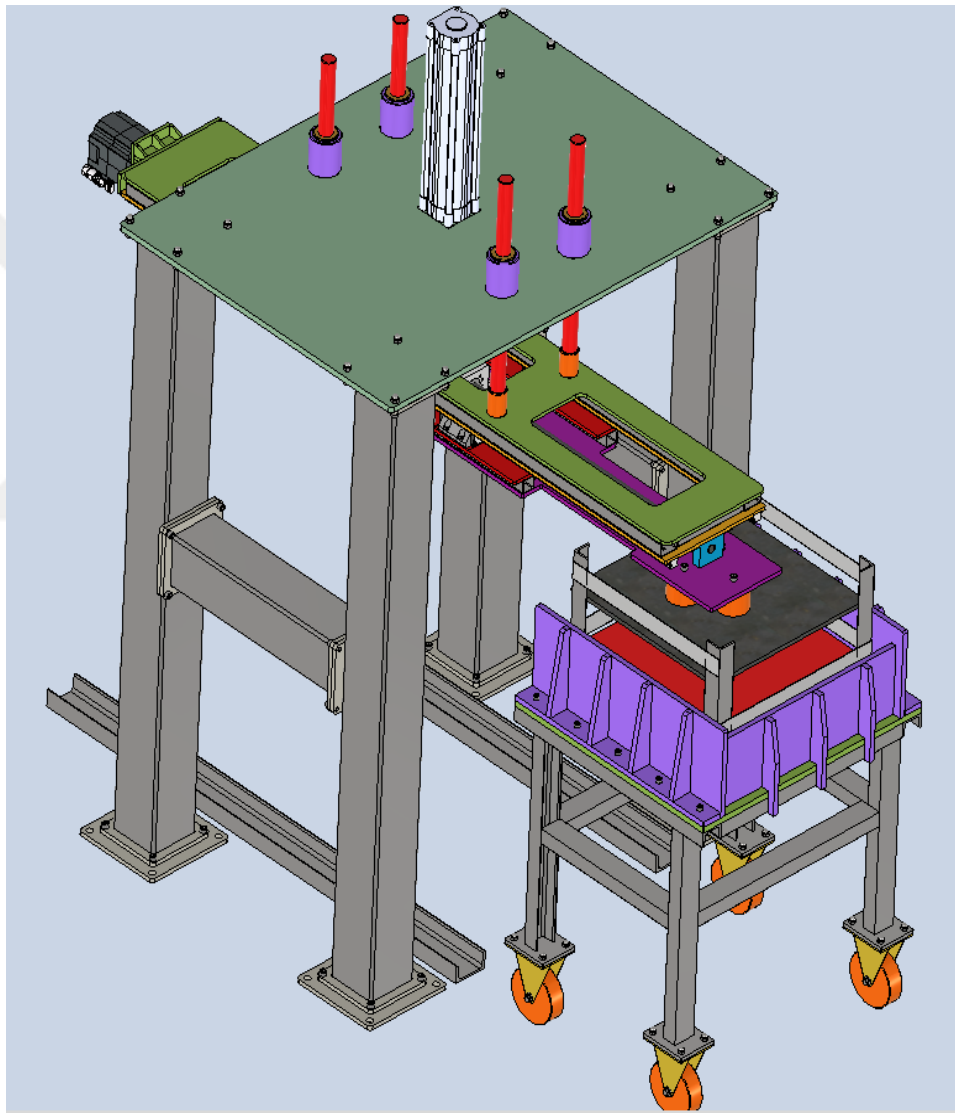


Figure 3.5 Designed of cartesian robot

3.2.4.1 First Robot Arm

It is the horizontal x axis, is acted between the product centering platform and press center for loading. The distance between the press center and the center of the stacked product centering platform is 1450 mm.

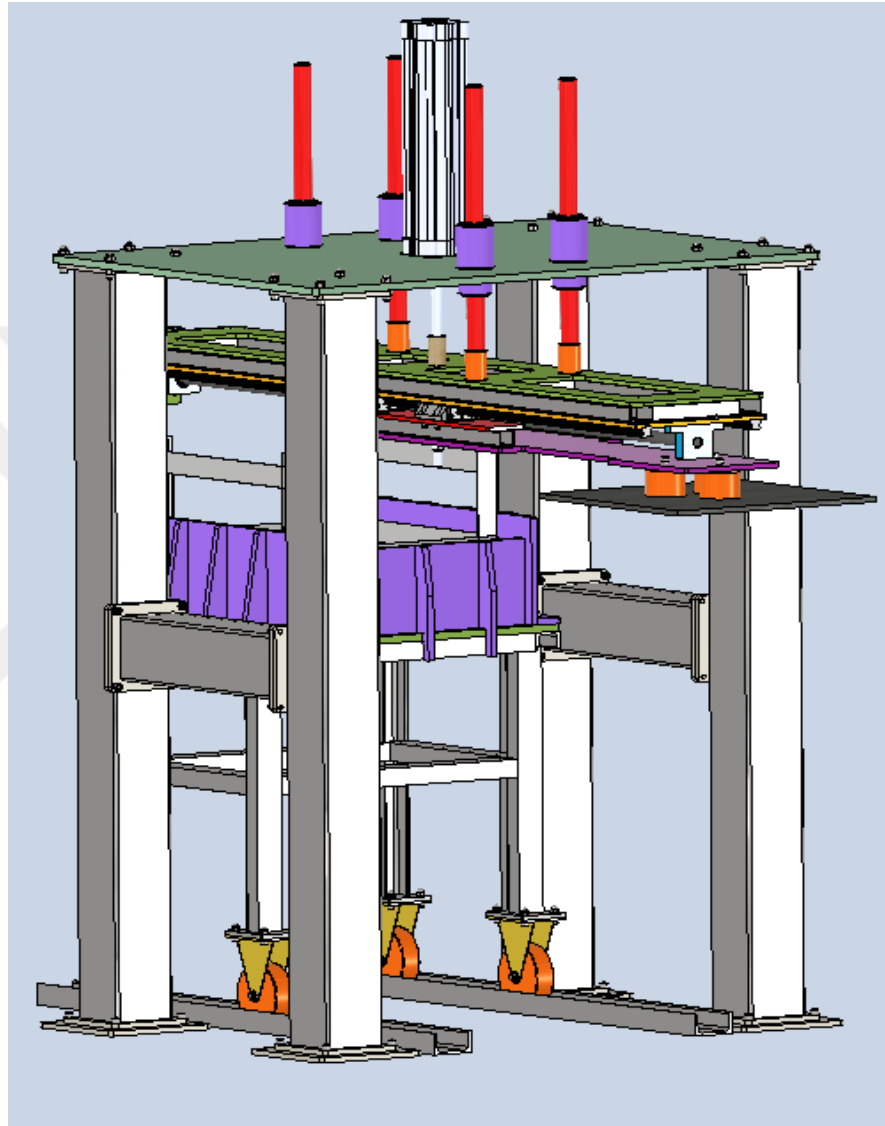


Figure 3.6 First robot arm view

Movement transfer between these two axes is provided by ball screw-nut and linear guideway-bearing carriage systems. Screw shaft nut is preferred for motion transmission. The guide system, which decides the quality and precision of the movement of the system, is chosen from high quality, ready-made systems for preventing the errors that may arise from the machine tools.

As a result of the calculations made depending on the press dimensions, centering platform position and the cartesian robot design idea, the materials in the following dimensions were preferred.

Ball screw and nut specifications are preferred as follows.

- Diameter: M30 mm, Length: 2000 mm, Pitch: 10 mm
- Ball screw nut is used LTRM 3006 RH

The trapezoidal screw shaft and nut are preferred because of these materials are more suitable and useful for ambient conditions. It has been determined that ball nuts fail faster due to dusty and oily ambient conditions.

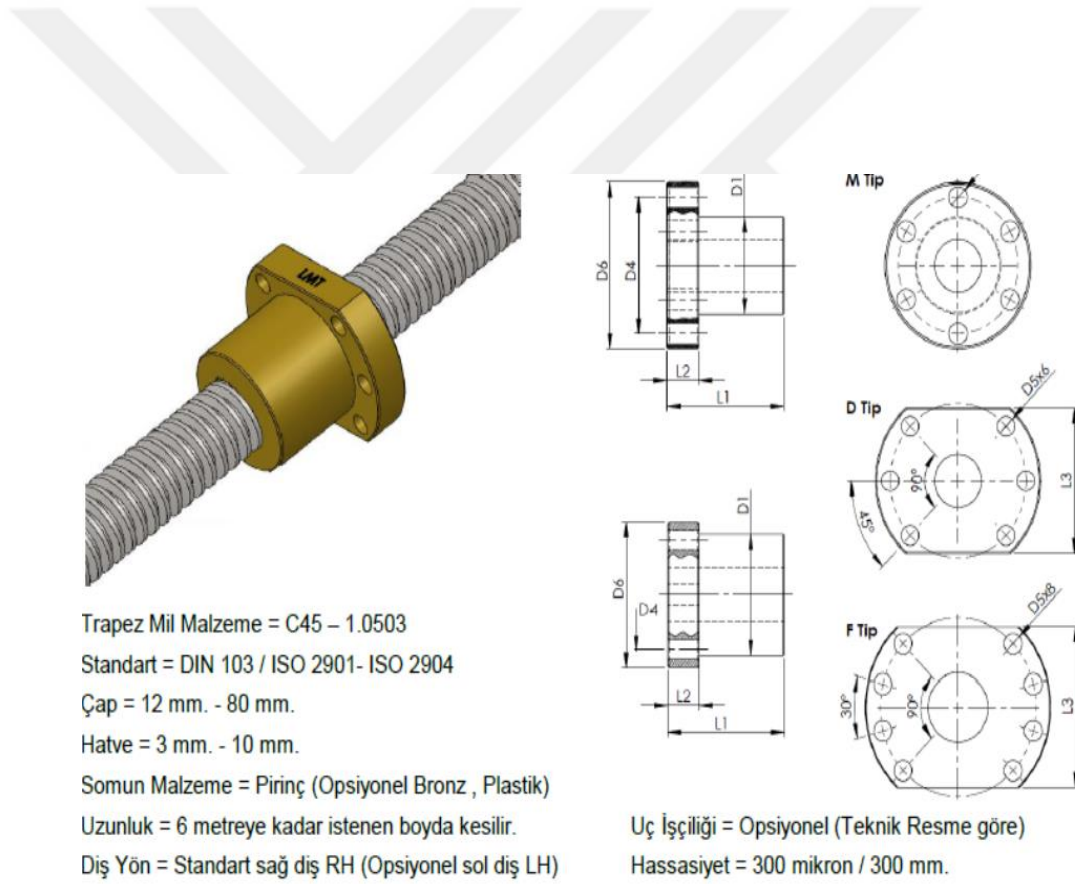


Figure 3.7 Screw shaft nut properties

A servo motor is used to provide horizontal movement. The servo motor is preferred is to provide positioning and centering precision. Also, using servo motor and driver systems will make the design more efficient.

Servo motor selection is made by considering the following data.

- Horizontal loading capacity: 150 kg
- Distance between two axes in the horizontal position: 1450 mm
- Transportation speed of the product between two axes: 145 mm/sn
- Transportation time of the product between two axes: 145 mm/sn
- Screw shaft diameter: M30 mm
- Screw shaft pitch: 10 mm
- Screw shaft length: 1925 mm

Based on these data;

- 1 KW, (1230 rpm – 2000 rpm) range, (3.8 – 4.8 Nm) torque value range

Servo motor selection will be appropriate.

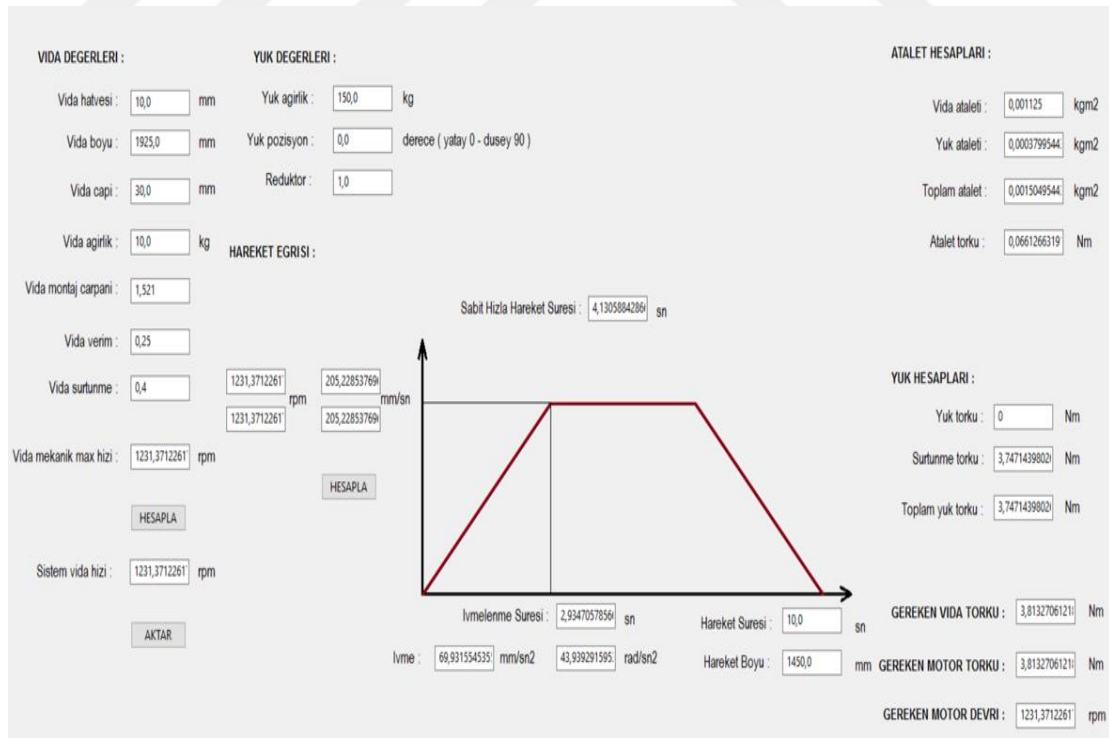


Figure 3.8 Servo motor selection calculations

Engineering data		Mechanical data	
Rated speed	2000 rpm	Motor type	High Inertia
Rated torque (100 K)	4.78 Nm	Motor type	Permanent-magnet synchronous motor
Rated current	3.0 A	Shaft height	65
Rated power	1.00 kW / 1.36 hp	Encoder system	Incremental encoder TTL, 2500 S/R (13 bit)
Max. speed	3000 rpm	Cooling	Natural cooling
Maximum torque	14.30 Nm	Shaft end	Feather key
Max. current	9.0 A	Radial runout tolerance	Class N
Static torque	6.00 Nm	Vibration severity grade	Grade A
Moment of inertia	11.700 kgcm ²	Degree of protection	IP65
Physical constants		Design acc. to Code I	IM B5 (IM V1, IM V3)
Torque constant	1.70 Nm/A	Connection type	Angular connector (rotatable)
Thermal class	B (130 °C)		
Net weight	7.00 kg		

Figure 3.9 Selected servo motor values

Accounting the safety factor;

1 KW, 2000 rpm, 4.8 Nm servo motor values is selected.

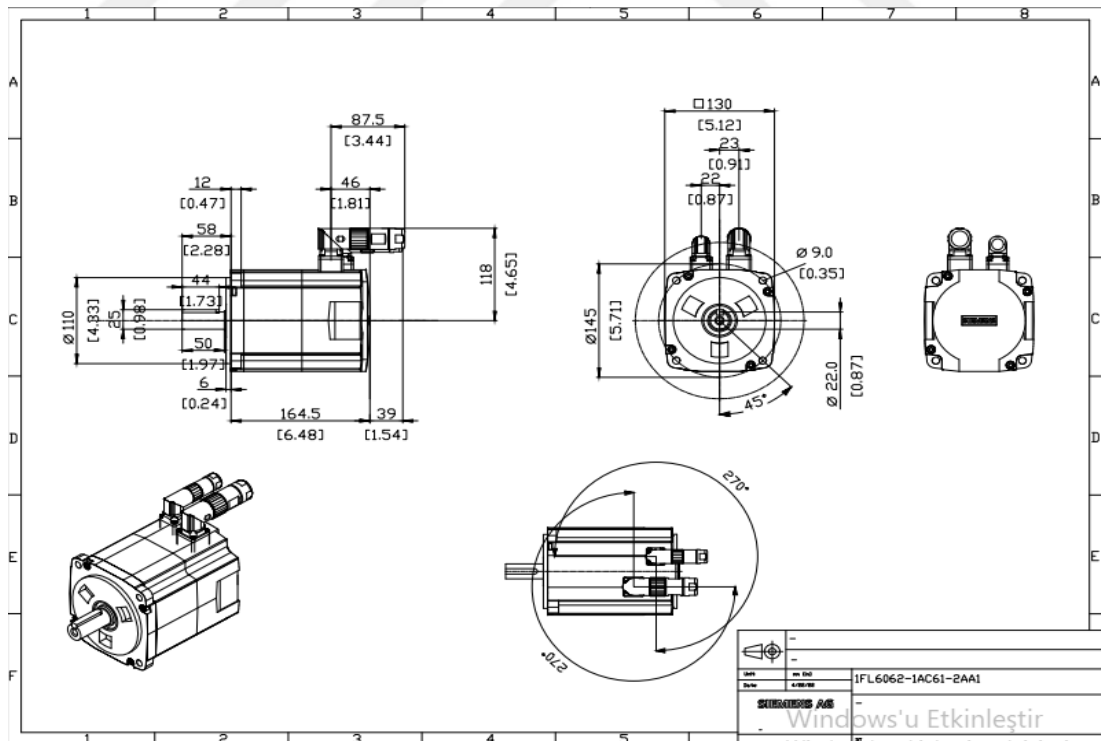


Figure 3.10 Selected servo motor technical drawing

In order to provide power transmission safety, servo coupling is preferred with the following features.

- Screw shaft diameter: 30 mm
- Motor shaft diameter: 25 mm

Based on the screw shaft diameter and motor shaft diameter data;

- SJC 55C – RD GS 24 Servo coupling
(Max. inner diameter: 28 mm & Min. inner diameter: 12 mm)

The guide system, which decides the quality and precision of the movement of the system, is chosen from high quality, ready-made systems for preventing the errors that may arise from the machine tools.

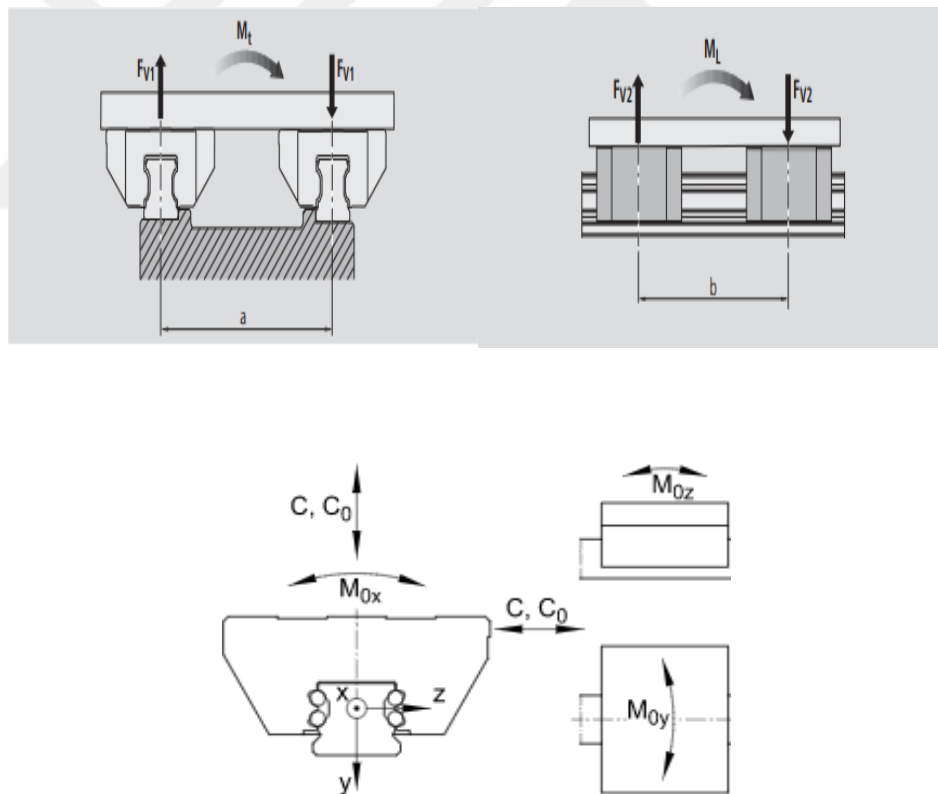


Figure 3.11 Linear bearing carriage moment values

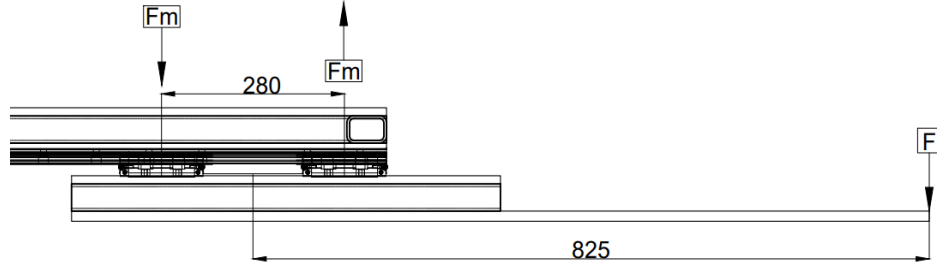


Figure 3. 12 Force distribution of bearing system

$$F = 2000 \text{ N} , a = 825 \text{ mm} , b = 280 \text{ mm}$$

$$F \times a = 2 \times Fm \times b$$

$$2000 \text{ N} \times 800 \text{ mm} = 2 \times Fm \times 280$$

$$Fm = 2857 \text{ N}$$

After these calculations; when the bearing catalogue is examined, the suitability of the KUBE 30-BL linear bearings is determined. By calculating the carried load and moment values, (4 pieces) KUBE 30 BL linear bearing carriage systems and (2 pieces) linear guideway with a length of - 2 meters - are preferred. For the system, moment calculations are completed. In this system, Mx, My, Mz moment values are blocked depending on the connection type of linear bearings.

Also, 2 pieces fixed fasteners are designed to fix the screw shaft to the chassis. In this design, 6005 fixed bearings are preferred depending on the ball screw size.

3.2.4.2 Second Robot Arm

Second robot arm, which is the vertical y axis, is acted with respect to decreasing or increasing stacked of the disc products. The product transport distance between the vertical movement distance of the designed system and the stacking center is determined as 400 mm.

Pneumatic cylinder is preferred with the following features

- Vertical carrying capacity: 250 kg

Based on the vertical carrying capacity data;

- Ø 100 mm, Stroke: 400 mm – Pneumatic cylinder

Safety factor is preferred approximately 2 values.

SİLİNDİR Ø (mm)	MİL Ø (mm)	İTME ve ÇEKME KUVVETLERİ (6Bar)	
		İtme Kuvveti (N)	Çekme Kuvveti (N)
32	12	482	415
40	16	754	633
50	20	1178	990
63	20	1870	1682
80	25	3016	2721
100	25	4712	4418
125	32	7363	6881

Figure 3.13 Pneumatic cylinder force values

First of all, it is preferred that the displacement be with the pneumatic cylinder because of without oil leakage problems, available cost and taking less place. In this system, position accuracy is provided by using a linear position sensor.

Also, vertical movement shaft bearings are provided with bronze material and diameter 40 induction chrome shafts.

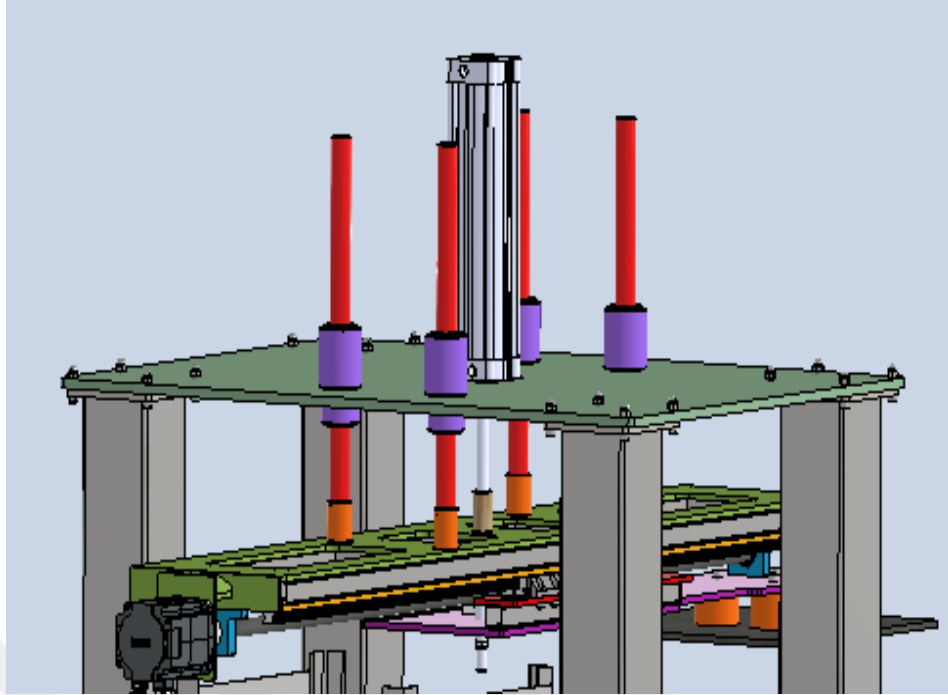


Figure 3.14 Second robot arm view

3.2.4.3 Gripper

In the gripper design; working conditions, product diameters and weights were studied and product selection was made. According to these variables, it was determined that the most suitable gripper was the magnetic. Accordingly, that, the chassis design has been developed.

The designed gripper is aimed to be of minimum length and light weight. Transporting sheet materials (525x525x15) mm from the stacking point to the center of the press at a distance of 1450 mm will increase the risk of bending stress in this area. The static analysis is given the result that area is critical region. This part of the robot, which is still under production, will be strengthened by making different trials.

Three electrical magnets are used to hold the product. Despite the fact that two magnets are sufficient for transportation under normal conditions, the risk of the product not sticking is reduced by using 3 magnets due to reasons such as curved, rough and oily products.

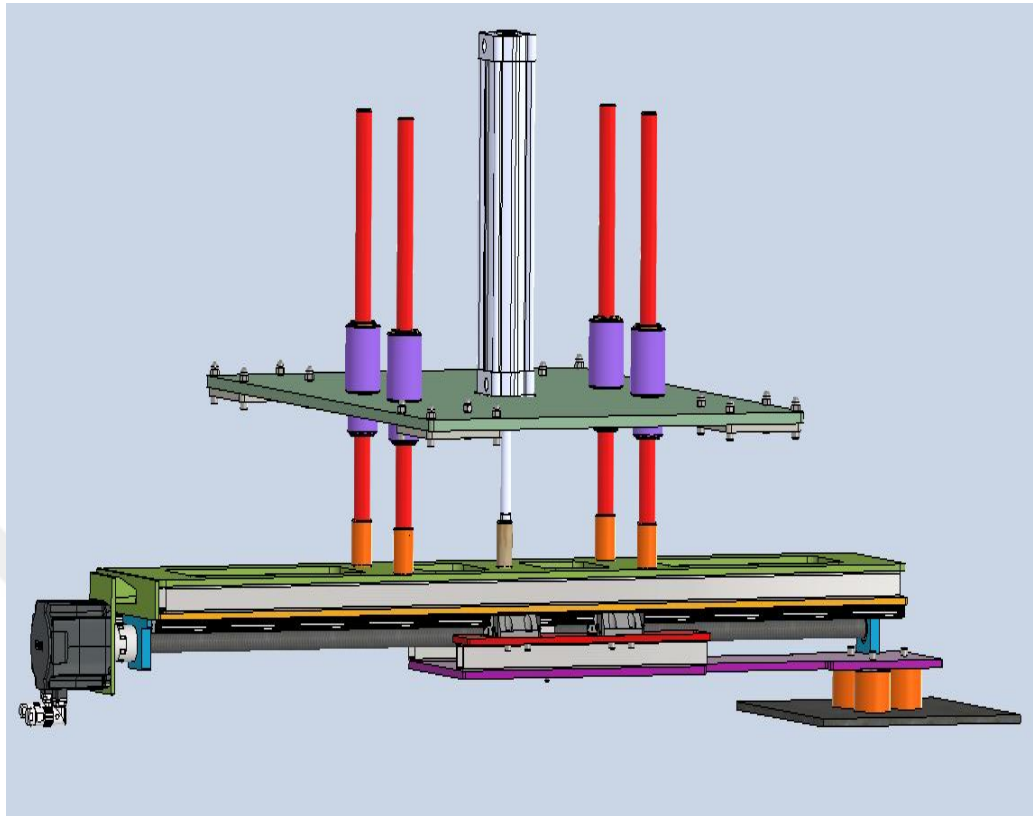


Figure 3.15 Gripper

3.2.4.4 Product Centering Platform

In the design of the product centering platform, the details of the press loading height, the maximum stacked product height and the easy loading of the forklift on the platform were studied.

It is aimed to place the special purpose stacking carrier exactly in the center by making supports on both sides and back of the platform. The maximum carrying capacity of the platform is determined as 2000 kg.

Based on the carrying capacity, platform weight, carriage roller pieces data;

- Fixed carriage rollers / M391-551-150 (2 pieces)
- Movable carriage rollers / M360-551-150 (2 pieces)

For roller movement, a U profile suitable for the thickness of the roller is used. In this way, the movement restrictions of the platform have been made and the problems related to centering have been prevented.



Figure 3.16 Movable carriage roller



Figure 3.17 Fixed carriage roller

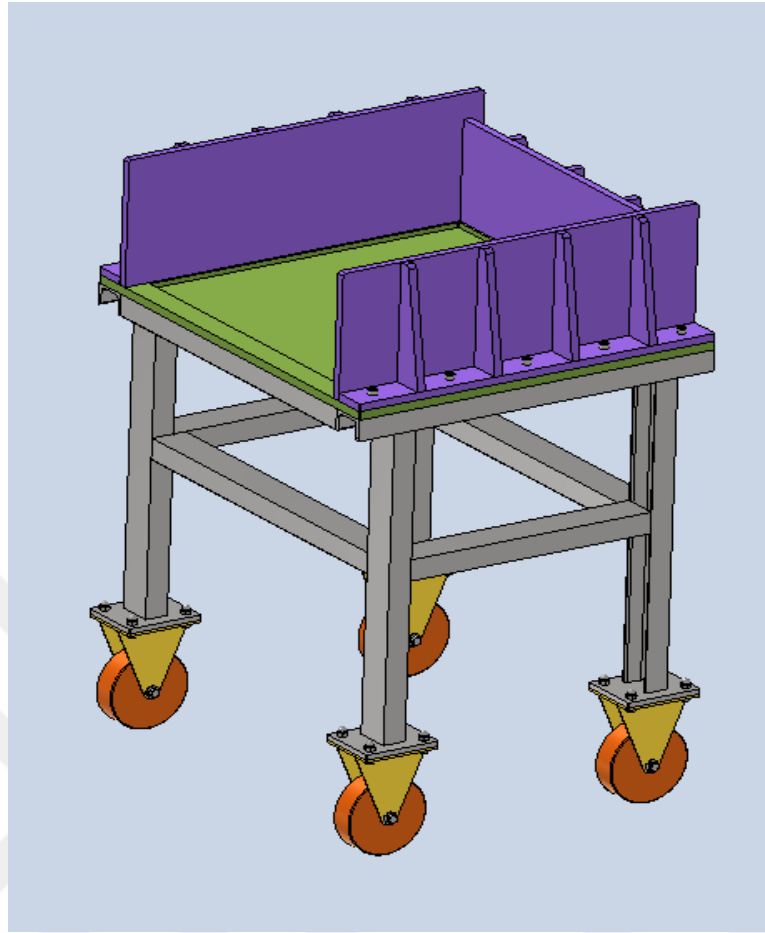


Figure 3.18 Product centering platform

3.2.4.5 Special Purpose Stacking Carrier

In the design of the special purpose stacking carrier, the details of the press loading height, the maximum stacked product height and the easy loading of the forklift on the platform were studied.

The design was made taking into account the maximum and minimum opening and closing of forklift blades. The chassis plate restrictions on the platform are made for the proper placement of the sheet metal on the carrier. The front and rear restraints have been canceled due to the restriction of gripper movement.

The purpose of this chassis is to ensure that the products are brought centered from the sheet metal cutting area.

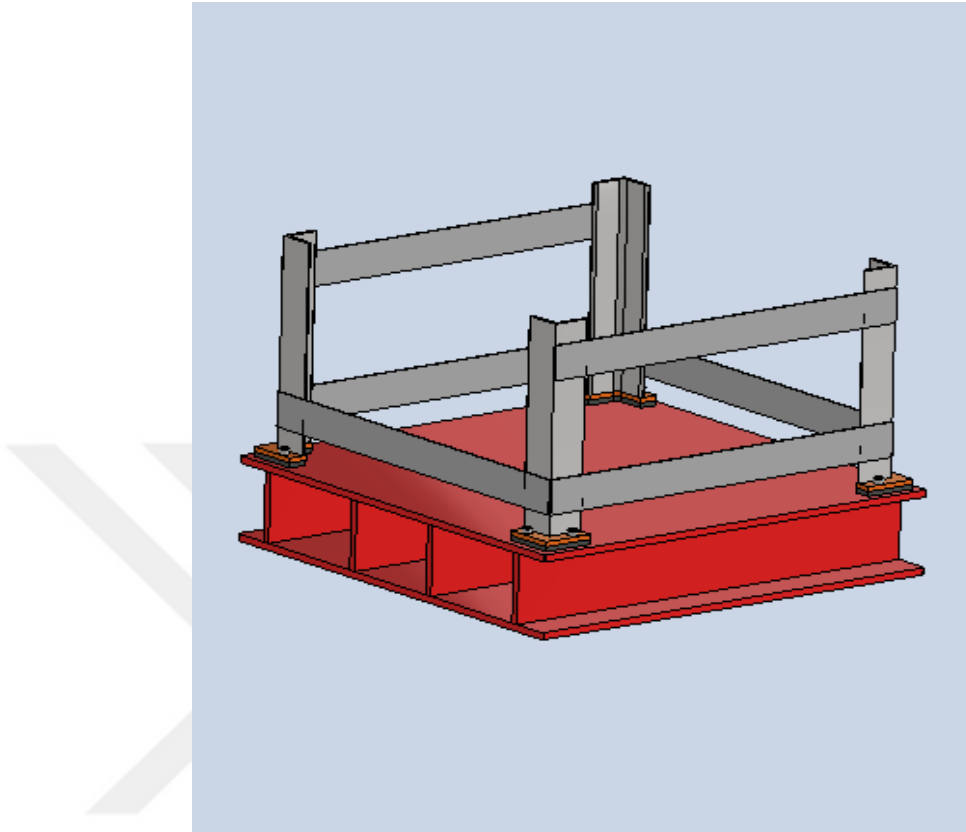


Figure 3.19 Special purpose stacking carrier

3.2.5 Mechanical System Production Details

First of all, the working press was measured in detail. Accordingly, 2-dimensional technical drawings were drawn by Autocad program and 3-dimensional technical drawings were drawn by Autocad Inventor program. As a result of the design, details about the system were determined, material lists were created and orders were given. The same procedures were done for the electrical part. Plate and sheet metal plate cuttings were completed in the company's laser machine. Detailed technical drawings of the materials to be manufactured were prepared and operated in the company's workshop.

Depending on the completed works, the assembly process of the system has been started by the department operators and 80 percent has been completed.



Figure 3.20 General front view of the system



Figure 3.21 General side view of the system



Figure 3.22 View of product centering platform



Figure 3.23 View of special purpose stacking carrier

3.3 Electrical Control Design

3.3.1 Definition of PLC

Programmable Logic Control (PLC) organ processes binary input signals and creates output signals that will directly (directly) affect technical operations, studies and steps of these studies.

In this system, it is preferred to use CPX-FEC programmable logic controller. With its small dimensions and powerful instruction set, CPX-FEC can be used in any branch of small automation projects.

Some application areas; It is used in many branches such as building automation, hydraulic presses, transport systems (Pick Place), automatic doors, elevators, mixers, bottling machines, packaging machines, pumps, pneumatic lifting platforms. These:

- Conveyor system: A program is written to stop and start the motors and count the incoming materials. Thus, the materials transported separately can be counted and the stocks can be kept more easily.
- Door control system: It fits even the smallest machines with its small dimensions. For example, it can control the doors at the entrance and exit, and automatically open and close the doors when the vehicle arrives.
- Transport systems (Pick Place): It is used to transport materials from one point to another. It has a wide range of application areas.

3.3.2 Advantages and Disadvantages of PLC

The main advantages of PLC applications are:

*Flexibility: In the past, each machine had its own control circuit. 15 pieces If there is a machine, 15 of these control circuit sets would be required. Today, a PLC can enter all the machines by entering 15 subprograms can control. Pressing just one button to change an action enough. PLC is very flexible for this.

*Numerous contacts: Numerous auxiliary contacts, auxiliary relays and counters available in PLC. If you only have four auxiliary relay contacts and if you need three more contacts due to operation, you need to change the system. That increases the cost. However, PLC If the memory is sufficient, only the program is changed.

*Low price: With the co-development of technology and science, PLC becomes more powerful and has become cheaper. Relay, counter, timer and other. You can get a PLC with functions at a very low price.

*Pre-simulate: A single PLC module can be simulated before loading the program and mounting it in place. Operators change the program according to the desired conditions by observing the LEDs on the I/O module. This causes us to save a lot of time when searching for faults in the system compared to the old relay systems.

*Fast processing time: The operating time of the relays is quite slow. But PLC It can execute different commands in just a few microseconds. Consecutive the processing time of the commands takes only $0.65\mu\text{s}$.

*Use of ladder diagram in circuit planning: Computer-connected PLC can use ladder diagram editing software or ladder diagram compiler to make PLC program with relay control circuit.

*Robustness and easy maintenance: PLC consist of a combination of digital electronic circuits. Compared to mechanical and relay systems, it is more robust and maintenance cost is very low.

*Facilitating the purchasing process of the elements in the control system: You may need to order the materials used in conventional relay-controlled circuits from different companies. The delivery time of each element will not be the same. PLC all materials can be ordered at once and all delivered at the same time. This avoids delays in delivery and simplifies the purchasing process.

*Easy conversion to data file: program the PLC (e.g., ladder diagram) as output from a PLC or a printer connected to the computer you can take. Thus, all the information in the PLC can be converted into a file.

*High security: We can set a password to prevent the loss of the program loaded on the PLC or to prevent it from being seen by unwanted people. Thus, the data in the PLC is safe.

*Ease of changing the program: All programs in the PLC can be changed easily with the program writing device.

Despite the above advantages of PLC, some disadvantages are as follows:

*New technique: Some engineers may not be able to adapt old relay systems to the new PLC programming technique.

*Not suitable for places with fixed use: The biggest advantage of PLC is that it can easily change its program to achieve the desired goal from the control functions. If these functions cannot be changed, if it is a simple circuit, it will be very, it may take time.

*Environmental effects: PLC may not be suitable for high temperatures, places with vibration and electrical interference

3.3.3 Construction of PLC

A suitable definition for PLCs can be made as follows; PLCs are digital computer controlled electronic devices that can execute special functions such as logic, timing, counting and arithmetic operations to control machines and processes and use programmable memory to store orders. (Matic, 2004)

Mekanik kontaklar, proximity switchler, analog girişler vb.

GİRİŞLER

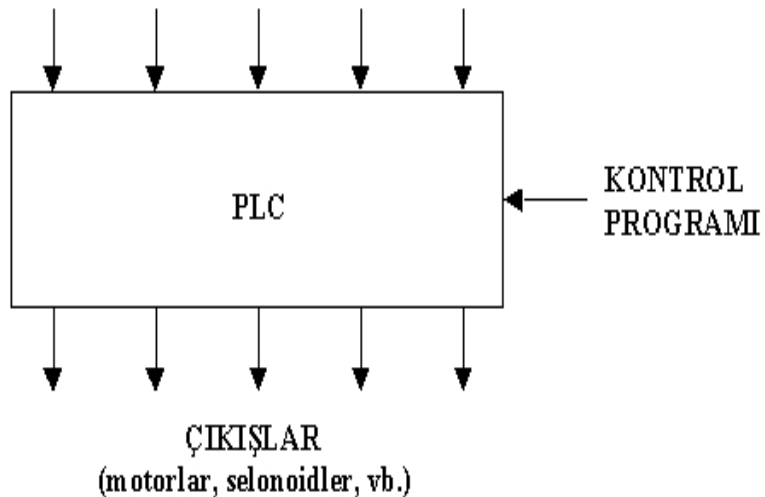


Figure 3.24 General display of PLC control process

The PLC continuously reads the inputs in accordance with the user program, executes the user program and loads the necessary changes to the outputs. By making the necessary changes in the user program, the algorithm is changed without changing the hardware. A typical PLC generally consists of the parts given in the figure below.

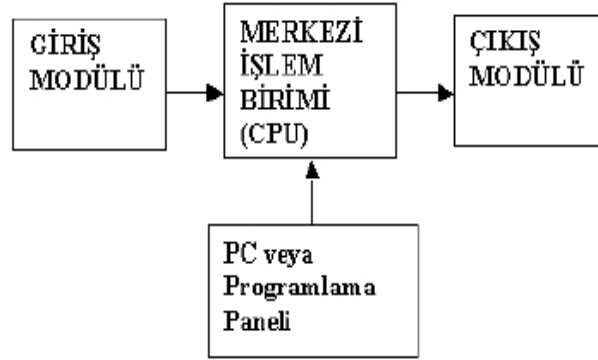


Figure 3.25 Parts of PLC

3.3.3.1 Connection Scheme

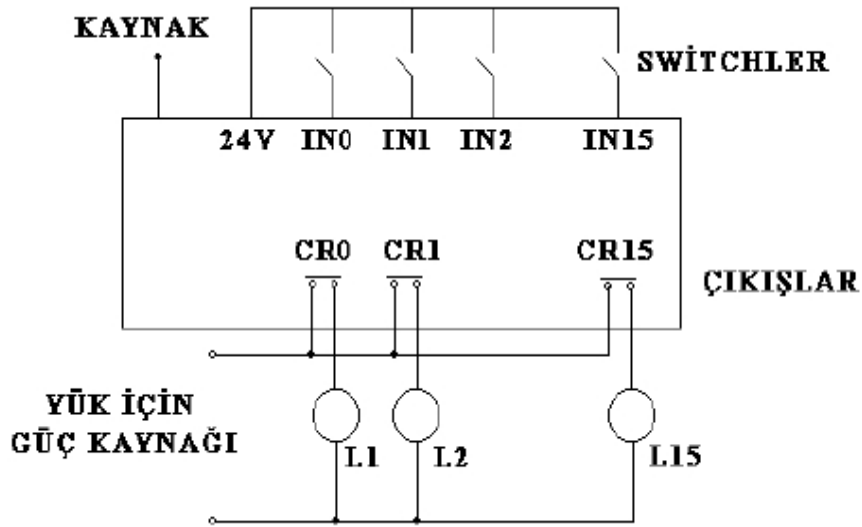


Figure 3.26 PLC input- output connection scheme

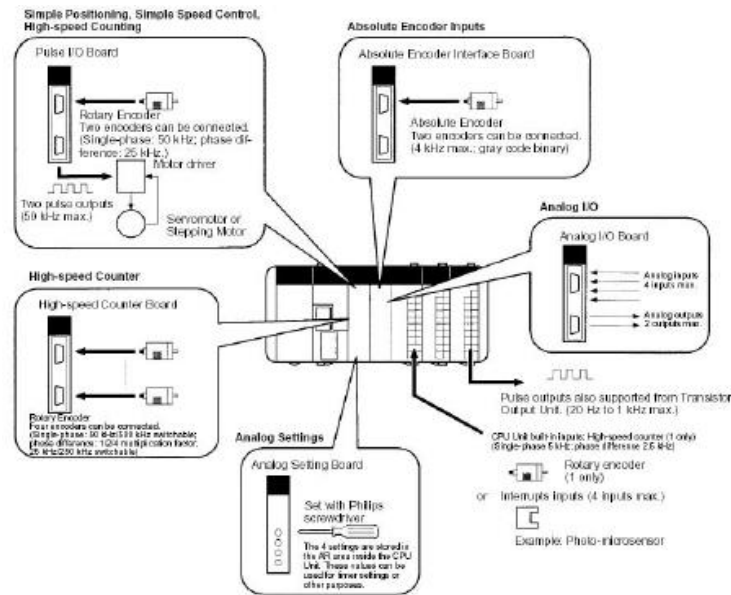


Figure 3.27 PLC module connection

A 24V or 220V source is used to supply PLCs. For inputs, mechanical or proximity switches (inductive, capacitive or optical) are used. In addition, analog input modules and spindle encoders are used at the inputs. In PLC outputs, modules with relay, transistor or triac outputs to drive loads are used. There are also D/A converter modules at the output. The programming logic used in PLCs is unique and is called ladder (ladder logic).

3.3.3.2 Internal Construction and Working System

The block diagram of the internal structure of a PLC is shown in Figure 5.6. As in Figure 5.6, the structure consists of the central processing unit (CPU), main memory, input/output video memories and input-output interface device blocks that connect the input/output devices to the video memories. The communication path is the common path group that each unit uses to exchange information with each other.³⁰ Input display memory, binary number system is applied to show ON-OFF status coming from the input gates. That is, binary 1 for ON status, binary 0 for OFF status is recorded in the image memory.

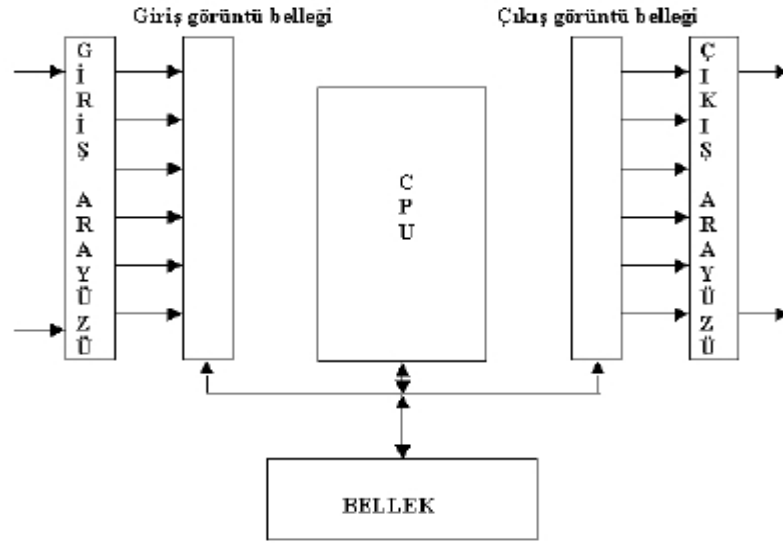


Figure 3.28 PLC internal connection

3.3.3.3 Principle of Working

All PLC operating systems execute the ladder program by scanning the logic values of the inputs and outputs saved in the image memory. First, the operating system scans all entries. Then the program written by the user is executed. Finally, the outputs are scanned and keyed according to the results of the executed program and the status of the inputs. Program and, or, not etc. may contain functions or it can include counting, timing, mathematical functions and various functions.

3.3.4 Electrical Working Principle of the System

- The forklift operator will place the raw material stack on the sheet centering platform.
- Next, the operator will advance the wheeled disc centering platform to the loading point.
- The system will start to work when the disc centering platform sees its sensors in place and the beacon lights yellow (ready) indicating that there is nothing between the light barriers.
- The system will start to work after the operator prepares the required recipe on the HMI Screen and gives the system ready command.

- The servo system will come to the starting point with the home switch.
- With the proximity sensor placed on the gripper, it will move down with the hydraulic or pneumatic system until it can take the disc.
- When the proximity sensor sees the disk, the disk will be held with the help of electromagnets.
- The disc held by electromagnets will then be lifted up to the up-position switch by pneumatic or hydraulic system.
- As soon as the position switch is seen, the servo will move the distance specified on the HMI Display.
- After reaching the specified distance, the position that it can leave to the press center will move down to the switch.
- Then, it will cut off the energy of the electromagnets and put the rim in the center of the press.
- With the servo system, the gripper will come back to the stack center position on the disc centering platform. This process will repeat until all the stacked discs are finished. And the process will be completed.

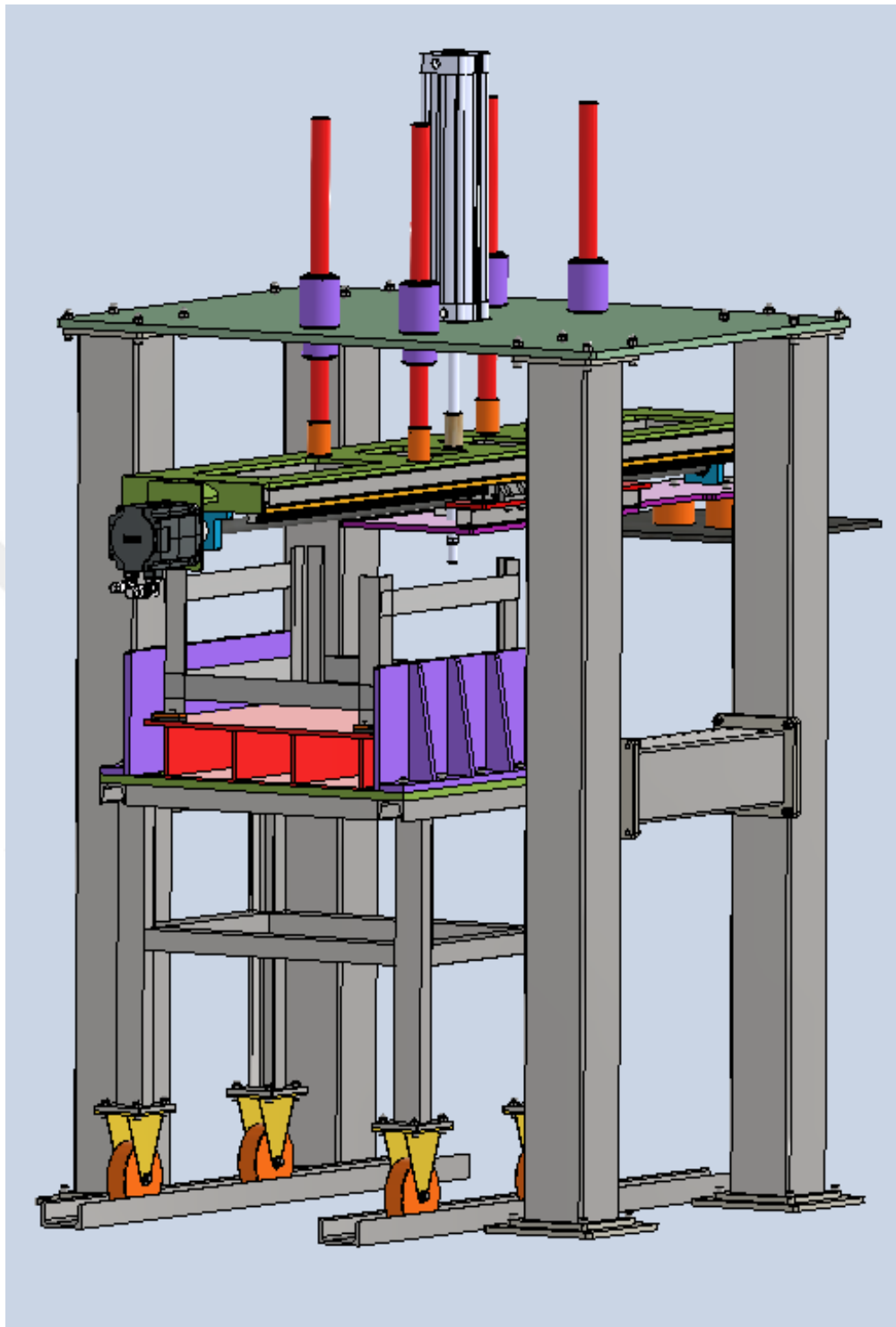


Figure 3.29 Cartesian robot view

3.3.5 Definition of the Electrical Materials

Table 3.2 Electrical material list

MATERIAL NAME	COUNT
PLC (FX5U-32MR/DS)	1
HMI SCREEN (GS2107-WTBD-N)	1
1KW SERVO SET (1 KW-2000rpm-4.77 N/m)	1
SERVO ENGINE	1
SERVO DRIVER	1
ENCODER CABLE (5 meter)	1
POWER CABLE (5 meter)	1
BRAKE CABLE (5 meter)	1
LIGHT BARRIER (1.5 meter)	1
HOME SWITCH	1
ELECTROMAGNETS	4
PROXIMITY SENSOR	1
POSITION SWITCH	2
PLATFORM IN PLACE SENSOR	2
TOP LIGHT THREE COLOR	1
SAFETY RELAY	1
ETHERNET SWITCH	1
SLIM RELAY	10
CONTACTOR (3 KW)	4
ENGINE PROTECTION BREAKER (0.25 – 0.4 A)	4
INPUT CIRCUIT BREAKER	1
INPUT SOURCE BREAKER	1
24 VDC POWER SOURCE	1
GALVENIZED METAL PANEL (600X800X210 mm)	1
ELECTRIC TERMINAL	50

3.3.6 Purpose of the Usage Electrical Materials

- **16DI 16DO PLC (FX5U-32MR/DS)- (1 piece)**

PLC will be used for the operation and control of the general system. It will be ensured that the products to be used in the system are operated with PLC and necessary information is obtained from the products.

The program is written in the internal structure of the function block related to the PLC is attached. The figure below is the block state.

- **1kW; 2000rpm; 4,77Nm; Modbus TCP or CC Link IE Field Basic with Control Servo Set- (1 set)**

MR-JE-100C - (Servo Driver)

HG-SN102BJK - (Servo Engine)

MR-PWCNS4 - (Encoder Cable)

MR-J3ENSCBL5M-L - (Power Cable)

MR-BKCNS1 - (Break Connector)

The use of servo will be used in the movement of the wheels to be fed to the press. The reason for using servo is that with the encoder information we will get from the servo, the pressing distance of the wheels can be adjusted more precisely.

The settings related to the servo motor on the HMI Screen are as in the figure below. The pdf with the other pages is attached.

- **HMI Ekran (GS2107-WTBD-N)- (1 piece)**

Displaying the information, we receive from the PLC on the screen and operating the system. Thanks to the screen, the operator will be able to control the distance that the servo motor can travel, and he will be able to view the number of wheels produced and similar information and control it with the recipes he has created.

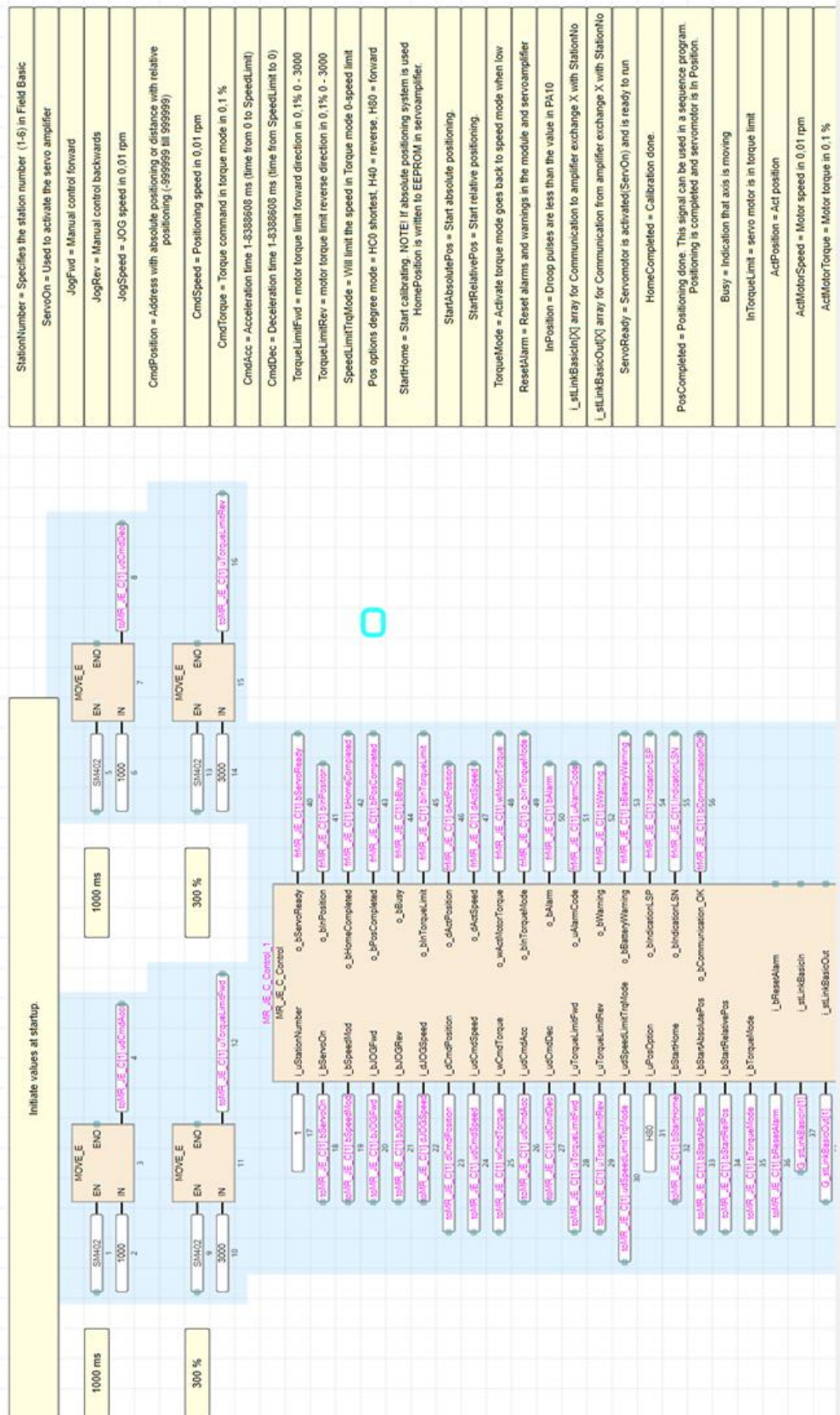


Figure 3.30 PLC function blok

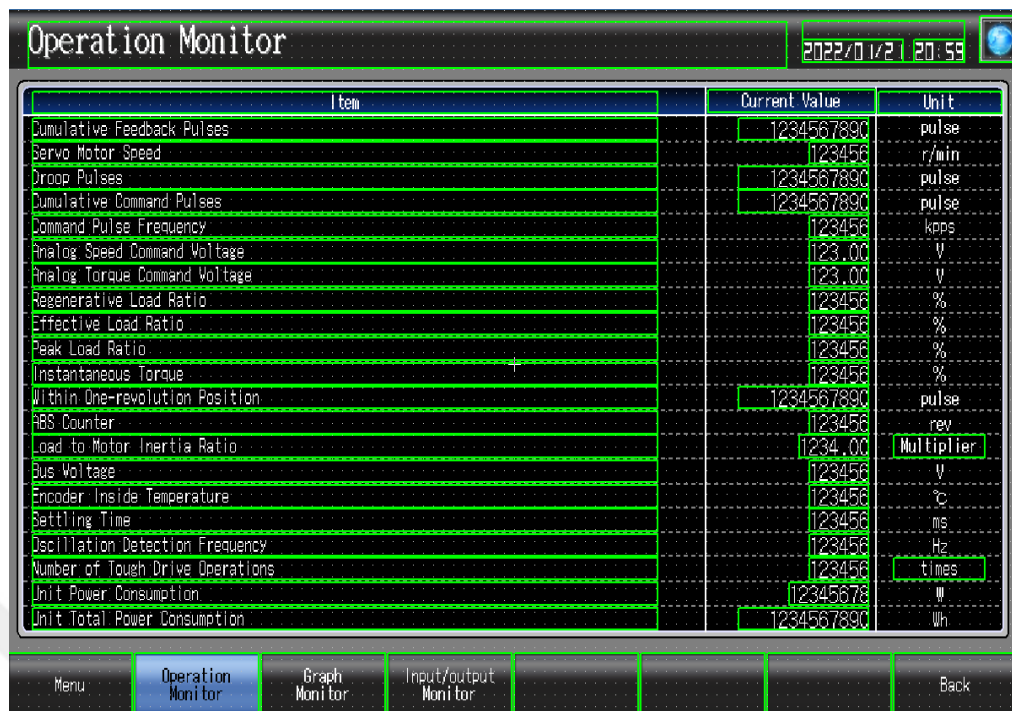


Figure 3.31 HMI screen first view of the servo system

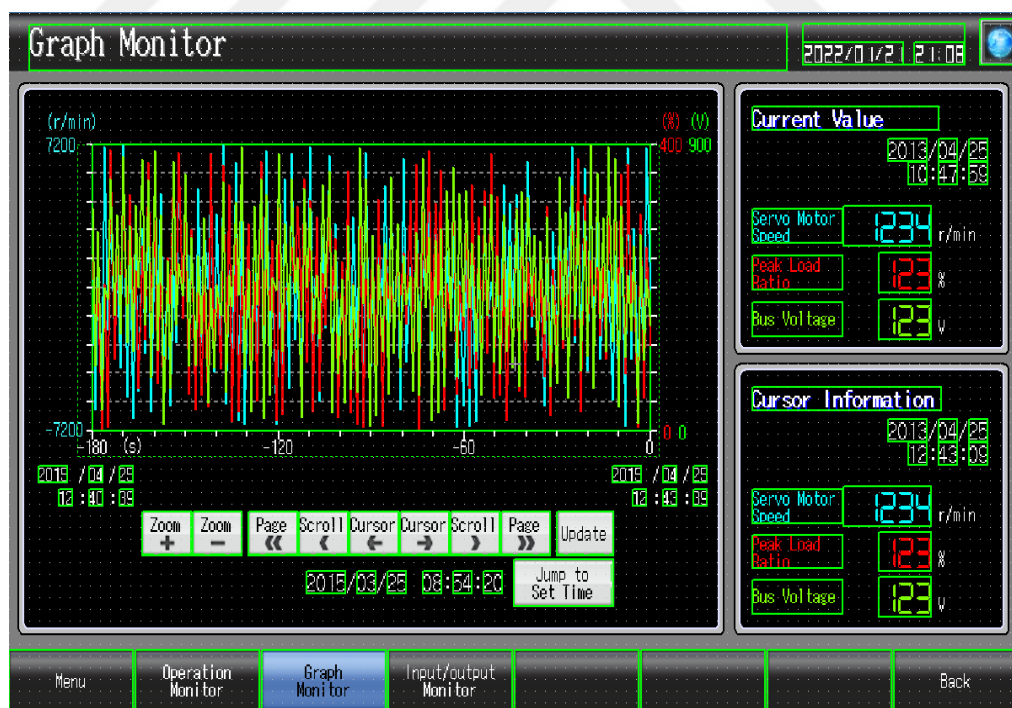


Figure 3.32 HMI screen second view of the servo system

- **Light Barrier and Protection Construction - (1 piece)**

It will be used to stop the system as a result of anything entering the area where the system is located during production. (Height: 1.5 m)

- **Home Switch - (1 piece)**

It will be used to determine the starting position of the servo.

- **Electromagnets - (4 pieces)**

It will be used to keep the discs in the air in the distance from the stock area of the discs to the press feeding area by mounting them on the gripper created to hold the discs.

- **Proximity Sensor - (1 piece)**

It will be used to determine the required distance while mounting the sensor to the gripper and moving forward to hold the disc with hydraulic or pneumatic.

- **Position Switch - (2 pieces)**

After catching the disc and holding it with a magnet, the switch will be used to determine the distance it should stay above and it will be used to stop the disc at the required distance to place it in the press center.

- **Platform in Place Sensor - (2 pieces)**

After the platform with the discs to be fed is finished, it will be used for the operator to put the discs back in the same position after placing them on the platform. The reason for using 2 pieces is to prevent any diameter possibility.

- **Top Light - (1 piece)**

When the disc runs out on the disc feeding platform or when one of the light barriers passes, the system will stop by turning on the red light and inform the operator. When the operator puts the discs on the disc feeding platform and then puts them back in their full alignment, the yellow lamp will turn on and indicate that the system is ready to work. The green lamp will turn on when the operator starts the system from the screen.

3.4 Static Analysis

Static analyzes of the designed system were made separately for each of them: gripper, product centering platform, main chassis and special purpose stacking carrier. critical regions were determined and the system was improved and developed with respect to these values. Von misses stress, displacement and safety factor values were examined in the static analysis. The aim is to ensure the creation of the optimum system.

3.4.1 Analysis Results of Gripper

The force was applied to the gripper end point with our maximum carrying weight of 700 N. As a result, displacement, factor of safety and von misses stress values were investigated. The critical displacement for the end point with risk in the bending direction was calculated as 2.55 mm. The data were obtained suitable for the system.

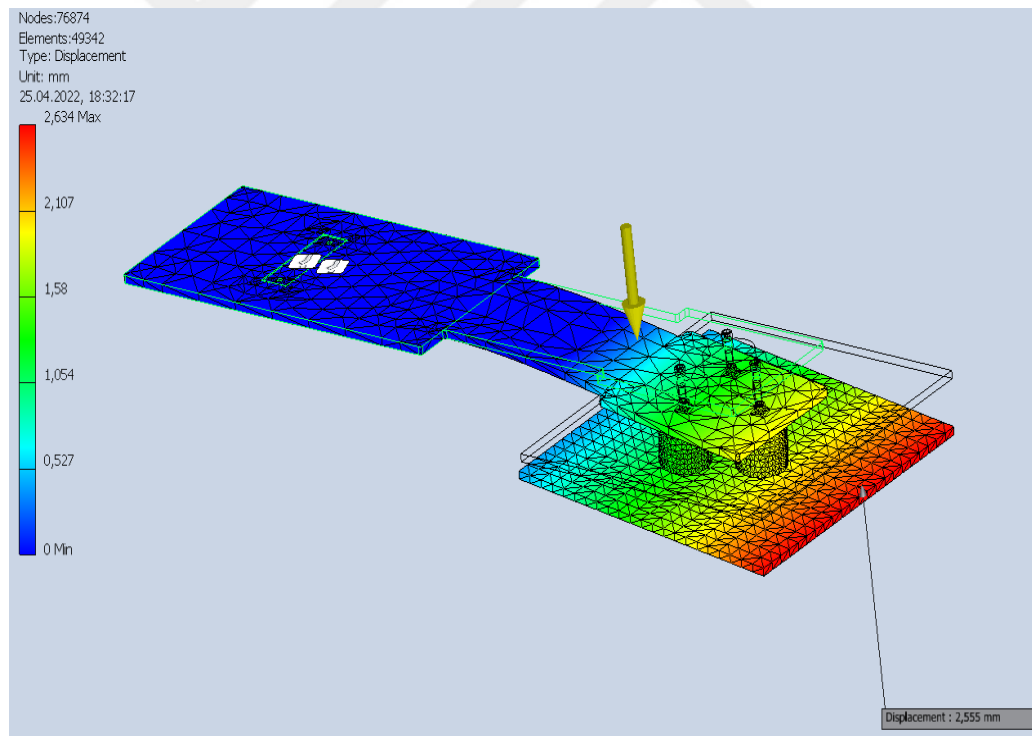


Figure 3.33 Displacement results of gripper

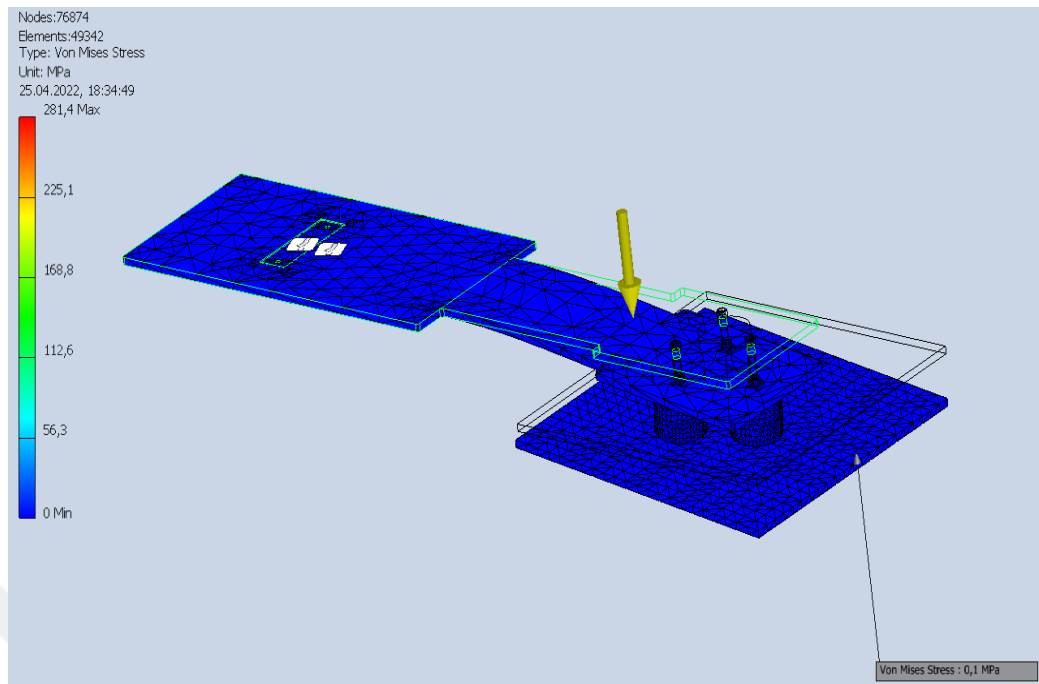


Figure 3.34 Von mises stress results of gripper

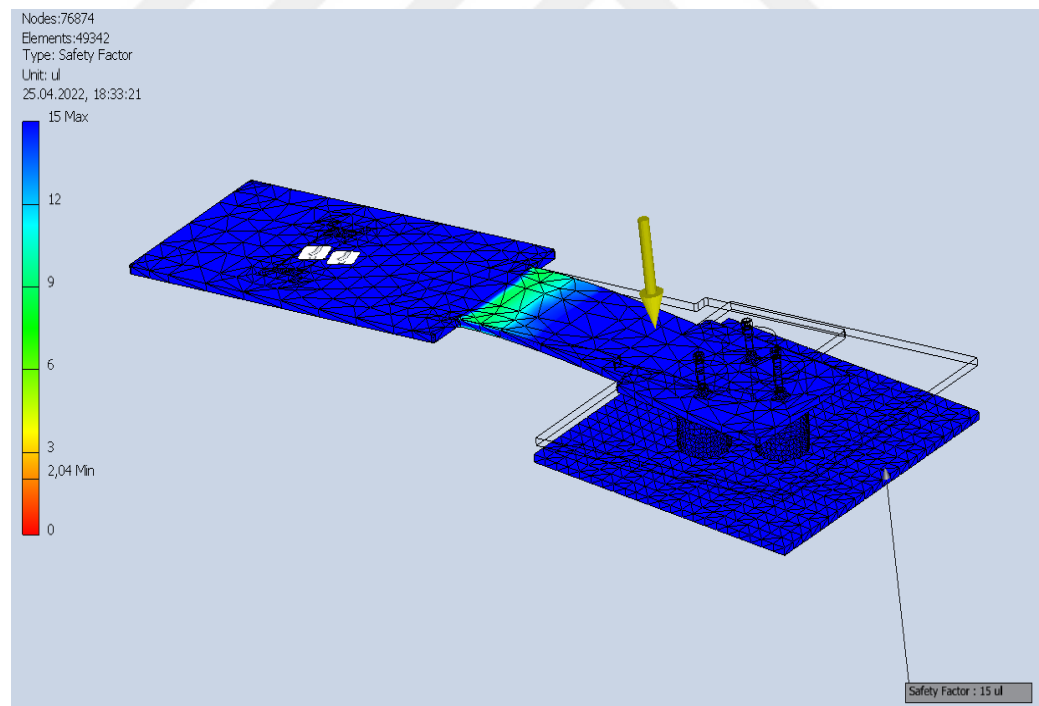


Figure 3.35 Safety factor results of gripper

3.4.2 Analysis Results of Product Centering Platform

The force was applied to the platform face with our maximum carrying capacity of 20000 N within total plate weight. As a result, displacement, factor of safety and von misses stress values were investigated. The critical displacement was determined center of the platform 1.3 mm. The data were obtained suitable for the von misses stress and safety factor, too.

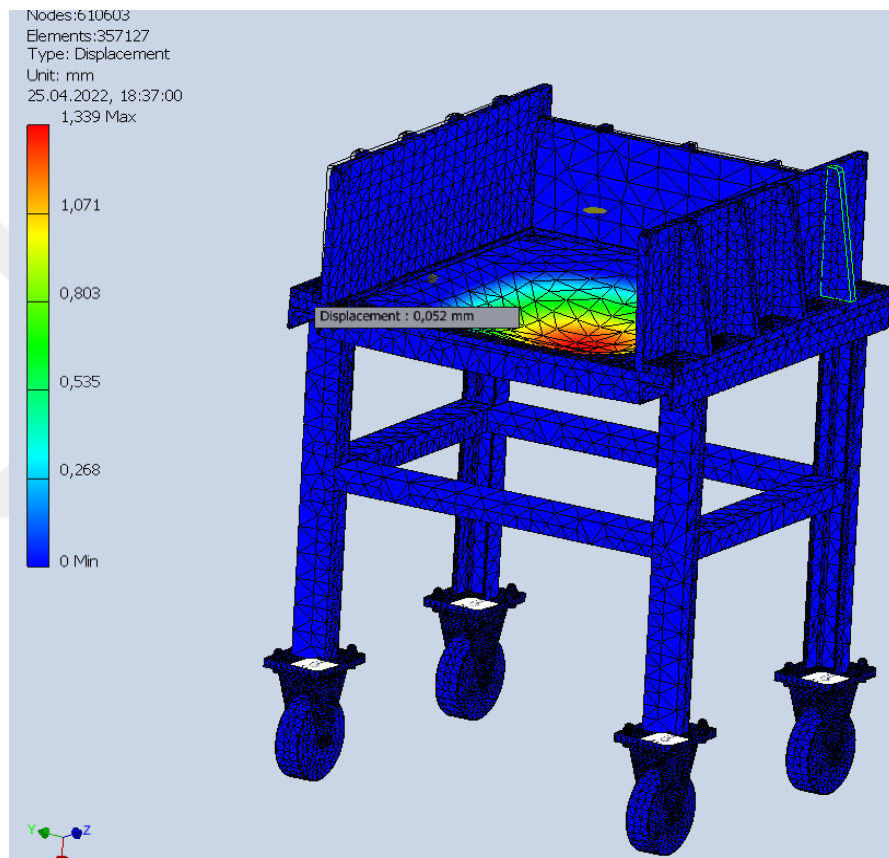


Figure 3.36 Displacement results of product centering platform

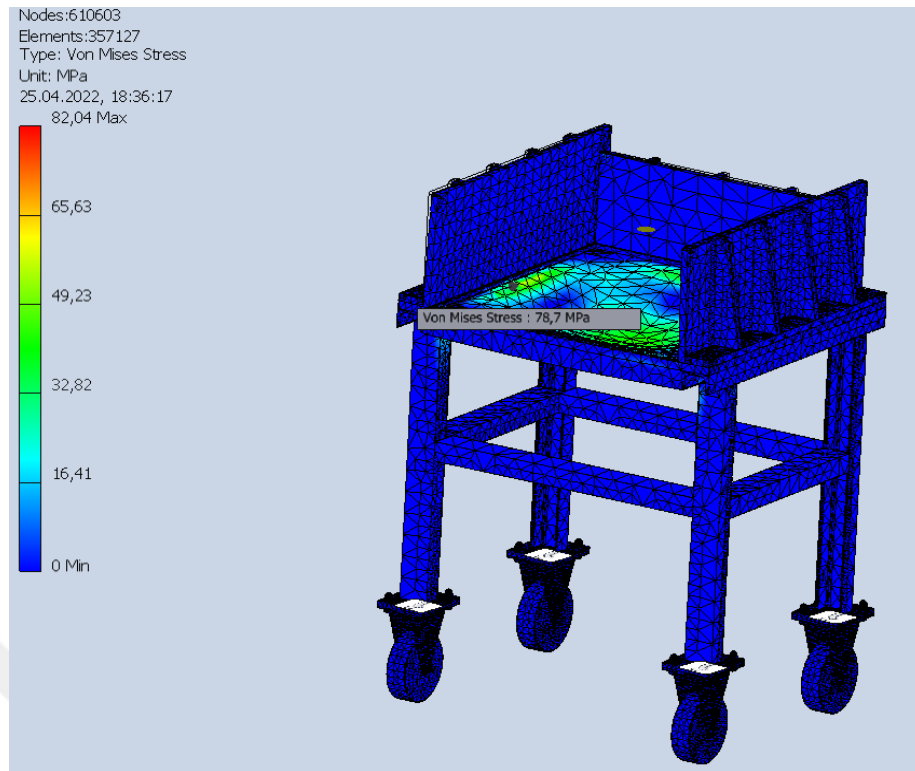


Figure 3.37 Von misses stress results of product centering platform

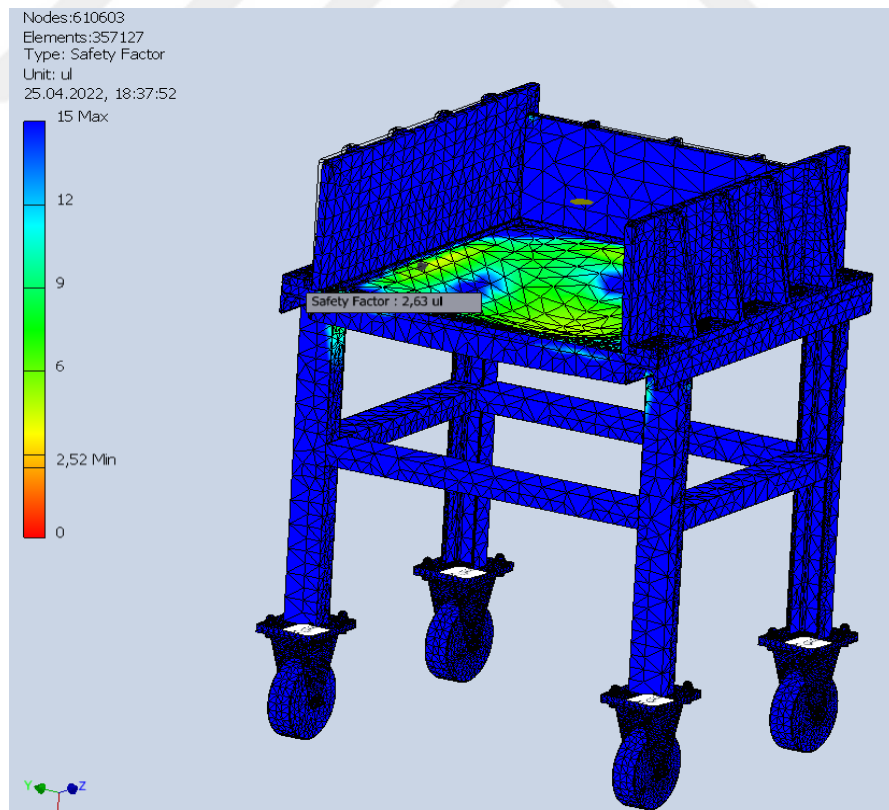


Figure 3.38 Safety factor results of product centering platform

3.4.3 Analysis Results of Main Chassis

The force was applied to the main chassis top face with our maximum carrying capacity of nearly 2500 N within total plate weight and carriage chassis weight. As a result, displacement, factor of safety and von mises stress values were investigated. The critical displacement was determined center of the platform 0.0488 mm. The data were obtained suitable for the von mises stress and safety factor, too.

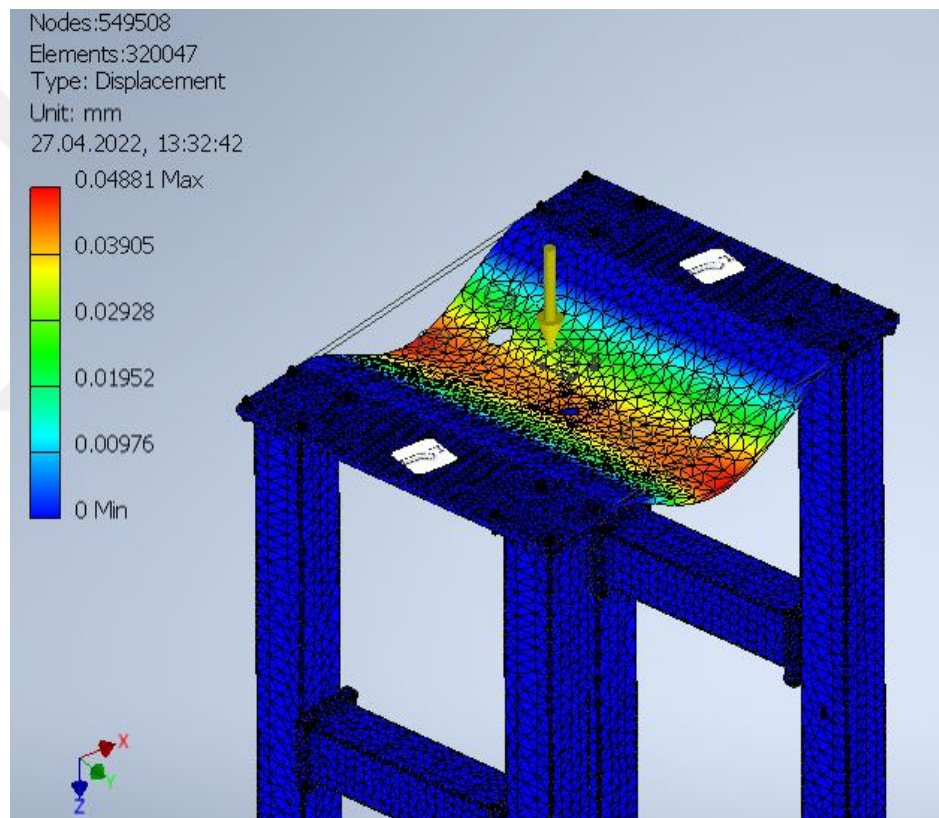


Figure 3.39 Displacement results of main chassis

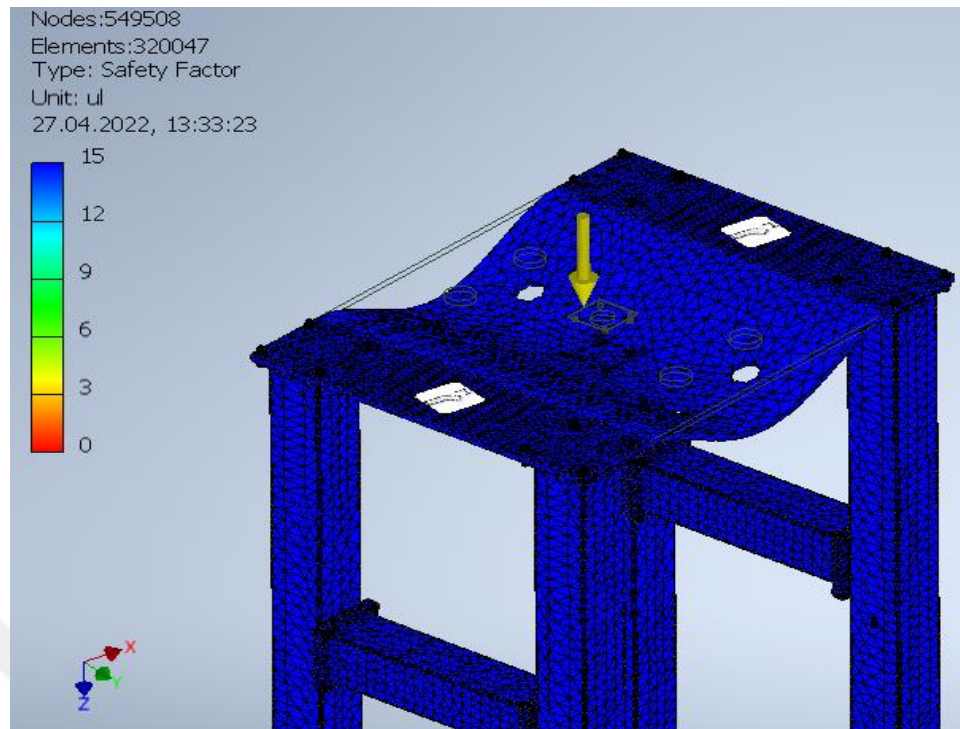


Figure 3.40 Safety factor results of main chassis

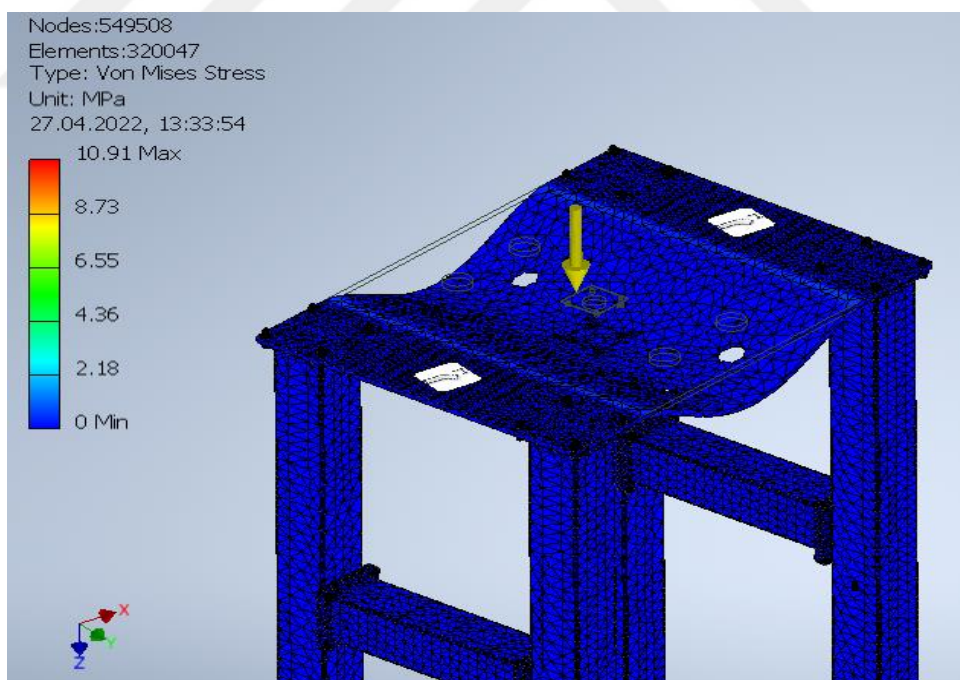


Figure 3.41 Von misses stress results of main chassis

3.4.3 Analysis Results of Stacking Carriage Table

The force was applied to the platform face with our maximum carrying capacity of nearly 20000 N within total plate weight. As a result, displacement, factor of safety and von misses stress values were investigated. The critical displacement was determined center of the platform 0.0133 mm. The data were obtained suitable for the von misses stress and safety factor, too.

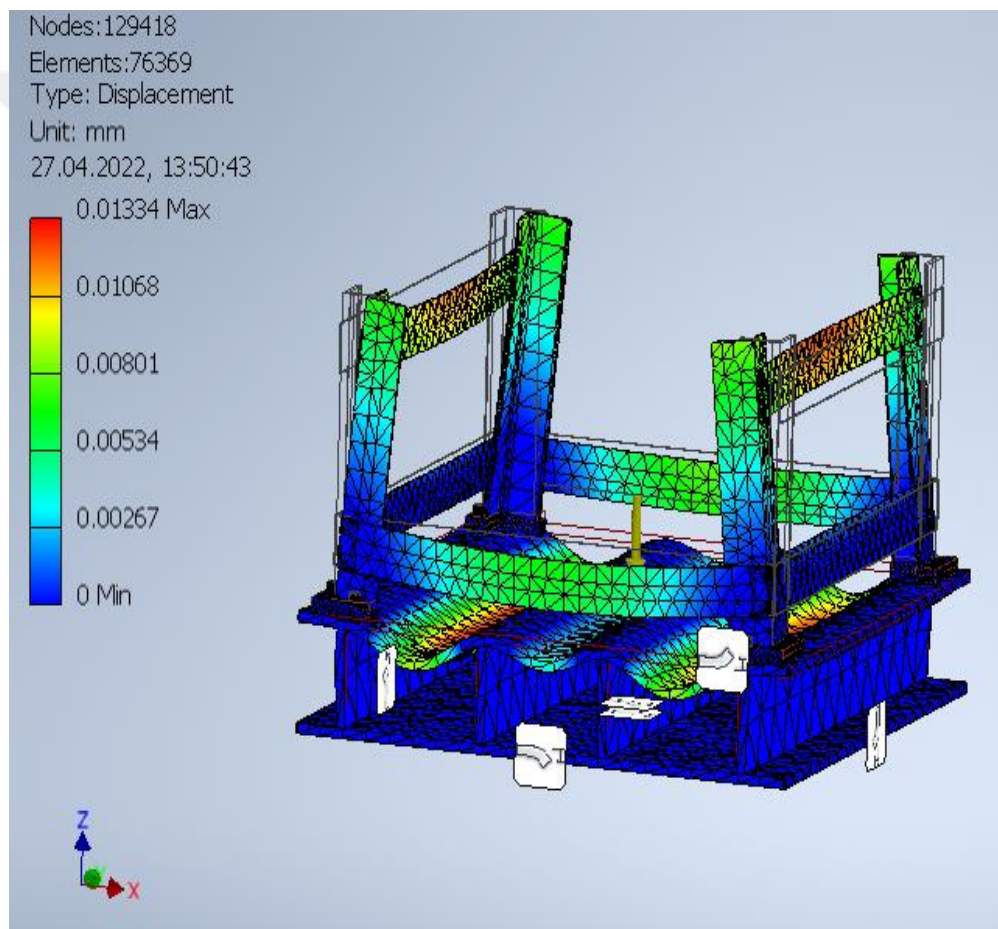


Figure 3.42 Displacement results of stacking carriage table

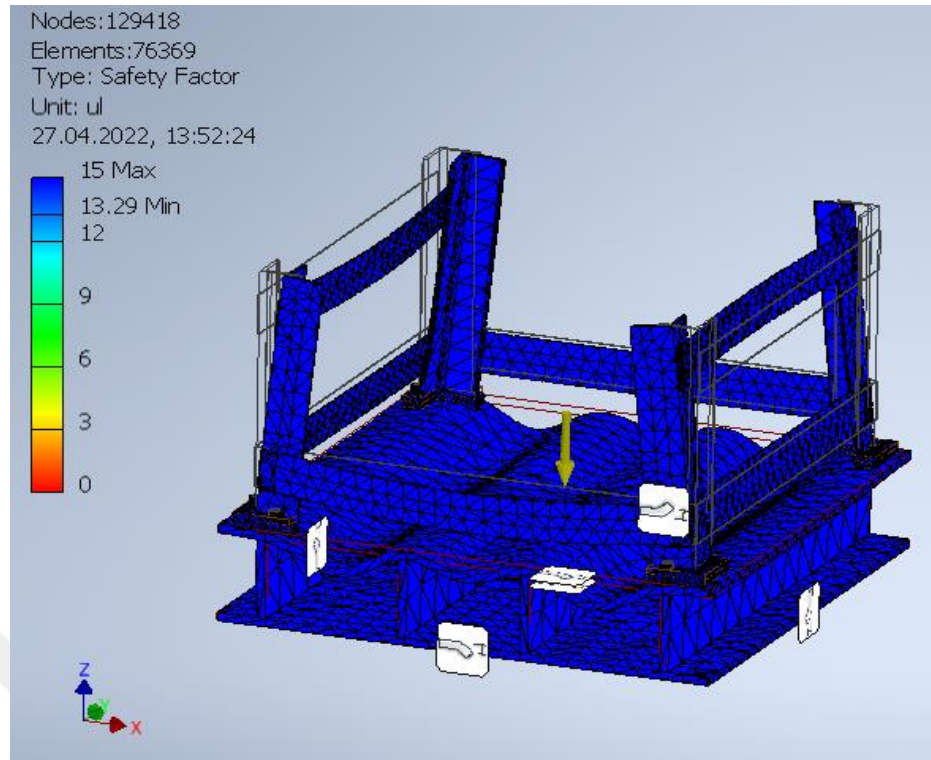


Figure 3.43 Safety factor results of stacking carriage table

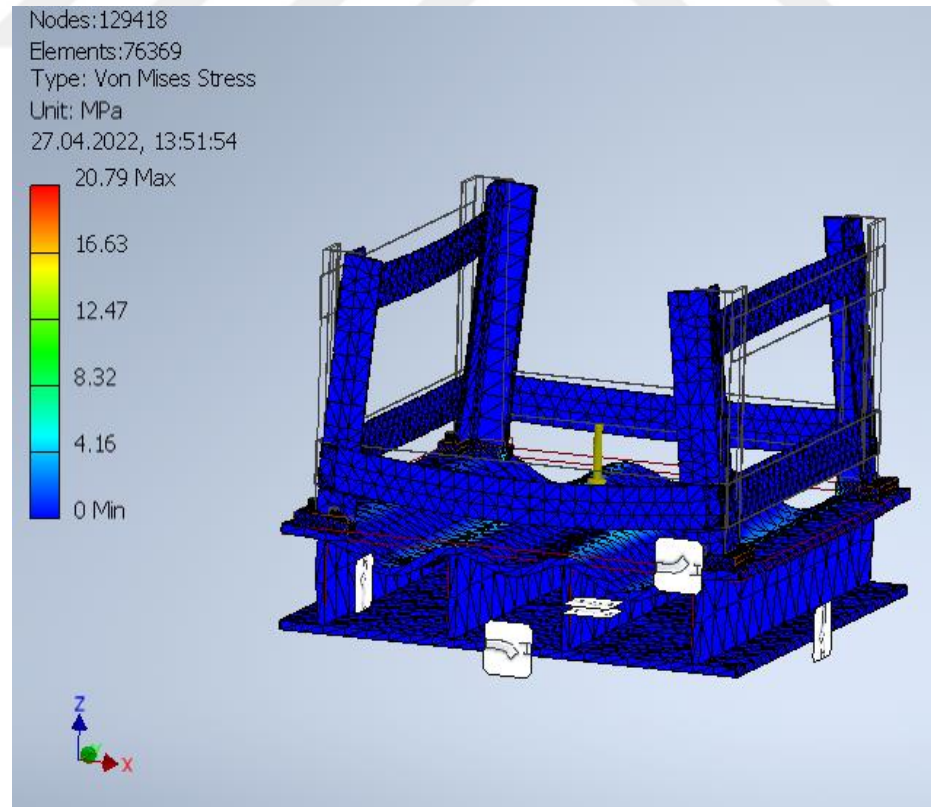


Figure 3.44 Von misses stress results of stacking carriage table

CHAPTER 4

INDICATOR ANALYSIS

4.1 Process Risk Assessment Analysis

The purposes of risk analysis are:

- * Finding risk centers,
- * Evaluate them,
- * To determine the measures,
 - ✓ determining the order of measures,
 - ✓ determining the savings that can be made,
 - ✓ to determine the costs that may arise,
 - ✓ best for business without sacrificing security to determine the economic method,
- * Ensuring the realization of the measures,
 - ✓ to determine whether the goal has been achieved,
 - ✓ avoiding one risk while avoiding another.

The studies in the risk identification and evaluation process were evaluated in 5 steps.

Step 1: Hazard Recognition

* In accordance with the work flow in the workplace, without skipping any point, and based on experience, what can harm employees, products and work equipment is checked.

* First of all, a hazard list is created by identifying all hazards and sources of danger without distinguishing between major and minor, important and unimportant.

* Since risk assessment is a team work, everyone's opinions are taken into account.

* Information about all registered and unregistered work accidents in the past belonging to the unit for which risk determination is made is searched.

* Machine manufacturers' instructions and material safety data sheets are reviewed to identify hazards.

Step 2: Assessment of Risks

The risk assessment table method is used in the quantitative evaluation of the risk. RDT is a technique used to prioritize which jobs according to risk assessment results and where resources are allocated first. The preparation of this table is based on the understanding of applying experience gained from past events for estimating the risk of the system.

Vertical axis is expressed severity levels. (0–5).

* Horizontal axis is represented the increasing probability of the outcome.

* Boxes in the table are defined the decreasing risk levels from the upper left corner to the lower right corner of the table.

* Table is divided red, blue and green areas for defining the level of risk.

While evaluating the risks, the severity and probability of the event caused by the hazard were taken into account. 5x5 Risk Assessment Table was used for the identified risks. Here, the risk is calculated with the formula:

$$\text{Risk} = \text{Probability} \times \text{Severity} \quad (4.1)$$

The values given in the tables below are used for the probability and severity values in the formula (4.1).

Table 4.1 Probability values for risk analysis

Frequency	Probability	Probability value
One year	Very small	1
Three months	Small	2
One month	Medium	3
One week	High	4
Every day	Very high	5

Table 4.2 Intensity values for risk analysis

Incident	Intensity	Intensity value
No work hour loss, required first aid	Very small	1
No work day loss, required first aid	Small	2
Minor injury, treatment needed	Medium	3
Death, occupational disease	High	4
More death, incapacity	Very high	5

Table 4.3 Risk results

Color	Risk value	Evaluation	Action
Red	15-16-20-25	Unacceptable risk	Very fast action
Blue	8-9-10-12	Important risk	Fast action
Green	1-2-3-4-5-6	Acceptable risk	Action

Step 3: Determining the Control Measures

In this step, necessary control measures have been taken in order to reduce the risks to an acceptable level. Basic rule is eliminated the danger completely. If this situation isn't possible, the risks will be minimized using other methods.

These are;

- * Less risky methods, materials, machinery and equipment.
- * Redesign of equipment, working method, process or machine.
- * Isolation of danger.

Step 4: Completing the Control Methods

Completion of control measures are included the following factors.

- * Development of working methods.
- * Communication.
- * Providing the education.
- * Discipline and Control.

Step 5: Process of Monitoring and Repeating

- * Are the selected controlled measures completed in the planned time?
- * Have these control measures been implemented?
- * Were these control measures implemented correctly?
- * Have the exposure to assessed risks been eliminated or reduced enough?
- * Has the intended result been achieved?

By recording all the activities described in the five steps are aimed to determine the definition measures and their effectiveness.

When we applied the risk assessment analysis to our study, a total of 21 risks were determined. 11 of these risks were identified as being in the high-risk group with depending the formulation calculations. With the designed system is aimed to reduce the number of high risks from 11 to 5. Reducing the number of risks will be an extremely important factor for increasing ergonomics, providing OHS conditions and reducing the number of work accidents.

Table 4.4 Risk assessment analysis

WORK	DANGER	RISK	RISK LEVEL			
			Ş	F	O	R
PRODUCTION	STEP 1	INJURY	15	3	3	135
	STEP 2	INJURY	15	10	3	450
	STEP 3	INJURY	7	3	1	21
	STEP 4	HAND INJURY	15	10	3	450
	STEP 5	LOSS OF SENSE	7	3	3	63
	STEP 6	INJURY	15	10	3	450
	STEP 7	HAND INJURY	15	10	3	450
	STEP 8	DISEASE	15	10	3	450
	STEP 9	HAND INJURY	15	10	3	450
	STEP 10	LOSS OF SENSE	7	3	3	63
	STEP 11	INJURY	15	10	3	450
	STEP 12	INJURY	15	10	3	450
	STEP 13	INJURY	3	0.5	1	1,5
MAINTANANCE	STEP 1	INJURY	7	10	3	210
	STEP 2	INJURY	7	10	3	210
	STEP 3	DIED	15	10	3	450
	STEP 4	DIED	40	1	1	40
MOLD CHANGE	STEP 1	INJURY	15	10	3	450
	STEP 2	INJURY	7	10	3	210
	STEP 3	INJURY	7	10	3	210
	STEP4	INJURY	15	10	3	450

4.2 REBA Analysis

Rapid body assessment (REBA) is an ergonomics analysis that examines working conditions. It allows the employee to examine his body biomechanically. Depending on this, musculoskeletal disorders can be detected. Correct working conditions are determined based on the analysis. The advantage of this analysis; It is simple, fast and cheap. The analysis was examined with details in the below.

A) Determining the work

It is important to identify the inappropriate business area. The process should be determined by examining past accident reports and identifying operator complaints.

B) Analyzing the work

Examining the details of the job by video analysis will facilitate the detection. In this process, it is important to understand the wishes of the operators.

C) Detection of high-risk area and position

The riskiest area will be determined after necessary business analysis and operator interviews as stated in steps A and B. Important factors such as posture disorders, repeated risky movements, exposure to high loads will affect our risk assessment.

D) Visualization

Take a photo or video of an operator lifting a 70 kg disc material from a pallet located on the floor, or a photo of an operator reaching across the width of a press to retrieve a 70 kg disc material bundle.

E) Creation of the REBA data form

All body parts in the REBA evaluation form should be scored and the table required for the scoring stage should be created. It is important to evaluate all body parts. If necessary, right and left body parts should be evaluated separately.

F) Determining the REBA score

REBA; The scoring determined in the table should be done by evaluating factors such as posture positions, movement type, movement frequency.

Scoring is in the range of 1-15 points. Each of the scoring values has a meaning in the table. A score of 8 and above is a high-risk group. An urgent solution is required for this.

REBA Employee Assessment Worksheet

Based on Technical note: Rapid Entire Body Assessment (REBA), Hignett, McAtamney, Applied Ergonomics 31 (2000) 201-208

A. Neck, Trunk and Leg Analysis

Step 1: Locate Neck Position

Step 1a: Adjust...
If neck is twisted: +1
If neck is side bending: +1

Neck Score

Neck	
	1 2 3
Legs	1 2 3 4 1 2 3 4 1 2 3 4
Trunk Posture Score	1 1 2 3 4 1 2 3 4 1 2 3 4 2 2 3 4 5 3 4 5 6 4 5 6 7 3 2 4 5 6 4 5 6 7 5 6 7 8 4 3 5 6 7 5 6 7 8 6 7 8 9 5 4 6 7 8 6 7 8 9 7 8 9 9

Step 2: Locate Trunk Position

Step 2a: Adjust...
If trunk is twisted: +1
If trunk is side bending: +1

Trunk Score

Lower Arm	
	1 2
Wrist	1 2 3 1 2 3
Upper Arm Score	1 1 2 2 1 2 3 2 1 2 3 2 3 4 3 3 4 4 5 4 5 5 4 4 5 5 5 6 6 7 5 6 7 8 7 8 8 9 6 7 8 8 8 9 9 9

Step 3: Legs

Adjust: 30-60° +60°

Leg Score

Step 4: Look-up Posture Score in Table A
Using values from steps 1-3 above, locate score in Table A.

Score A

Step 5: Add Force/Load Score
If load = 11 lbs: +0
If load 11 to 22 lbs: +1
If load = 22 lbs: +2
Adjust: If lock or rapid build up of force: add +1

Force and Load Score

Step 6: Score A. Find Row in Table C
Add values from steps 4 & 5 to obtain Score A. Find Row in Table C.

Scoring:
1 = negligible risk
2 or 3 = low risk, change may be needed
4 to 7 = medium risk, further investigation, change soon
8 to 10 = high risk, investigate and implement change
11+ = very high risk, implement change

B. Arm and Wrist Analysis

Step 7: Locate Upper Arm Position:

Step 7a: Adjust...
If shoulder is raised: +1
If upper arm is abducted: +1
If arm is supported or person is leaning: -1

Upper Arm Score

Step 8: Locate Lower Arm Position:

Step 8a: Adjust...
If wrist is bent from midline or twisted: Add +1

Lower Arm Score

Step 9: Locate Wrist Position:

Step 9a: Adjust...
If wrist is bent from midline or twisted: Add +1

Wrist Score

Step 10: Look-up Posture Score in Table B
Using values from steps 7-9 above, locate score in Table B.

Score B

Step 11: Add Coupling Score
Well fitting Handle and mid range power grip: good: +0
Acceptable but not ideal hand hold or coupling acceptable with another body part: fair: +1
Hand hold not acceptable but possible: poor: +2
No handle, awkward, unsafe with any body part: unacceptable: +3

Coupling Score

Step 12: Score B. Find Column in Table C
Add values from steps 10 & 11 to obtain Score B. Find column in Table C and match with Score A in row from step 6 to obtain Table C Score.

Table C Score

Step 13: Activity Score
+1 1 or more body parts are held for longer than 1 minute (static)
+1 Repeated small range actions (more than 4x per minute)
+1 Action causes rapid large range changes in postures or unstable base

Activity Score

Final REBA Score

Task name: _____ Reviewer: _____ Date: _____

This tool is provided without warranty. The author has provided this tool as a simple means for applying the concepts provided in REBA. © 2000 NIOS Consulting, Inc. provided by Practical Ergonomics rtharner@ergosmart.com (816) 444-1667

Figure 4.1 REBA employee assessment worksheet

Data and tables are shared above how to do the REBA analysis. Depending on this information, a REBA analysis was made for the press which our design will be adapted. For this study, time prism video analysis program was used. Analysis of operator behavior and movements was made slow motion with this program. Depending on the video analysis, all motion scores in the REBA analysis method were made for the current state loading and unloading processes separately and REBA analysis scores were obtained. Results, 11-12 values were determined as high-risk group. The scores were made again by predicting the changes in the behavior and movements of the operator, after the design was adapted. Results, 11-12 values were obtained as medium-risk group. These data were showed that there will be a 50% improvement in the REBA analysis value of the study.

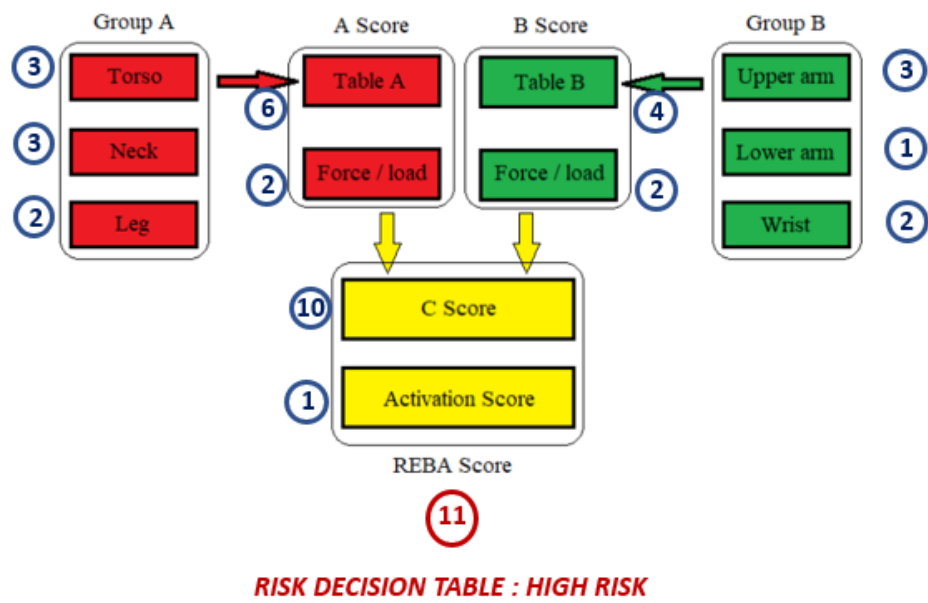


Figure 4.2 REBA analysis for press loading process

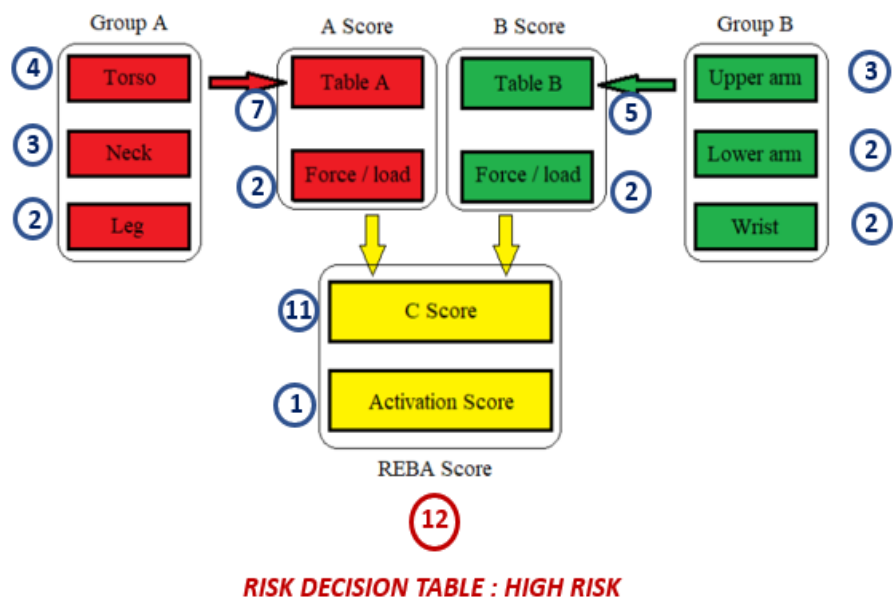


Figure 4.3 REBA analysis for unloading process

4.3 Accident Frequency Rate

Occupational accident frequency rate or rate is referred the number of work accidents experienced in a given working period. For example, the number of occupational accidents per 1 million working hours is used as a general comparison method.

While we are calculating the occupational accident frequency rate, we need to know how many hours of work were done and how many work accidents were happened there in the calculation period. The total hours worked can be found by calculating how long all employees worked during that period. Weekend holidays, public holidays, workers' leave and sick leave etc. should be taken from this period making an accurate calculation. It is necessary to subtract the periods.

$$F.R. = \frac{\text{Number of accidents} \times 1.000.000}{\text{Total man hours of work performed}} \quad (4.2)$$

As seen in the formulation (4.2), the accident frequency rate is calculated by dividing the number of work accidents by the total working time. The number 1,000,000 is used to rate how many accidents occur per 1,000,000 hours of operation. If you wish, you can multiply by a different coefficient and calculate according to your own targets. But that will be difficult when comparing with other companies' calculations. This calculation method is used by the many businesses, associations and institutions.

Accident frequency rate calculations are also adapted to the working area which we will make improvements. For this study; theoretical working hours, actual working hours, lost hours due to work accidents and reports, overtime and other lost hours data were obtained from the human resources department for the 2020-2021 years. Using the accident frequency rate formulation with these data, the current accident frequency rate was determined as 413.5. With the adaptation of the new design system is aimed to decrease the lost labor hours and increase the actual working hours by 25%.

Again, using the accident frequency rate formulation with these data, improved accident frequency rate was determined as 335. With this study, %20 improvement will be achieved in the accident frequency rate.

4.4 Cycle Time and Effects on The Number of Products

There are many parameters in examining the performance of production processes. One of the most important of these is cycle time. Cycle time covers the time from the initial production process stage of a product to the delivery of the product. Since the cycle time represents the processing time, it is also affected by many stops in this process. Forklift waiting, malfunctions, mold change times or unsuitable operating conditions are factors that affect the prolongation of the cycle time.

This situation causes a decrease in production numbers. Every positive improvement made in the production process will also positively affect the cycle time. For this reason, it is important to make and follow the analyzes in the processes. Many determinations can be made depending on the results of these analysis. Some of those;

- Identifying production process problems,
- Identification of areas where improvement and development are needed,
- Determining the product costs.

Cycle time calculation should not be confused with takt time calculation. There is a simple formula for calculating the cycle time.

The calculation is based on two parameters.

- * The total number of produced products,
- * The total time required to producing,

With these two data points in mind, the formula is:

$$\text{Cycle Time} = \frac{\text{Total production time}}{\text{Number of produced products}} \quad (4.3)$$

Depending on the manufacturer, there may be a few different variations of this formula. The above example, however, is the simplest method for understanding average cycle time on a basic level. According to the data in the explanations, the cycle time calculations are determined for the current process state which is worked by us and also as a result of this the number of products are determined for the one shift.

- Total production time is 26100 seconds for the one shift. The time details of the other steps are given in the table below.

Table 4.5 Distribution of time for current state

CURRENT STATE TIME DISTRUBITION	
Press Process Time	6 sec.
Loading Time	12 sec.
Unloading Time	12 sec.
Total Cycle Time	30 sec.

Using the formula (4.3);

$$30 \text{ sec.} = 26100 \text{ sec.} / (\text{Number of produced})$$

- Number of produced = 870 (For, one shift)
- For, three shifts number of produced is 2610.

It is aimed to reduce the cycle time from 30 seconds to 25 seconds with the cartesian robot system. Accordingly, the time distributions of the other steps for the improved state are calculated and given in the table below.

Table 4.6 Distrubition of time for improved state

IMPROVED STATE TIME DISTRUBITION	
Press Process Time	6 sec.
Loading Time	9.5 sec.
Unloading Time	9.5 sec.
Total Cycle Time	25 sec.

Using the formula (4.3);

$$25 \text{ sec.} = 26100 \text{ sec.} / (\text{Number of produced})$$

- Number of produced = 1045 (For, one shift)
- For, three shifts number of produced is 3135.

When the current situation and the improved situation are compared, it has been observed that an increasing percentage of twenty, 525 pieces, in daily production numbers. This result is represented an increasing in the number of products of 189.000 in 1 year. The annual return of this product increasing has been calculated as 2.500.000 USD on average.

4.5 Production Efficiency Factors and Labor Costs

The factors required to measure the productivity rate which are the factors used in production and affecting production. Factors of production are expenses that are necessary for the production of a product and are directly related to production. These expenses are raw materials, labor and general production expenses. The units of measurement of production factors can be listed as follows.

- * The labor force which is determined by the labor hour is the most important production factor.
- * The most important factors for the capital factor are machines and machine hours.
- * Raw material as direct material and auxiliary material as indirect material and operating material elements are defined for the material factor.

The partial productivity rate instead of the overall productivity rate is a correct method for making comparisons within and between companies and productivity control. This method is preferred for the labor costs primarily, which is the production factor. The reasons for this; the workforce is a factor of production that enters all production units, the statistical information which is necessary for its measurement can be collected, it is an important cost element and it is easy to calculate. Depending on the explanations, the effects of our study on the labor cost, which is one of the most important factors in productivity measurement, were evaluated.

Currently, two operators are worked one shift in the disc rounding process for loading and unloading. For three shifts, it means six workers. With the adaptation of the cartesian robot, the number of two workers for each shift will be decreased to one. The duty of this worker will be provided system control and follow-up. Currently, the number of workers will be decreased from 6 to 3 in a day. According to the data received from the human resources department, the annual cost of 6 workers was determined as 36000 USD. After the improvement with cartesian robot, the labor cost gain will be 18000 USD in one year. This result is showed that the study will contribute significantly to the production.

4.6 Cost Calculations

One of the most important issues while making a design is the cost. First of all, our cost study has been evaluated under 5 main headings.

These are;

- * Electricity
- * Hydraulics
- * Pneumatics
- * Workmanship
- * Materials

Considering the problems that may be experienced in reality due to the design related the theory and the cost study, the design details were created by considering 4 main headings. First of all; hydraulic, electrical, labor and material cost calculations were obtained. A pneumatic system was preferred instead of the hydraulic system because of considering the problems such as oil and control. This decision was had a positive impact on our cost, as well as on design. In the table below, the list of materials, their quantities and prices are given in detail.

Table 4.7 Material cost list

MATERIAL	COUNT	PRICE
KUVE30 - Bearing carriage	4	308 USD
KUVE 30 - Guideway	1	232 USD
LTRM 3006 RH - Ball screw nut	1	113 USD
M30 - L=2000 mm Ball screw	1	172 USD
Fixed end bearing	2	183 USD
Diameter: 90mm Length: 60mm Electromagnet	3	220 USD
HC02 - P 100 -70 h;400 mm	1	185 USD
Steel material kg/USD	300 kg	365 USD
Bronze material kg/USD	6 kg	75 USD
Servo engine	1	500 USD
Profile construction	3 lengths	700 USD
Hydraulic system (Block, lock direction control valve, pressure reducer)	1	450 USD
Pneumatic cylinder PNC - Ø100 mm, L=400 mm	1	180 USD
Electric automation	1	5650 USD
Workmanship	3	300 USD

CHAPTER 5

CONCLUSIONS

5.1 Subject and Purpose of the Thesis

Our primary starting point in determining the subject of this thesis was to determine the most inconvenient area in terms of ergonomics and the most occupational accidents in the company, and to develop an idea and study accordingly.

In order to make this determination, the total company occupational accident data for the last 3 years were obtained from the occupational health and safety department in detail. Depending on the data, statistical data analysis based on lines was made using the Minitab program. As a result of this analysis, the region with the highest occupational accidents was determined the cutting line rate of percentage of % 12. A statistical data analysis was made again depending on all the machines in the cutting line. As a result of this analysis, it was determined that the disk rounding presses were the most dangerous machine with the highest accident rate by percentage of % 60.

These data were showed that the loading process of disc products weighing 70 kg into disc rounding presses should be done by a robotic system instead of manually by the operators.

With the continuous development of technology, the diversity of industrial robots and their usage in every field are continued to increase. In this diversity; cartesian robots are one of the most preferred robot types in terms of product loading, unloading and stacking. In particular, cartesian robots were developed with medium-weight loads that require repeated stacking, increase productivity by saving manpower and reducing damage caused by improper stacking. Also, it is provided valuable floor space as they work above the work area, unlike articulated robots that need their own floor space.

Since these systems provide efficient, high quality and ergonomic production and solve the reasons I have determined, it has been decided to design a cartesian robot in our work area.

5.2 Studies and Recommendations

In our study, a cartesian loading robot with a tip carrying capacity of 70 kg was designed. It consists of four parts: two-axis motion-controlled robot arms, special purpose magnetic gripper, product centering platform, special purpose stacking carrier.

First robot arm, which is the horizontal x axis, is acted between the product centering platform and press center for loading. Screw shaft nut is preferred for motion transmission. The guide system, which decides the quality and precision of the movement of the system, is chosen from high quality, ready-made systems for preventing the errors that may arise from the machine tools. A servo motor is used to provide horizontal movement. The servo motor is preferred is to provide positioning and centering precision. Also, using servo motor and driver systems will make the design more efficient.

Second robot arm, which is the vertical y axis, is acted with respect to decreasing or increasing stacked of the disc products. First of all, the hydraulic system was studied to provide vertical movement. However, the pneumatic system was preferred due to factors such as working area, oil leakage problems and cost in the hydraulic system. Position accuracy is provided by using a linear position sensor.

In the gripper design; working conditions, product diameters and weights were studied and product selection was made. According to these variables, it was determined that the most suitable gripper was the magnetic. Accordingly, the chassis design has been developed. Max. plate dimension is 525 x 525 x 15 mm. With respect to this information is calculated other details.

In the design of the product centering platform, the details of the press loading height, the maximum stacked product height and the easy loading of the forklift on the platform were studied. Some studies on the product centering platform were made and canceled. First of all, the materials in the product stacking pallet are positioned in a quadruple style. Accordingly, location centering problems are foreseen and the products are positioned from a specified one point. Our work has been completed in theory, and our manufacturing and trial process has started.

In the design of the special purpose of stacking carrier, the details of the press loading height, the maximum stacked product height and the easy loading of the forklift on the platform were studied. The design was made taking into account the maximum and minimum opening and closing of forklift blades. The purpose of this chassis is to ensure that the products are brought centered from the sheet metal cutting area.

5.3 Improvement and Development Opportunities

This cartesian robot designed for the disc rounding press loading process can also be applied for the unloading process. This will be required a design revision on the gripper part of the unloading system. For this part, a pneumatic magnetic gripper design has been made. This design will be a good solution.

There is a total of five disc rounding presses in the company that we have worked on it. In the case of ensuring the proper functioning of the system, both pecuniary and spiritual improvements will be achieved and our study can be expanded all of them.

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APPENDICES

File Name:Untitled1
Date:2022-01-21

[Screen Image / Setting]

Base Screen30001

[Base Screen Details]

Screen Name	Menu
Size	800X480
Detailed Description	This screen shows the menu. The screen is used to set the station number of the servo amplifier and switch between the screens.
Security	0
Individually set the screen design	Yes
Background Color	Dark White
Switch Station No.	No
Switch buffer memory unit No.	No
Pop up alarms	Yes
Display Position	Bottom

[Key Window]

Key Window Setting

Key Window Setting	Same as the project setting
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Key Window/Cursor Display Setting

Key Window/Cursor Display Setting	Same as the project setting
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Key Window/Cursor Movement

Key Window/Cursor Movement	Same as the project setting
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[Dialog Window]

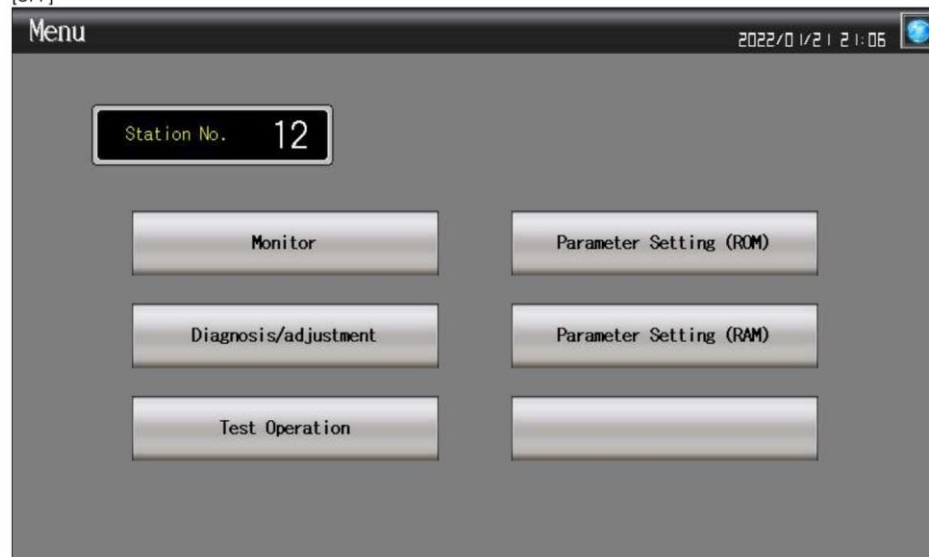
Dialog Window	Same as the project setting
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[Screen Image]

[Screen Title]Menu

[Screen size]800X480

[OFF]



[Object List]

	Object ID	Coordinates	Device
Switch	10000	104,176	-
	10001	104,256	-

[Object List]

	10002	432,176	-
	10003	432,256	-
	10004	104,336	-
	10005	432,336	-
	20013	768,4	-
Special Function Switch	20018	628,7	-
Numerical Input	10011	225,94	GD10
Date Display	20016	628,20	-
Time Display	20015	716,20	-
Simple Comment	10012	81,94	-
	20017	16,8	-

Base Screen30011

[Base Screen Details]

Screen Name	Monitor Menu
Size	800X480
Detailed Description	This is the menu screen for monitor.
Security	0
Individually set the screen design	Yes
Background Color	Dark White
Switch Station No.	No
Switch buffer memory unit No.	No
Pop up alarms	Yes
Display Position	Bottom

[Key Window]

Key Window Setting

Key Window Setting	Same as the project setting
--------------------	-----------------------------

Key Window/Cursor Display Setting

Key Window/Cursor Display Setting	Same as the project setting
-----------------------------------	-----------------------------

Key Window/Cursor Movement

Key Window/Cursor Movement	Same as the project setting
----------------------------	-----------------------------

[Dialog Window]

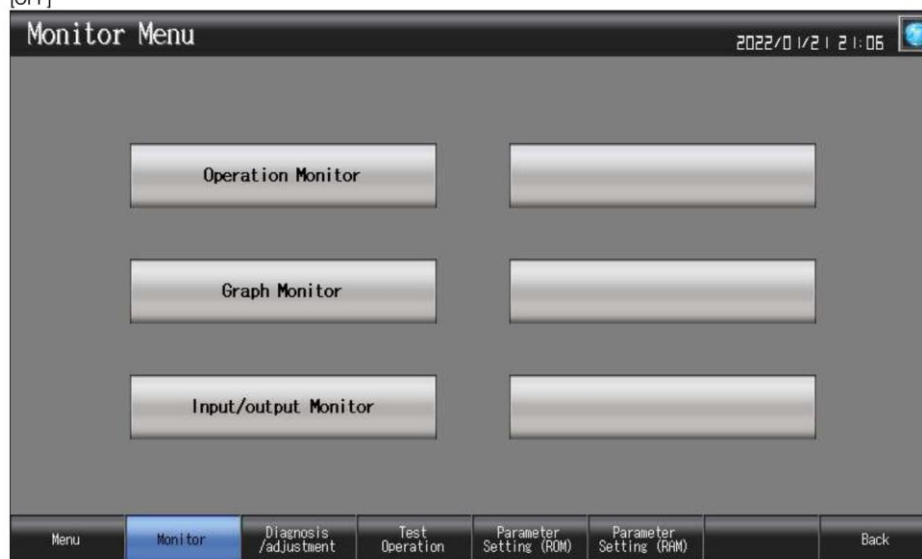
Dialog Window	Same as the project setting
---------------	-----------------------------

[Screen Image]

[Screen Title]Monitor Menu

[Screen size]800X480

[OFF]



[Object List]

	Object ID	Coordinates	Device
Switch	10001	104,115	-
	10002	104,215	-
	10003	104,315	-
	10004	432,115	-
	10005	432,215	-
	10006	432,315	-

[Object List]

	10014	0,436	-
	10015	300,436	-
	10016	100,436	-
	10017	200,436	-
	10018	400,436	-
	10019	500,436	-
	10020	600,436	-
	10021	700,436	-
	10025	768,4	-
Special Function Switch	10026	628,7	-
Date Display	10023	628,20	-
Time Display	10022	716,20	-
Simple Comment	10013	16,8	-

Base Screen30012

[Base Screen Details]

Screen Name	Operation Monitor
Size	800X480
Detailed Description	This screen is used to display the status of the servo amplifier in operation.
Security	0
Individually set the screen design	Yes
Background Color	Dark White
Switch Station No.	No
Switch buffer memory unit No.	No
Pop up alarms	Yes
Display Position	Bottom

[Key Window]

Key Window Setting

Key Window Setting	Same as the project setting
--------------------	-----------------------------

Key Window/Cursor Display Setting

Key Window/Cursor Display Setting	Same as the project setting
-----------------------------------	-----------------------------

Key Window/Cursor Movement

Key Window/Cursor Movement	Same as the project setting
----------------------------	-----------------------------

[Dialog Window]

Dialog Window	Same as the project setting
---------------	-----------------------------

[Screen Image]

[Screen Title]Operation Monitor

[Screen size]800X480

[OFF]

Operation Monitor			2022/01/21 21:05
Item	Current Value	Unit	
Cumulative Feedback Pulses	1234567890	pulse	
Servo Motor Speed	123456	r/min	
Droop Pulses	1234567890	pulse	
Cumulative Command Pulses	1234567890	pulse	
Command Pulse Frequency	123456	kp/s	
Analog Speed Command Voltage	123.00	V	
Analog Torque Command Voltage	123.00	V	
Regenerative Load Ratio	123456	%	
Effective Load Ratio	123456	%	
Peak Load Ratio	123456	%	
Instantaneous Torque	123456	%	
Within One-revolution Position	1234567890	pulse	
ABS Counter	123456	rev	
Load to Motor Inertia Ratio	1234.00	Multiplier	
Bus Voltage	123456	V	
Encoder Inside Temperature	123456	°C	
Settling Time	123456	ms	
Oscillation Detection Frequency	123456	Hz	
Number of Tough Drive Operations	123456	times	
Unit Power Consumption	12345678	W	
Unit Total Power Consumption	1234567890	W	

[Object List]

	Object ID	Coordinates	Device
Switch	10000	0,436	-
	10001	500,436	-
	10002	100,436	-
	10003	200,436	-

[Object List]

	10004	300,436	-
	10005	400,436	-
	10006	600,436	-
	10007	700,436	-
	20076	768,4	-
Special Function Switch	20077	628,7	-
Numerical Display	10010	577,73	@2:0-100 ST0
	10011	633,89	@2:0-100 ST1
	10012	577,106	@2:0-100 ST2
	10013	577,122	@2:0-100 ST3
	10014	633,139	@2:0-100 ST4
	10015	633,156	@2:0-100 ST5
	10016	633,172	@2:0-100 ST6
	10017	633,189	@2:0-100 ST7
	10018	633,205	@2:0-100 ST8
	10019	633,222	@2:0-100 ST9
	10020	633,239	@2:0-100 ST10
	10021	577,255	@2:0-100 ST11
	10022	633,272	@2:0-100 ST12
	10023	625,288	@2:0-100 ST13
	10024	633,305	@2:0-100 ST14
	10025	633,322	@2:0-100 ST32
	10026	633,338	@2:0-100 ST33
	10027	633,355	@2:0-100 ST34
	10028	633,371	@2:0-100 ST35
	10029	617,388	@2:0-100 ST40
	10030	577,405	@2:0-100 ST41
Date Display	20074	628,20	-
Time Display	20073	716,20	-
Simple Comment	10031	19,55	-
	10032	553,54	-
	10033	688,55	-
	10034	19,73	-
	10035	19,89	-
	10036	19,106	-
	10037	19,122	-
	10038	19,139	-
	10039	19,156	-
	10040	19,172	-
	10041	19,189	-
	10042	19,205	-
	10043	19,222	-
	10044	19,239	-
	10045	19,255	-
	10046	19,272	-
	10047	19,288	-
	10048	19,305	-
	10049	19,322	-
	10050	19,338	-
	10051	19,355	-
	10052	19,371	-
	10053	19,388	-
	10054	19,405	-
	10068	700,288	-
	10073	700,371	-
	20052	16,8	-

Base Screen30013

[Base Screen Details]

Screen Name	Graph Monitor
Size	800X480
Detailed Description	This screen is used to display the data such as the servo motor speed, peak load ratio, and bus voltage, which are collected by using the logging function, in the numerical value and historical trend graph.
Security	0
Individually set the screen design	Yes
Background Color	Dark White
Switch Station No.	No
Switch buffer memory unit No.	No
Pop up alarms	Yes
Display Position	Bottom

[Key Window]

Key Window Setting

Key Window Setting	Same as the project setting
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Key Window/Cursor Display Setting

Key Window/Cursor Display Setting	Same as the project setting
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Key Window/Cursor Movement

Key Window/Cursor Movement	Same as the project setting
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[Dialog Window]

Dialog Window	Same as the project setting
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[Script]

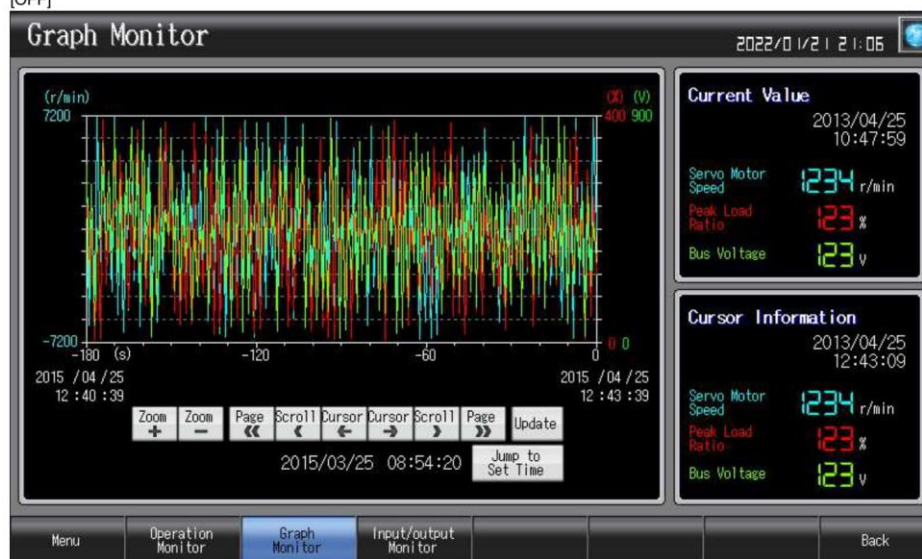
Order	Script No.	Comment	Trigger Type
1	30002	Obtain current time	Rise(GB40)

[Screen Image]

[Screen Title]Graph Monitor

[Screen size]800X480

[OFF]



[Object List]

	Object ID	Coordinates	Device
Switch	10017	269,341	-
	10018	309,341	-
	10048	399,374	-
	20049	0,436	-
	20050	500,436	-
	20051	100,436	-
	20052	200,436	-
	20053	300,436	-
	20054	400,436	-
	20055	600,436	-
	20056	700,436	-
	20078	768,4	-
Special Function Switch	20079	628,7	-
Key Code Switch	10015	189,341	-
	10016	229,341	-
	10019	349,341	-
	10020	389,341	-
	10021	105,341	-
	10022	145,341	-
	10023	433,341	-
Numerical Display	10009	660,132	@2:0-100 ST1
	10010	688,164	@2:0-100 ST9
	10011	688,196	@2:0-100 ST14
	10012	660,324	GD1151
	10013	688,355	GD1159
	10014	688,386	GD1164
	10024	695,86	GS650
	10025	735,86	GS650
	10026	759,86	GS651
	10027	711,102	GS651
	10028	735,102	GS652
	10029	759,102	GS652
	10030	695,278	GD1171
	10031	735,278	GD1171
	10032	759,278	GD1172
	10033	711,294	GD1172
	10034	735,294	GD1173
	10035	759,294	GD1173
	10036	477,310	GD1175
	10037	517,310	GD1175
	10038	541,310	GD1176
	10039	493,326	GD1176
	10040	517,326	GD1177
	10041	541,326	GD1177
	10042	23,310	GD1179
	10043	63,310	GD1179
	10044	87,310	GD1180
	10045	39,326	GD1180
	10046	63,326	GD1181
	10047	87,326	GD1181
Numerical Input	10049	235,382	GD1183
	10050	275,382	GD1183
	10051	299,382	GD1184
	10052	327,382	GD1184
	10053	351,382	GD1185
	10054	375,382	GD1185
Date Display	20076	628,20	-
Time Display	20075	716,20	-
Simple Comment	10058	588,64	-
	10059	588,256	-
	10060	588,134	-
	10061	588,166	-
	10062	588,198	-

[Object List]

	10063	588,326	-
	10064	588,357	-
	10065	588,388	-
	20039	16,8	-
Historical Trend Graph	10008	66,90	-

Base Screen30014

[Base Screen Details]

Screen Name	Input/output monitor
Size	800X480
Detailed Description	This screen is used to display the status of the input/output signal.
Security	0
Individually set the screen design	Yes
Background Color	Dark White
Switch Station No.	No
Switch buffer memory unit No.	No
Pop up alarms	Yes
Display Position	Bottom

[Key Window]

Key Window Setting

Key Window Setting	Same as the project setting
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Key Window/Cursor Display Setting

Key Window/Cursor Display Setting	Same as the project setting
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Key Window/Cursor Movement

Key Window/Cursor Movement	Same as the project setting
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[Dialog Window]

Dialog Window	Same as the project setting
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[Script]

Order	Script No.	Comment	Trigger Type
1	30105	In/output DeviceMonitorProcess	Ordinary

[Screen Image]

[Screen Title]Input/output monitor

[Screen size]800X480

[OFF]

[Object List]

	Object ID	Coordinates	Device
Switch	20021	0,436	-

[Object List]

	20022	500,436	-
	20023	100,436	-
	20024	200,436	-
	20025	300,436	-
	20026	400,436	-
	20027	600,436	-
	20028	700,436	-
	20077	768,4	-
Special Function Switch	20078	628,7	-
Word Lamp	10010	23,96	@2-0-100 DI1
	10011	23,114	@2-0-100 DI1
	10012	23,132	@2-0-100 DI1
	10013	23,150	@2-0-100 DI1
	10014	23,168	@2-0-100 DI1
	10015	23,186	@2-0-100 DI1
	10020	412,96	@2-0-100 DO1
	10021	412,114	@2-0-100 DO1
	10022	412,132	@2-0-100 DO1
	10025	412,150	@2-0-100 DO1
	10026	412,168	@2-0-100 DO1
	10027	23,282	@2-0-100 DI0
	10028	23,300	@2-0-100 DI0
	10029	23,318	@2-0-100 DI0
	10030	23,336	@2-0-100 DI0
	10031	23,354	@2-0-100 DI0
	10032	23,372	@2-0-100 DI0
	10033	23,390	@2-0-100 DI0
	10034	123,282	@2-0-100 DI0
	10035	123,300	@2-0-100 DI0
	10036	123,318	@2-0-100 DI0
	10037	123,336	@2-0-100 DI0
	10038	123,354	@2-0-100 DI0
	10039	123,372	@2-0-100 DI0
	10040	123,390	@2-0-100 DI0
	10041	223,282	@2-0-100 DI0
	10042	223,300	@2-0-100 DI0
	10043	412,282	@2-0-100 DO0
	10044	412,300	@2-0-100 DO0
	10045	412,318	@2-0-100 DO0
	10046	412,336	@2-0-100 DO0
	10047	412,354	@2-0-100 DO0
	10048	412,372	@2-0-100 DO0
	10049	412,390	@2-0-100 DO0
	10050	512,282	@2-0-100 DO0
	10051	512,300	@2-0-100 DO0
	10052	512,318	@2-0-100 DO0
	10053	512,336	@2-0-100 DO0
	10054	512,354	@2-0-100 DO0
	10055	512,372	@2-0-100 DO0
	10057	512,390	GD1003
	10059	223,318	GD1001
	10060	223,336	GD1002
	10116	608,282	GD1005
Date Display	20075	628,20	-
Time Display	20074	716,20	-
Simple Comment	10061	23,60	-
	10062	412,60	-
	10080	23,246	-
	10099	412,246	-
	20020	16,8	-

Base Screen30022

[Base Screen Details]

Screen Name	Tuning
Size	800X480
Detailed Description	This screen is used to set the parameter required for gain adjustment.
Security	0
Individually set the screen design	Yes
Background Color	Dark White
Switch Station No.	No
Switch buffer memory unit No.	No
Pop up alarms	Yes
Display Position	Bottom

[Key Window]

Key Window Setting

Key Window Setting	Same as the project setting
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Key Window/Cursor Display Setting

Key Window/Cursor Display Setting	Same as the project setting
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Key Window/Cursor Movement

Key Window/Cursor Movement	Same as the project setting
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[Dialog Window]

Dialog Window	Same as the project setting
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[Script]

Order	Script No.	Comment	Trigger Type
1	30110	Gain adjustment mode selection	Ordinary

[Screen Image]

[Screen Title]Tuning

[Screen size]800X480

[OFF]



[Object List]

	Object ID	Coordinates	Device
Switch	20175	223,358	@2:0-100 PA1009

[Object List]

	20176	65,358	@2:0-100 PA1009
	20184	614,286	@2:0-100 PB1007
	20185	588,286	@2:0-100 PB1007
	20186	614,316	@2:0-100 PB1008
	20187	588,316	@2:0-100 PB1008
	20188	614,347	@2:0-100 PB1009
	20189	588,347	@2:0-100 PB1009
	20190	614,378	@2:0-100 PB1010
	20191	588,378	@2:0-100 PB1010
	20240	26,77	@2:0-100 PA1008
	20241	26,101	@2:0-100 PA1008
	20242	26,125	@2:0-100 PA1008
	20243	26,149	@2:0-100 PA1008
	20244	26,173	@2:0-100 PA1008
	20262	0,436	-
	20263	500,436	-
	20264	100,436	-
	20265	200,436	-
	20266	300,436	-
	20267	400,436	-
	20268	600,436	-
	20269	700,436	-
	20273	768,4	-
	20173	465,228	@2:0-100 PB1006
	20174	439,228	@2:0-100 PB1006
	20274	628,7	-
Special Function Switch	20170	371,208	GD1140
Word Lamp	20171	141,256	GD1140
	20172	512,256	GD1140
	20179	31,81	@2:0-100 PA1008
	20180	31,106	@2:0-100 PA1008
	20181	31,130	@2:0-100 PA1008
	20182	31,155	@2:0-100 PA1008
	20183	31,178	@2:0-100 PA1008
Numerical Input	20157	533,289	@2:0-100 PB1007
	20158	533,319	@2:0-100 PB1008
	20159	533,350	@2:0-100 PB1009
	20161	533,381	@2:0-100 PB1010
	20156	385,232	@2:0-100 PB1006
	20168	199,386	@2:0-100 PA1009
Date Display	20271	628,20	-
Time Display	20270	716,20	-
Simple Comment	20114	16,8	-
	20200	38,59	-
	20202	48,76	-
	20203	200,76	-
	20204	48,100	-
	20205	200,100	-
	20206	48,124	-
	20207	200,124	-
	20208	48,148	-
	20209	200,148	-
	20210	48,172	-
	20211	200,172	-
	20228	64,210	-
	20231	30,263	-
	20234	310,263	-
	20235	307,286	-
	20236	307,316	-
	20237	307,347	-
	20238	307,377	-
	20229	59,232	-
	20239	491,232	-
	20232	32,383	-

[Object List]			
Panelmeter	20177	83,286	@2:0-100 PA1009

Base Screen30024
[Base Screen Details]

Screen Name	Machine diagnosis
Size	800X480
Detailed Description	This screen is used to display the result of the machine diagnosis.
Security	0
Individually set the screen design	Yes
Background Color	Dark White
Switch Station No.	No
Switch buffer memory unit No.	No
Pop up alarms	Yes
Display Position	Bottom

[Key Window]

Key Window Setting

Key Window Setting	Same as the project setting
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Key Window/Cursor Display Setting

Key Window/Cursor Display Setting	Same as the project setting
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Key Window/Cursor Movement

Key Window/Cursor Movement	Same as the project setting
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[Dialog Window]

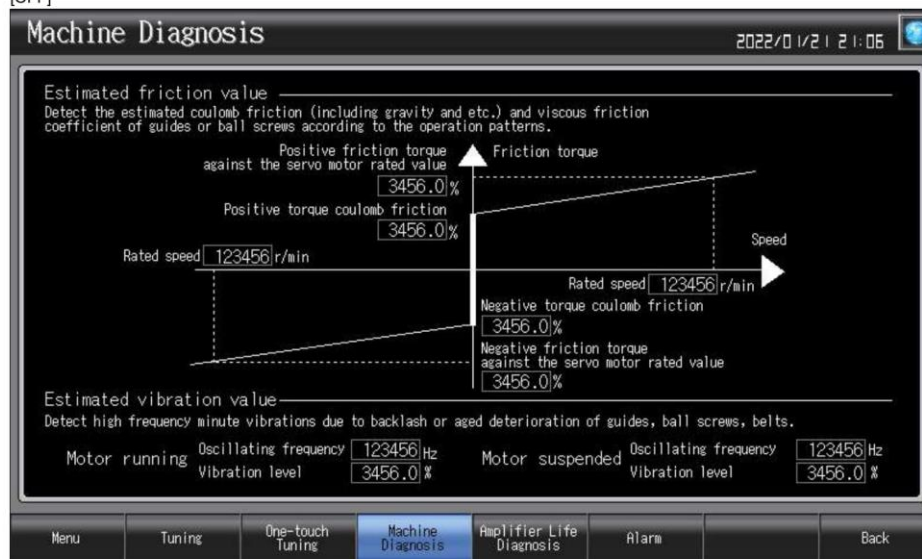
Dialog Window	Same as the project setting
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[Screen Image]

[Screen Title]Machine diagnosis

[Screen size]800X480

[OFF]



[Object List]

	Object ID	Coordinates	Device
Switch	20191	0,436	-
	20197	600,436	-
	20198	700,436	-
	20202	768,4	-
	20207	500,436	-

[Object List]

	20208	100,436	-
	20209	200,436	-
	20210	300,436	-
	20211	400,436	-
Special Function Switch	20203	628,7	-
Numerical Display	20092	410,314	@2:0-100 MD6
	20079	169,206	@2:0-100 MD11
	20084	554,230	@2:0-100 MD11
	20086	410,266	@2:0-100 MD5
	20088	297,373	@2:0-100 MD9
	20089	297,393	@2:0-100 MD10
	20090	682,373	@2:0-100 MD7
	20091	682,393	@2:0-100 MD8
	20066	320,183	@2:0-100 MD3
	20077	320,145	@2:0-100 MD4
Date Display	20200	628,20	-
Time Display	20199	716,20	-
Simple Comment	20108	16,8	-
	20117	31,64	-
	20118	31,81	-
	20125	31,329	-
	20119	78,116	-
	20120	78,166	-
	20121	92,206	-
	20122	408,249	-
	20123	408,287	-
	20124	477,230	-
	20188	419,116	-
	20189	642,192	-
	20126	31,347	-
	20127	50,380	-
	20128	164,371	-
	20129	164,391	-
	20130	409,380	-
	20131	537,371	-
	20132	537,391	-

Base Screen30025
[Base Screen Details]

Screen Name	Amplifier life diagnosis
Size	800X480
Detailed Description	This screen is used to display the result of the amplifier life diagnosis.
Security	0
Individually set the screen design	Yes
Background Color	Dark White
Switch Station No.	No
Switch buffer memory unit No.	No
Pop up alarms	Yes
Display Position	Bottom

[Key Window]

Key Window Setting

Key Window Setting	Same as the project setting
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Key Window/Cursor Display Setting

Key Window/Cursor Display Setting	Same as the project setting
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Key Window/Cursor Movement

Key Window/Cursor Movement	Same as the project setting
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[Dialog Window]

Dialog Window	Same as the project setting
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[Screen Image]

[Screen Title]Amplifier life diagnosis

[Screen size]800X480

[OFF]

[Object List]

	Object ID	Coordinates	Device
Switch	20149	0,436	-
	20155	600,436	-
	20156	700,436	-
	20160	768,4	-
	20164	500,436	-

[Object List]

	20165	100,436	-
	20166	200,436	-
	20167	300,436	-
	20168	400,436	-
Special Function Switch	20161	628,7	-
Numerical Display	20072	204,295	@2:0-100 ALD1
	20071	226,143	@2:0-100 ALD0
	20085	202,172	@2:0-100 ALD0
Date Display	20158	628,20	-
Time Display	20157	716,20	-
Simple Comment	20067	16,8	-
	20097	50,74	-
	20104	50,238	-
	20110	207,346	-
	20098	123,113	-
	20099	471,113	-
	20100	471,173	-
	20101	380,139	-
	20102	380,199	-
	20103	585,143	-
	20105	123,269	-
	20106	476,269	-
	20107	380,294	-
	20108	269,297	-
	20109	585,297	-
	20130	291,175	-

Base Screen30026

[Base Screen Details]

Screen Name	Alarm
Size	800X480
Detailed Description	This screen is used to display the current alarm and alarm history.
Security	0
Individually set the screen design	Yes
Background Color	Dark White
Switch Station No.	No
Switch buffer memory unit No.	No
Pop up alarms	Yes
Display Position	Bottom

[Key Window]

Key Window Setting

Key Window Setting	Same as the project setting
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Key Window/Cursor Display Setting

Key Window/Cursor Display Setting	Same as the project setting
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Key Window/Cursor Movement

Key Window/Cursor Movement	Same as the project setting
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[Dialog Window]

Dialog Window	Same as the project setting
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[Screen Image]

[Screen Title]Alarm

[Screen size]800X480

[OFF]

Alarm						
2022/01/21 21:06						
Current Alarm						
Alarm No.	Alarm Contents					
AL3456.56	There is no alarm.					
Alarm History						
History No.	Alarm No.	Alarm Contents	Occurrence Time(HR)	Detail Information (h)		
latest	AL240.0	No Alarms	123456	0		
1	AL240.0	No Alarms	123456	0		
2	AL240.0	No Alarms	123456	0		
3	AL240.0	No Alarms	123456	0		
4	AL240.0	No Alarms	123456	0		
5	AL240.0	No Alarms	123456	0		
6	AL240.0	No Alarms	123456	0		
7	AL240.0	No Alarms	123456	0		
8	AL240.0	No Alarms	123456	0		
Status Display at Alarm Occurrence Current Alarm Reset Alarm History Clear * Reset/Clear can be performed with a 3-second long press.						
Menu	Tuning	One-touch Tuning	Machine Diagnosis	Amplifier Life Diagnosis	Alarm	Back

[Object List]

	Object ID	Coordinates	Device
Switch	10014	145,384	@2:0-100 SP1
	10031	276,384	@2:0-100 SP2
	10032	14,384	-
	20044	0,436	-
	20050	600,436	-

[Object List]

	20051	700,436	-
	20066	768,4	-
	20085	500,436	-
	20086	100,436	-
	20087	200,436	-
	20088	300,436	-
	20089	400,436	-
Special Function Switch	20067	628,7	-
Word Lamp	20053	180,199	@2:0-100 ALM200
	20054	180,219	@2:0-100 ALM201
	20055	180,239	@2:0-100 ALM202
	20056	180,259	@2:0-100 ALM203
	20057	180,279	@2:0-100 ALM204
	20058	180,299	@2:0-100 ALM205
	20059	180,319	@2:0-100 ALM206
	20060	180,339	@2:0-100 ALM207
	20061	180,359	@2:0-100 ALM208
	20062	144,112	@2:0-100 ALM0
Numerical Display	10015	104,199	@2:0-100 ALM200
	10016	104,219	@2:0-100 ALM201
	10017	591,200	@2:0-100 ALM220
	10018	591,220	@2:0-100 ALM221
	10019	725,200	@2:0-100 ALM240
	10020	725,220	@2:0-100 ALM241
	10022	104,239	@2:0-100 ALM202
	10023	591,240	@2:0-100 ALM222
	10024	725,240	@2:0-100 ALM242
	10025	104,259	@2:0-100 ALM203
	10026	591,260	@2:0-100 ALM223
	10027	725,260	@2:0-100 ALM243
	10028	104,279	@2:0-100 ALM204
	10029	591,280	@2:0-100 ALM224
	10030	725,280	@2:0-100 ALM244
	10033	104,299	@2:0-100 ALM205
	10034	591,300	@2:0-100 ALM225
	10035	725,300	@2:0-100 ALM245
	10036	104,319	@2:0-100 ALM206
	10037	591,320	@2:0-100 ALM226
	10038	725,320	@2:0-100 ALM246
	10039	104,339	@2:0-100 ALM207
	10040	591,340	@2:0-100 ALM227
	10041	725,340	@2:0-100 ALM247
	10042	104,359	@2:0-100 ALM208
	10043	591,360	@2:0-100 ALM228
	10044	725,360	@2:0-100 ALM248
	20076	153,199	@2:0-100 ALM240
	20077	153,219	@2:0-100 ALM241
	20078	153,239	@2:0-100 ALM242
	20079	153,259	@2:0-100 ALM243
	20080	153,279	@2:0-100 ALM244
	20081	153,299	@2:0-100 ALM245
	20082	153,319	@2:0-100 ALM246
	20083	153,339	@2:0-100 ALM247
	20084	153,359	@2:0-100 ALM248
	10013	40,113	@2:0-100 ALM0
	10063	87,113	@2:0-100 ALM1
Date Display	20064	628,20	-
Time Display	20063	716,20	-
Simple Comment	10045	13,80	-
	10046	19,140	-
	10047	13,166	-
	10048	95,166	-
	10049	575,166	-
	10050	670,166	-

[Object List]

	10051	25,200	-
	10066	180,166	-
	10083	407,386	-
	20034	16,8	-
	20036	19,54	-
	20039	144,80	-

Base Screen30041

[Base Screen Details]

Screen Name	Parameter Setting (ROM) Menu
Size	800X480
Detailed Description	This screen shows the menu for the parameter setting (ROM).
Security	0
Individually set the screen design	Yes
Background Color	Dark White
Switch Station No.	No
Switch buffer memory unit No.	No
Pop up alarms	Yes
Display Position	Bottom

[Key Window]

Key Window Setting

Key Window Setting	Same as the project setting
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Key Window/Cursor Display Setting

Key Window/Cursor Display Setting	Same as the project setting
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Key Window/Cursor Movement

Key Window/Cursor Movement	Same as the project setting
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[Dialog Window]

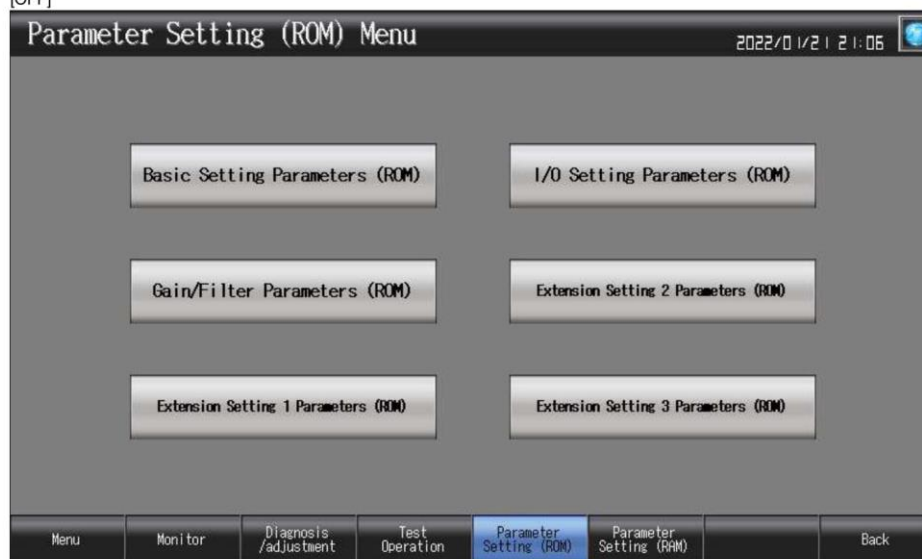
Dialog Window	Same as the project setting
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[Screen Image]

[Screen Title]Parameter Setting (ROM) Menu

[Screen size]800X480

[OFF]



[Object List]

	Object ID	Coordinates	Device
Switch	10000	104,115	-
	10001	104,215	-
	10002	104,315	-
	10003	432,115	-
	10014	432,215	-
	10015	432,315	-

[Object List]

	20015	0,436	-
	20021	600,436	-
	20022	700,436	-
	20026	768,4	-
	20028	300,436	-
	20029	100,436	-
	20030	200,436	-
	20031	400,436	-
	20032	500,436	-
Special Function Switch	20027	628,7	-
Date Display	20024	628,20	-
Time Display	20023	716,20	-
Simple Comment	20014	16,8	-

Base Screen30042

[Base Screen Details]

Screen Name	Basic Setting Parameters(ROM)1/2
Size	800X480
Detailed Description	This screen is used to display the value of the basic setting parameter of EEPROM in the servo amplifier. On the screen, the operator can set the value of the parameter.
Security	0
Individually set the screen design	Yes
Background Color	Dark White
Switch Station No.	No
Switch buffer memory unit No.	No
Pop up alarms	Yes
Display Position	Bottom

[Key Window]

Key Window Setting

Key Window Setting	Same as the project setting
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Key Window/Cursor Display Setting

Key Window/Cursor Display Setting	Same as the project setting
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Key Window/Cursor Movement

Key Window/Cursor Movement	Same as the project setting
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[Dialog Window]

Dialog Window	Same as the project setting
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[Screen Image]

[Screen Title]Basic Setting Parameters(ROM)1/2

[Screen size]800X480

[OFF]

Basic Setting Parameters (ROM) 1/2

2022/01/21 21:05

No.	Symbol	Name	Set Value	Unit
PA01	*STY	Operation Mode	1234h	
PA02	*REG	Regenerative Option	1234h	
PA04	*AOP1	Function Selection A-1	1234h	
PA05	*FBP	Number of Command Input Pulses per Revolution	12345678	
PA06	CMK	Electronic Gear Numerator	12345678	
PA07	CDV	Electronic Gear Denominator	12345678	
PA08	ATU	Auto Tuning Mode	1234h	
PA09	RSP	Auto Tuning Response	12345678	
PA10	INP	In-position Range	12345678	
PA11	TLP	Forward Rotation Torque Limit	123456.0	%
PA12	TLN	Reverse Rotation Torque Limit	123456.0	%
PA13	*PLSS	Command Pulse Input Form	1234h	
PA14	*POL	Rotation Direction Selection	12345678	
PA15	*ENR	Encoder Output Pulses	12345678	pulse/rev
PA16	*ENR2	Encoder Output Pulses 2	12345678	
PA19	*BLK	Parameter Writing Inhibit	1234h	
PA20	*TDS	Tough Drive Setting	1234h	
PA21	*AOP3	Function Selection A-3	1234h	
PA23	*DART	Drive Recorder Arbitrary Alarm Trigger Setting	1234h	
PA24	*AOP4	Function Selection A-4	1234h	

*: Once data is written, the data becomes valid after turning on the amplifier power again.

To RAM

Menu

Basic Setting (ROM)

Gain/Filter (ROM)

Extension Setting 1 (ROM)

I/O Setting (ROM)

Extension Setting 2 (ROM)

Extension Setting 3 (ROM)

Back

[Object List]

	Object ID	Coordinates	Device
Switch	10020	665,404	-
	10105	0,436	-
	10107	100,436	-
	10108	200,436	-

[Object List]

	10109	300,436	-
	10110	400,436	-
	10111	500,436	-
	10112	700,436	-
	10113	756,73	-
	10114	756,365	-
	20044	600,436	-
	20121	768,4	-
Special Function Switch	20122	628,7	-
Numerical Input	10000	634,75	@2:0-100 PA1001
	10001	634,91	@2:0-100 PA1002
	10003	634,107	@2:0-100 PA1004
	10004	610,123	@2:0-100 PA1005
	10005	610,139	@2:0-100 PA1006
	10006	610,155	@2:0-100 PA1007
	10007	634,171	@2:0-100 PA1008
	10008	610,187	@2:0-100 PA1009
	10009	610,203	@2:0-100 PA1010
	10010	610,219	@2:0-100 PA1011
	10011	610,235	@2:0-100 PA1012
	10012	634,251	@2:0-100 PA1013
	10013	610,267	@2:0-100 PA1014
	10014	610,283	@2:0-100 PA1015
	10015	610,299	@2:0-100 PA1016
	10016	634,315	@2:0-100 PA1019
	10017	634,331	@2:0-100 PA1020
	10018	634,347	@2:0-100 PA1021
	10019	634,363	@2:0-100 PA1023
	20046	634,379	@2:0-100 PA1024
Date Display	20119	628,20	-
Time Display	20118	716,20	-
Simple Comment	10061	115,75	-
	10062	115,91	-
	10064	115,107	-
	10065	115,123	-
	10066	115,139	-
	10067	115,155	-
	10068	115,171	-
	10069	115,187	-
	10070	115,203	-
	10071	115,219	-
	10072	115,235	-
	10073	115,251	-
	10074	115,267	-
	10075	115,283	-
	10076	115,299	-
	10077	115,315	-
	10078	115,331	-
	10079	115,347	-
	10080	115,363	-
	10103	12,402	-
	20042	16,8	-
	20049	115,379	-
	20143	12,52	-
	20144	57,52	-
	20145	109,52	-
	20146	572,52	-
	20147	682,52	-

Base Screen30102

[Base Screen Details]

Screen Name	JOG Operation
Size	800X480
Detailed Description	This screen is used to perform the JOG operation test.
Security	0
Individually set the screen design	Yes
Background Color	Dark White
Switch Station No.	No
Switch buffer memory unit No.	No
Pop up alarms	Yes
Display Position	Bottom

[Key Window]

Key Window Setting

Key Window Setting	Same as the project setting
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Key Window/Cursor Display Setting

Key Window/Cursor Display Setting	Same as the project setting
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Key Window/Cursor Movement

Key Window/Cursor Movement	Same as the project setting
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[Dialog Window]

Dialog Window	Same as the project setting
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[Window Position]

Title	Coordinates
Overlap Window1	-
Overlap Window2	-
Superimpose Window1	12,72
Superimpose Window2	-
Key Window	-

[Script]

Order	Script No.	Comment	Trigger Type
1	30120	Superimpose window control	Rise(GB40)
2	30125	Start/end JOG operation	Rise/Fall(GB110)
3	30126	Transfer motor speed	Rise(GB111)
4	30127	Transfer accel/decel constant	Rise(GB112)
5	30128	Forward rotation operation	Rise/Fall(GB113)
6	30129	Reverse rotation operation	Rise/Fall(GB114)

[Object List]

Object List	Object ID	Coordinates	Device
Switch	10000	0,436	@2:0-100 OM0
	10001	100,436	-
	10002	200,436	-
	10004	300,436	-
	10005	600,436	-
	10006	500,436	-
	20045	400,436	-
	10012	655,362	GB114
	10013	525,362	GB113
	20061	754,71	GD116
	20062	754,260	GD116
	20072	768,4	-
	20075	700,436	-
	Bit Switch	20066	22,303
Special Function Switch	20073	628,7	-
Numerical Input	10008	310,355	GD1201
	10009	310,384	GD1203
Date Display	20070	628,20	-
Time Display	20069	716,20	-
Simple Comment	10038	520,54	-
	10039	652,54	-
	10061	12,54	-
	20044	16,8	-
	10010	30,355	-
	10011	30,384	-
	20067	58,309	-

Base Screen30103

[Base Screen Details]

Screen Name	Positioning Operation
Size	800X480
Detailed Description	This screen is used to perform the positioning operation test.
Security	0
Individually set the screen design	Yes
Background Color	Dark White
Switch Station No.	No
Switch buffer memory unit No.	No
Pop up alarms	Yes
Display Position	Bottom

[Key Window]

Key Window Setting

Key Window Setting	Same as the project setting
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Key Window/Cursor Display Setting

Key Window/Cursor Display Setting	Same as the project setting
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Key Window/Cursor Movement

Key Window/Cursor Movement	Same as the project setting
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[Dialog Window]

Dialog Window	Same as the project setting
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[Window Position]

Title	Coordinates
Overlap Window1	-
Overlap Window2	-
Superimpose Window1	12,72
Superimpose Window2	-
Key Window	-

[Script]

Order	Script No.	Comment	Trigger Type
1	30120	Superimpose window control	Rise(GB40)
2	30130	Start/end Positioning Operation	Rise/Fall(GB116)
3	30126	Transfer motor speed	Rise(GB111)
4	30127	Transfer accel/decel constant	Rise(GB112)
5	30131	Transfer travel distance	Rise(GB115)

[Screen Image]
[Screen Title]Positioning Operation
[Screen size]800X480
[OFF]

[illegible]

[Object List]	Object ID	Coordinates	Device	
Switch	10000	0,436	@2:0-100 OM0	
	10001	100,436	-	
	10002	200,436	-	
	10004	300,436	-	
	10005	600,436	-	
	10006	500,436	-	
	10010	520,336	@2:0-100 TMi0	
	10011	585,336	@2:0-100 TMi0	
	10015	520,376	@2:0-100 TMB1	
	10016	650,336	@2:0-100 TMB5	
	10017	650,376	@2:0-100 TMB6	
	20046	400,436	-	
	20074	754,71	GD116	
	20075	754,260	GD116	
Bit Switch	20079	768,4	-	
	20107	700,436	-	
	20071	22,303	GB116	
	Special Function Switch	20080	628,7	-
		10012	310,337	GD1201
	Numerical Input	10013	310,362	GD1203
		10014	262,387	GD1205
Date Display	20077	628,20	-	
Time Display	20076	716,20	-	
Simple Comment	10008	30,336	-	
	10009	30,361	-	
	10018	30,386	-	
	20045	16,8	-	
	20072	58,309	-	
	20108	520,54	-	
	20109	652,54	-	
	20110	12,54	-	

Base Screen30104

[Base Screen Details]

Screen Name	Output Signal(DO) Forced Output
Size	800X480
Detailed Description	This screen is used to perform the forced output of the output signal.
Security	0
Individually set the screen design	Yes
Background Color	Dark White
Switch Station No.	No
Switch buffer memory unit No.	No
Pop up alarms	Yes
Display Position	Bottom

[Key Window]

Key Window Setting

Key Window Setting	Same as the project setting
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Key Window/Cursor Display Setting

Key Window/Cursor Display Setting	Same as the project setting
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Key Window/Cursor Movement

Key Window/Cursor Movement	Same as the project setting
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[Dialog Window]

Dialog Window	Same as the project setting
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[Script]

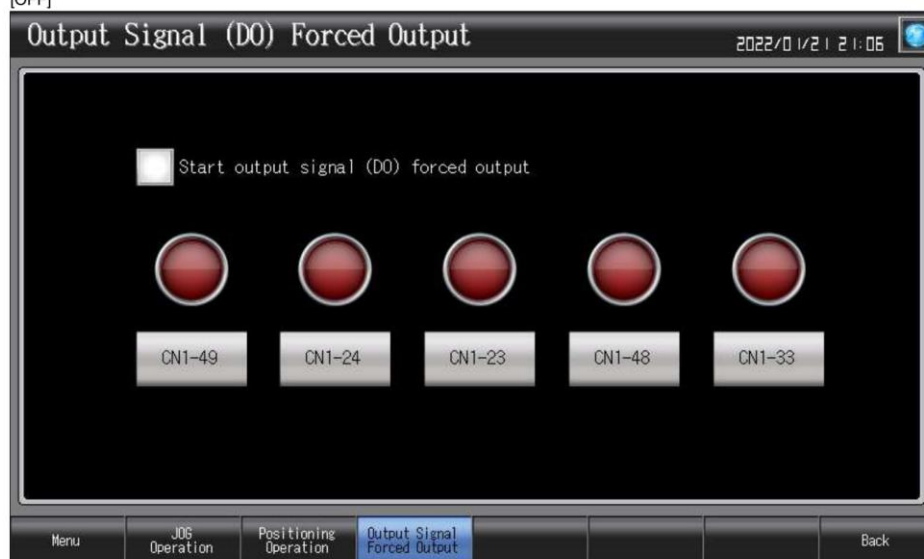
Order	Script No.	Comment	Trigger Type
1	30135	Start/end (DO) forced output	Rise/Fall(GB117)
2	30136	Output signal selection	ON(GB117)

[Screen Image]

[Screen Title]Output Signal(DO) Forced Output

[Screen size]800X480

[OFF]



[Object List]

Object ID	Coordinates	Device
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[Object List]

Switch	10000	0,436	@2:0-100 OM0
	10001	100,436	-
	10002	200,436	-
	10004	300,436	-
	10005	500,436	-
	10006	400,436	-
	10007	600,436	-
	20023	768,4	-
	10008	109,276	GD1210.b0
	10009	233,276	GD1210.b1
	10010	358,276	GD1210.b2
	10012	483,276	GD1210.b5
	10013	608,276	GD1210.b6
	20028	700,436	-
Bit Switch	20018	109,118	GB117
Special Function Switch	20024	628,7	-
Bit Lamp	10020	125,191	GD1210.b0
	10021	249,191	GD1210.b1
	10022	374,191	GD1210.b2
	10024	499,191	GD1210.b5
	10025	624,191	GD1210.b6
Date Display	20021	628,20	-
Time Display	20020	716,20	-
Simple Comment	20015	16,8	-
	20019	147,126	-

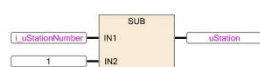
Function Block

Persons responsible for the application and the product must themselves ensure that each application is in compliance with all relevant requirements, standards and legislation in respect to configuration and safety.

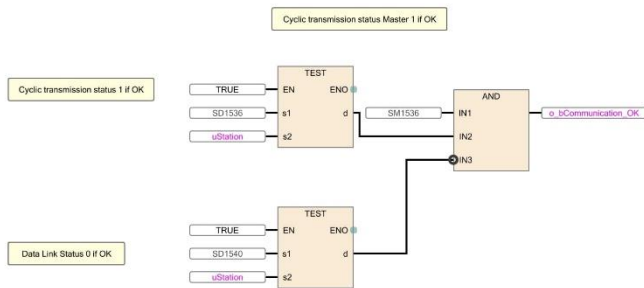
Mitsubishi Electric cannot assume any liability if these examples are used in real applications.

Version 1.00
Function block to handle one MR-JE-C amplifier in CC-Link IE Basic mode
Created in GX Works3 ver. 1.046Y 2018-08-07
Version 1.01 fixed PosCompleted active at power up 2018-09-06 GX Works3 ver. 1.046Y
Version 1.02 fixed Busy signal when JOG in torque limit 2018-10-24 GX Works3 ver. 1.047Z
Version 1.04 implemented torque mode 2018-10-26 GX Works3 ver. 1.047Z
Version 1.04 fixed home problem 2019-01-07 GX Works3 ver. 1.050C
Version 1.05 added position options when using Degree 2019-01-10 GX Works3 ver. 1.052C
Version 1.06 fix bug in LSP and LSN indication 2019-01-14 GX Works3 ver. 1.052C
Version 1.07 fix PosCompleted pulse when aborting move or jog mode 2019-08-14 GX Works3 ver. 1.056J

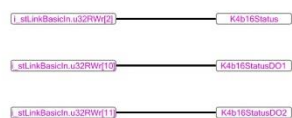
Create station number that starts from zero



Check CC-Link communication



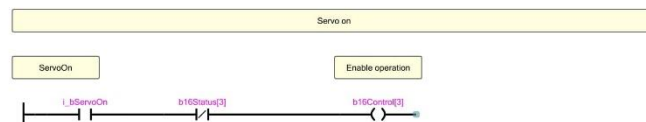
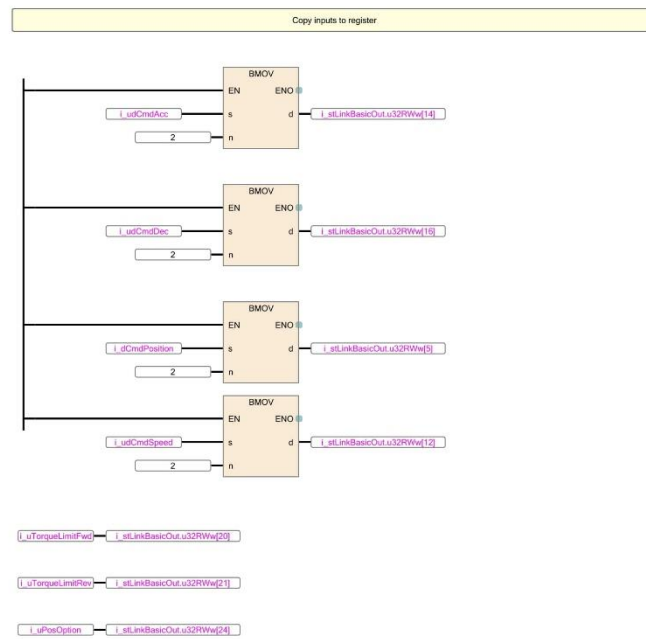
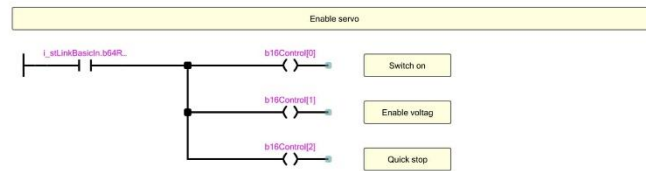
Reading status from servo



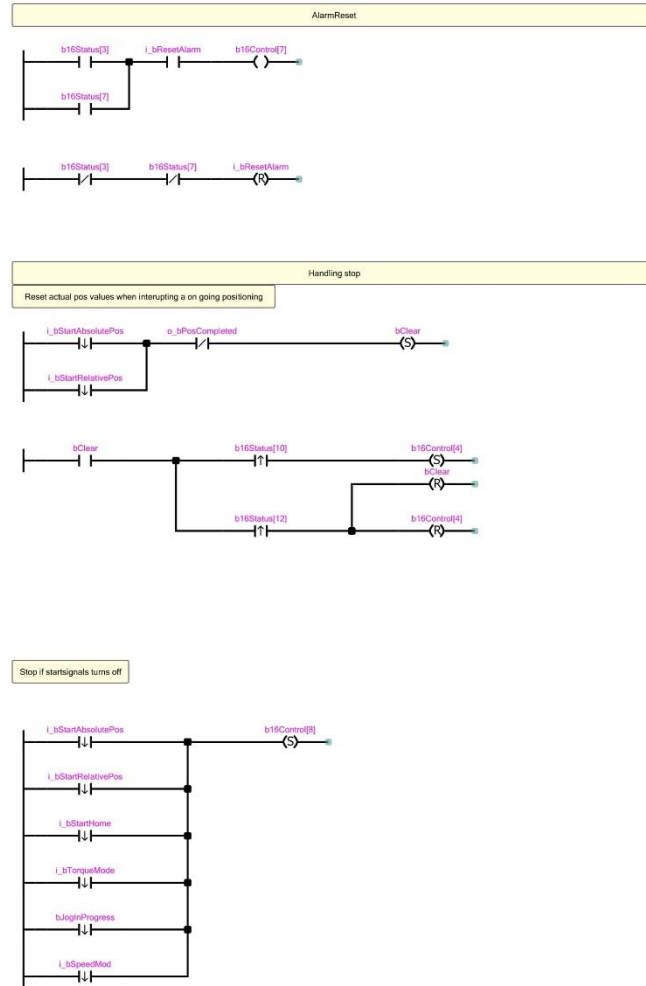
Init and startup



Function Block

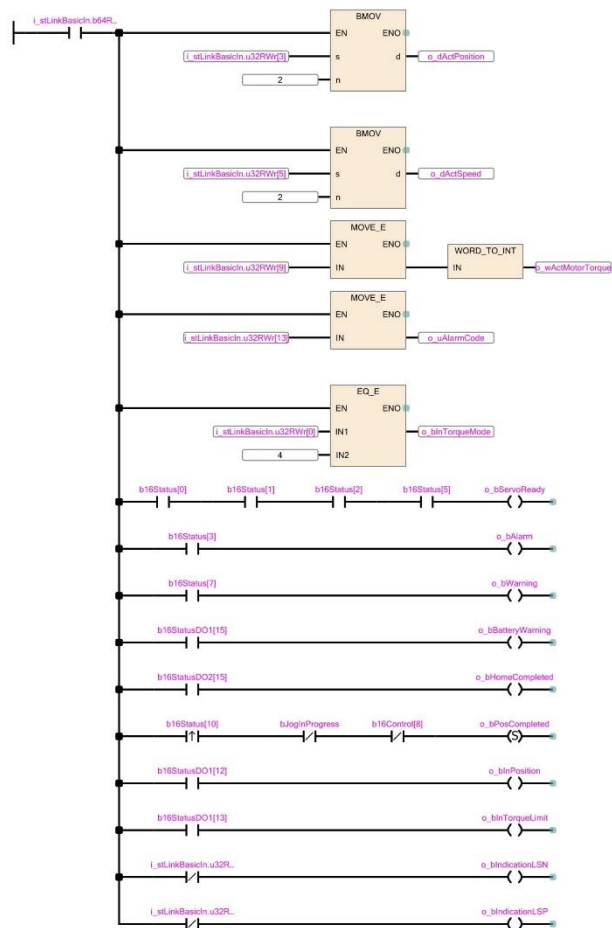


Function Block



Function Block

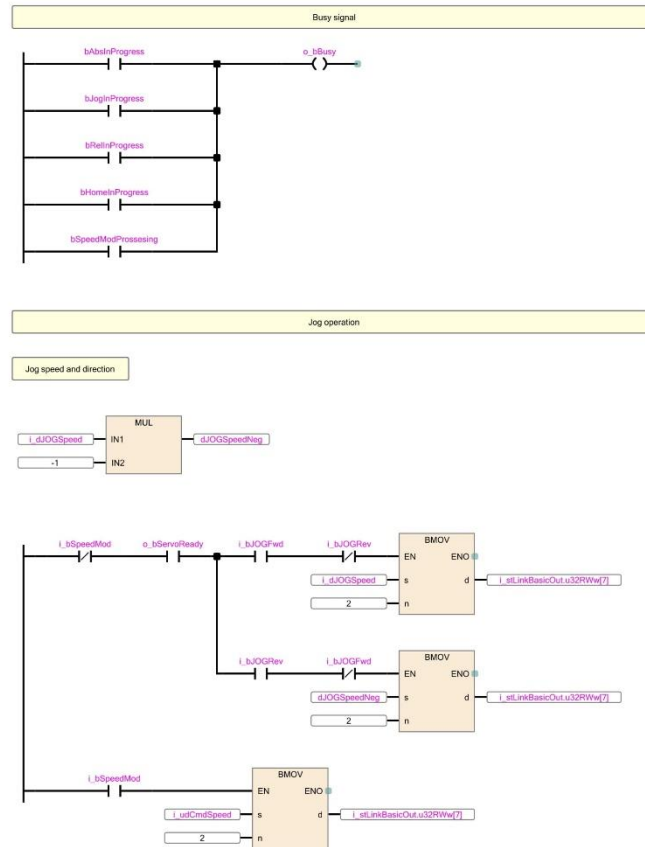
Monitor register



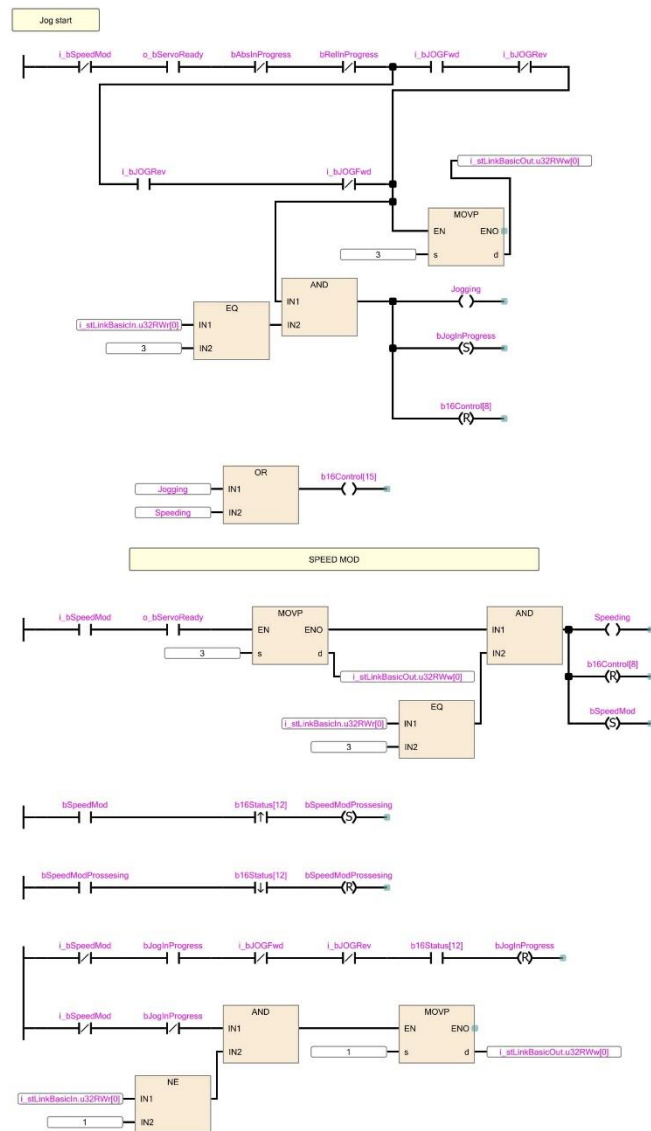
Reset PosCompleted if no start signals are active

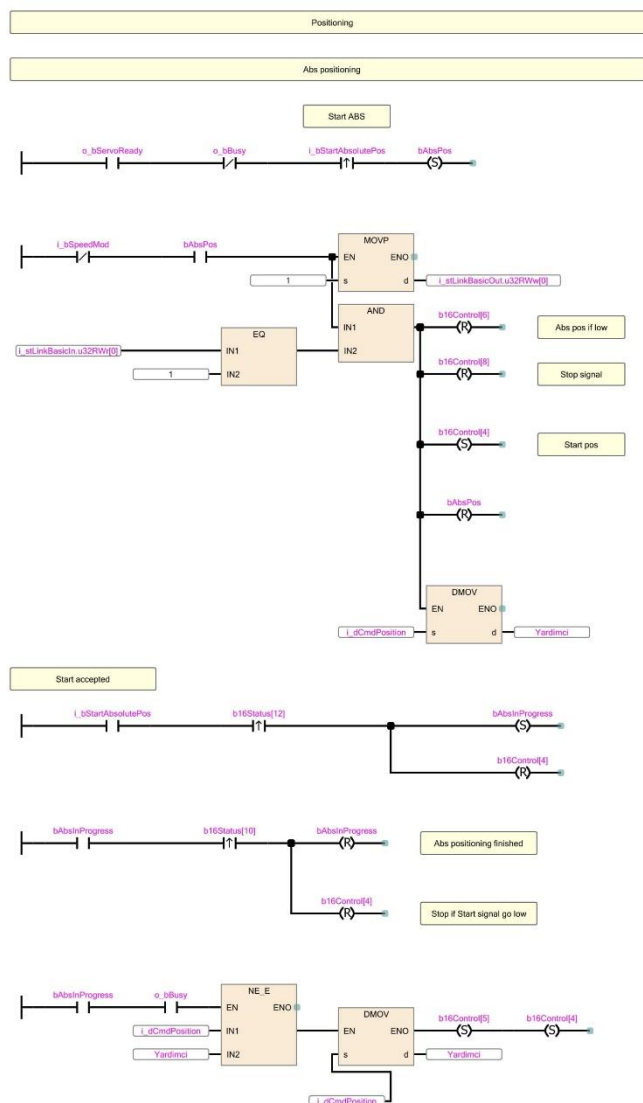


Function Block

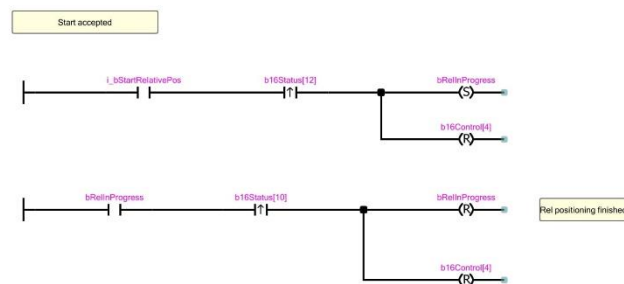
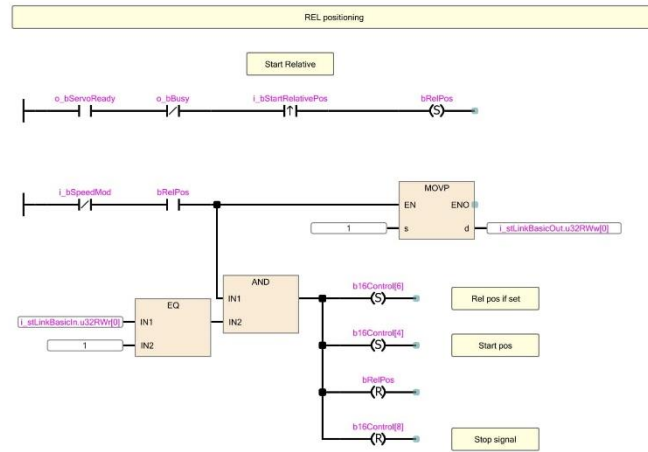


Function Block

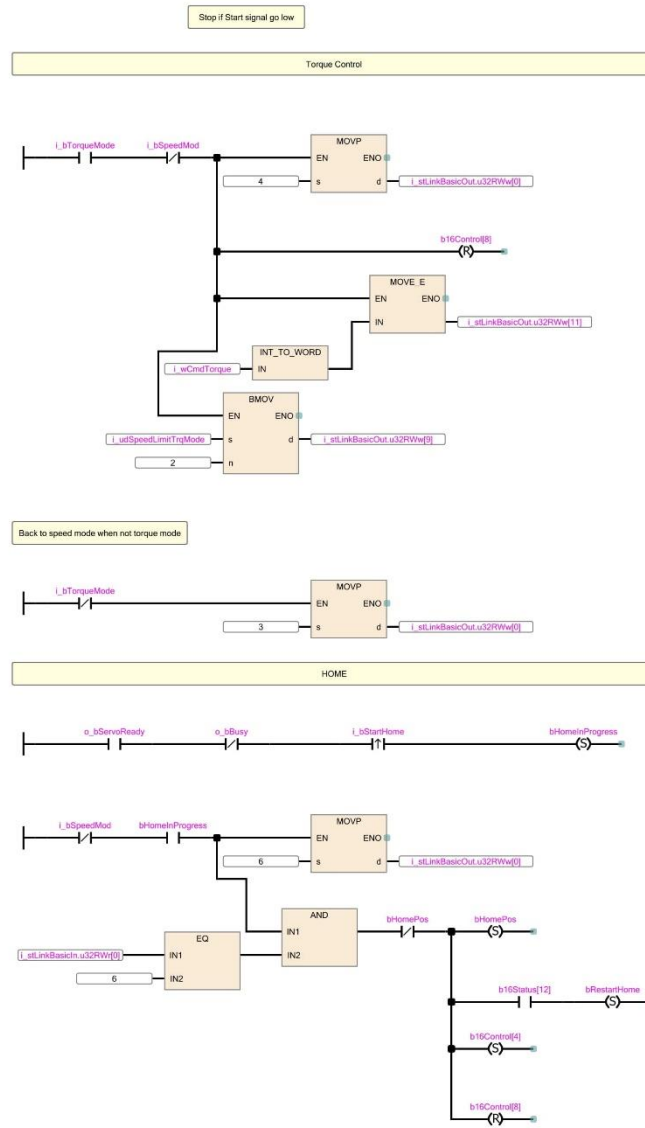




Function Block

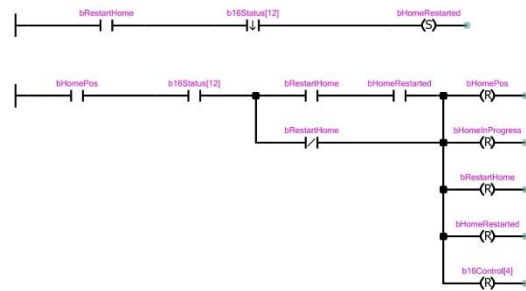


Function Block



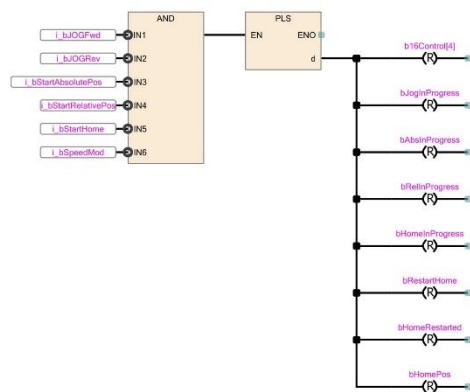
Function Block

If axis already homed we need to wait for status bit 12 to be zero before it starts a new home



Clear bits if no startsignal

Stop if Start signal go low



Mapping till servo

