ÇUKUROVA UNIVERSITY
INSTITUTE OF NATURAL AND APPLIED SCIENCES

MSc THESIS

Özge FIRTANA

PARAMETRIC DESIGN OF A SEMI-TRAILER CHASSIS

DEPARTMENT OF MECHANICAL ENGINEERING

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We certify that the thesis titled above was reviewed and approved for the award of degree of the Doctor of Philosophy by the board of jury on 25/06/2018.

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This MSc Thesis is written at the Department of institute of Natural and Applied Sciences of Çukurova University.
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ABSTRACT

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PARAMETRIC DESIGN OF A SEMI- TRAILER CHASSIS

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This study examines the application of parametric design of a semi-trailer chassis with the purpose of adding flexibility to the design process required by fast evolving transportation technology. Parametric design allows the design of parts that are similar but have different geometric measurements to be made in a short time and to pass the designs onto production quickly. Catia V5 design software was used for software development. In Catia V5, parametric design is done by using VBA because user defined forms can be utilized in code writing. The design environment is a structure in which we can control the whole semi-trailer chassis within the framework of the designer specified rules. In the system, the basic parameters that make up the chassis are entered by the user and the chassis is dimensioned and then the drawing, modelling, static and dynamic analysis of the chassis can be performed automatically in the software environment. This work allowed a standard design that meets certain criteria for design, allowing the revision to be faster and more functional compared to conventional design techniques.

Key Words: Semi-trailer Chassis, Catia, VBA, CAD.FEA

ÖZ

YÜKSEK LİSANS TEZİ

YARI RÖMORK ŞASİSİNİN PARAMETRİK TASARIMI

Özge FIRTANA

ÇUKUROVA ÜNİVERSİTESİ
FEN BİLİMLERİ ENSTİTÜSÜ
MAKİNE MÜHENDİSLİĞİ ANABİLİM DALI

Danışman : Prof. Dr. Hakan YAVUZ
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: Prof. Dr. Mehmet BİLGİLİ
: Doç. Dr. Naime Filiz ÖZDİL

Bu çalışma gelişen teknoloji ile birlikte tasarıma esneklik katmayı amaçlayan parametrik tasarımın yarı römork şasisinin tasarımına uygulamasını ele almaktadır. Parametrik tasarım birbirine benzeyen ancak geometrik ölçüleri farklı olan parçaların tasarımının kısa sürede yapılıp, üretime geçilmesine olanak sağlamaktadır. Bu çalışmada, yarı römork şasisinin (Bilgisayar Destekli Tasarım) ortamında parametrik olarak çizimi, modellenmesi ve analizi için bir yazılım geliştirilmiştir. Yazılım geliştirmede Catia V5 tasarım yazılımı kullanılmıştır. Catia V5 içine kod yazımında, kullanıcı tanımlı formlarının kullanılabilmesi nedeniyle VBA kullanılarak parametrik tasarım yapılmıştır. Tasarım ortamı, belirlenen kurallar çerçevesinde yarı römork şasisinin bütününü kontrol edebildiğimiz bir yapıdır. Sistemde, şasiyi oluşturan temel parametreler kullanıcı tarafından girilerek, şasi boyutlandırılmakta ve daha sonra yazılım ortamında şasinin çizimi, modellenmesi, statik ve dinamik analizi otomatik olarak yapılabilmektedir. Bu çalışma, tasarımın belli kriterlere uyan standart bir tasarım olmasını sağlayarak, tasarımın revizyonun da daha hızlı ve işlevsel olmasına olanak sağlanmıştır.

Anahtar Kelimeler: Yarı Römork Şasisi, Catia, VBA, CAD.FEA

EXTENDED ABSTRACT

Computer aided design mainly used in automotive, aviation and many more industrial areas because obtaining the 3D solid model of the production part before production phase. For this reason, designers have chance to revision the model if it is needed.

The design process is the most important stage of production. Both during design and after design phase, static, dynamic and related necessary analysis are needed for completing the design. Because of this, according to the results, same changes can be done during the design phase for improving the design. However, the time which is spent during design development, directly affects the time it takes to complete the part production. On the other hand, rapid design changes may be required to reshape an existing product quickly and to get all the necessary engineering analysis tasks required. For this reason, the parametric design technique is used to responds this need. This study examines the application of parametric design of a semi-trailer chassis with the purpose of adding flexibility to the design process required by fast evolving transportation technology.

The goal of the CAD parametric modelling is to create a 3D representation, flexible and complex enough to encourage the engineer to easily consider a variety of designs. In parametric modelling techniques, parameters are used in for defining the geometry of the model. If the changes are made to the parameters, the all model is update according to new value. Nowadays, there are many software programs which available for parametric design. Catia is one of this software program to response this need. This program combines modelling, analyzing, code writing, learning function and more. Code writing in Catia bases on user identification and parameter creation.

Each parameter description and codes in design software makes design a standard design with a certain criterion. These created parameters are important because reducing the design time and error occur.

In CATIA V5, code can be written using VBA program. In this way, user defined forms can be obtained. Code development in Catia involves accessing Catia objects (a product, a part, a pad, etc.) with the help of VBA, modifying the properties of these objects, and invoking object methods.

Macros can also be created with this program environment. In application of a Catia macro, macro recorder properties can be used to record your actions which is doing manually just to get an idea of what the code might look like. The process is start with the macro recorder and perform the action, then look at the recorded code to get an idea of what the code looks like, then modify the program so it will work on other parts all the time.

As a model, a semi-trailer chassis is designed to be used for cargo transportation on the highway. Previous studies based on design of semi-trailer systems consists of dynamic and static analysis of the semi-trailer chassis. This is improving the strength of the chassis while decreasing the weight of the system. This is the main objective of the typical optimization study for such systems. Parametric design approach provides necessary design tools to minimize the design process time so that reshaping an existing product quickly is an easy task.

In this study, parametric design techniques are performed on two different semi-trailer chassis. One of them is flatbed semi-trailer chassis and the other one is container carrier semi-trailer chassis. Catia software solid programme is used for parametric design environment. VBA macro programming is used for parametric design of the chassis. In addition, a user interface module is developed to capture the design requirements and then designing, static, dynamic analysis of the chassis are performed automatically.

Briefly, the presented study offers a better and incredibly faster design approach for development of semi-trailer chassis designs. With the possible integration of the developed design software to manufacturing process, it may allow considerable reduction in product design, development and manufacturing time.

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CONTENTS **PAGE**

LIST OF TABLES **PAGE**

LIST OF FIGURES **PAGE**

ABBREVIATIONS END SYMBOLS

CAD	: Computer Aided Design
CAM	: Computer Aided Manufacturing
CAE	: Computer-Aided Engineering
FEA	: Finite Element Analysis
GUI	: Graphical User Interface
KBE	: Knowledge Base Engineering
HLCT	: High Level CAD Templates
ITER	: International Thermonuclear Experimental Reactor
API	: Application Programming Interface
VBA	: Visual Basic Application
VB	: Visual Basic
CAA	: Component Application Architecture
G	: Maximum weight of mass produced by the manufacturer
I	: Maximum loaded mass of the first axle
II	: Maximum loaded mass of the second axle
P_K	: Kingpin max load mass
R_K	: Maximum loaded mass of the back axle
K	: Maximum permissible axle mass
G_S	: Mass of unloaded chassis
G_{SI}	: Mass of unloaded chassis for the first axle
G_{SII}	: Mass of unloaded chassis for the second axle
Ps	: Mass of unloaded chassis for kingpin
Rs	: Mass of unloaded chassis for back axle

$G_N + G_{\dot{I}}$: Maximum calculated loaded mass

G_N : Calculated mass with body and in action

$G_{\dot{I}}$: Calculated loaded mass

P : Maximum calculated kingpin loaded mass

R : Maximum calculated back axle loaded mass

P_N : Calculated kingpin mass with body and in action

R_N : Calculated back axle mass with body and in action

$P_{\dot{I}}$: Load that comes to the kingpin from the calculated loaded mass

$R_{\dot{I}}$: Load that comes to the back axle from the calculated loaded mass

P_K : Maximum load of the kingpin

R_K : Maximum load of the back-axle group

$d1$: Distance between kingpin and second axle

A : Distance between kingpin and back axle

L : Length of the semi-trailer

C_1 : Distance between front end and back end of semi-trailer

C_2 : Distance between center of back axle and back end of semi-trailer

b : Distance between center of gravity of semi-trailer and center of back axle

1. INTRODUCTION

Today computer-aided design is used by companies and specialized engineers operating in different production areas. In the design process, any incompatibility negatively affects the production process. Most final products are achieved by connecting sub-assemblies. One of the best way of exploring such designs is to computer aided design software where the design is visually presented in solid model form. This way, the designer can decide for the necessary revisions of the design and prevent the problems that can occur during the production process.

The design process is the most important stage of production. A new design requires static, dynamic and stress calculations related analysis during and after the design phase. For this reason, the design can change frequently during the development stage. However, in this case, rapid design changes may be required to reshape an existing product quickly and to red all the necessary engineering analysis tasks required. Because of this need, a new design technique so called as parametric design has emerged.

In automotive industry, the present approach allows implementation of an integrated vehicle model by improving the conceptual design stage of the automotive product development. Modern parametric CAD programs are particularly well suited to product development by allowing the designer to gradually refine and improve their designs without having to start from the beginning for each revision.

The main purpose of the presented work is to create a user interface module to allow designing the vehicle chassis by using a suitable CAD program. For this purpose, parametric modelling technique is introduced and used in design of two different types of vehicle chassis development.

As a model, a semi-trailer chassis is designed to be used for cargo transportation on the highway. It is a vehicle that some of them are sitting on motor vehicles or vehicles. The load it carries, and the part of its own weight carried by the motor vehicle. Previous studies based on design of semi-trailer systems consists of dynamic and static analysis of the semi-trailer chassis. This is improving the strength of the chassis while decreasing the weight of the system. This is the main objective of the typical optimization study for such systems. Parametric design approach provides necessary design tools to minimize the design process time so that reshaping an existing product quickly is an easy task.

Design and modelling of the chassis were performed in Catia. Because It combines identification, code writing and learning functions and more. Visual Basic for Applications (VBA) or Visual Basic (VB) scripts can be preferred because of the ability to write user-defined forms in Catia code. And also, in Catia, macros which written in a scripting language that is grouped in a single command can be created to perform the requested task automatically. Code development in Catia involves accessing Catia objects (a product, a part, a pad, etc.) with the help of VBA, modifying the properties of these objects, and invoking object methods.

In Figure 1.1 the 3D solid model of the container carrier semi-trailer chassis is shown. It is wanted the model them manually, it takes about one week for completing the design. This study provides a better and incredibly faster approach for development of semi-trailer chassis designs by decreasing the design time from weeks to seconds.

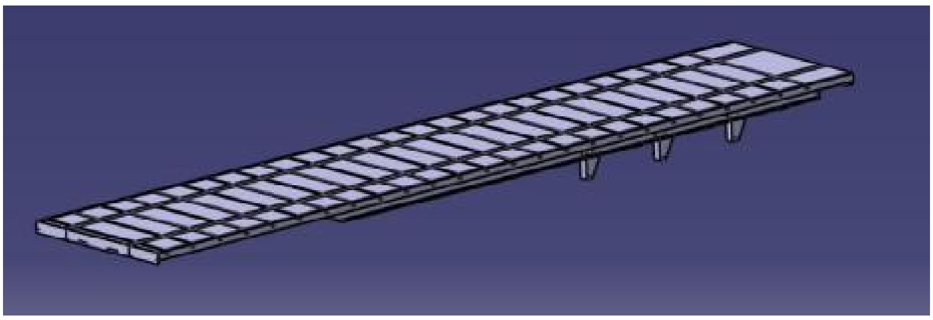


Figure 1.1. 3D solid modelling of semi-trailer chassis designed using Catia V5

The goal of the CAD parametric modelling is to create a 3D representation, flexible and complex enough to encourage the engineer to easily consider a variety of designs.

These are the some of the benefits of this approach;

- Automatic updates to the model if changes are made to the design.
- The ability to easily capture design intent, which makes it easier to define how the model should behave when something is changed.
- Easy definition and automatic creation of families of parts.
- Excellent integration with manufacturing processes, resulting in a decrease in production time.

The design parameters are based on the regulations according to the 128. clause in Turkish highway traffic guidelines for vehicle (loaded or unloaded) dimensions and permitted vehicles loads (aiming at protecting the roads from damages due over loads) have been used during the design parametric design stage. For the calculation of the load distribution the same guidelines were taken as a reference.

With the benefit of achieving the design in a fraction of conventional design time, the parametric modelling technique gives a clearer feel for what the final product will look like. Besides, the overall look as well as design details can be observed. Because the parametric design process requires only a few seconds, varying design parameters and repeating the design process and related analysis works make is easier to test various trailer models requested by the customer. This allows development of several different chassis geometries rapidly. This not only reduces the design time but also pleases the customer as it does not take weeks to price a product.

This presented study offers a better and incredibly faster design approach for development of semi-trailer chassis design. With the possible integration of the developed design software to manufacturing process, it may allow considerable reduction in product design, development and manufacturing time.

Briefly, the presented study offers the following benefits:

- A better and incredibly faster approach for development of semi-trailer chassis designs.
- A high potential for integration to manufacturing process
- Allows incredibly fast reduction in product design and development
- Eliminates most calculation errors
- Drastically reduces manufacturing time
- Design modifications can be done in seconds
- The design model is ready for evaluation and pricing in no time.

In the following sections of the thesis, firstly parametric modelling related previous studies are presented. In the next section, the material and method related issues are addressed. In this section, solid modelling technique, parametric modelling process and related issues are addressed. In the following section, the results and related discussion is presented. The section provides the details of the achievements made by the developed software that allows parametric modelling. In the final section, the conclusion is provided along with the future recommendations.

2. PREVIOUS STUDY

H. Yogesh et al. (2015) presented automated modelling of screw conveyor components in Catia. In this study, the system is developed for generation of 3D model of horizontal screw conveyor components in Catia V5 software. The developed system consists of Excel spreadsheet for design calculations and the determination of parameters of screw conveyor components and GUI in Catia, for entering of components parameters. Catia V5 is an open system for creation of macros in the design environment. In addition, VBA language is also used for generation of screw conveyor components and different loops are used in Excel for automatic determination of screw conveyor components parameters. A screw conveyor has large varieties according to convey capacity, the number of components and the handling material types used. The developed system is used for generation of 18 components having 29 subcomponents.

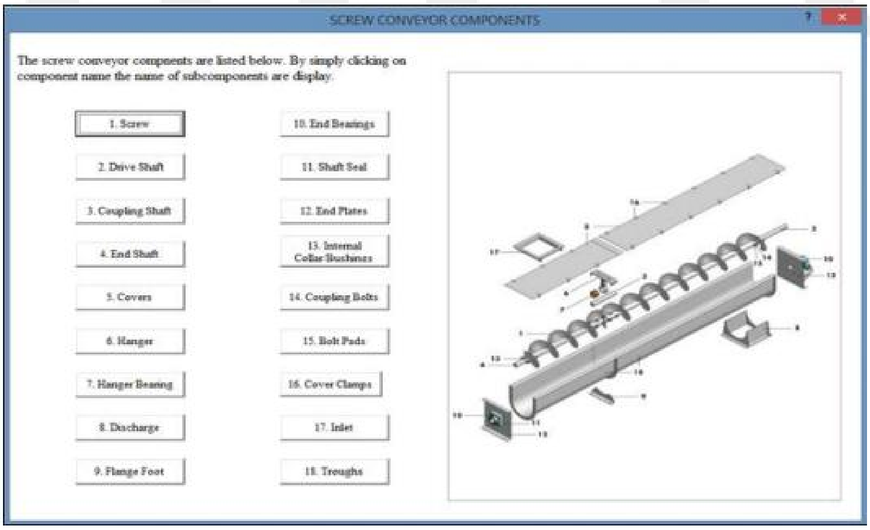


Figure 2.1. Screw conveyor components user form

The user can simply enter the parameters of component via developed GUI, the system automatically generates 3D model. The advantage of this developed system is that the end user is not required to have the knowledge of complicated CAD software. The results of this work are presented in Figure 2.1 and Figure 2.2.

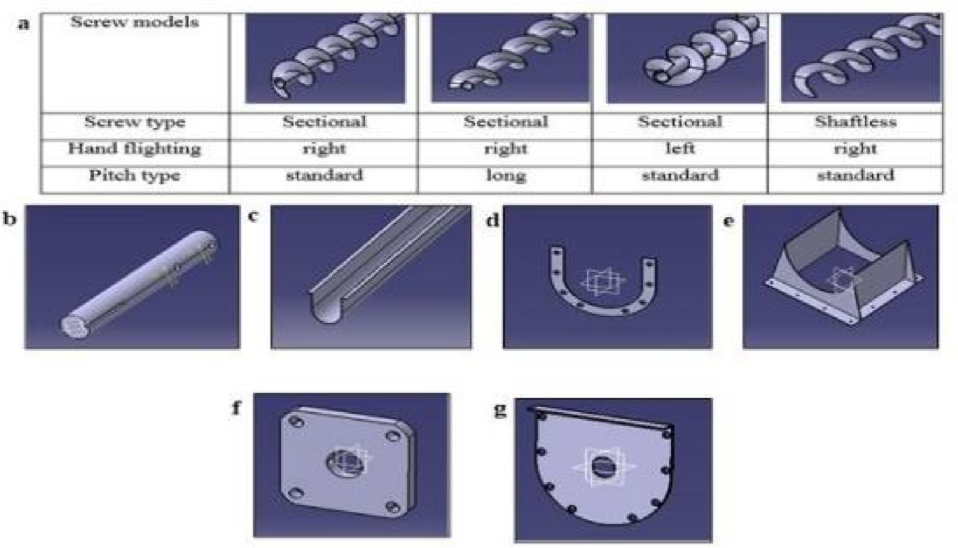


Figure 2.2. Screw conveyor components a) Screw. b) 2-Bolt Drive Shaft. c) U-Trough. d) U-Trough End Flange e) Standard Discharge. f) Plate Seal. g) U-Trough Style End Plate

Richter T. et all (2002) presented a study on integrated parametric aircraft design. In this approach, planes can be designed with permanent three-dimensional visual control. The input, output and data management are controlled by the user interface Pad3D. This front end of the user interface was developed to be understood in a way that it presents the parts previously created and detailed. It then allowed them to be added to the actual configuration as a set of or as single components as shown in Figure 2.3. For most parts, they provided the user with 4 inputs that can be visually checked in the preview window and in others these can be controlled with the maximum and minimum dimensions in which these parameters normally must be set. So, for almost every wrong input before execution of command of "Create in Catia", it is checked to ensure to avoid any unreasonable or erroneous results. The automatically created 3-dimensional geometric result in Catia V5 is shown in Figure 2.4.

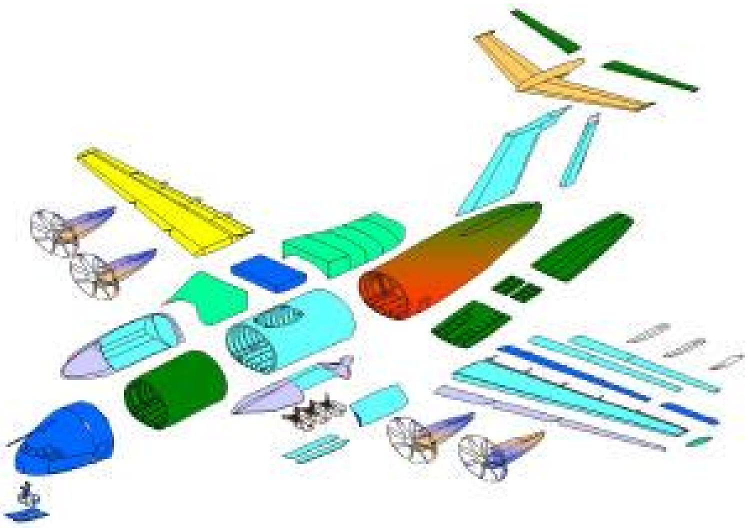


Figure 2.3 Reasonable components reflecting the modular design approach applied on an aircraft

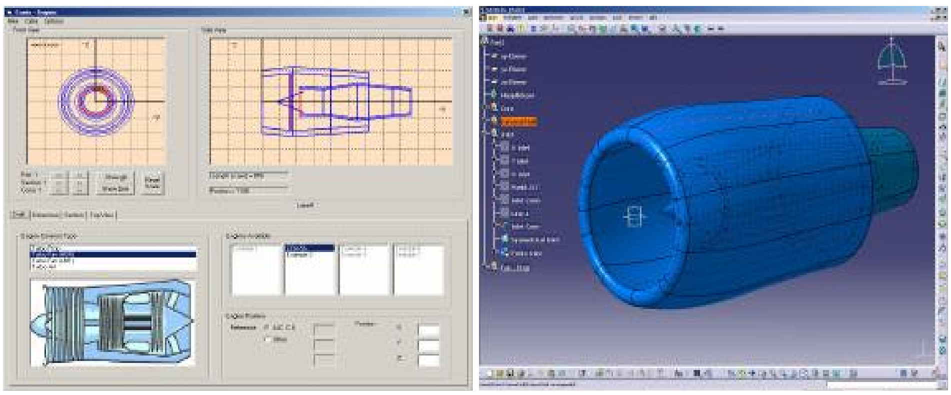


Figure 2.4. The automatically created 3-dimensional geometric result in Catia V5

CAD system Catia V5, which is the basic 3D tool of aircraft manufacturers, is used from the beginning of the aircraft designing process. The major advantages of approach are that it takes all the necessary calculation data and related inputs for the analysis the methods used from a single database; thus, allowing various analyses to be performed on the same data set. Another advantage is that results are used as an early input to the next phase or as a direct input to the concept phase.

Mokhede Y. at all (2017) presents a study on automation of bearing modelling and drafting using Catia VBA approach. To see the design solution for the rolling design, a system with an automatic modelling and design solution with two approaches was developed and presented.

The aim of the study presented by Mokhede Y. at all (2017) is to understand how knowledge based engineering (KBE) system can be used to improve the design phase of bearing industry. In addition, the system has been developed in Catia using VBA to effectively solve and automate repetitive engineering problems of a design team and their organization.

In this study, a system with an automatic modelling and design solution with two approaches was developed to provide design solution for rolling design. This automated design tool helps to fill the gap between design engineers and computer specialists with analysis during the product development process. The details of the approach and the results of the parametric design work achieved by Mokhede Y. at all (2017) are illustrated in Figure 2.5 and Figure 2.6.

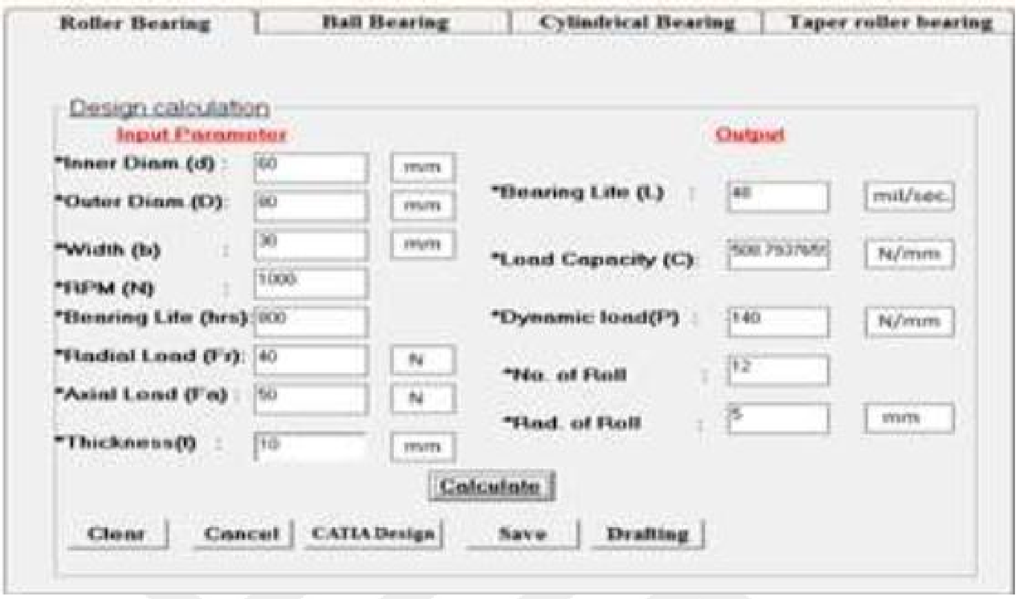


Figure 2.5. User interface for roller bearing

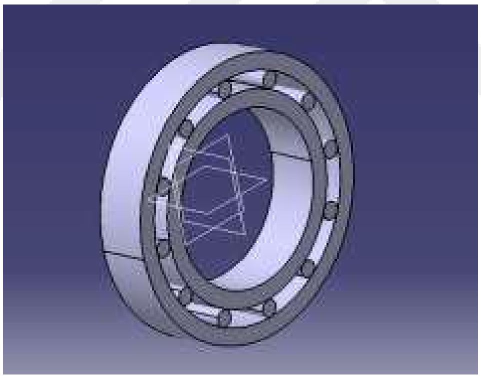


Figure 2.6. 3D CAD output of ball bearing

The following conclusions can be drawn from this research based on the developed rolling system.

- There are four different types of bearings produced based on the presented the automation and modelling procedure: Ball bearing, roller bearings, cylindrical roller bearings, tapered roller bearings.

- The system also offers an automated design solution for the required customer specifications; e.g. bearing life and loading conditions.
- The draft activity is partially automated. The system registers the parameter using MS Access database. Outputs the results in the system in a few seconds. Hence, the time required for the design process is minimized.
- The automation of 3D CAD modelling using HLCTs helps to reduce the manual input providing and command using errors during modelling, as the user must give several entries in a single user interface without using any of the Catia commands.

The above presented work can be further developed by making the modelling process more realistic by automating the object dressing feature allowing automatic generation of fillet, chamfer and corner radius properties. In the drafting activity, automatic sizing can be very much useful in performing the repetitive tasks. The automatic design approach is mainly performed only for four different types of bearings. The other tasks can be included for calculation of other types of bearings. The presented work can also be expanded to cover production planning and assessing product manufacturability and life cycle simulation for cost estimation tasks.

Yuxia S. at all (2012) presents a study on parametric design of straight bevel gears based on SolidWorks software. In this study, the structural characteristics of straight bevel gears were analyzed, design variables are specified, and the interactive interface is provided. In addition, the cartesian coordinate system was established, the coordinates of the control points were determined according to the geometric relationships. The parametric design of the straight bevel gear with Visual Basic language and SolidWorks API functions were performed. The results have showed that the parametric modelling of the bevel gear was very quick and accurate. In addition, the 3D modelling of the straight bevel gears in SolidWorks would be achieved in a very short design time. The main window for this study is shown in Figure 2.7 and 2.8.

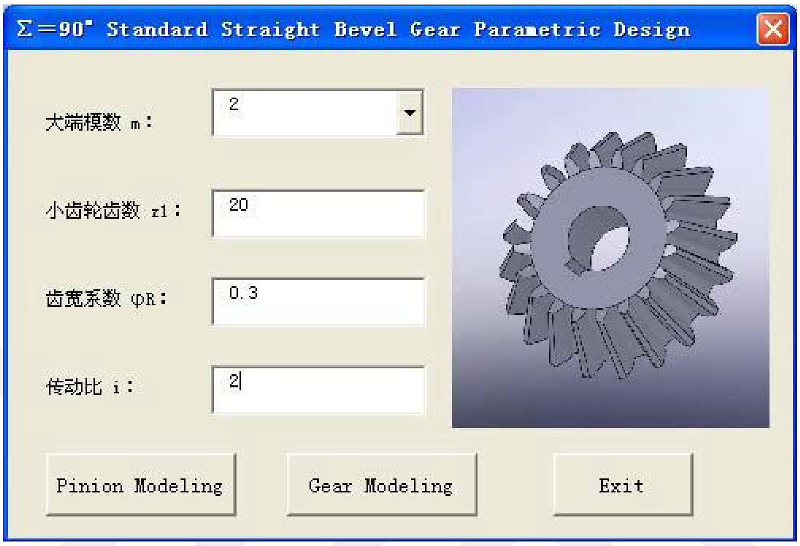


Figure 2.7. Main window

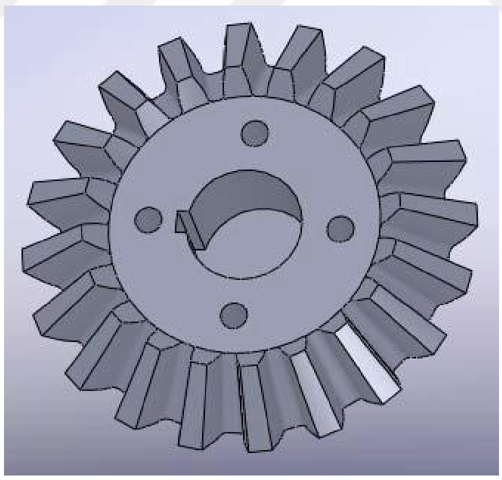


Figure 2.8. Completed bevel gear model

However, the methodology recommended in this article is addressed mainly for straight bevel gears intersecting at right angles but provides references for other angles and spiral bevel gears. According to base on these results, the next step of the study is to examine and evaluate the acceptability of the parametric design model produced in SolidWorks.

Zhou at all (2013) presented a study about parametric design of turbo drill bearing section based on Visual Basic and SolidWorks. In this study, the basic structure of turbo drill is examined, and the necessity of parametric design is presented. SolidWorks parameter design compared to other methods is a choice to develop a parametric program that can automatically generate a set of models at different sizes. The design of the installation of the bed section of the turbo drill was created to develop models of each piece. This is a particularly effective way of linking the dimensions of each model. In this study, the parametric design of turbo drill and the cooperative design process are examined. The parametric program has been developed and each form has been created in addition to the main interface. The details of this study, the user interface module and the relevant solid models are presented in Figures 2.9 to 2.12.

The Figures 2.9 shown below illustrates the details of the draft form of the assembly for the turbo drill. In Figure 2.10, the main user interface menu is presented. In this menu, the user provides the main design parameters necessary for parametric modelling.

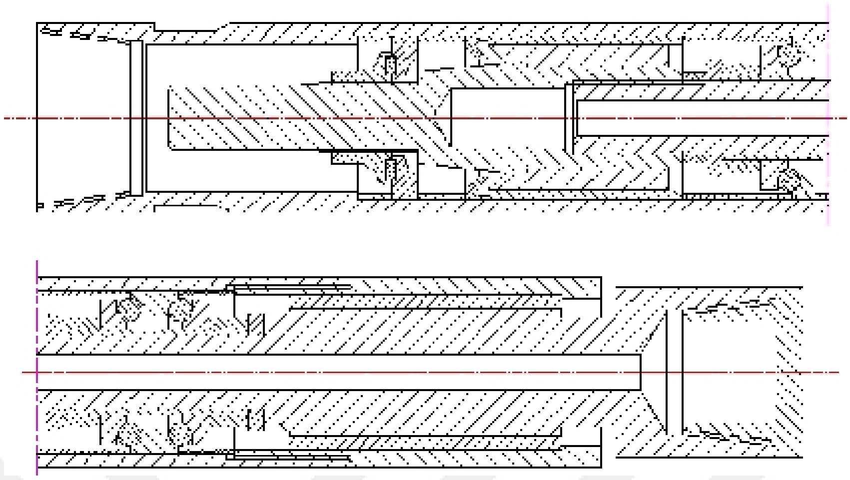


Figure 2.9. 3D model assembly draft of turbo drill

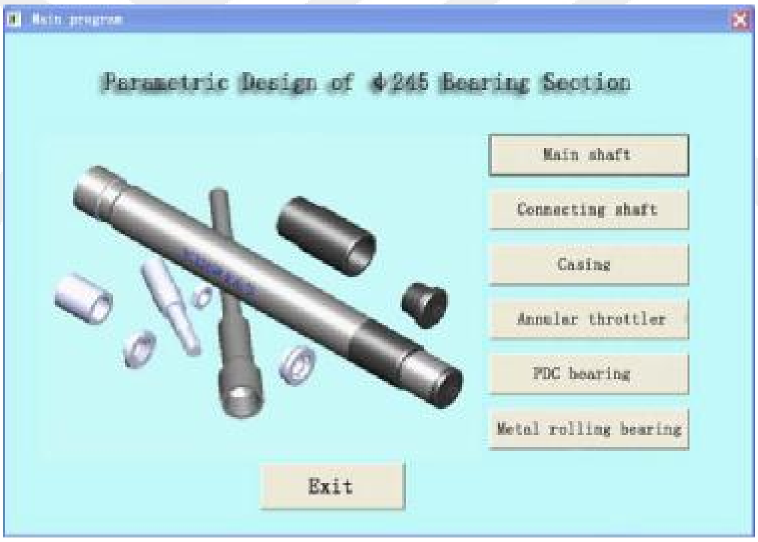


Figure 2.10. Interface of the program

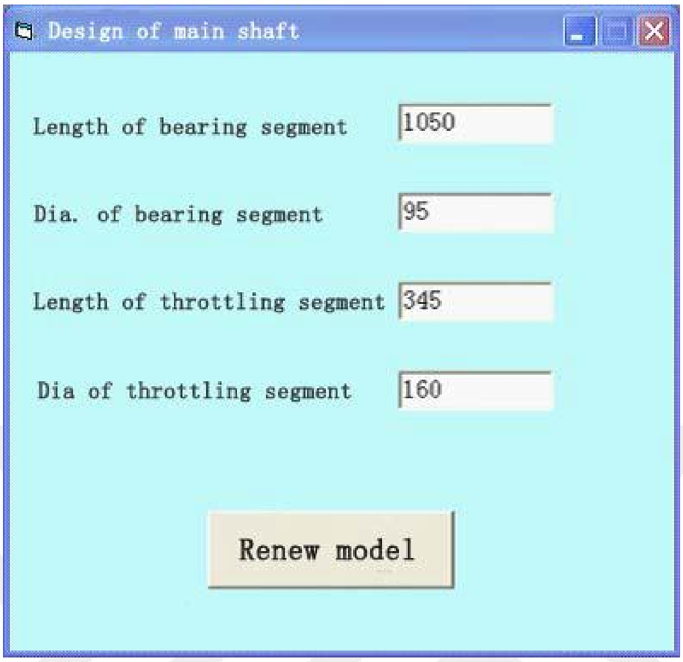


Figure 2.11. Form of designing main shaft

The Figure 2.11 above illustrates the user interface and input module for main shaft design page. The input values provided in Figure 2.11 are used in calculations for shaft design and then by pressing the 'Renew model' button, a new model is created as shown in Figure 2.12.

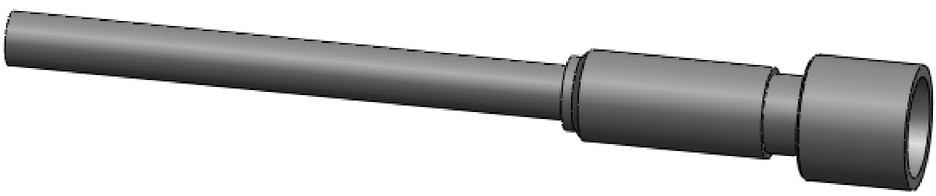


Figure 2.12 Model of main shaft

Ge J. et all (2011) presents a study on parametric design of ITER cryostat based on Catia. In their study, they present a parametric design method of based on

Catia and realized the 3-D modelling of cryostat quickly and accurately. This method simplifies the design process and improves design efficiency. Cryostat is an important equipment of International Thermonuclear Experimental Reactor (ITER). Cryostat is the outer part of ITER Tokamak. In this study, three issues are taken to complete the parametric design of cryostat;

These topics are;

- Parametric description of cryostat model
- Designing of the program
- Establishing of database.

In this study, a simple model of the cryostat is taken as an example. After finishing the description of the cryostat parametrically, the parametric design of cryostat has been executed through ACCESS Database and Catia under VB (Visual Basic).

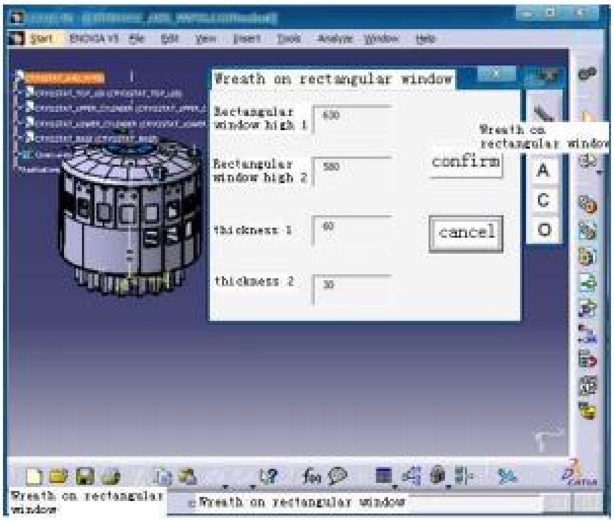


Figure 2.13. Design system menu and user interface module

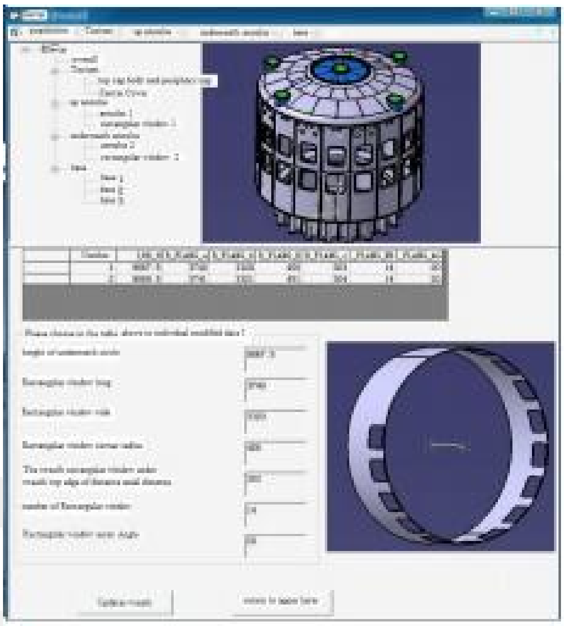


Figure 2.14. Outer structure design system menu and user interface

The illustration provided in Figure 2.13 shows design system menu and user interface module reported by Ge J. et all (2011). Also, in Figure 2.14, outer structure design system menu and user interface modules are illustrated.

3. MATERIAL AND METHOD

3.1. CAD based Solid Modelling Techniques

CAD based Solid modeling techniques utilizes clearly defined, accurate and exact representations of mechanical components. In simple terms, solid modeling makes clear definition of the object in design space thereby defining its interaction with the rest of the mechanical system.

CAD based solid modeling software packages provides features to enhance productivity of the solid modelling process. In the following section, each of the feature in the below list is presented with in necessary level of details.

I. Feature-Based Modelling
II. Constraint-Based Modelling
III. History-Based Modelling
IV. Associative Modelling
V. Parametric Modelling

3.1.1. Feature-Based Modelling

In feature-based modeling, a solid model is generated and modified for showing the how geometries are made by using the general manufacturing processes. The meaning of a base feature is that a solid model which has approximately same shape and size with the part wanted to be created.

It can be considered as a basis feature for the work to be done. All the other features take as a reference the base one directly or indirectly. Base feature has the similar shape of the geometry which is wanted to product. This gains an ability to the engineer that easily generate and modify the parts. Consequently, production planning of a part is simplified by the interaction between the features and the processes needed to generate them.

3.1.2. Constraint-Based Modelling

Constraint-based modelling provides the designer combining “intelligence” with the design. This is basic purpose of this modeling method. In this method, it is not expected to do that two-dimensional drafting of the part must be entirely true. It is just enough to introduce the basic form of the geometry. The advantage of this modeling method is that when the part is modified or changes the design is not entirely unchanged. So, this provides the engineer's design purpose remains substantial**.** As an example, if a hole localized according to a distance from an edge. It will stay at that point even though the edge is move from there.

In this method, there are two type basic restrictions. One of them is dimensional contains which are used for specifying the distance between items. The other one is geometric constrain includes the relationship for geometric position between the items in a solid model. For example; tangency, parallelism, symmetry, concentricity, and the like. In general, both of constrain types are combined for completely constrain items in solid model.

3.1.3. History-Based Modelling

In history-based modelling, the final model which is wanted to obtain depends on the formation history of the part. As an example, for creating a hole first, the solid volume where the hole is placed must be obtained. If the solid volume is deleted, the hole is also removed according to a parent-child relationship. In here, hole is taken as a child and the solid model taken as a parent. Parent-child relationships has the very important place for continuing the design purpose. In most solid modelling program, the features (ex. a hole) are removed if the solid volume which their located on it is deleted.

As a result, planning and organization of the basic features and the continuing features has an important place for easily modify and generated the solid model which is wanted to obtain.

3.1.4. Associative Modelling

Changing of one object causes to modification in all the object which is associated. For example, if the diameter of the hole sketch is changed, the diameter of the hole which is located at the solid body will also change. Additionally, if this part is in assembly group, and the hole diameter is changed on that part, the assembly group and drawings are also will changed. This property makes the parts more controllable and reduce the design errors.

3.1.5. Parametric Modelling

The meaning of the parametric modelling is that parameters of the model can be changed, to modify geometry of the model. For example, a dimension can be taken as a simple example, when one dimension is modified, part geometry is updated according to the new value. Additionally, relations and equations can be used during creating parameters, this is the power of this method, when a dimension is modified, all the other linked dimensions are changed due to the mathematical equations.

The goal of the CAD parametric modelling is to create a 3D representation, flexible and complex enough to encourage the engineer to easily consider a variety of designs.

3.2. Details of Parametric Modelling

The benefits of parametric modelling techniques are;

- Automatic updates to the model if changes are made to the design.
- The ability to easily capture design intent, which makes it easier to define how the model should behave when something is changed.
- Easy definition and automatic creation of families of parts.

- Excellent integration with manufacturing processes, resulting in a decrease in production time.

Nowadays, for the designers, there are many software's which are available for the parametric modelling.

These software's can be classified at three groups.

(i) Small scale use
(ii) Large scale use
(iii) Industry specific modelling

The last one from this classification, industry specific modelling has the most popularity. Some of the software's which are used in industry are;

Of the three, the last category (Industry specific parametric software) has gained in popularity in recent years. A few of the leading industry software are as follows:

SolidWorks: It has a place at design environment in 1995. Dassault Systems purchased it in 1997. SolidWorks is firstly used in application of mechanical design and then strongly used in plastic industry.

Catia: It is created by Catia at the end of the 1970s in France. Application areas of this program; automotive, aeronautic, shipbuilding industries.

Autodesk Inventor: It is build up Autodesk which is based U.S. Software Company. It is a software that 3D prototypes are created with simulation and visualization properties.

Siemens NX: Nowadays, it is known as Unigraphics. In 1977, this software was bought by McDonnell Douglas. The last versions of this program have properties about increasing the product efficiency. This program combines engineering intelligent, manufacturing solution and product design.

Table 3.1. Comparison of most well-known cad software systems

Company	Product	Geometric Kernel	Operating System	Class
Autodesk	Inventor 2010	Autodesk shape manager®	Window	Mid-range
Dassault systems	Catia v6	V6	Windows	High range
Dassault systems	Solid works 2010	Parasolid®	Windows	Mid-range
Ptc	Pro/engineer wildfire 5.0	Granite®	Linux, mac os, Unix, windows	High range
Siemens	Nx 7	Parasolid®	Linux, mac os, Unix, windows	High range
Siemens	Solid edge with Synchronoustec nology 2	Parasolid®	Windows	Mid-range

3.3. Parametric Design Methods in Catia V5 and Related Design Process

The parametric design allows the designer to complete the design in the direction of the design purpose. Parametric modelling means that parameter of the model can be modified at any time, to change the geometry of the model.

Parametric modelling is achieved by creating and detecting of basic principles of design with the help of computer aided software. The design parameters which are described as a parametric relation at the sketches are used for modifying and updating the model more quickly.

The main structure of a process with general sections is introduced in below Figure 3.1. Generally, design process involves the customer input and used them in application system to get an output which is wanted to obtain.

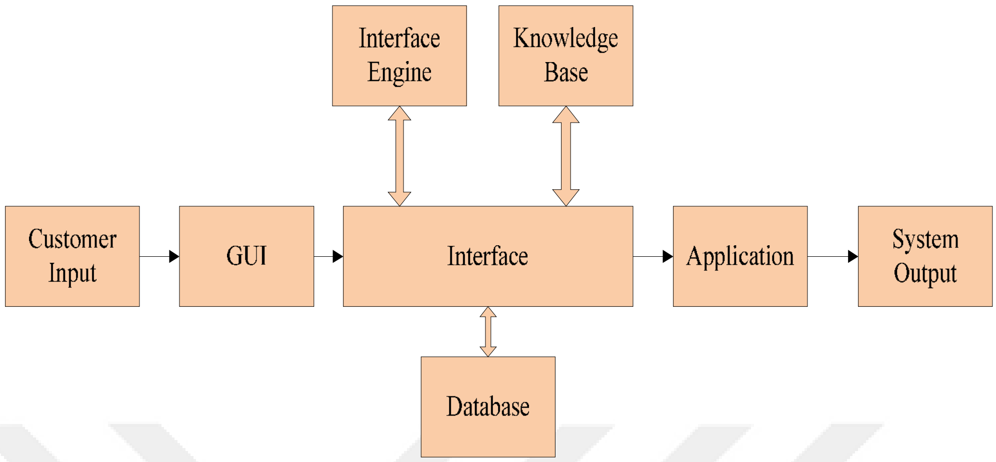


Figure 3.1. Main structure of design process with general section is structured

In this study, Catia V5 CAD design software is used as a programming and design environment. Because, Catia V5 design software combines identification, code writing and learning functions and more. In Catia V5, learning is done through knowledge modules. These modules allow capture, sharing and reuse of design information with very simple expression without requiring programming knowledge.

Visual Basic for Applications (VBA) or Visual Basic (VB) scripts are preferred because of the ability to write user-defined forms in Catia code. Additionally, the VBA software development environment is a license-free environment makes more helpful this program.

Macros can also be created with this program environment. As a definition, a macro is a series of functions written in a scripting language that is grouped in a single command to perform the requested task automatically. Macro window is opened by "Tools-Macro-Macros" command which is shown in Figure 3.2. sequence to write a new macro on Catia and use an existing macro. With this "Run" button in the window you can run an existing macro. You can change this macro with "Edit" button, you can create a new macro with "Create" button.

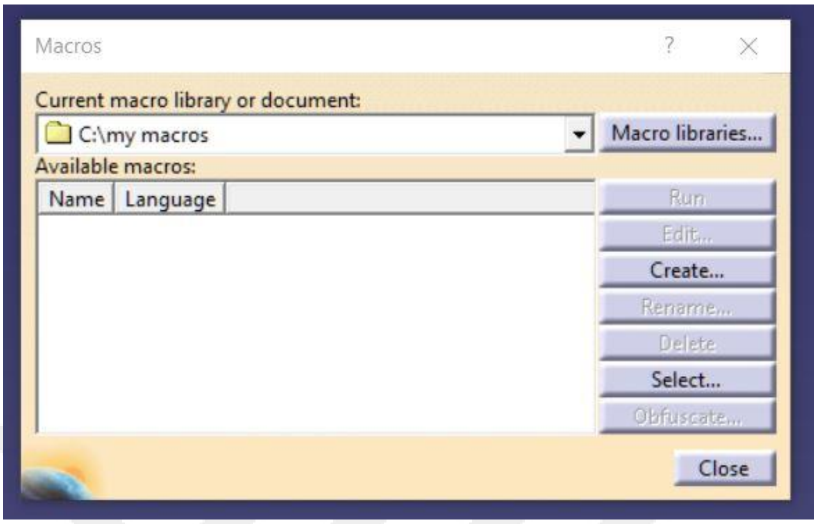


Figure 3.2. Macro libraries window

In application of a Catia macro, macro recorder properties can be used to record your actions which is doing manually just to get an idea of what the code might look like. The process is start with the macro recorder and perform the action, then look at the recorded code to get an idea of what the code looks like, then modify the program so it will work on other parts all the time.

Catia's help documentation includes a list of all features and methods. In addition, this documentation provides detailed information on features and methods. Catia help documentation is a resource that Catia users programming will use as reference documents.

Over time, because of reducing design time and increasing the design efficiency, writing code into the design software will become more important, and the expansions of the software companies in this direction will be further expanded. For this reason, users should develop themselves in this direction (not only in VBA but also in other features of learning software at the same time).

3.4 General Approach of the Trailer System

A trailer is a vehicle that has no power and it is pulled by powered vehicle. Generally, it is used for transportation. Some of them produced for personal, like a business the others which are called as semi-trailers made for cargo transportation.

Another type of truck tractor is used for pulling a semi-trailer that has a special design. The wheel base of the chassis is shorter than the standard truck. They have the engine, transmission system, single or double axel according to the design specification.

A semi-trailer is connected to the tractor with fifth wheel hitch so the most of weight of the trailer is carries by the tractor. Because of this, tractor and semi-trailer are separated from each other. They are having their own design criteria.

3.4.1. Design Principle of The Semi-Trailer Chassis

In generally, according to type of it, a semi -trailer includes frames for making chassis, spring, suspension system, fifth wheel hitch for connection to truck and landing gears. Semi-trailer chassis are similar to the conventional truck chassis. As a different it has more frames and also same cross members and the section which is design for fifth well zone.

In the past, side members and frames of the semi -trailer has a huge height value. This was done for made them straighter. However, these frames are not conventional, because increasing in the height of the members also increasing the center of the gravity of vehicle. This situation causes the overturn the semi-trailer, easily.

In chassis design, cross members and frames are located on placed that the highest stress occurs. The shape of the cross members can be box shape or tabular channel. They are welded to the side members to make the chassis more rigid and strong.

Kingpin and Plate: Semi-trailer is attached to the truck with the fifth-wheel plate which is located at under of front end of the truck chassis. This plate serves as a support between the two vehicles. Semi-trailer is connected to the fifth wheel plate with its king pin. Because of this, semi -trailer pulled by the truck tractor.

Fifth Wheel: For moves of fifth wheel, it has some part in the lower section of fifth wheel to move and assembly of semi-trailer to the tractor. The circular piece of the heavy cast steel plate is the bearing surface that semi-trailer front plate lower part is rides on plate. They are some circular groves on the surface of lower plate. This serves as an oil retainer between the upper and lower plate. Because of lower plate pivoting on a rocker pin diagonally to the truck tractor, this is cause generating a free-swinging movement between truck tractor and semi-trailer.

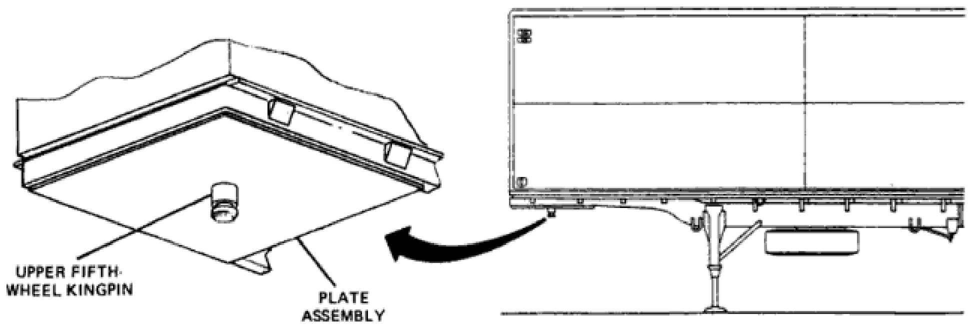


Figure 3.3. Kingpin and plate

Air Suspension Systems: As innovation of the technology, air suspension systems develop as lighter and has more price vying for practical applications. Additionally, air suspension provides increasing the trade-in value of semi-trailers. As the developing of the technological innovations, it is continued to make air suspensions systems as standard add-ons. Air suspension systems can change their spring rate to balance the load which it’s carried. Because of this, air suspension systems have some benefits that spring suspension systems cannot provide.

Figure 3.4. Air suspension system for semi-trailer

Frame bracket: It is represented as hangers, towers or support boxes. The axles are connected to the semi-trailer with frame brackets.

Air Spring: Sometimes it is called as air bag. İt is hold a certain volume of air to support the semi-trailer.

Bead Plate: Bead plates are using for mounting the air springs to the semi-trailers.

These parts which are listed and explaining in the above are main parts of the semi-trailer vehicles. These parts are connected to the running part and connect to the load.

3.4.2. Highway Guidelines for Heavy Duty Truck in Turkey

The regulations according to the 128. clause in Turkish highway traffic guidelines for vehicle (loaded or unloaded) dimensions and permitted vehicles loads (aiming at protecting the roads from damages due over loads) are shown in the list below:

The dimension and weight of the vehicles;

- Maximum width: 2.55 meter
- For the fligoric vehicles only the fligoric width: 2.60 meter
- Maximum height: 4.00 meter
- For the semi-trailer: 16.50 meter

1-Single axle maximum;

- For the non-driven axle: 10 tone,
- For the drive axle: 11.5 tone

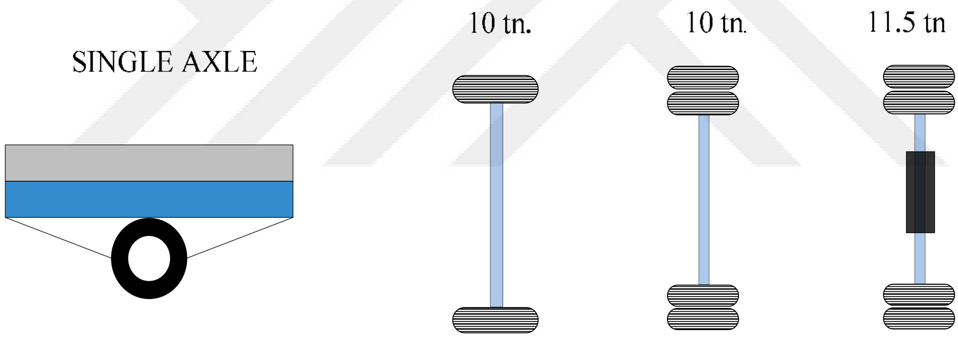


Figure 3.5. Maximum weight for single axle

2-Maximums for a vehicle of two-axle group;

Axle group weight for the vehicle which has the motors;

- If the gap between the axles are less than 1 meter (1m <d): 11,5 tone,
- If the gap between the axles are between 1 and 1.3 meters (1m ≤ d < 1.3m) :16 tone,
- If the gap between the axles are between 1 and 1.3 meters (1.3 ≤ d < 1.8m) :18 tone,

- If the gap between the axles are between 1 and 1.3 meters according to the condition in TOY (1.3 ≤ d <1.8m) :19 tone,

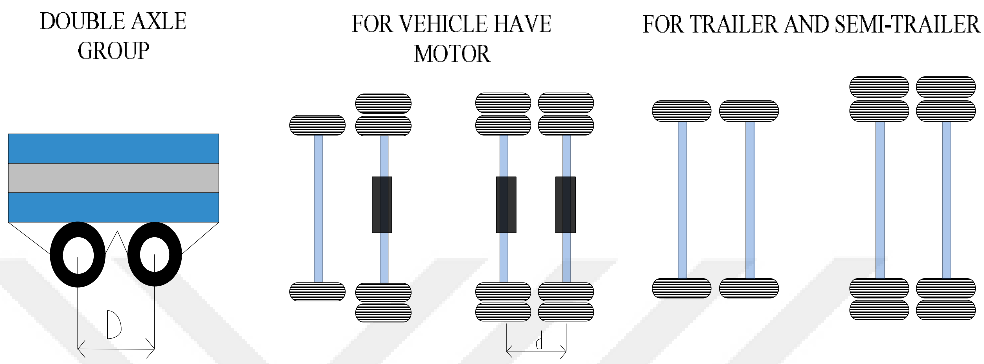


Figure 3.6. Maximum weight for double axle

For the trailers and semi-trailers maximum axle group weights are;

- If the gap between the axles are less than 1 meter (1m <d): 11 tone,
- If the gap between the axles are between 1 and 1.3 meters (1m ≤ d < 1.3m) :16 tone,
- If the gap between the axles are between 1 and 1.3 meters (1.3 ≤ d < 1.8m) :18 tone,
- If the gap between the axles are bigger than 1.3 meters (1.8 ≤ d) :20 tone,

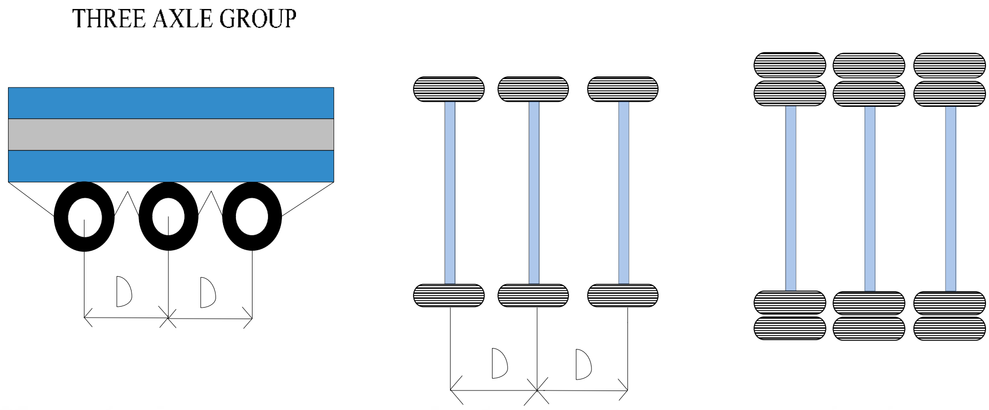


Figure 3.7. Maximum weight for three axles

3-Maximum for a vehicle of three-axle group;

- If the gap between the axles are less than 1 meter (d≤1,3): 21 tone,
- If the gap between the axles are between 1.3 and 1.4 meters (1.3m ≤ d < 1.4m) :24 tone

Maximum weights are;

- Motor vehicle and trailers with two axles: 18 tone,
- Motor vehicle with three axles 25 tone,
- Motor vehicle with three axles according to the TOY condition 26 tone,
- Semi-trailer with three axle and articulated bus: 28 tone,
- Motor vehicle four axle 32 tone,
- Semi-trailer with four axles 36 tone,
- Semi-trailer with four axles, Semi-trailer for axle group weight 20 ton :38 tone,
- Semi-trailer or trailer with five or more than five axles :40 tone,
- For container carrier semi-trailers (with ISO container 3- S 2/3) :44 tone.

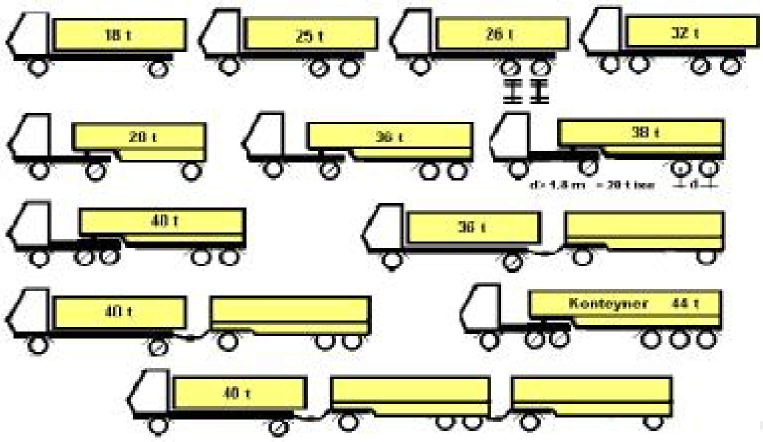


Figure 3.8. Maximum weight for semi-trailer

The vast majority of international loads are carried in standard size boxes. Container carrier semi-trailer which is shown in Figure 3.9. is used for carrying these different size containers. In general, these containers are called 40, 30, 30 ft. That can be arranged with twist locks (4/8/12 locks). In the design of the container carrier chassis the highway regulations for the placement of the lock centers are taken as reference parameters.

Figure 3.9. Picture of the container carrier semi-trailer

Twist lock is the name of the mechanical part that connect the container to the chassis of the semi-trailer. According to regulation of manufacture, modification and assembly of vehicles; the placement of the twist lock centers is shown in the Figure 3.10.

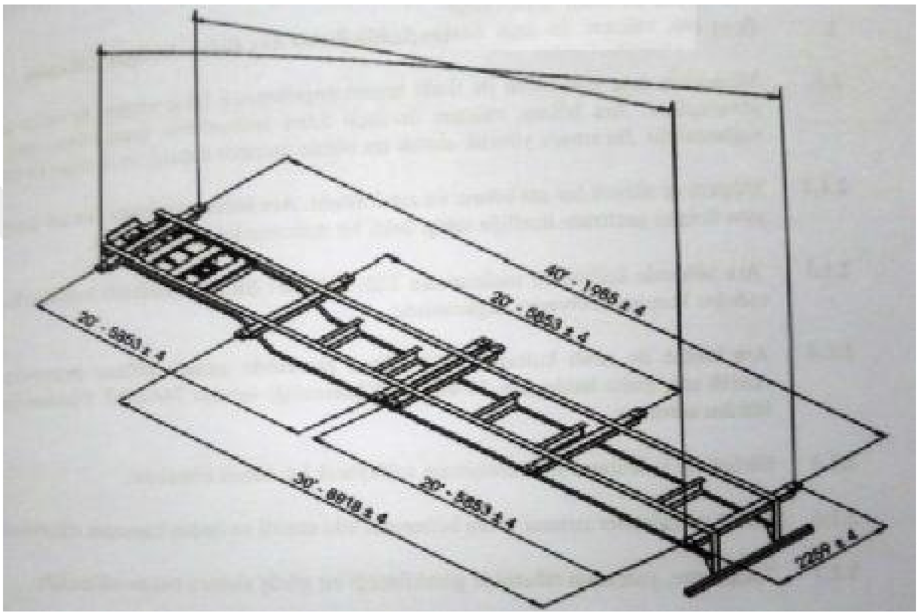


Figure 3.10. The placement of the twist lock centers

3.4.3. Project Calculation for Semi-Trailers

For balanced load distribution the conditions at the below equations;

$$P_{\dot{I}} + P_N < P_K \tag{3.1}$$

And

$$R_{\dot{I}} + R_N < R_K \tag{3.2}$$

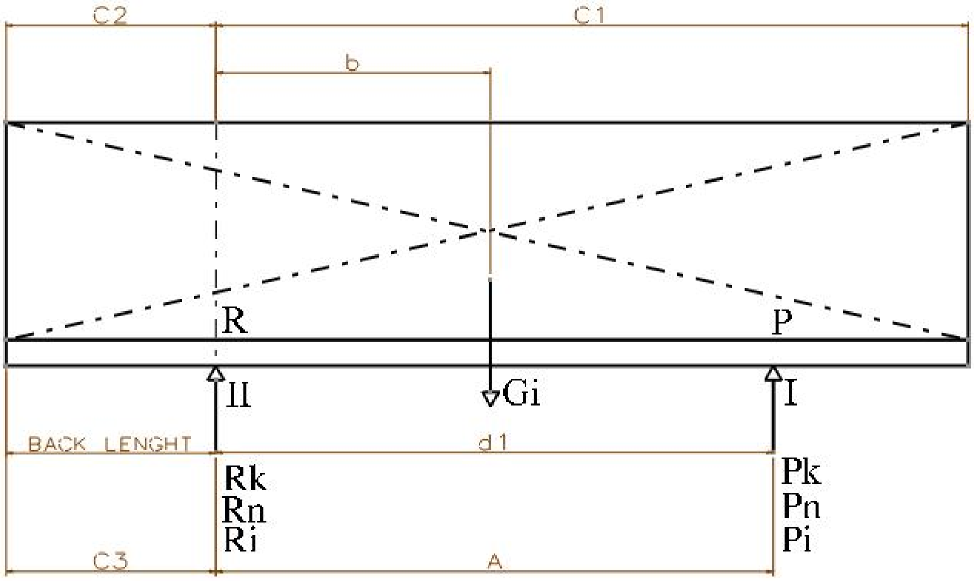


Figure 3.11. Project calculation for semi-trailers with one axles

King pin load according to the selected load mass;

$$P_i = \frac{G_i . b}{A} \tag{3.3}$$

Calculated maximum kingpin load;

$$P = P_i + P_N \tag{3.4}$$

Axle load according to the selected load mass;

$$R_i = G_i \frac{A - b}{A} \tag{3.5}$$

Calculated maximum axle load;

$$R = R_i + R_N \tag{3.6}$$

For verifying the calculations;

If $R \leq K$ and $P \leq P_K$ the load distribution is available.

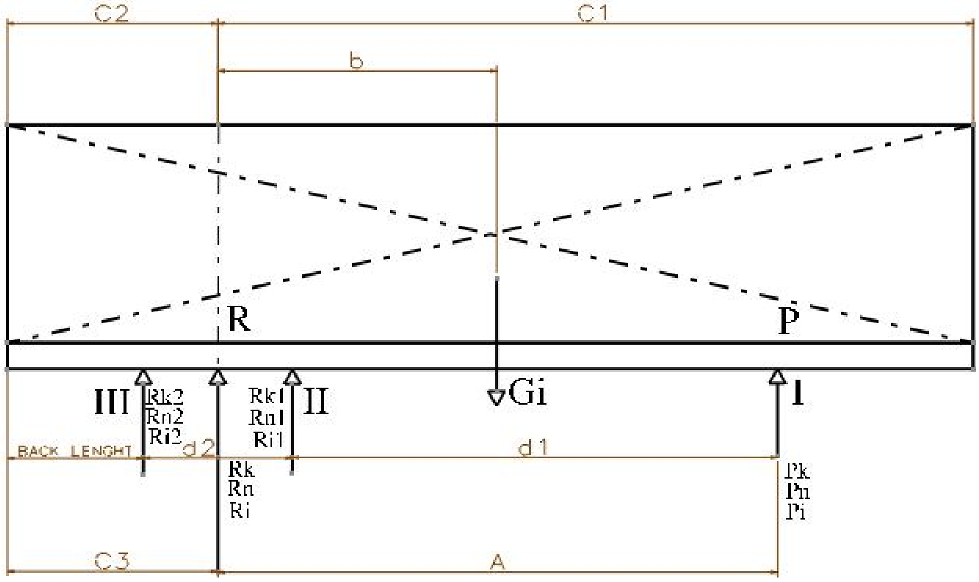


Figure 3.12. Project calculation for semi-trailers with two axles

Kingpin load according to the selected load mass;

$$P_i = \frac{G_i * b}{A} \tag{3.7}$$

Calculated maximum kingpin load;

$$P = P_i + P_N \tag{3.8}$$

Axle load according to the selected load mass;

$$R_i = G_i \frac{A - b}{A} \tag{3.9}$$

Calculated maximum axle load;

$$R = R_i + R_N \tag{3.10}$$

For verifying the calculations;

If $R \leq K$ and $P \leq P_K$ the load distribution is available.

For the back-axle group load distribution

$$P = GN1 + Pi \tag{3.11}$$

$$R1 = GN2 + Ri1 \tag{3.12}$$

$$R2 = GN3 + Ri2 \tag{3.13}$$

For verifying the calculations

$P < I$, $R1 < II$, $R2 < III$, the load distribution is available

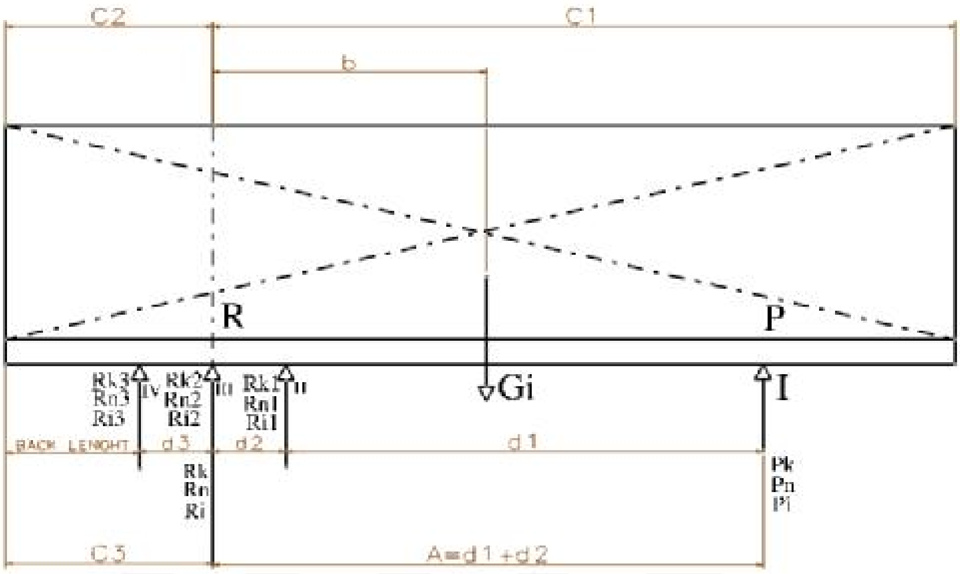


Figure 3.13. Project calculation for semi-trailers with three axles

Kingpin load according to the selected load mass;

$$P_i = \frac{G_i * b}{A} \tag{3.14}$$

Calculated maximum kingpin load;

$$P = P_i + P_N \tag{3.15}$$

Axle load according to the selected load mass;

$$R_i = G_i \frac{A - b}{A} \tag{3.16}$$

Calculated maximum axle load;

$$R = R_l + R_N \tag{3.17}$$

For verifying the calculations;

If $R \leq K$ and $P \leq P_K$ the load distribution is available.

For the back-axle group load distribution

$$P = GN1 + Pi \tag{3.18}$$

$$R1 = GN2 + Ri1 \tag{3.19}$$

$$R2 = GN3 + Ri2 \tag{3.20}$$

$$R3 = GN4 + Ri3 \tag{3.21}$$

For verifying the calculations;

$P < I$, $R1 < II$, $R2 < III$, and $R3 < IV$ the load distribution is available.

3.5. Flow Chart Diagram

In the beginning of this study, design requirement of this study is investigated. The aspects that make this study useful are researched. Then, the model which is used for parametric modelling was determined. In addition, literature studies about parametric modelling were investigated. Then, solid modelling program which is used for parametric design is found. During this, the listed software program in Figure 3.13 are examined separately. It is continued to parametric design modelling with Catia solid program.

After making decision for the solid program, design criteria are specified for making design. For this, VBA properties of the Catia is investigated for creating macros in program. Then design parameters for creating chassis were approached. For making value of the design parameters changeable a user interface was created by using user form properties of VBA language in Catia.

In finally, solid models of the chassis were completed parametrically using the Catia program. Then, completing the static and dynamic analysis automatically for the chassis were performed. In following Figure 3.14. flow chart diagram of this study is shown.

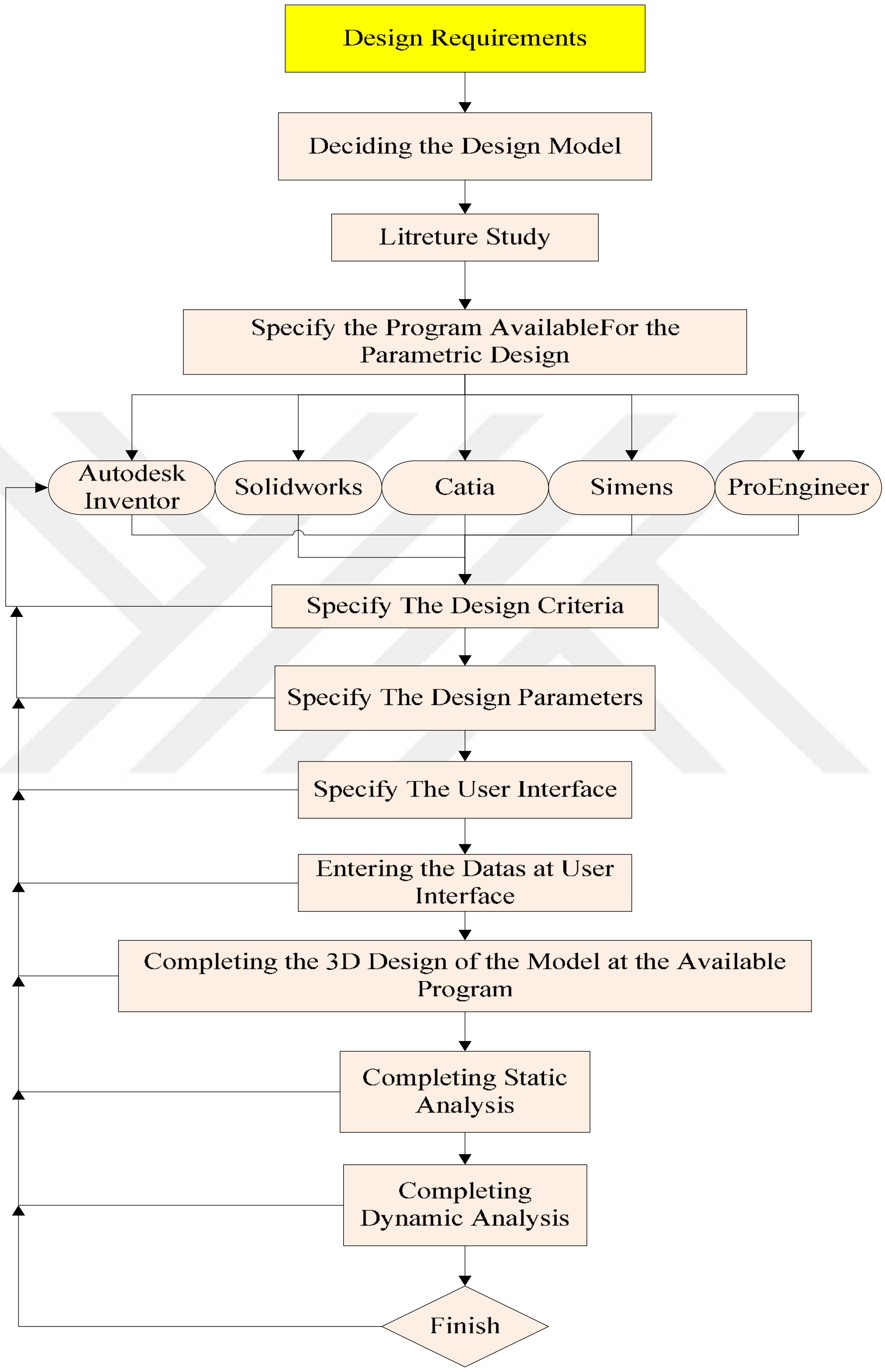


Figure 3.14. Flow chart diagram

4. RESULTS AND DISCUSSION

4.1. Design of the Semi-Trailer Chassis in the Catia V5

In generally, semi-trailer chassis is done by bringing together two of longitudinal carriers. The interconnections are done by folded sheet metal pieces which have the shape of ‘c’, ‘u’. These metal pieces are welded to the longitudinal carriers for bring them together.

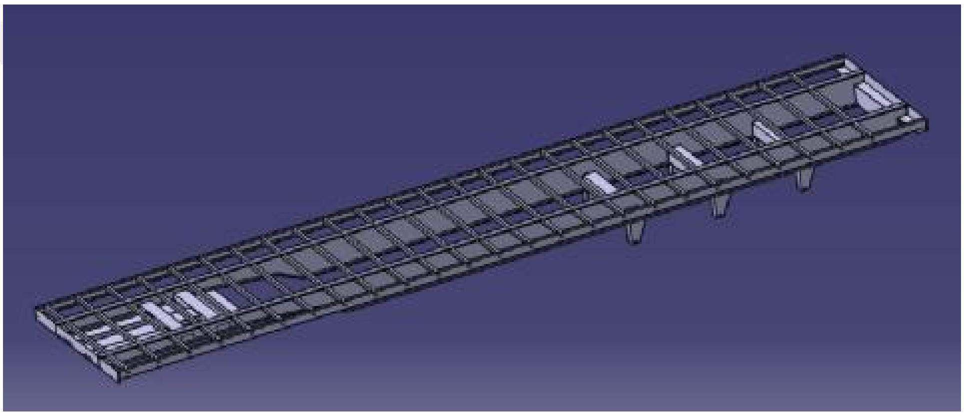


Figure.4.1. Longitudinal carriers and interconnection parts

In this study, two different types of semi-trailer chassis been designed. One of them is a flatbed semi-trailer and the other one is container carrier semi-trailer chassis. Flatbed semi-trailers are using for carrying heavy items such as construction equipment and machinery. On the other hand, container carrying semi-trailers used for transport have a different type of container. These containers are separated according to their lengths.

According to their work space, the semi-trailers can be single wheeled and double wheeled. Depending on this feature, the distance between the longitudinal carriers may vary. The chassis of container carrier semi-trailers are different from the flatbed semi-trailers. The sheet metal plates folded to the shape of ‘u’ that are laid according to regulation of manufacture, modification and montage of vehicles are welded to the longitudinal carriers. Container semi-trailers are named depending on their container sizes like 40 ft., 30ft., 20ft. etc. In the design of the container carrier chassis the highway regulations for the placement of the lock centers are taken as a reference.

The materials that are used for manufacturing the chassis may vary according to their area of application. Generally, in industry Domex700, St52-3, St37-2 steels materials are used. In this study, St52-3 steel is used as the main body material.

Kingpin is the connection element between the vehicle and semi-trailer. For the design of the semi-trailer chassis, the placement of the kingpin and the axle group on the chassis must be calculated. For this calculation, the tonnage values of the kingpin and axle group must be known.

4.2. Parametric Design of the Semi-Trailer Chassis in Catia VBA

For parametric design, the algorithm in Figure 4.2 is used as the basis for the macro-development process. Catia V5 offers very good and flexible solutions for programming with VBA, and in many places the limits are determined by the imagination of the user. For this reason, the algorithm in Figure 4.2 with Catia V5 and is reconstructed as shown in below.

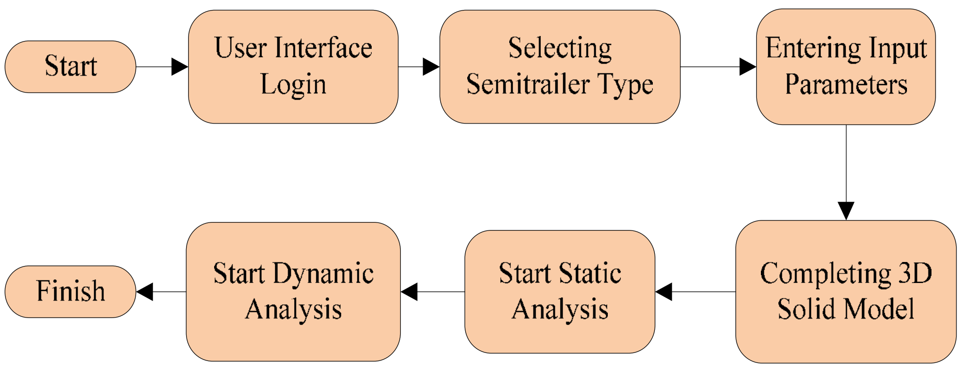


Figure.4.2. Algorithm diagram of chassis parametric design process

In this study, Catia V5 CAD design software was used for the study as a programming and design environment. Catia V5 package is a type of software that combines code identification, code writing and learning functions and more. For parametric design, Visual Basic for Applications (VBA) or Visual Basic (VB) scripts is preferred because of the ability to write user-defined forms in Catia code. The user interface which is done for creating semi-trailer chassis is shown in Figure 4.3.

Figure.4.3. User interface for semitrailer chassis design

4.2.1. Parametric Design of the Flatbed Semi-Trailer Chassis

Flatbed semi-trailers are used for carrying heavy items such as construction equipment and machinery. Semi-trailer chassis are manufactured by bringing together of two longitudinal carriers. The interconnections are done by folded sheet metal pieces which have the shape of ‘c’, ‘u’. These metal pieces are welded to the longitudinal carriers for bring them together

The parameters that are used during the design stages are;

1) ***Length of the Chassis:*** it is the dimension from the front of the semi-trailer chassis to the back side of it.
2) ***Max. Load Capacity of the Kingpin:*** it is the load that is carried by the kingpin and it is specified by the manufacturer of the kingpin.
3) ***Max. Load Capacity of the Axle Group:*** it is the load that is carried by the axle group and it is specified by the manufacturer of the axle.
4) ***Max. Load Capacity of the Semi-trailer:*** it is the load that is carried by the semi-trailer and it is specified by the manufacturer of the semi-trailer.

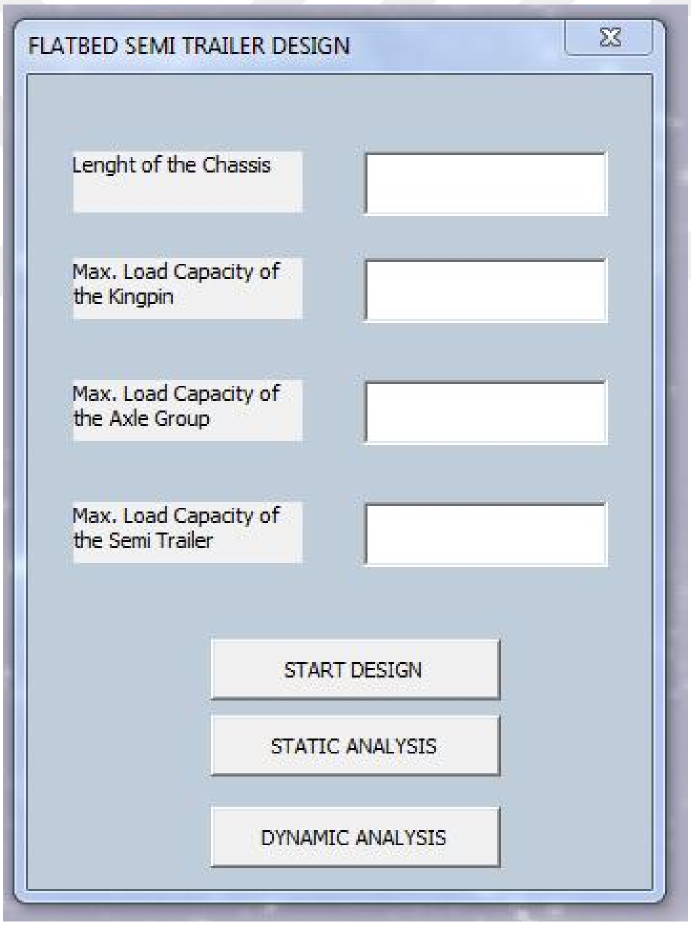


Figure.4.4. User interface for flatbed semi-trailer chassis design

When parameters are entered in the user interface, the chassis is designed by making appropriate calculations. For this, first the intermediate traverses are reordered depending on the size of the chassis. Then load distribution is calculated by using other parameters. With this calculation, the center of the axle is located, and the design of the chassis is completed. After completion of the design, the static analysis is performed to the trailer chassis developed.

As a model for static analysis, the frame is fixed by holding it from the 5th wheel zone on the front side of the road-contacting chassis and the suspension zone on the rear side where the tires and axles are connected since the frame is subjected to vertical loads. The semi-trailer case boundary conditions are defined in the chassis connection points of the hanger brackets in the chassis of the semi-trailer chassis and also in the chassis connection points of the air suspension bridge and in the kingpin area. In accordance with these boundary conditions, the evenly distributed load on the vehicle is analyzed.

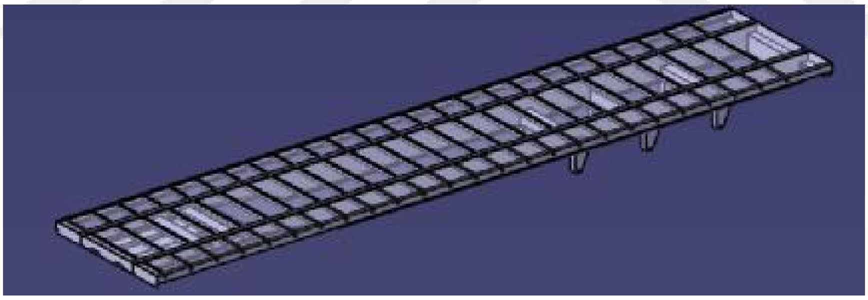


Figure.4.5. Flatbed semi-trailer chassis

4.2.2. Parametric Design of the Container Carrier Semi-Trailer Chassis

In the design of the container carrier chassis the highway regulations for the placement of the lock centers are taken as a reference. Flatbed semi-trailers are used for carrying heavy items such as construction equipment and machinery. For the other hand, container carrying semi-trailers are used for carrying a different type of container. Containers are separated according to their lengths.

The parameters that are used during the design stages are;

1) ***Length of the Container:*** it is the dimension of the container from the front and back side of it.
2) ***Max. Load Capacity of the Kingpin:*** it is the load that is carried by the kingpin and it is specified by the manufacturer of the kingpin.
3) ***Max. Load Capacity of the Axle Group:*** it is the load that is carried by the axle group and it is specified by the manufacturer of the axle.
4) ***Max. Load Capacity of the Semi-trailer:*** it is the load that is carried by the semi-trailer and it is specified by the manufacturer of the semi-trailer.

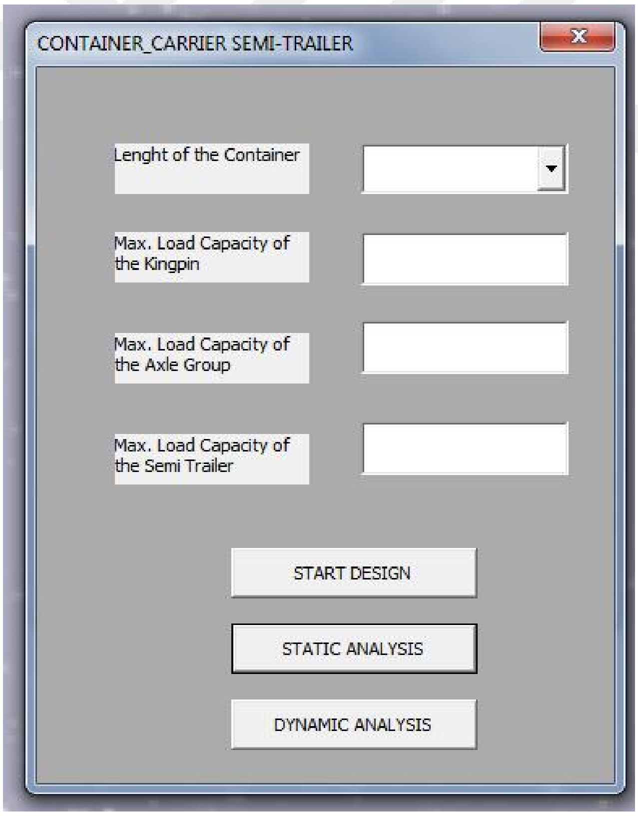


Figure.4.6. User interface for a container carrier semi-trailer chassis design

Process of creating container carrier is similar with the flatbed semi-trailer processing. When parameters are entered in the user interface, the chassis is designed by making appropriate calculations. For this, first the intermediate traverses are reordered depending on the size of the chassis. Then, the load distribution is calculated by using other parameters. With this calculation, the center of the axle is located, container lock centers are
rearranged and the design of the chassis is completed. After completion of the design, the static analysis is performed on developed chassis model.

For the static analysis model, the frame is fixed by holding it from the 5th wheel zone on the front side of the road-contacting chassis and the suspension zone on the rear side where the tires and axles are connected since the frame is subjected to vertical loads. The semi-trailer case boundary conditions are defined in the chassis connection points of the hanger brackets, in the chassis of the semi-trailer chassis, in the chassis connection points of the air suspension bridge and in the kingpin area. In accordance with these boundary conditions, the evenly distributed load on the vehicle is analyzed.

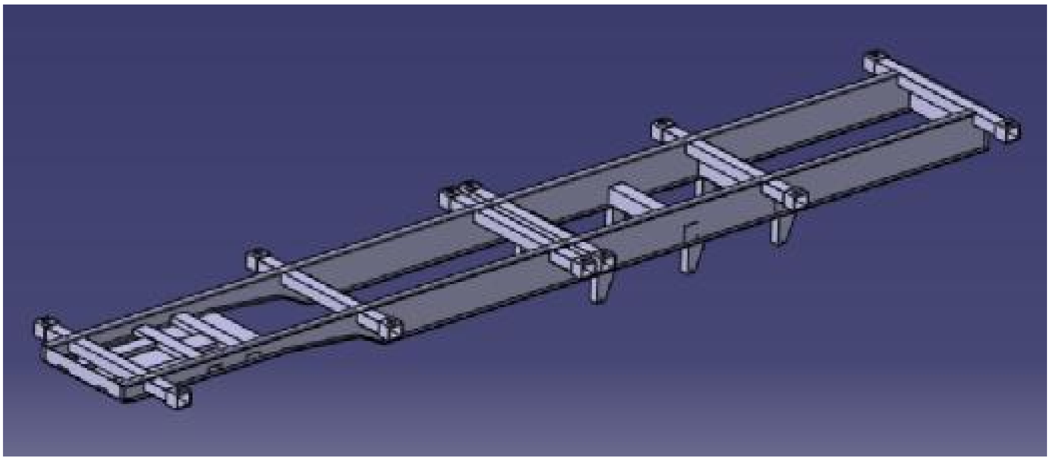


Figure.4.7. Container carrier semi-trailer chassis

4.3. Finite Element Analysis Automation for Semi-Trailer Chassis

The finite element analysis (FEA) is becoming increasingly popular among design engineers using it as one of many product design tools. It has been used for the solution of many types of problems. Competition in the market puts tremendous pressure on the corporations to launch reasonably priced products in short time. This situation making them to rely more on virtual tools (CAD/CAE) accelerate the design and development of products. FEA is used to predict multiple types of static and dynamic structural responses. For example, companies in the automotive industry use it to predict, stress, strain, deformations and failure of many different types of components. FEA reduces the need for costly experiments and allows engineers to optimize parts before they are built and implemented.

With macro recording tasks that below are captured for static and dynamic analysis.

- Create studies
- Define study properties (static studies)
- Apply material
- Apply loads and boundary conditions
- Create mesh and mesh control
- Run study

The presented study offers a better and incredibly faster design approach for development of semi-trailer chassis designs.

4.3.1. Static Analysis of Semi-Trailer Chassis

The purpose of this work is to determine the stresses and deformations that occur while the vehicle is in static condition with the help of the designed command in the user interface. For the calculation of the load distribution the regulation according to highway guidelines was taken as a reference.

For generating static analysis, the frame is fixed at fifth wheel zone and suspension zone. The boundary conditions are defined in points that frame bracket, bead plate and king pin connection area. According to these boundary conditions, the load is distributed and analyzed. The maximum load quantities are also indicated in the Figure 3.8. The maximum load capacity that semi-trailer or trailer with five or more than five axles 40 tone. For container carrier semi-trailers (with ISO container 3- S 2/3) maximum load capacity is 44 tones. The design is based on these maximum capacity values of the chassis.

During the process of creating a model for static analysis, the frame of the model is fixed to the roadside as it is subjected to vertical loads during this study. The boundary conditions of the semi-trailer are defined at the connection points of the hanger brackets seen in the solid model of the semi-trailer frame, air suspension bellows flange to the connection points of the chassis and kingpin area. In accordance with the boundary conditions, the distributed load on the vehicle is analyzed with the designed software.

The location of maximum Von Mises stress are located at corner of side bar, which is the kingpin is located. Results are shown in Figure 4.8 and Figure 4.9. The Von Misses stress magnitude of critical points are 66,7146 MPa for the flatbed semi-trailer chassis and 26,2142 MPa for the container carrier semi-trailer chassis.

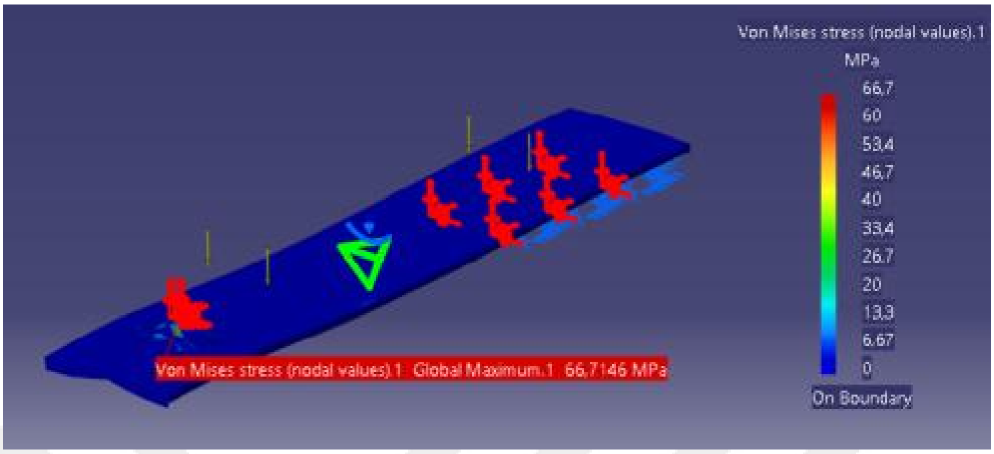


Figure.4.8. Static analysis result of flatbed semi-trailer chassis

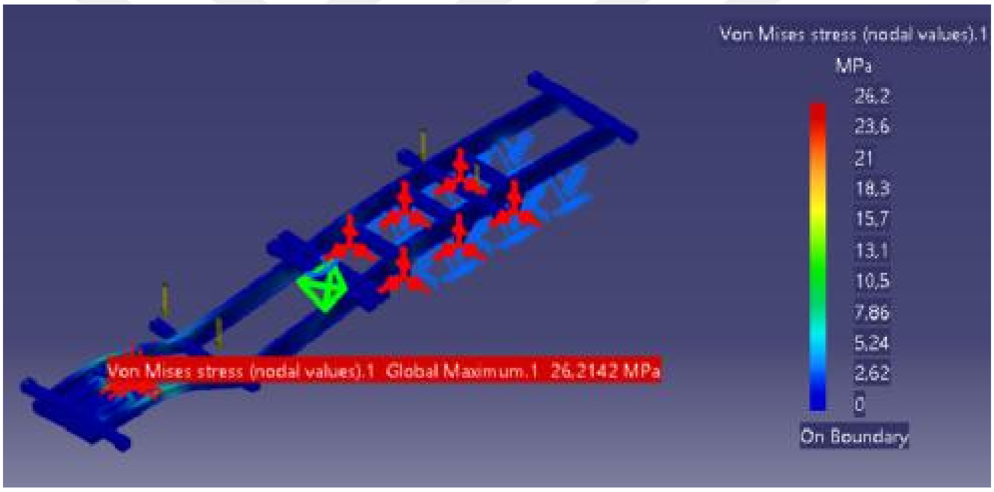


Figure.4.9. Static analysis result of container carrier semi-trailer chassis

4.3.2. Dynamic Analysis of Semi-Trailer Chassis

Today, one of the largest users of the modal analysis technology are automotive industry. The modal behavior of the semi-trailer chassis is part of the information needed to examine the chassis dynamic behavior. In this article, the modal analysis of the semi-trailer chassis is examined.

As a vehicle travels along the road, its chassis is affected by dynamic forces generated by the road roughness. Because of this acting force, vehicle chassis tends to vibrate. If the value of the vibration of the structure matches with the frequency value of the external excitation, resonance occurs. This situation causes failure and excessive deflections of the chassis.

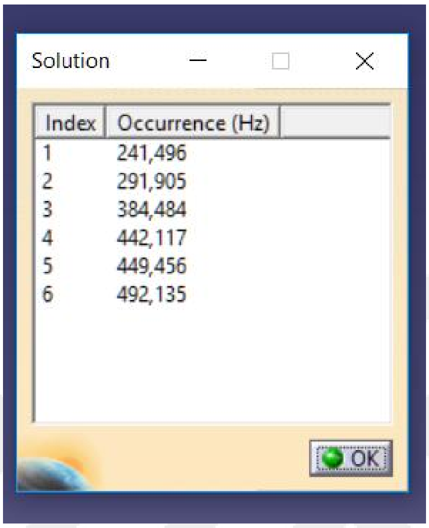
The semi-trailer is always affected by the road surface during driving. Because of this is necessary to generate modal analysis for the optimization and development of the chassis for the bad road condition. For providing safe driving, it is important that determining the natural frequency value of the chassis.

From the natural frequencies obtained by modal analysis, the harmonic analysis determines which vibration modes contribute more significantly to the dynamic response of the structure through frequency response curves. Harmonic analysis is done to identify the von misses stresses for which the chassis frame at that natural frequency where maximum deformations are developed in chassis frame.

Poisson’s Ratio, Young’s Modulus and mass density properties are the required input parameters for harmonic analysis. The other material properties may be specified but they are not used in harmonic analysis calculation.

Since the modal solution is the building block of the next dynamic analysis, it is needed to make sure that enough modes are set. Enough modes should be calculated to include at least a natural frequency that is at least twice the maximum operating frequency. For example, if the input frequency is between zero and 60 hertz, there should be enough modes to include 120 hertz at the natural frequency list. In this study, this analysis is carried in the frequency range of 50 Hz to 1000Hz at solution interval of 500Hz and vibration at different location is measured in terms of amplitude.

The result indicated in the below figures (Figure 4.10, Figure 4.11, Figure 4.12) are useful dynamic analysis solution seen as a result. For the flatbed semi-trailer chassis, natural frequency values, harmonic response analysis and frequency response plots are shown in figures. The boundary conditions for modal analysis are the same as the boundary conditions for static analysis. The results have been calculated for the first 6 modes frequencies.


Solution

Index	Occurrence (Hz)
1	241,496
2	291,905
3	384,484
4	442,117
5	449,456
6	492,135

OK

Figure.4.10. Natural frequency values obtained from nodal analysis for flatbed semi-trailer chassis

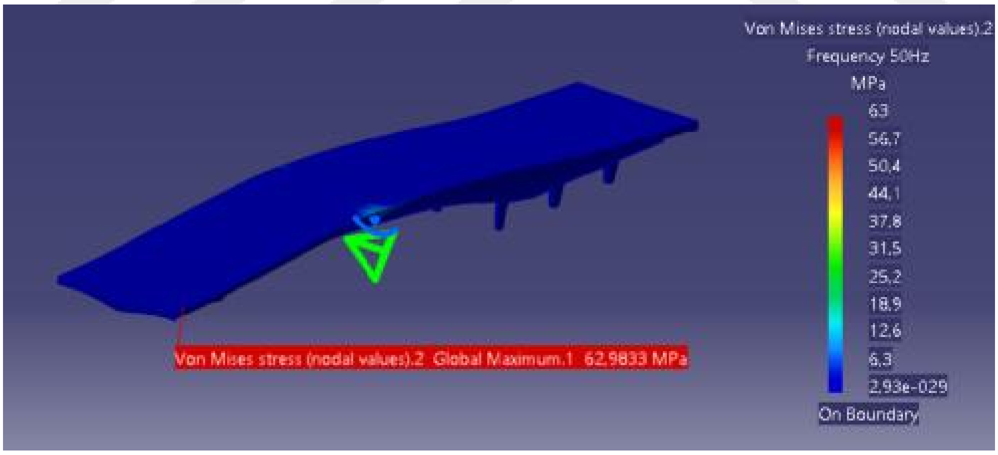


Figure.4.11. Dynamic harmonic analysis results of flatbed semi-trailer chassis

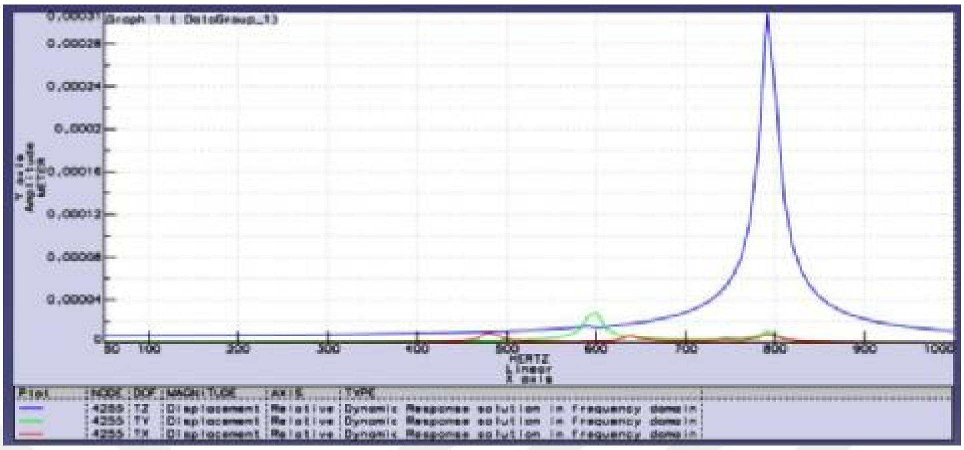


Figure.4.12. Displacement results plot for flatbed semi-trailer chassis

For the container carrier semi-trailer chassis, the same solution can be obtained. The results are shown in Figure 4.11, Figure 4.12 and Figure 4.13.

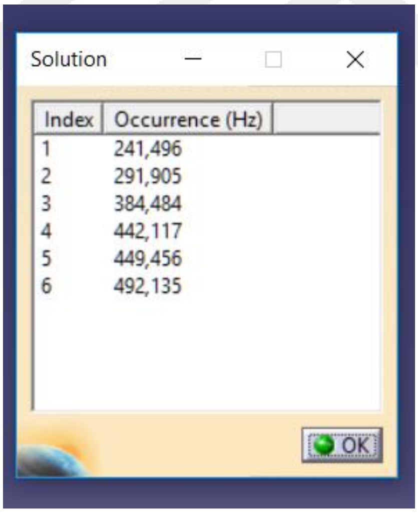


Figure.4.13. Natural frequency values obtained from nodal analysis for container carrier semi-trailer chassis

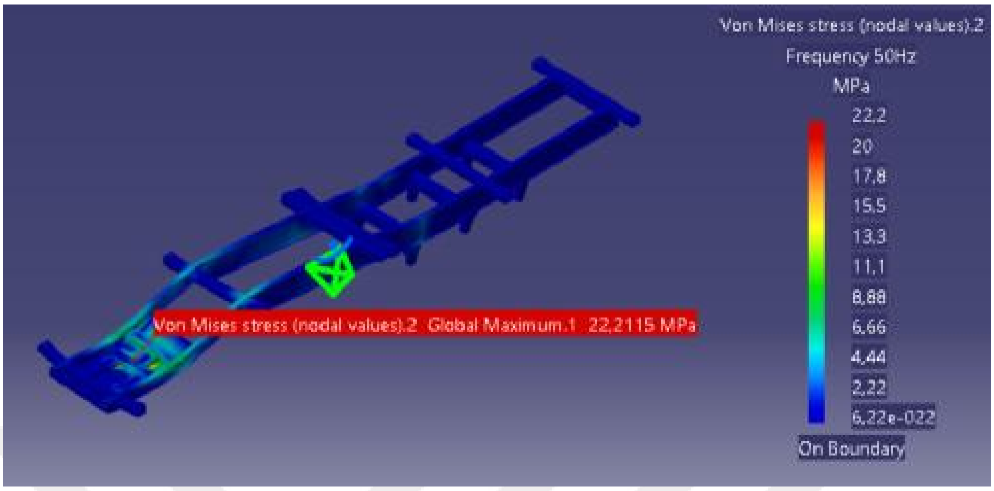


Figure.4.14. Dynamic harmonic analysis results of container carrier semi-trailer chassis

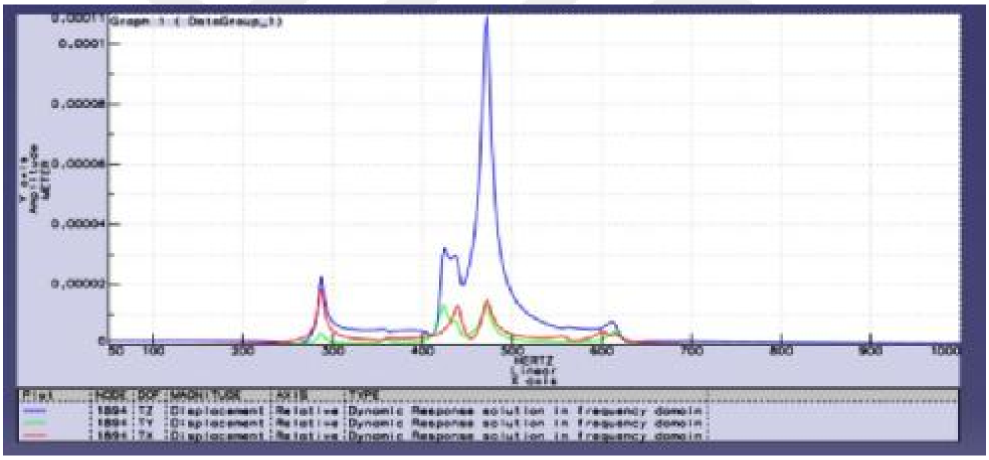


Figure.4.15. Displacement results plot for container carrier semi-trailer chassis

5. CONCLUSION

For automotive industry, the presented approach allows the implementation of an integrated vehicle model development with the aim of improving the conceptual design based automotive systems development. Modern parametric CAD programs are particularly well suited to this process by allowing the designer to gradually refine and improve the design shape without having to start over for each revision.

The main purpose of the presented work is to create a user interface module to allow designing the semi-trailer chassis by using a suitable CAD program. For this purpose, parametric modelling technique is introduced and used in design of two different types of vehicle chassis development. It is wanted the model them manually, it takes about one week for completing the design. This study provides a better and incredibly faster approach for development of semi-trailer chassis designs by decreasing the design time from weeks to seconds.

With the benefit of achieving the design in a fraction of conventional design time, the parametric modelling technique gives a clearer feel for what the final product will look like. Besides, the overall look as well as design details can be observed. Because the parametric design process requires only a few seconds, varying design parameters and repeating the design process and related analysis works make is easier to test various semi-trailer models requested by the customer. This allows development of several different chassis geometries rapidly. This not only reduces the design time but also pleases the customer as it does not take weeks to price a product.

Briefly, the presented study offers a better and incredibly faster design approach for development of semi-trailer chassis designs. With the possible integration of the developed design software to manufacturing process, it may allow considerable reduction in product design, development and manufacturing time.

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CURRICULUM VITAE

Özge Fırtana was born in Adana on August 19, 1991. She graduated from Adana Borsa High School in 2009. Then, she started her BSc. degree in 2009 at Çukurova University, Mechanical Engineering Department. She started her MSc study in the same department of Çukurova University in 2015. She has been working as a project engineer in Ceytech Makina A.Ş. since 2015.

APPENDIX

Appendix A

Examples of Parametric Designs with Relevant Details

In the examples given, the semi-trailer chassis were examined separately. Different design parameters were used during examination. The design results and static dynamic analysis solutions are given separately. Both flatbed semi-trailer and container carrier semi-trailer chassis are investigated separately by giving twelve examples. These examples are listed following section.

Examples of Parametric Design of Flatbed Semi-Trailer

For the given parametric values given at the below the results are indicated in the figures.

Length of the Chassis: 12000mm

Max. Load Capacity of the Kingpin: 11500kg

Max. Load Capacity of the Axle Group: 24000kg

Max. Load Capacity of the Semitrailer: 35500kg

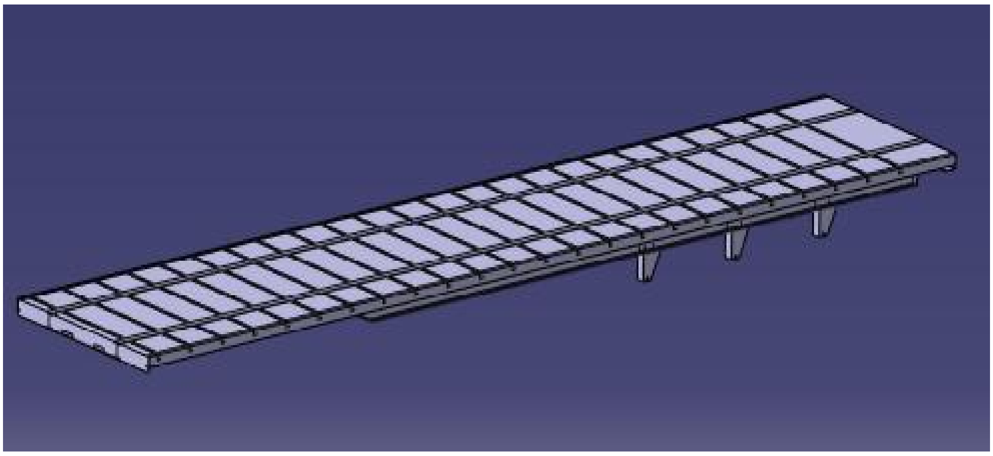


Figure A.1. Flatbed semi-trailer chassis

The location of maximum Von Mises stress are located at corner of side bar, which is the kingpin is located. Results are shown in Figure A.2. The Von Misses stress magnitude of critical points are 57,6289 MPa for the flatbed semi-trailer chassis. The results indicated in the below figures (Figure A.3, Figure A.4, Figure A.5) are dynamic analysis solutions.

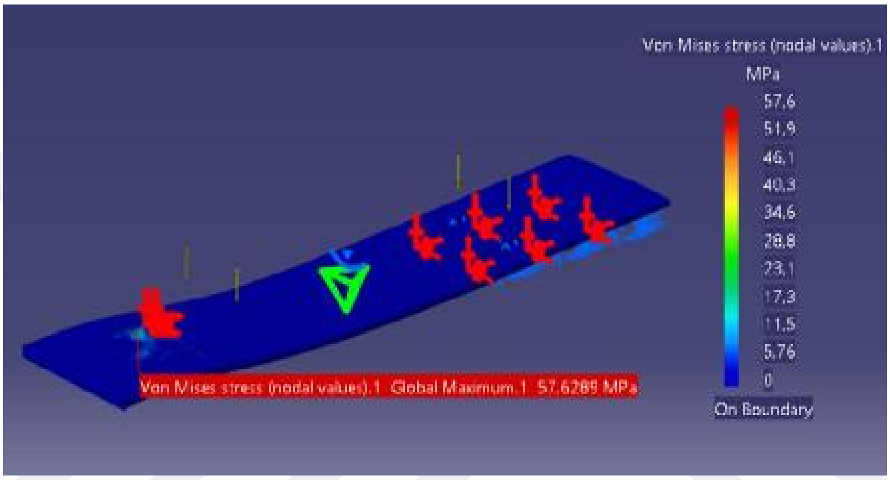


Figure A.2. Static analysis result of flatbed semi-trailer chassis

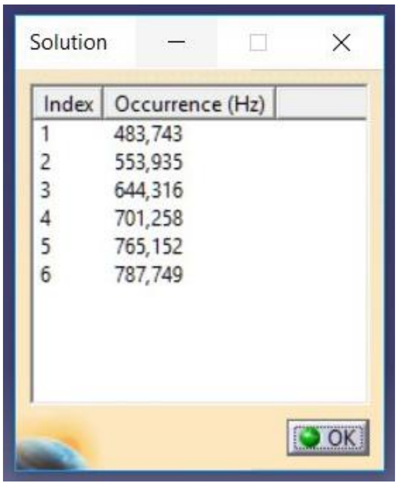


Figure A.3. Natural frequency values obtained from nodal analysis for flatbed semi-trailer chassis

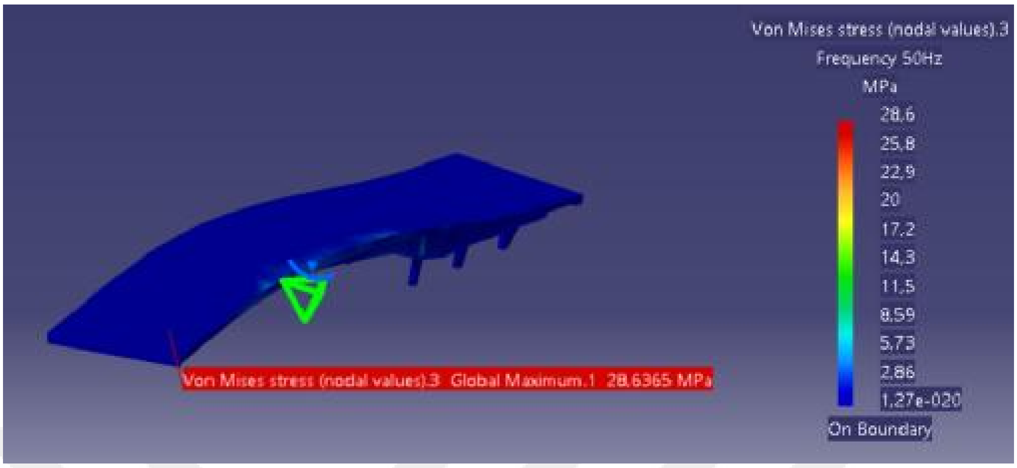


Figure A.4. Dynamic harmonic analysis results of flatbed semi-trailer chassis

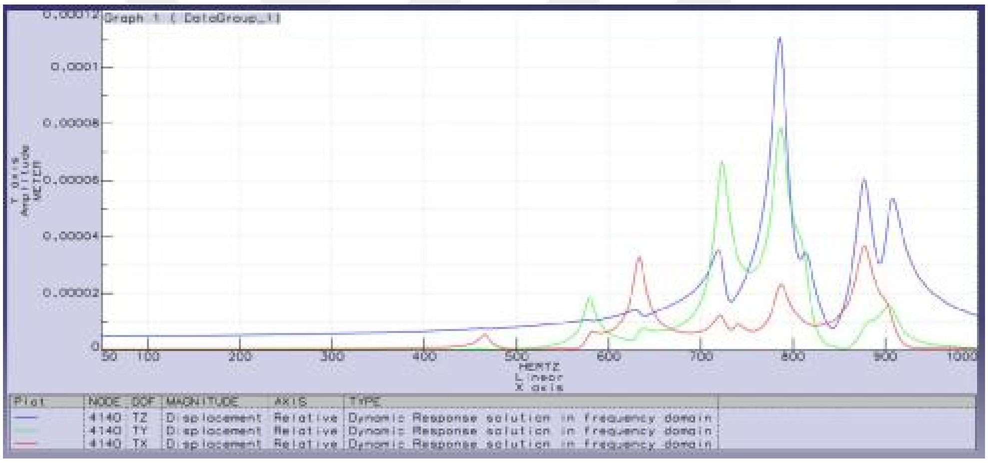


Figure A.5 Frequency response plot for flatbed semi-trailer chassis

For the given parametric values given at the below the results are indicated in the figures.

Length of the Chassis: 13000

Max. Load Capacity of the Kingpin: 11500

Max. Load Capacity of the Axle Group: 24000

Max. Load Capacity of the Semitrailer: 35500

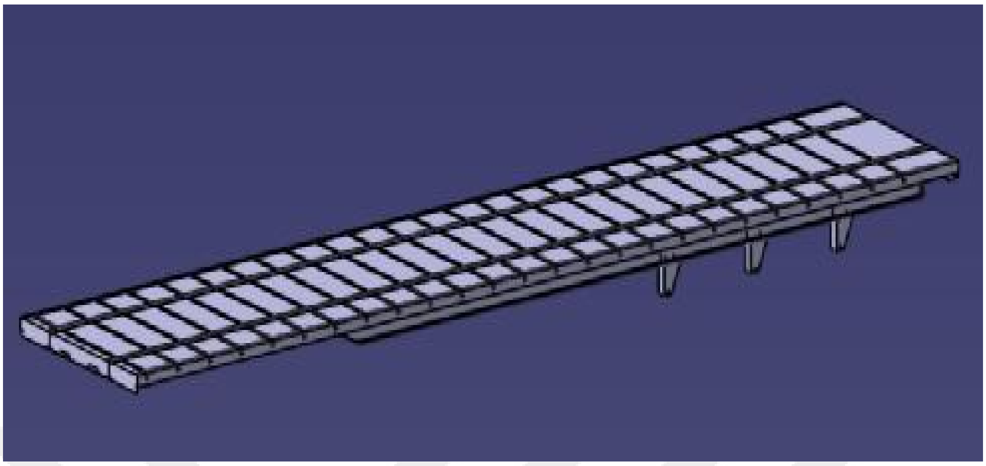


Figure A.6. Flatbed semi-trailer chassis

The location of maximum Von Mises stress are located at corner of side bar, which is the kingpin is located. Results are shown in Figure A.7. The Von Misses stress magnitude of critical points are 57,3537 MPa for the flatbed semi-trailer chassis. The result indicated in the below figures (Figure A.8, Figure A.9, Figure A.10) are dynamic analysis solution.

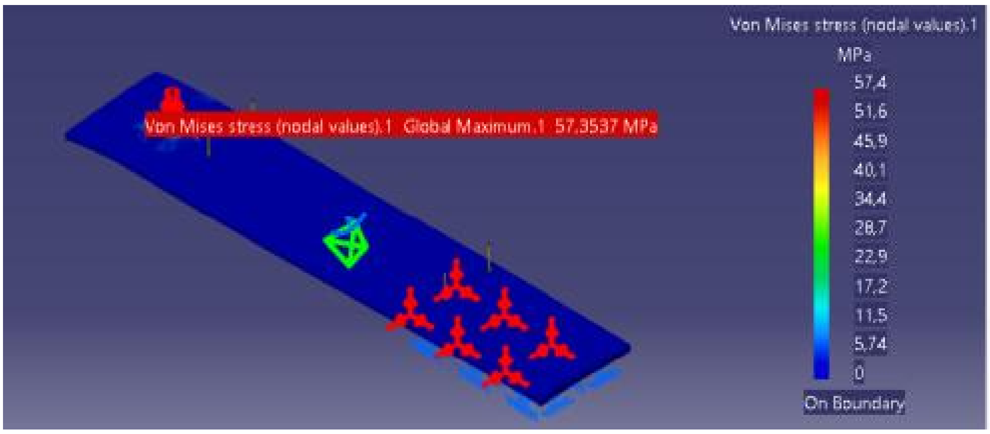


Figure A.7. Static analysis result of flatbed semi-trailer chassis

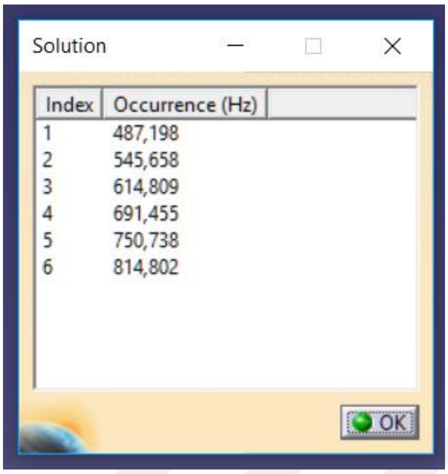


Figure A.8. Natural frequency values obtained from nodal analysis for flatbed semi-trailer chassis

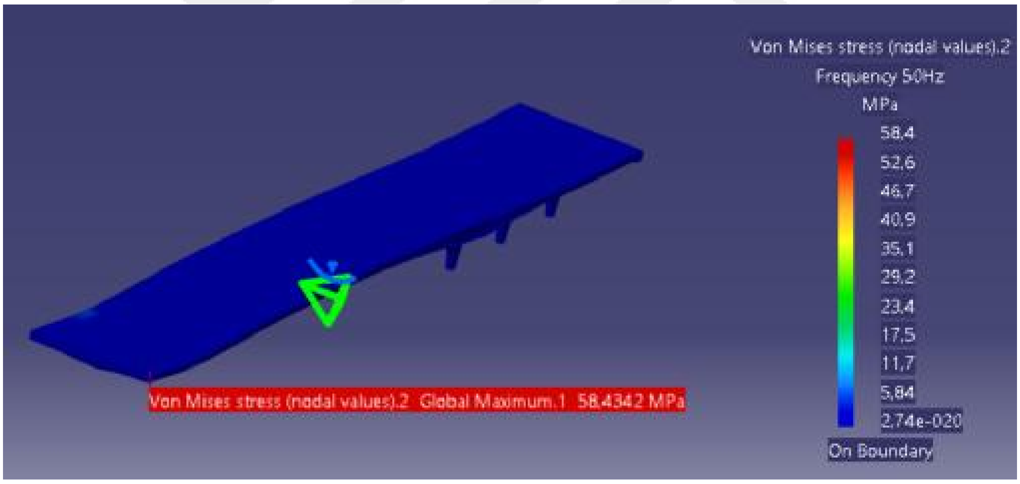


Figure A.9. Dynamic harmonic analysis results of flatbed semi-trailer chassis

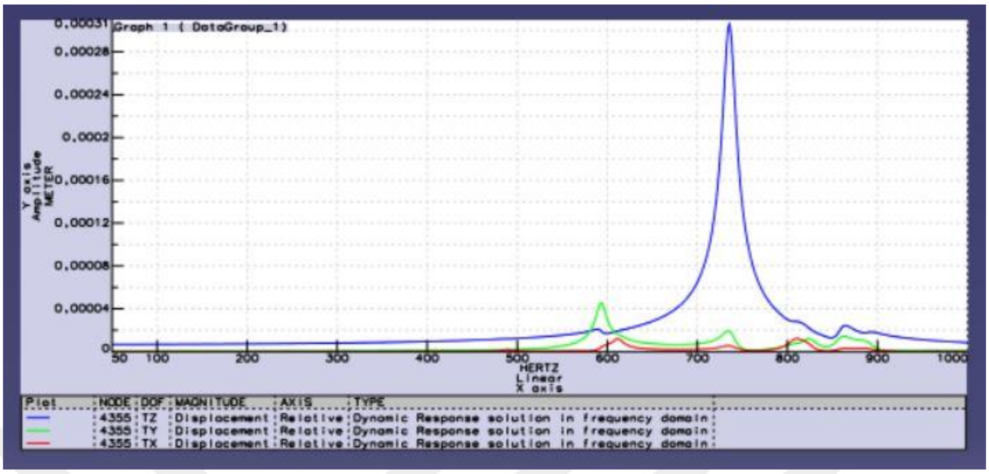


Figure A.10. Frequency response plot for flatbed semi-trailer chassis

For the given parametric values given at the below the results are indicated in the figures.

Length of the Chassis: 11750

Max. Load Capacity of the Kingpin: 11500

Max. Load Capacity of the Axle Group: 24000

Max. Load Capacity of the Semitrailer: 35500

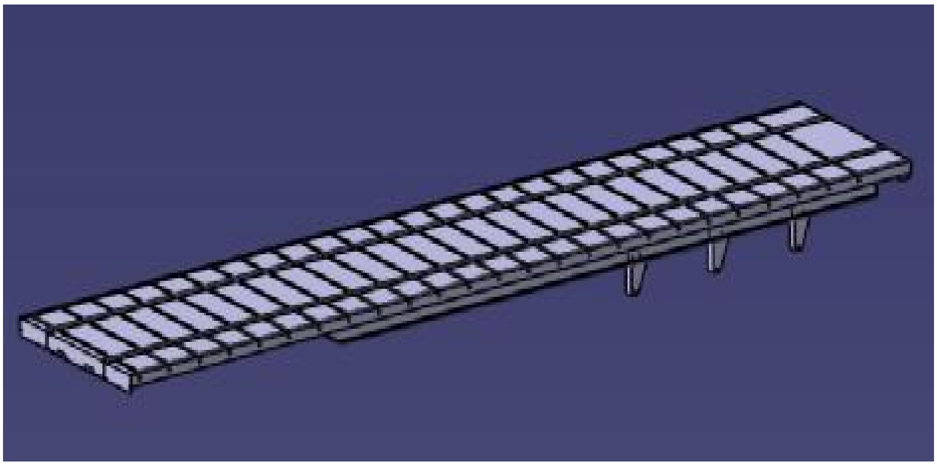


Figure A.11. Flatbed semi-trailer chassis

The location of maximum Von Mises stress are located at corner of side bar, which is the kingpin is located. Results are shown in Figure A.12. The Von Misses stress magnitude of critical points are 43,8404 MPa for the flatbed semi-trailer chassis. The result indicated in the below figures (Figure A.13, Figure A.14, Figure A.15) are dynamic analysis solution.

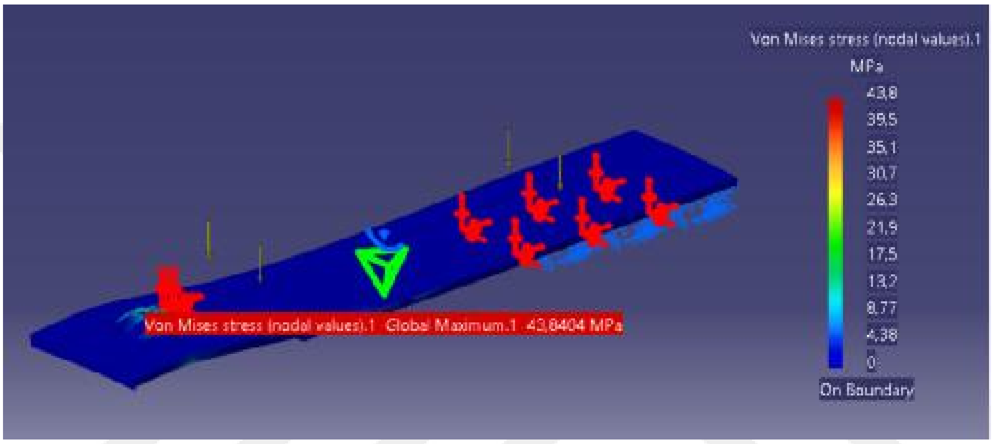


Figure A.12. Static analysis result of flatbed semi-trailer chassis

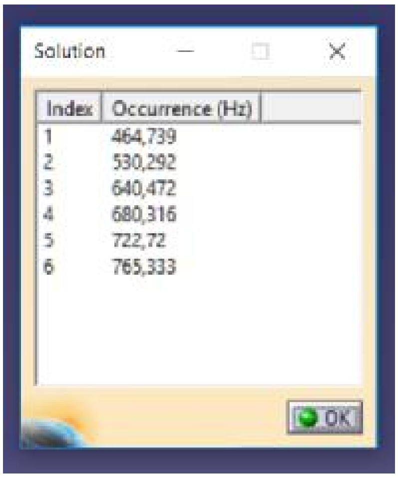


Figure A.13. Natural frequency values obtained from nodal analysis for flatbed semi-trailer chassis

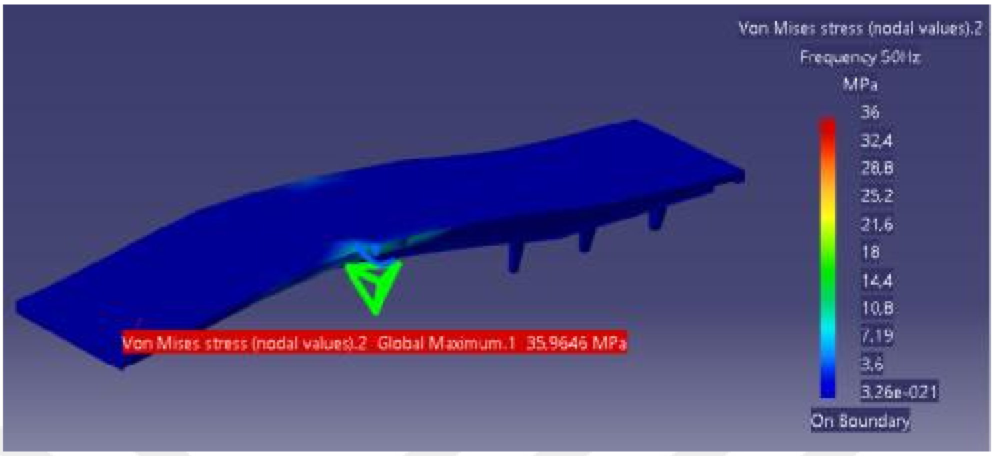


Figure A.14. Dynamic harmonic analysis results of flatbed semi-trailer chassis

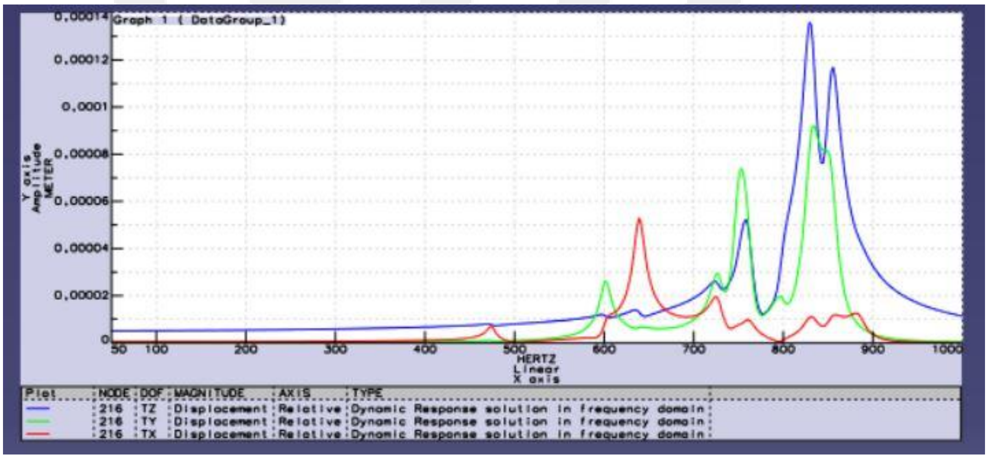


Figure A.15. Frequency response plot for flatbed semi-trailer chassis

For the given parametric values given at the below the results are indicated in the figures.

Length of the Container: 30ft.

Max. Load Capacity of the Kingpin: 11500kg

Max. Load Capacity of the Axle Group: 24000kg

Max. Load Capacity of the Semi-trailer: 35500kg

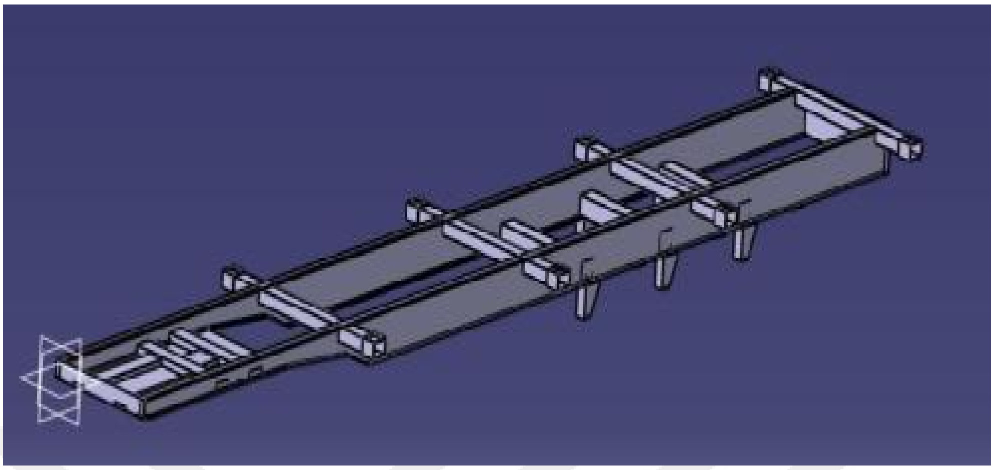


Figure A.16. Container carrier semi-trailer chassis

The location of maximum Von Mises stress are located at corner of side bar, which is the kingpin is located. Results are shown in Figure A.17. The Von Misses stress magnitude of critical points are 37,5399 MPa for the container carrier semi-trailer chassis. The result indicated in the below figures (Figure A.18, Figure A.19, Figure A.20) are dynamic analysis solution.

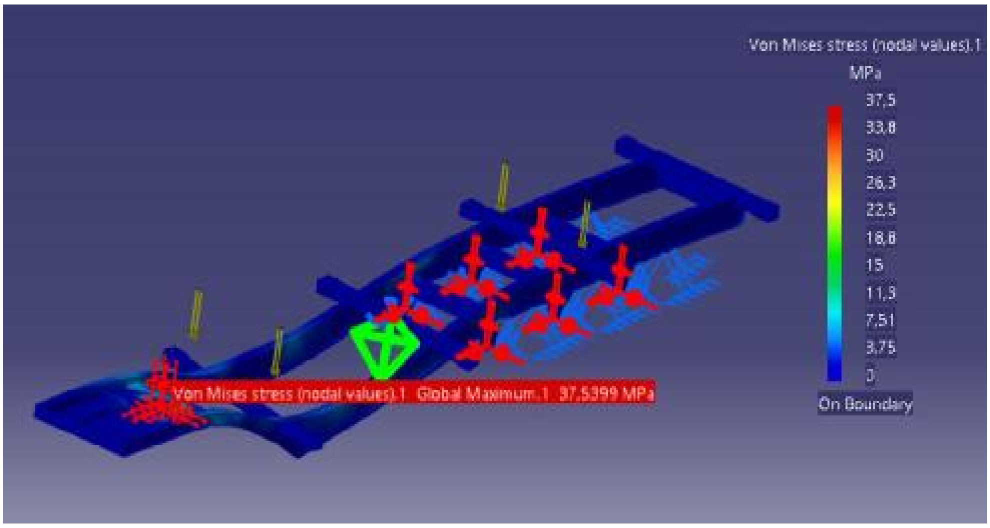


Figure A.17. Static analysis result of container carrier semi-trailer chassis

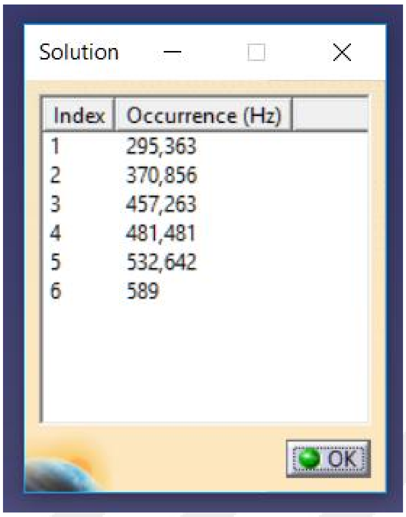


Figure A.18. Natural frequency values obtained from nodal analysis for container carrier semi-trailer chassis

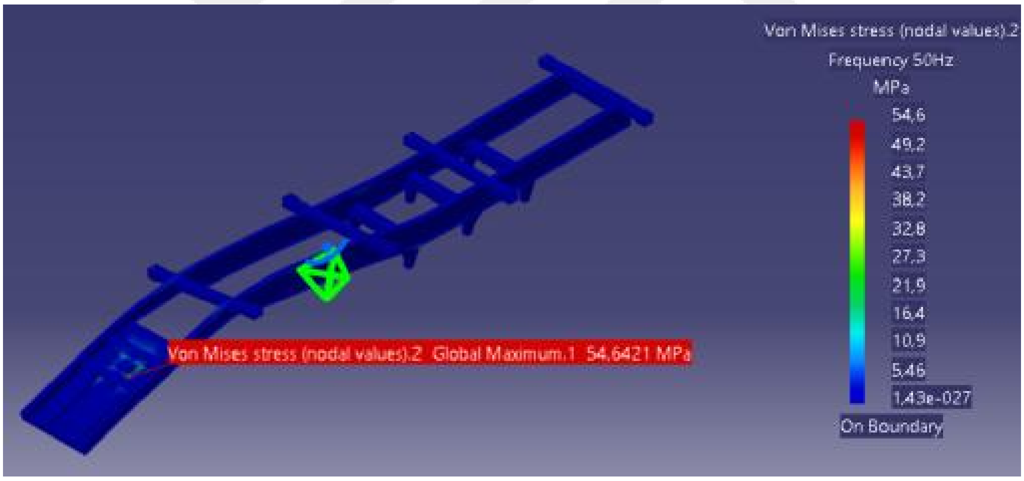


Figure A.19. Dynamic harmonic analysis results of container carrier semi-trailer chassis

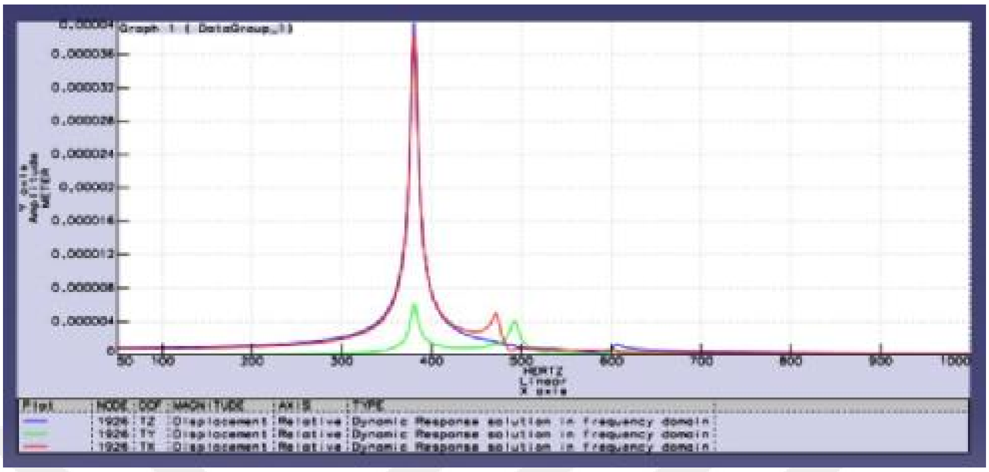


Figure A.20. Frequency response plot for container carrier semi-trailer chassis

For the given parametric values given at the below the results are indicated in the figures.

Length of the Container: 20ft.

Max. Load Capacity of the Kingpin: 11500kg

Max. Load Capacity of the Axle Group: 24000kg

Max. Load Capacity of the Semi-trailer: 35500kg

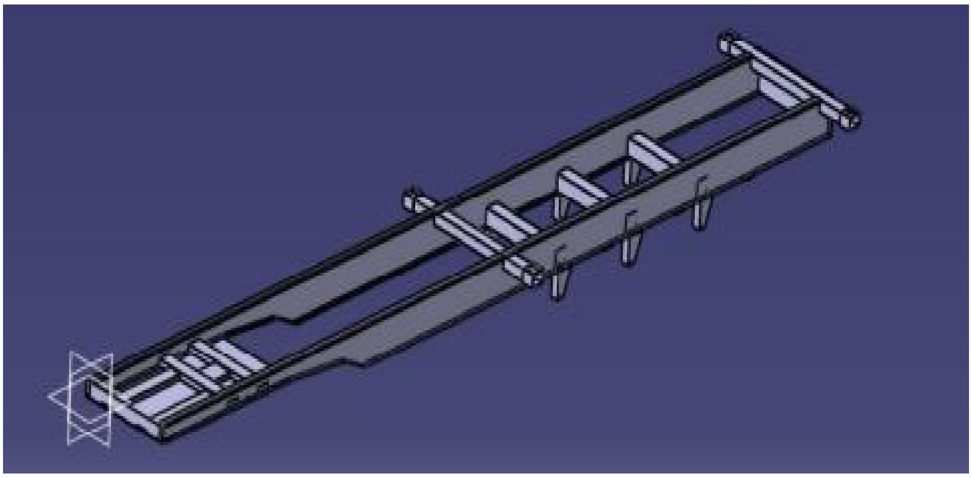


Figure A.21. Container carrier semi-trailer chassis

The location of maximum Von Mises stress are located at corner of side bar, which is the kingpin is located. Results are shown in Figure A.22. The Von Misses stress magnitude of critical points are 15,3367 MPa for the container carrier semi-trailer chassis. The result indicated in the below figures (Figure A.23, Figure A.24, Figure A.25) are dynamic analysis solution.

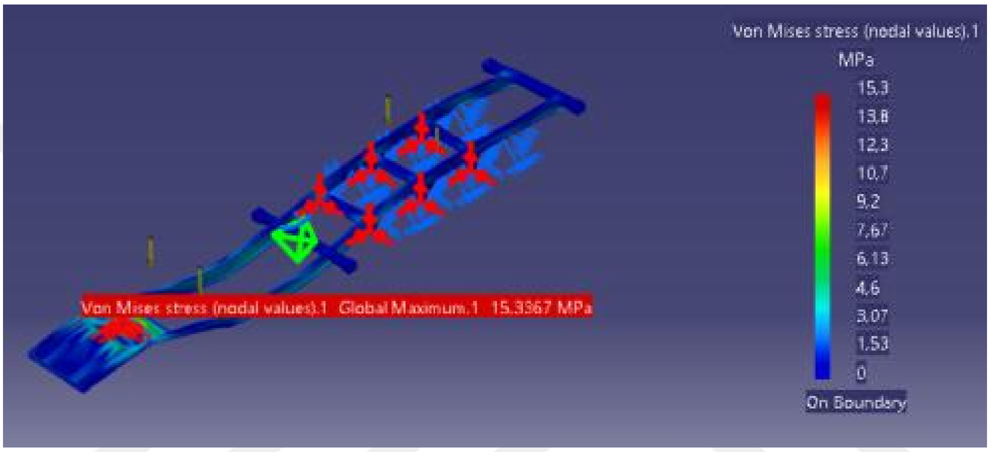
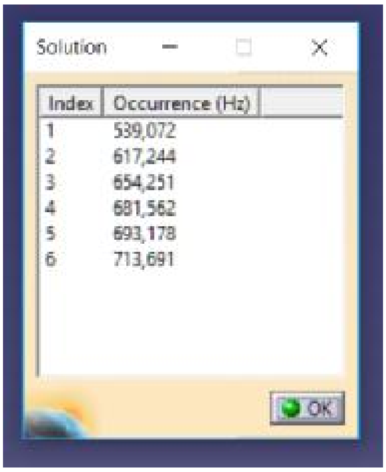


Figure A.22. Static analysis result of container carrier semi-trailer chassis


Solution

Index	Occurrence (Hz)
1	539,072
2	617,244
3	654,251
4	681,562
5	693,178
6	713,691

OK

Figure A.23. Natural frequency values obtained from nodal analysis for container carrier semi-trailer chassis

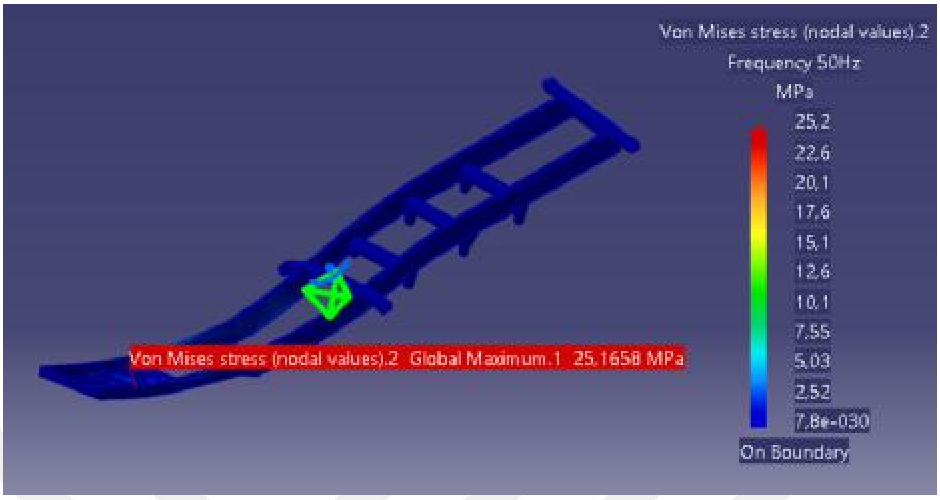


Figure A.24. Dynamic harmonic analysis results of container carrier semi-trailer chassis

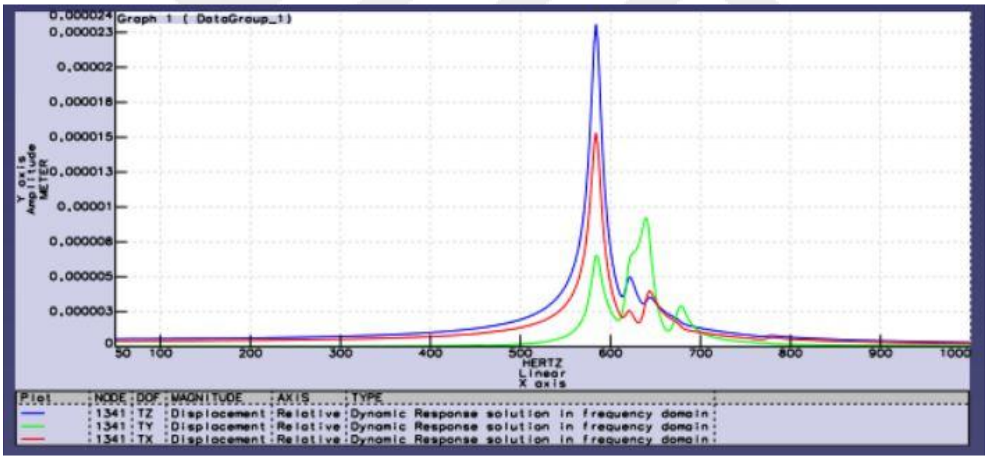


Figure A.25. Frequency response plot for container carrier semi-trailer chassis

Appendix B

Creating a Cylinder with a Hole as a Simple Example for Parametric Modelling in Catia

1-Getting Started Drawing

Macros are created by two primary methods:

- Macro recorder
- Write custom code with the macro editor

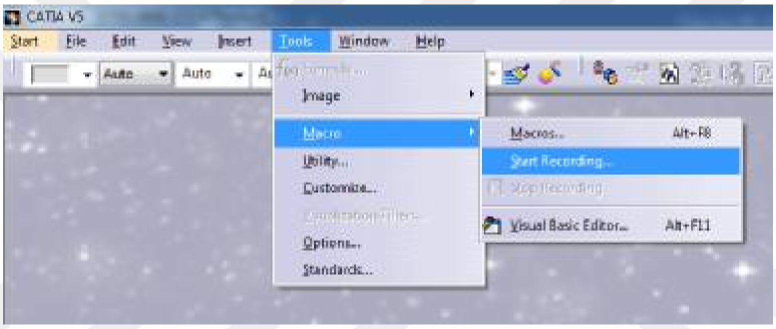


Figure B.1. Main window for macro recording

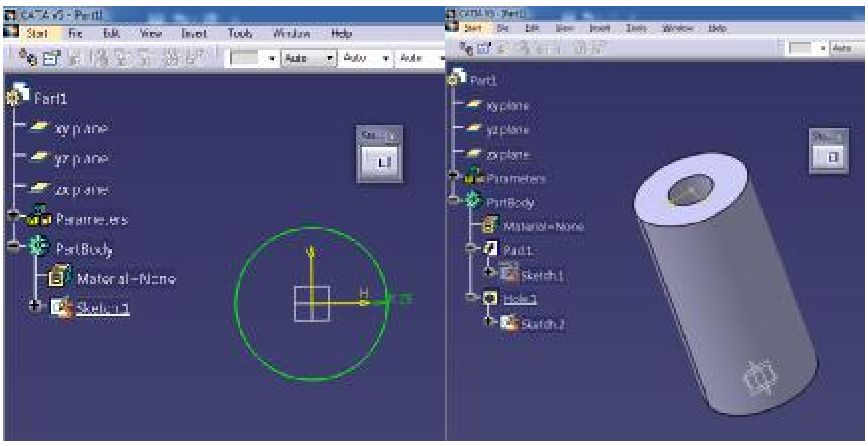


Figure B.2. Drawing stage of cylinder with a hole

A few things to keep in mind when recording a macro:

- DON’T: Switch workbenches while recording a macro.
- DON’T: Record more than is absolutely necessary.
- DON’T: Use the UNDO button when recording a macro.
- DO: Be aware of CATSettings when recording.
- DO: Exit sketches before stopping recording.
- DO: Check each macro after it’s recorded

2- Code of Program

For getting the codes;

Tools>>Macros>>Visual Basic Editor is opened from the toolbox.

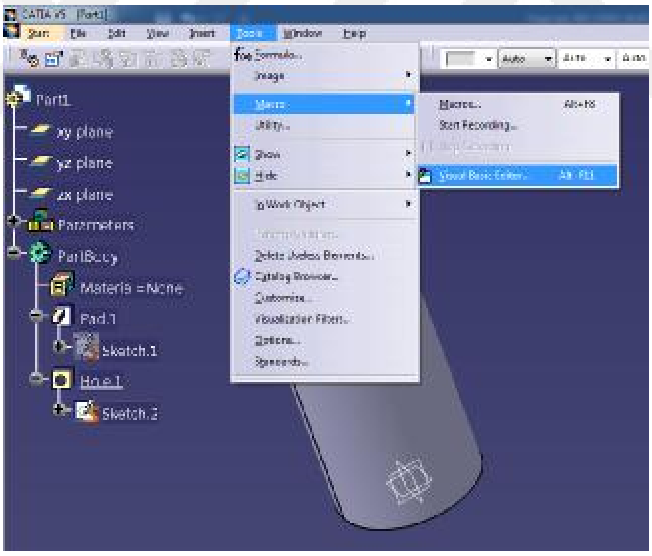


Figure B.3. Main window visual basic editor of Catia.

```
Sub CATMain()
Dim documents1 As Documents
Set documents1 = Catia.Documents
```

```
Dim partDocument1 As PartDocument
Set partDocument1 = documents1.Add("Part")

Dim part1 As Part
Set part1 = partDocument1.Part

Dim bodies1 As Bodies
Set bodies1 = part1.Bodies

Dim body1 As Body
Set body1 = bodies1.Item("PartBody")

Dim sketches1 As Sketches
Set sketches1 = body1.Sketches

Dim originElements1 As OriginElements
Set originElements1 = part1.OriginElement
Dim reference1 As Reference
Set reference1 = originElements1.PlaneXY

Dim sketch1 As Sketch
Set sketch1 = sketches1.Add(reference1)

Dim arrayOfVariantOfDouble1(8)
arrayOfVariantOfDouble1(0) = 0#
arrayOfVariantOfDouble1(1) = 0#
arrayOfVariantOfDouble1(2) = 0#
arrayOfVariantOfDouble1(3) = 1#
arrayOfVariantOfDouble1(4) = 0#
```

```
arrayOfVariantOfDouble1(5) = 0#
arrayOfVariantOfDouble1(6) = 0#
arrayOfVariantOfDouble1(7) = 1#
arrayOfVariantOfDouble1(8) = 0#
Set sketch1Variant = sketch1
sketch1Variant.SetAbsoluteAxisData arrayOfVariantOfDouble1

part1.InWorkObject = sketch1

Dim factory2D1 As Factory2D
Set factory2D1 = sketch1.OpenEdition()

Dim geometricElements1 As GeometricElements
Set geometricElements1 = sketch1.GeometricElements

Dim axis2D1 As Axis2D
Set axis2D1 = geometricElements1.Item("AbsoluteAxis")

Dim line2D1 As Line2D
Set line2D1 = axis2D1.GetItem("HDirection")

line2D1.ReportName = 1

Dim line2D2 As Line2D
Set line2D2 = axis2D1.GetItem("VDirection")

line2D2.ReportName = 2
Dim circle2D1 As Circle2D
Set circle2D1 = factory2D1.CreateClosedCircle(0#, 0#, 21.545513)
```

```
Dim point2D1 As Point2D
Set point2D1 = axis2D1.GetItem("Origin")

circle2D1.CenterPoint = point2D1

circle2D1.ReportName = 3

Dim constraints1 As Constraints
Set constraints1 = sketch1.Constraints

Dim reference2 As Reference
Set reference2 = part1.CreateReferenceFromObject(circle2D1)

Dim constraint1 As Constraint
Set constraint1 = constraints1.AddMonoEltCst(catCstTypeRadius, reference2)

constraint1.Mode = catCstModeDrivingDimension

Dim length1 As Length
Set length1 = constraint1.Dimension

length1.Value = 21.545513

sketch1.CloseEdition

part1.InWorkObject = sketch1
part1.Update
```

```
Dim shapeFactory1 As ShapeFactory
Set shapeFactory1 = part1.ShapeFactory

Dim pad1 As Pad
Set pad1 = shapeFactory1.AddNewPad(sketch1, 20#)

Dim limit1 As Limit
Set limit1 = pad1.FirstLimit

Dim length2 As Length
Set length2 = limit1.Dimension

length2.Value = 100#

part1.Update

Dim reference3 As Reference
Set reference3 = part1.CreateReferenceFromName("Selection_RSur:(Face:(Brp:(Pad.1;2);None:();Cf11:());Pad.1_ResultOUT;Z0;G6717)")

Dim sketch2 As Sketch
Set sketch2 = sketches1.Add(reference3)

Dim arrayOfVariantOfDouble2(8)
arrayOfVariantOfDouble2(0) = 0#
arrayOfVariantOfDouble2(1) = 0#
arrayOfVariantOfDouble2(2) = 100#
arrayOfVariantOfDouble2(3) = 1#
```

```
arrayOfVariantOfDouble2(4) = 0#
arrayOfVariantOfDouble2(5) = 0#
arrayOfVariantOfDouble2(6) = 0#
arrayOfVariantOfDouble2(7) = 1#
arrayOfVariantOfDouble2(8) = 0#
Set sketch2Variant = sketch2
sketch2Variant.SetAbsoluteAxisData arrayOfVariantOfDouble2

part1.InWorkObject = sketch2

Dim factory2D2 As Factory2D
Set factory2D2 = sketch2.OpenEdition()

Dim geometricElements2 As GeometricElements
Set geometricElements2 = sketch2.GeometricElements

Dim axis2D2 As Axis2D
Set axis2D2 = geometricElements2.Item("AbsoluteAxis")

Dim line2D3 As Line2D
Set line2D3 = axis2D2.GetItem("HDirection")

line2D3.ReportName = 1

Dim line2D4 As Line2D
Set line2D4 = axis2D2.GetItem("VDirection")

line2D4.ReportName = 2
```

```
Dim circle2D2 As Circle2D
Set circle2D2 = factory2D2.CreateClosedCircle(0#, 0#, 10#)

Dim point2D2 As Point2D
Set point2D2 = axis2D2.GetItem("Origin")

circle2D2.CenterPoint = point2D2

circle2D2.ReportName = 3

Dim constraints2 As Constraints
Set constraints2 = sketch2.Constraints

Dim reference4 As Reference
Set reference4 = part1.CreateReferenceFromObject(circle2D2)

Dim constraint2 As Constraint
Set constraint2 = constraints2.AddMonoEltCst(catCstTypeRadius, reference4)

constraint2.Mode = catCstModeDrivingDimension

Dim length3 As Length
Set length3 = constraint2.Dimension

length3.Value = 10#

sketch2.CloseEdition
part1.InWorkObject = sketch2
```

```
part1.Update

Dim pocket1 As Pocket
Set pocket1 = shapeFactory1.AddNewPocket(sketch2, 100#)

part1.Update

Set partDocument1 = Catia.ActiveDocument

partDocument1.SaveAs "C:\ Users\OZPC\Desktop \Part1.CATPart"

End Sub
```

3-Creatin User Interface

For making the design parameters changeable user interface is created.
Insert>> User form is opened from the toolbox.

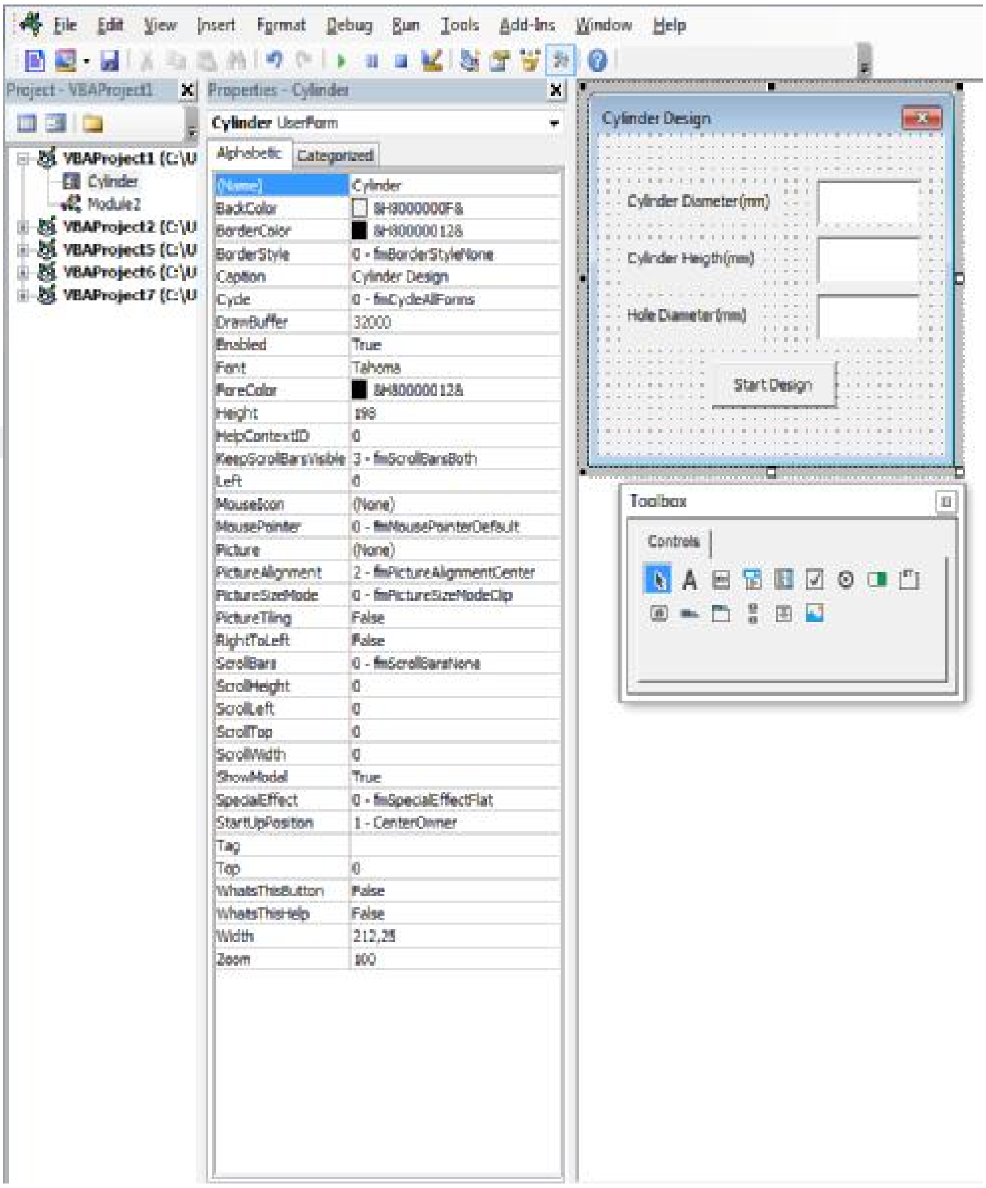


Figure B.4. Main window for user form generating

4-Modifying Code

length1.Value = 25# → length1.Value=TextBox1

length2.Value = 100# → length2.Value=TextBox2

length3.Value = 10# → length3.Value=TextBox3

For active start design button, the program code is added in command button.

The main procedure is starting the application is changed;

Sub CATMain() → Private Sub CommandButton1_Click()

5- The User Interface and Solid Model Occurred

The parameters are entered in the user interface. Then cylinder design is completed according to entered data's.

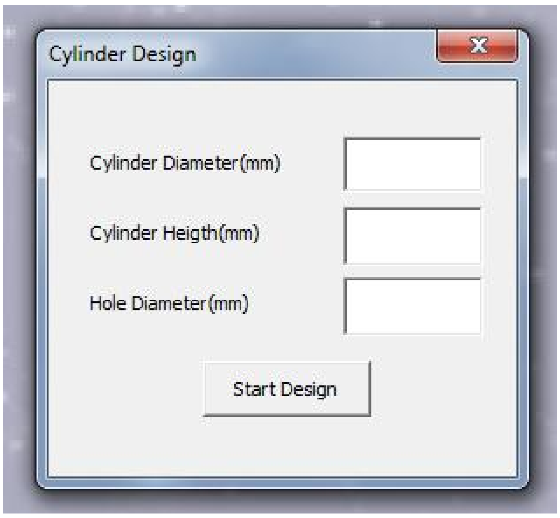


Figure B.5. Main window for user interface for Cylinder Design

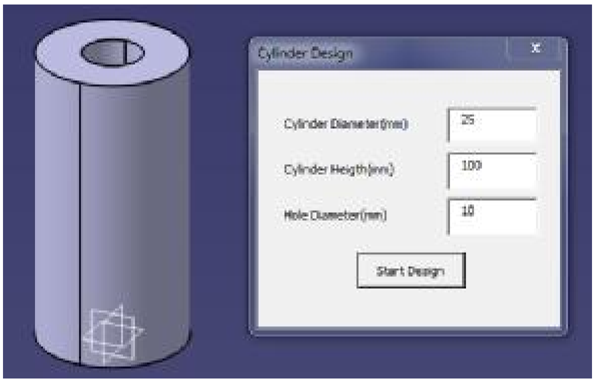


Figure B.6. 3D solid model of the cylinder

Appendix C

Pseudo Code of Program:

In here the main structure of the code for making calculation is shown.

1-Making calculation for the center of axle group;

```
………………
Dim objInertia    As Inertia
Dim objProd       As Product
Set objProd = Catia.ActiveDocument.Product
Set objInertia = objProd.ReferenceProduct.GetTechnologicalObject("Inertia")

Set ProdDoc = Catia.ActiveDocument
Dim Prod
Set Prod = ProdDoc.Product
Dim ProdSel
Set ProdSel = ProdDoc.Selection
ProdSel.Add Prod
Catia.StartCommand ("Measure Inertia")

Dim Ydim
Ydim = Prod.Parameters.Item("Gy").Value
length1.Value = TextBox1.Text
Dim KingPinLoad As Integer
KingPinLoad = TextBox2.Text
Dim AxleLoad As Integer
AxleLoad = TextBox3.Text
```

```
length12.Value = (((objInertia.Mass * 7.86 * (Ydim)) + ((TextBox4.Text - (objInertia.Mass * 7.86) - 750) * length1.Value / 2) + 1065000 - (TextBox3.Text * 1420) - (length6.Value * KingPinLoad)) / (TextBox3.Text - 750)) - 1310
part1.Update

intParam3.Value = (TextBox1.Text / 500)
part1.InWorkObject = sketch1
Set factory2D1 = sketch1.OpenEdition()
……………….
```

2- Adding St52-3 as a material property of the chassis;

```
……………….
Dim MaterialDocPath As String
Dim MaterialName As String, MaterialFamilyName As String

MaterialName = "St52-3"
MaterialFamilyName = " Metal "
MaterialDocPath = "C:\ Users\OZPC\Desktop\Catalog.CATMaterial" '*

Dim oMaterial_document As Document
Set oMaterial_document = Catia.Documents.Read(MaterialDocPath)

Dim oMaterial As material
SetoMaterial=oMaterial_document.Families.Item(MaterialFamilyName).Materials.
Item(MaterialName)

Dim oPartDocument As Document
Set oPartDocument = Catia.ActiveDocument

Dim oRootPart As Part
```

```
Set oRootPart = oPartDocument.Part
Set oManager = oRootPart.GetItem("CATMatManagerVBExt")
        linkMode = 0
oManager.ApplyMaterialOnPart oRootPart, oMaterial, linkMode

partDocument1.SaveAs
"C:\Users\OZPC\Desktop\study\flatbed.CATPart"……………….
```