MARMARA UNIVERSITY
FACULTY OF ENGINEERING

FRONT SEAT ARMREST DESIGN WITH PHONE DRAWER

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Müdek Final Project Commission

The essential features of an acceptable design Project

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2	Report writing technique	✓	
3	Development of student creativity		✓
4	Use of open-ended problems		✓
5	Formation of design	✓	
6	Problem statement and specification	✓	
7	Synthesis of alternative solutions		✓
8	Feasibility	✓	
9	Detailed system description	✓	
10	Consideration of constraints (e.g. economic, safety, reliability, etc.)	✓	
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GRADUATION PROJECT REPORT

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Front Seat Armrest Design with Phone Drawer

by

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July, 2021 **Ahmet Fatih TURHAN - Muhammet Taha NAS**

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ÖZET

Telefon Çekmeceli Ön Koltuk Kolçak Tasarımı

Ahmet Fatih TURHAN & Muhammet Taha NAS

Koltuk kolçağı, otomobildeki yolcunun seyahat süresince otururken kolunu koyarak destek alabileceği, basıncının üniform bir şekilde koltukta dağılmasına katkıda bulunan ve konforlu bir şekilde seyahat edilmesini sağlayan önemli bir koltuk aksesuarıdır. Bu ürünlerin fonksiyonel olması kadar estetik, ergonomik ve ekonomik olması önemli bir tasarım ayrıntısıdır.

Bu proje kapsamında bir otomobil ön koltuğu için telefon yerleştirilebilir çekmeceye sahip bir kolçak tasarımı yapılmıştır. Projede özgün ve ergonomik bir koltuk kolçağı tasarımı yapıldıktan sonra bir bütün olarak kolçağın sonlu elemanlar yöntemi (FEM) kullanılarak simülasyonu yapılarak sistemi oluşturan parçaların malzemesi belirlendikten sonra her bir parça geometrisi için optimizasyon çalışması yapılmıştır. Elde edilmiş ürünler üzerinde mekanik hızlandırılmış testler ve ürün doğrulaması yapılarak proje tamamlanmıştır.

ABSTRACT

Front Seat Armrest with Phone Drawer Design

Ahmet Fatih TURHAN & Muhammet Taha NAS

The seat armrest is an important seat accessory in which the passenger in the car can sit, get support, contribute to the uniform distribution of pressure on the seat and travel comfortably while traveling. Being aesthetic, ergonomic and economical as well as being functional is an important design detail for these products.

Within the scope of this project, an armrest design with a drawer for a car front seat was designed. After designing an original and ergonomic seat armrest in the project, the armrest as a whole was simulated using the finite element method (FEM), and after determining the material of the parts that make up the system, optimization study was carried out for each part geometry. The project was completed by performing mechanical accelerated tests and product verification on the obtained products.

SYMBOLS

A **:** Cross-sectional area

D **:** Diameter

E **:** Young’s modulus

F **:** Force

ε **:** Strain (mm/mm)

υ **:** Poisson Ratio

ρ **:** Density

S **:** Stress

ABBREVIATIONS

CAD **:** Computer Aided Design

CAE **:** Computer Aided Engineering

CFD **:** Computational Fluid Dynamics

FEA **:** Finite Element Analysis

FEM **:** Finite Element Method

3-D **:** Three Dimensional

MPV **:** Multi-Purpose Vehicle

QFD **:** Quality Function Deployment

R&D **:** Research and Development

SUV **:** Sport Utility Vehicle

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1. INTRODUCTION

Within the scope of the project, the original, ergonomic, front seat armrest design with phone drawer was targeted. In the project, an ergonomic, functional and low-cost innovative armrest design was requested by using the existing CAE (Computer Aided Engineering) software. Existing armrests are designed and manufactured using standard steel and plastic materials to meet cost targets. This project focuses on finding the most ideal materials and placing a phone drawer as an extra feature on the car armrest. In addition, in line with the test requirements specific to armrests, it is aimed to complete the project by making product verification using analysis software and design improvements when necessary.

After a detailed literature review, material selection, determination of the working mechanism and cost analysis were made at the concept design stage. Optimal materials and phone drawer innovation have been used in the armrest to achieve a competitive product. Then, the three-dimensional design (3-D) phase was started and the design was carried out using optimization techniques during the design phase. In the meantime, mountability and manufacturability issues were also discussed.

After these stages, work continued in the Finite Element Analysis section. Stress-strain analysis and fatigue analysis stages were completed and reduction was achieved with the help of optimization techniques. All details of the project are mentioned in the rest of the report.

1.1. Literature Research

The functions of vehicle seats are to support, protect and ensure the comfortable seating position of their passengers. When the task analysis is made, it is revealed that there are three different types of passengers in the vehicles: the driver, the front seat passenger and the rear seat passenger. Figure 1.1 shows the different types of car seats (Subrata Kumar Mandal et al. 2015).

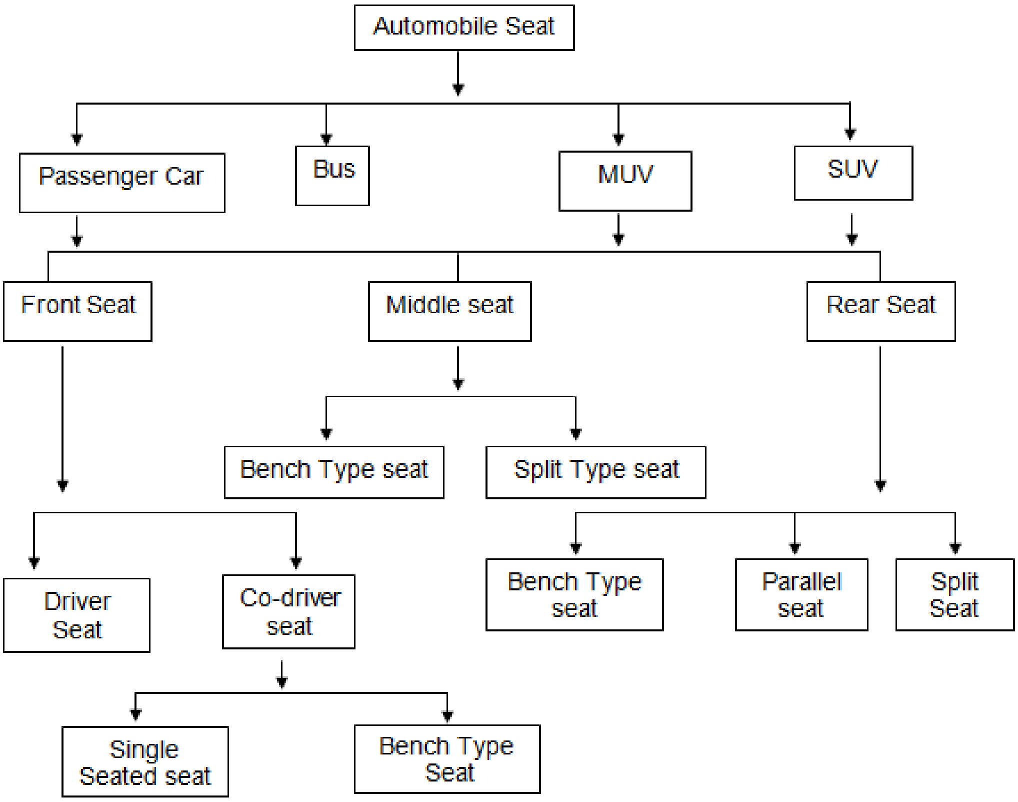

Figure 1.1. Different types of car seats

In the automotive sector, studies have been carried out to revise vehicle seats according to customer needs and wishes. For this purpose, QFD (Quality Function Deployment) analysis was performed. The findings obtained showed that the most important criterion is the seat option with 27.39%. While the material took second place with 25,94%, the third place was the dumping characteristic factor with 19,17%. In the study, it was stated that steps can be taken to improve the vehicle seat industry by making use of the order of importance of six features used: seat structure, seat type, rigidity, seat option, dumping characteristic, and seat material. (Purba, H.H. et al. 2020)

In the research conducted by Hanumant N. Kale and C. L. Dhamejani, it was mentioned that usually, a professional driver works more than eight hours a week, so the driver's seat should be designed considering all parameters. The uneven road condition causes vibration in a vehicle transmitted to the driver's body. The reason for the study is that a poorly designed driver's seat affects the health and mental state of the drivers. According to research, the three main goals of any driver's seat are driver safety, health and comfort.

The classification of parameters affecting the design of driver seats is shown in Figure-1.2. (Kale and Dhamejani 2015)

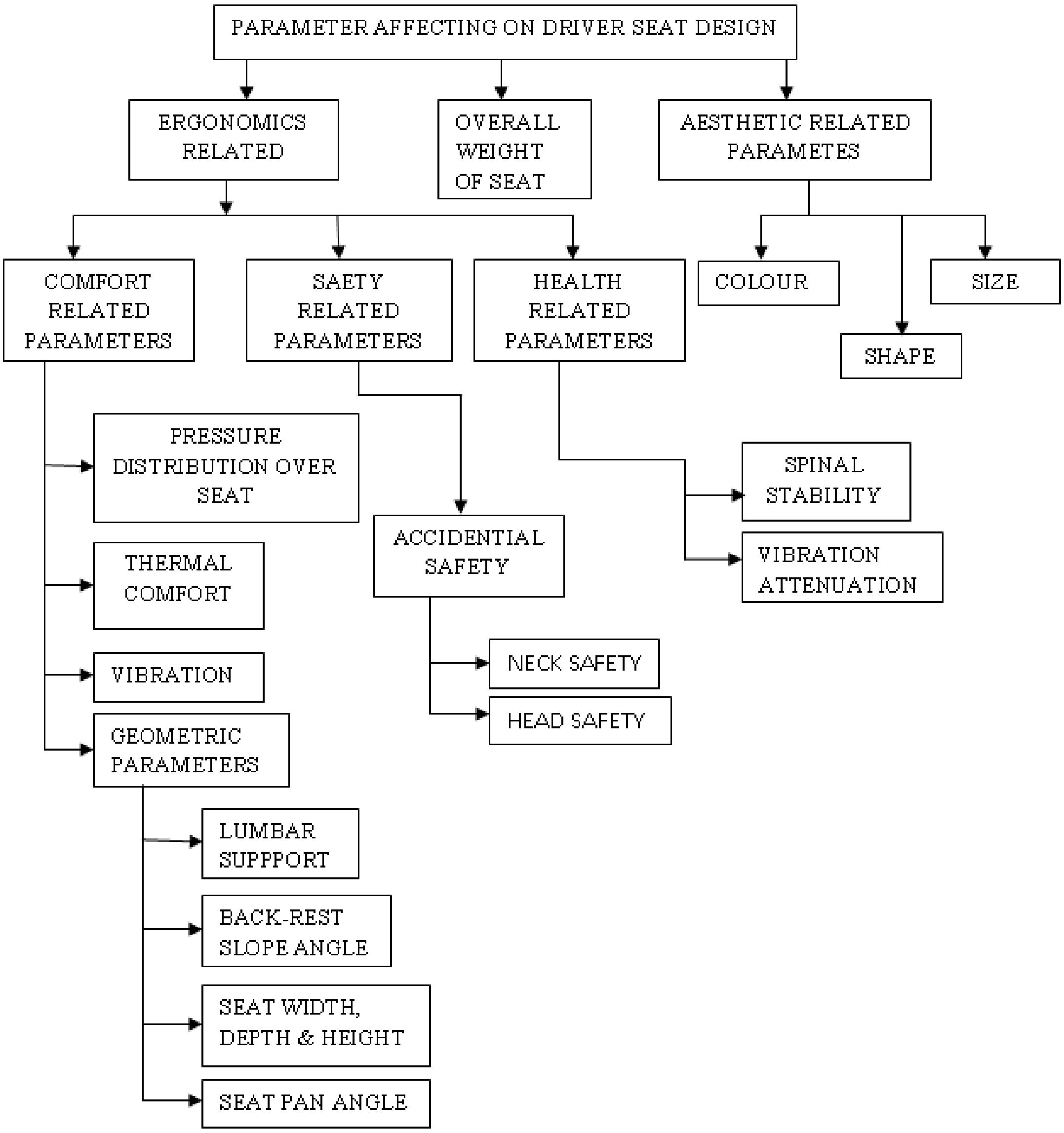

Figure 1.2. Classification of parameters affecting the design of driver seats

It has been reported that reducing the level of discomfort experienced does not always increase the level of comfort, but the level of discomfort must be low to reach a high level of comfort (Helander and Zhang 1997). The causes of discomfort while sitting in the vehicle seat are given in the table as in Figure 1.3.

Human Experience mode	Biomechanical		Seat/environment
	Physiology causes	Engineering causes	Source
Pain	Circulation occlusion	Pressure	Cushion stiffness
Pain	Ischemia	Pressure	Cushion stiffness
Pain	Nerve occlusion	Pressure	Seat contour
Discomfort	-	Vibration	Vehicle ride
Perspiration	Heat	Material Breathability	Vinyl upholstery
Perception	Visual/auditory/tactile	Design/vibration	Vehicle cost

Figure 1.3. Causes of seating discomfort

Van Veen et al. mentioned the effects of armrests on human health. It was stated that neck flexion was significantly reduced with the support of the armrests and the neutral position was approached. In addition, overall comfort and convenience increas significantly, especially in the neck area, when using armrests. Subjects appreciate the body posture provided by armrests, and the results show that 9 out of 10 people prefer using items with armrests compared to using items without armrests (Van Veen et al. 2013).

Car seats play a vital role in comfort for professional drivers. Professional drivers spend much longer hours in the car seat than passengers. For this reason, the comfort of vehicle seats plays an important role, especially for drivers. If the driver's seat is not comfortable, the driver's performance may be affected, resulting in a bad trip. Therefore, for the optimal design of driver seats, various technical design features should be considered in order to improve comfort (Mehta 2008).

The thesis “Designing Mechanic and Propulsion System of Driver Seat Simulator”, written by Murat Cihan Çalışkan (2014), was analayzed. In this thesis, the driver console prepared for driving simulation is designed. The seat of the driver was drawn, and the mechanical system was sized according to the anatomical characteristics of people. In the thesis, the maximum and minimum weights are calculated while designing the area where the driver sits. It has been controlled by the electronic devices used in the Prototypes produced. The efficiency of the system was evaluated. Thus, it was tested whether the driving courses could work less costly. (Çalışkan 2014)

The thesis “Investigation of Commercial Vehicle Driver Seat’s Dynamic Comfort by Using Different Damping Elements”, written by Cenk Çetin (2015), was analyzed. In this thesis, driver seat comfort is divided into two: static and dynamic. This thesis examines the dynamic comfort part. Dynamic comfort examines the transmission of vibrations made by the vehicle for different reasons to the driver's seat. Commercial vehicles are exposed to relatively more vibrations than passenger vehicles, which is why the driver of commercial vehicles gets tired more than other vehicles and causes loss of attention or attention. In order to find a solution to this situation, optimum driver seats were designed by discussing different suspension systems. After the model was created, the equation of motion of the system was revealed. For the equation of motion, Lagrangian method and linear graph method are used separately. The resulting mathematical equations were solved and analyzed with the MATLAB-Simulink software. (Çetin 2015)

Ayhan Balkan's (2018) thesis titled "Weight Reduction on The Commercial Vehicle Driver Seat with Structural Optimization" was written to increase the comfort of the driver's seat, since the driving time is longer than that of passenger cars since comfort and convenience are sought more in commercial vehicles. The subjects that the thesis deals with are the provision of comfort, suspension, the weight and lightness of the seat, and finally the material cost. Among these topics, this thesis is mainly aimed to reduce weight or to be structurally stronger at the same weight level. An optimum driver's seat is designed with the desired ones. The seat designed using the OptiStruct interface of the Altair/HyperWorks program and the AEK R14 seat belt pull test finite element analysis was examined and evaluated. (Balkan 2018)

In the article titled "Armrests and back support reduced biomechanical loading in the neck and upper extremities during mobile phone use" written by Kartheek Reddy Syamala et al. (2018), they examined the contribution of back support and presence of Armrest during phone use. In this review, tests were conducted with a group of 20 people, 10 of whom were men, with an average age of 23. As a result of their tests, they stated that back support and armrest support reduce biomedical stress and benefit human ergonomics. (Syamala, Ailneni, Kim, and Hwang, 2018).

In the article titled "Development of a bus armrest fabrication process with a high-vacuum, high-pressure die-casting process using the AM60 alloy" written by Myeonghan yoo et al. (2019), companies are buying magnesium in small vehicles with the desire to lighten vehicles, as carbon emissions are taken into account more in the world. They have done research, design, manufacturing and tests on the production of vehicle parts from magnesium alloy since there is not enough transformation in the parts of buses or large vehicles. Nastran FX program (ver 2.0) was used for structural simulation. Flow and solidification simulation program Anycasting (ver 7.0) was used for casting. As a result of the simulations, the mold design emerged. ES88001-50 HMC specifications were used in the studies. The geometric design was applied accordingly. With the work done, the armrest weight was reduced by 36%. Production parts reduced from 5 to 2. The vertical breaking load test is successful. The fatigue test has been successful and the target of 65000 cycles has been achieved. Its yield strength is over 130MPa. (Yoo, Song, Oh, Kang, Kim, Yang, and Moon 2019)

In the article titled “Finite Element Analysis and physical testing to solve bouncing effect during armrest opening” by Dilip S. Chaudhary et al. (2020), they correlated finite element analysis and physical testing of the bouncing effect during armrest opening to reduce the bouncing effect. Due to the estimation errors and uncertainty parameters, the finite element method may not always give accurate results. Therefore, finite element analysis and physical tests must be in a correlation. Existing models with validated finite element models were used. Ls-Dyna solver was used for finite element analysis. The CAD data of the current model and the data of the physical test were compared and used as input in the finite element simulation. The finite element model was created according to Yanfeng Automotive Interiors standards and compared with a baseline simulation of physical test results. Necessary updates were made in the finite element test until the results of the physical tests and the finite element tests were correlated. As a result of the tests, it has been seen that the desired result can be obtained simply. Testing of this design has been done using CATIA, LS-Dyna and Hyperworks-13 preprocessor. As a result, it was solved with minor changes in the design and contributed to the savings of the company. (Chaudhary, S. Desai, Patil, and A. Desai 2020)

In this article titled “Ergonomic Evaluation and Improvement of Bus Seat Armrest Design” by Hayoung Jung et al. (2016), ergonomic evaluations were made about armrest design in order to improve seat comfort and convenience by considering the posture of bus passengers and an ergonomic armrest design for the comfort of a bus seat. How much can be increased with 58 people participated in the research, experienced bus armrests with seven different designs, and were asked to score on five design dimensions (length, width, shape, angle, height from the seat floor) in their own opinion, it is a comprehensive project. Considering the results of this research, it has been analyzed in which design conditions people generally like armrest designs. It is aimed to reveal the most suitable design by determining the preferred design features and the needs expectations of the passengers. (Jung, Lee, Kim, Choi, and You 2016)

1.2. Vehicle Categories

Vehicle classes are defined according to the international classification. This classification is made for regulatory purposes. The main vehicle categories classified are: M, N, L and T categories. In this study, since studies on the seat structures of vehicles in the M and N categories were carried out, information about these two classes was given. The information was obtained by using the source European vehicle categories | EAFO (2021).

1.2.1. M-Segment

It is the vehicle segment whose primary purpose is the carriage of passengers. It is divided into 3 different categories as M1, M2 and M3.

1.2.1.1. M1 Category

Motor vehicles whose number of seats does not exceed 8, except for the driver seat. Vehicles in the M1 category are vehicle types in which passengers do not have a standing area. An example vehicle belonging to the M1 class is shown in Figure 1.4.

Figure 1.4. M1 Category vehicle

1.2.1.2. M2 Category

Motor vehicles with more than 8 seats other than the driver's seat and a maximum mass not exceeding 5 tons, intended for the carriage of passengers. Vehicles in this category may have space for passengers to stand in addition to their seats. An example vehicle belonging to the M2 class is shown in Figure 1.5.

Figure 1.5. M2 Category vehicle

1.2.1.3. M3 Category

Motor vehicles with more than 8 seats other than the driver's seat and a maximum mass exceeding 5 tons, intended for the carriage of passengers. Vehicles in this category may have space for passengers to stand in addition to their seats. An example vehicle belonging to the M3 class is shown in Figure 1.6.

Figure 1.6. M3 Category vehicle

1.2.2. N-Segment

It is the motor vehicle segment that has at least four wheels and is used for the carriage of goods. It is divided into 3 different categories as N1, N2 and N3.

1.2.2.1. N1 Category

Motor vehicles with a mass not exceeding 3.5 tons and used for the carriage of goods are in the N1 category. An example vehicle belonging to the N1 class is shown in Figure 1.7.

Figure 1.7. N1 Category vehicle

1.2.2.2. N2 Category

Motor vehicles with a mass exceeding 3.5 tons but not more than 12 tons and used for the carriage of goods are in the N2 category. An example vehicle belonging to the N2 class is shown in Figure 1.8.

Figure 1.8. N2 Category vehicle

1.2.2.3. N3 Category

Motor vehicles with a mass exceeding 12 tons and used for the carriage of goods are in the N3 category. An example vehicle belonging to the N3 class is shown in Figure 1.9.

Figure 1.9. N3 Category vehicle

Most of today's cars consist of M1 category vehicle models. This vehicle category is also the most popular vehicle model class in Turkey. Since this class of vehicles are intended for the carriage of passengers, they are designed with comfort in mind. One of the important comfort factors, especially for vehicle drivers, is the armrest. Companies that want to increase or maintain their vehicle sales have always aimed to make better armrest designs because they care about comfort.

1.3. Car Seats

Seat term in its most basic form means a structure, which may or may not be integral with the vehicle, structure complete with trim, intended to seat one adult person. Some of the main functions of automotive seating is to support, protect and to provide comfortable seating posture to its occupants.

The seat system is a very important part of the vehicle that is in contact with the passenger and the driver at any time while the vehicle is being driven, and also has a direct effect on the comfort and safety of the passenger and driver.

Standard car seats are designed to support the thighs, hips, lower and upper back and head. The driver and passenger seats of most vehicles are made up of three important parts: squab, seat base (cushion) and headrest. These sections are usually made of foam to provide comfort to the driver and passenger (Mandal, 2015)

The chart of different types of automotive seats taken from the same study is shown in Figure 1.10.

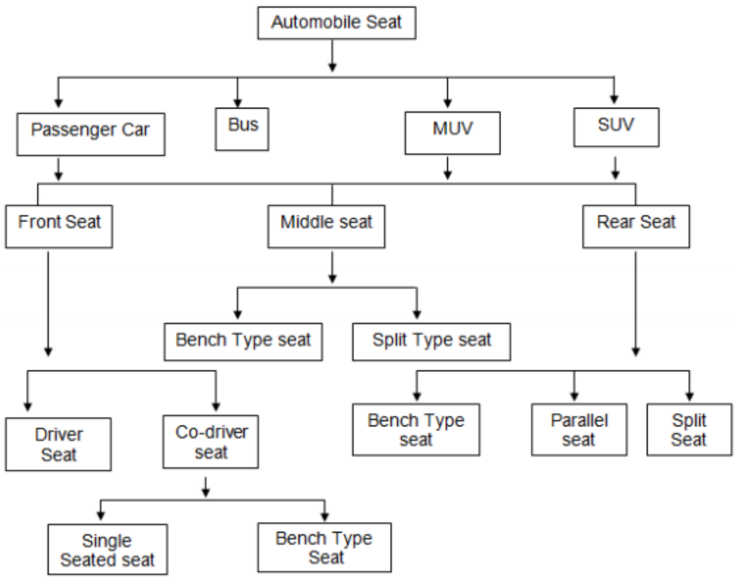

Figure 1.10. Different types of automotive seats

Car seats are designed by paying attention to the requirements in terms of safety. In the first step, the geometry of the seat frame, the materials used and the basic mechanisms to be used must meet the safety requirements. Afterwards details about the outline and appearance are added to the seat. In the last step, comfort elements such as sponges are added and basic features are determined according to the expectations of the customer. Apart from these basic features; Optional features such as heating, cooling, massage, armrest and electric mechanism are offered to customers as an extra. Based on these features, seat manufacturers have made a classification by taking into account the number of movements of the basic mechanisms of the seat. The classification, which is different from Figure 1.10, is as follows: Since there is only forward-backward seat movement if the seat has a slide mechanism, it is classified as 2-way (2W), if seat and mechanism in addition to the back tilt mechanism, front-back back movement is included in the total movement, it is classified as 4-way (4W). In addition to these, if there is a height adjustment mechanism, it is considered as a 6-way (6W) seat since it includes up-down seat movement. This classification is shown in the Figure 1.11.

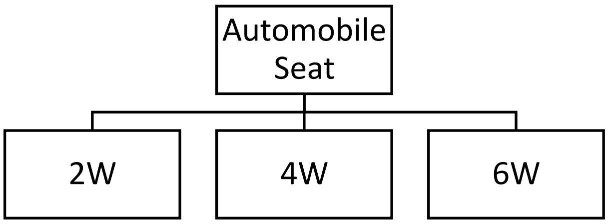

Figure 1.11. Movement classification

Car seats are where professional drivers spend the most time. According to research, truck drivers sit around 50 hours a week while driving. In this case, it is seen that drivers drive an average of 2350 hours per year. Being in constant contact with the passengers in the vehicle, automotive seats play an important role in improving the comfort of the driver and other passengers and therefore the working environment. The development of automotive seat systems, especially for drivers, has been of great interest for years because they use long hours. In order to help these drivers, the number of efforts to increase comfort in vehicle seats should be increased.

1.4. Car Armrests

Armrests mounted on the sides of the vehicle seats are widely used today in order to provide the comfort of the driver and passengers during travel in transportation vehicles such as cars, trucks and buses.

In the automotive context, it is an armrest found in many modern vehicles, on which passengers can recline their arms. Armrests are more productive in larger and more expensive car models.

The front of the car includes a central armrest, often a storage compartment and sometimes even cup holders, which can be folded down to the user's preference. Some also provide the location of controls for non-essential functions of the vehicle, such as climate control or window motors. One or two armrests can be attached to each seat, a feature that is sometimes common in minivans (MPVs) and some Sport utility vehicles (SUVs). Often there is another armrest that is built into the car door and usually forms part of the door pull handle.

A rear armrest will typically be folded down between the rear seats to allow the central seat to be used. In some designs emphasizing passenger safety, including some Volvo models, the armrest doubles as a child seat with a specially adjustable seat belt. As with the front, it is not uncommon for the armrests to be placed on the rear doors or on the side of the car if there is no rear door.

1.5. Types of Car Armrests

The seat armrest is an important seat accessory in which the passenger in the car can sit, get support, contribute to the uniform distribution of pressure on the seat and travel comfortably while traveling. These designs are classified according to the armrest's mobility, fixability and additional use. The armrest is classified as follows according to international standards.

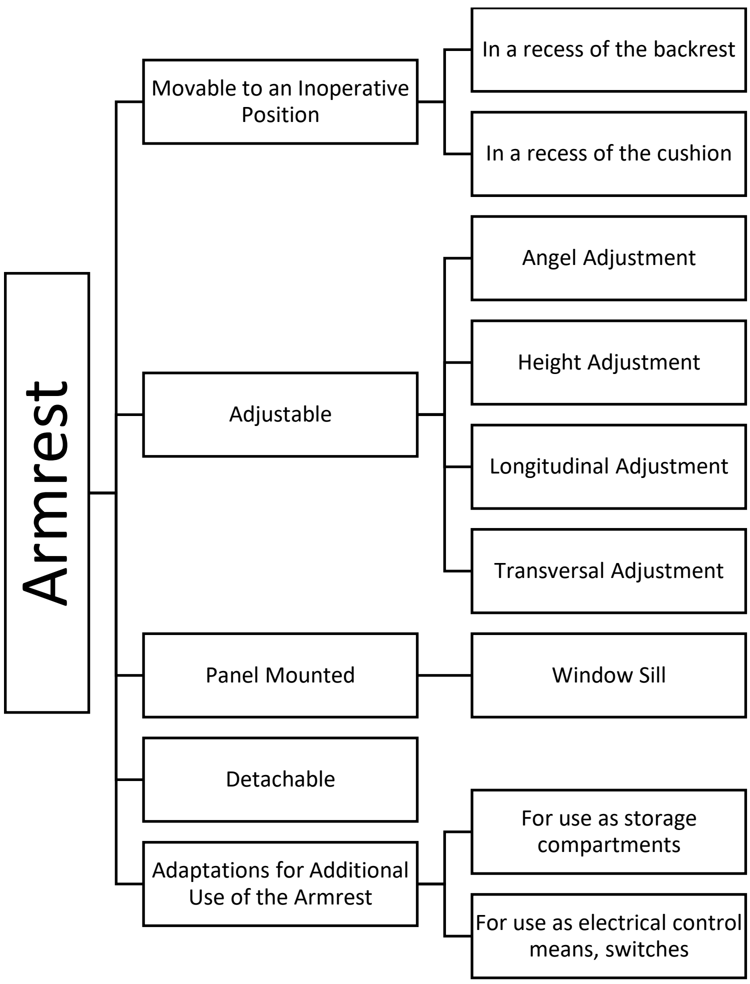

Figure.1.12. Armrest classification

1.5.1. Movable to an Inoperative Position

Movable to an inoperative position class armrests are designed to be able to be removed after use, thus saving space. It is divided into two parts.

First, the armrest, which is a folding seat, is mostly found in the back of the rear seat in M1 class vehicles. If it is necessary to free up space in the rear seat, it can be folded and opened. For example, if you want to sit with 3 people, the seat will appear when you close the armrest.

Figure 1.13. Armrest in a recess of the backrest

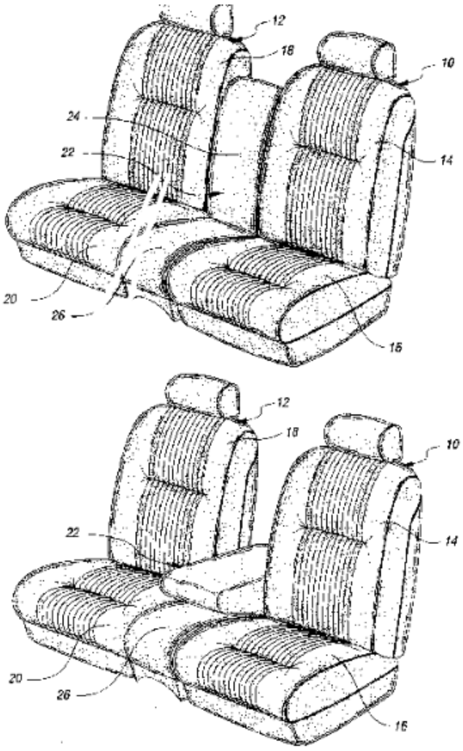

Figure 1.14. Armrest in a recess of the backrest drawing

Second, if you think the armrest in a recess of the cushion does not have enough comfort or ergonomics, you can use the armrest in a recess of the cushion to get the necessary comfort or ergonomic. When your use is finished or when you need to open space, you can turn it off and open it, and it can be easily used as a sitting area.

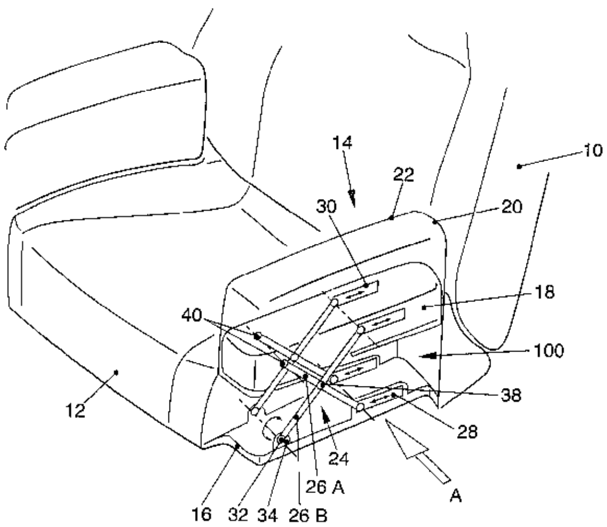

Figure 1.15. Armrest in a recess of the cushion

1.5.2. Adjustable

An adjustable class armrest is the characteristic of this class that it is not fixed and can move its angle, height, longitudinal or transverse according to the user's demand. In this way, we can provide the comfort desired by every user and thus increase the customer satisfaction rate.

This class consists of four parts: angle adjustable, height adjustable, longitudinally adjustable, and transverse adjustable as we listed above.

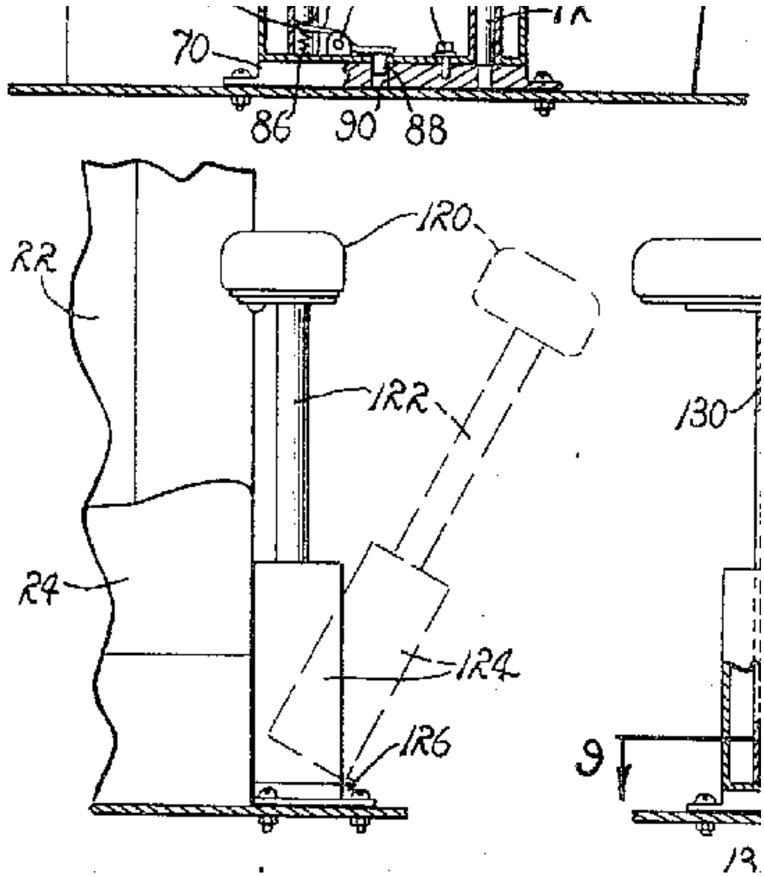

Figure 1.16. Transversal adjustable armrest

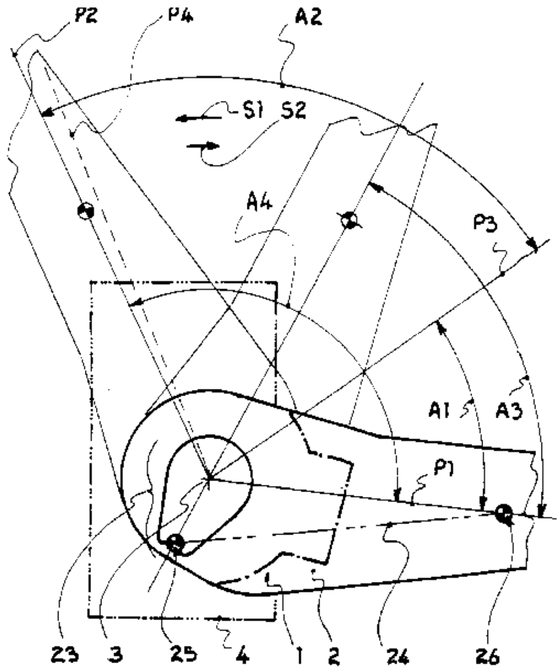

Figure 1.17. Angle adjustable armrest

1.5.3. Panel Mounted

Panel mounted armrests, as the name suggests, are panel mounted armrests. Usually, in M1 class vehicles, many vehicles have either an armrest for each seat or the other armrest is built into the door to save space. It is especially seen in the front seats in M1 class vehicles.

As explained above, the most common use of this class is window sill designs.

Figure 1.18. Window sill armrest

1.5.4. Detachable

Armrests, which are in the detachable class, have emerged as the demand of customers who are not satisfied with the armrest design, comfort or ergonomics while purchasing the product. These products have emerged because they are detachable, and their assembly is more suitable for the user level.

Regardless of the other 3 classes above, all of them have examples in this class.

Figure 1.19. Detachable armrest-I

Figure 1.20. Detachable armrest-II

1.5.5. Adaptations for Additional Use of the Armrest

Adaptations for additional use of the Armrest class armrests are designs that try to increase use with additional features, without sacrificing comfort and ergonomics in order to save in-car space. This class is divided into 2 main parts.

One of them is that there are similar features such as storage space and a cup holder in its interior design. Thanks to these designs, while not losing anything from a comfort or having a small amount of loss, an area has been created where you can put tools that should be with or should be at hand at all times.

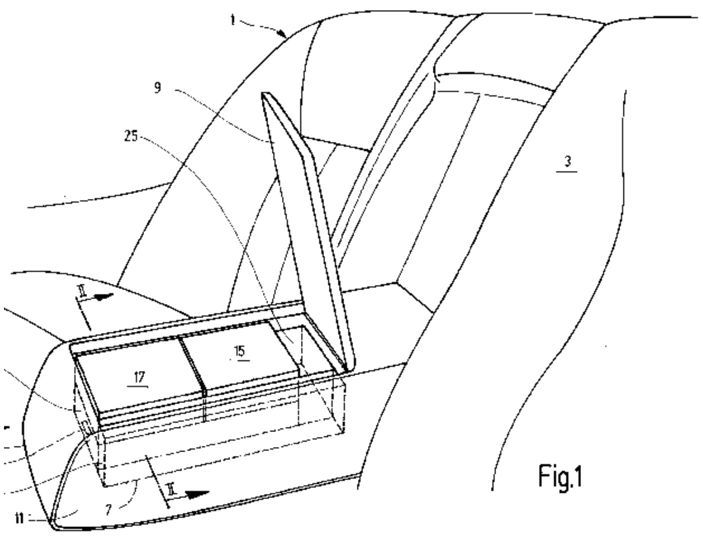

Figure 1.21. Armrest with storage compartments

Another is the designs in which the keys and electronics are required to open and close the in-car features in the design. Thanks to these designs, while you do not lose anything from comfort, a command that can be given to the vehicle that you can use at any time, for business purposes or for security purposes or for convenience, a key that can be easily reached by hand constitutes the design class.

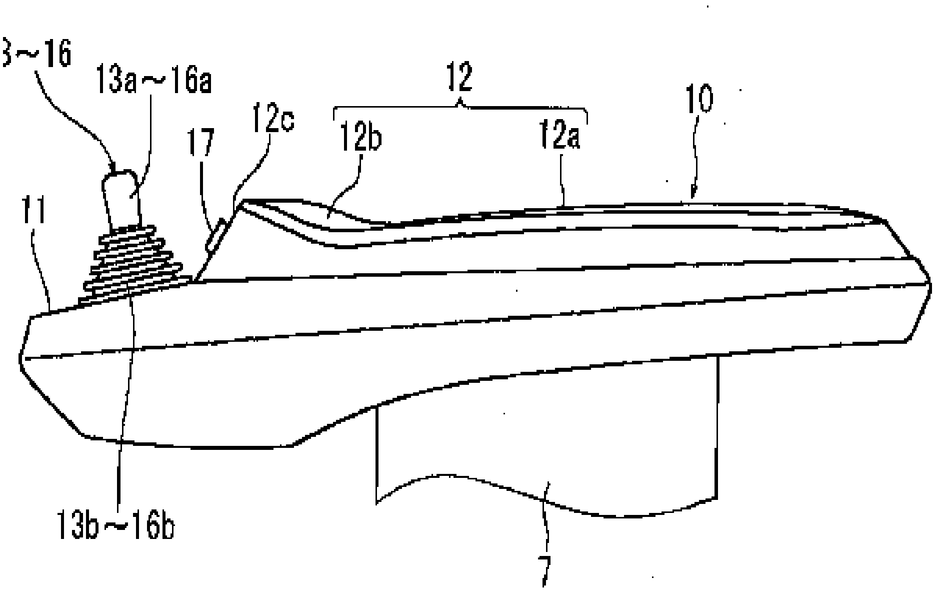

Figure 1.22. Armrest drawing with electrical controls compartments

Figure 1.23. Armrest with electrical controls compartments

2. MATERIALS AND METHODS

2.1. Used Computer Programs and Methods

2.1.1. SolidWorks

Solidworks is a computer aided design (CAD) and computer aided engineering (CAE) computer program that can create solid models. Solidworks is also known as DSS Solidworks. DSS is the abbreviation of Dassault Systems, a company that developed this program. Solidworks is a CAD software for creating 2D and 3D solid models simply, quickly, and effectively. SolidWorks' innovative features are highly functional. It is a very useful and Windows-specific three-dimensional design program. Compared to other CAD programs, the most important advantage is that it has a very useful interface. In addition, in this program; It includes modules such as solid part modeling, simulation, motion, assembly, Photoview 360, ScanTo3D, and e-drawings.

Solid modeling of almost any object can be done in SolidWorks. Phases such as design, development and improvement are very important in the manufacture of products. Performing the design and analysis of a product in a computer environment provides great savings. For example, RealView graphics enable you to realize your designs in real time, while PhotoView 360 enables us to create an advanced photo, realistic rendering, and animation. Both tools give you an idea of what your design will actually look like before it goes into production.

The main benefits of this CAD program to users and companies are as follows:

- Although it has a simple interface, advanced modeling can be done.
- Analysis, animation, and simulation can be done about the designed solid model.
- Provides detailed machine and parts with many sub-components, design, and combination with a practical interface.
- Provides visual enrichment by coloring the designed solid models.
- It has the feature of uploading the files of models designed in SolidWorks program to analysis programs such as ANSYS.
- It is a high-performance and low-cost computer program for companies as it contains many features such as design, analysis, animation, and simulation.

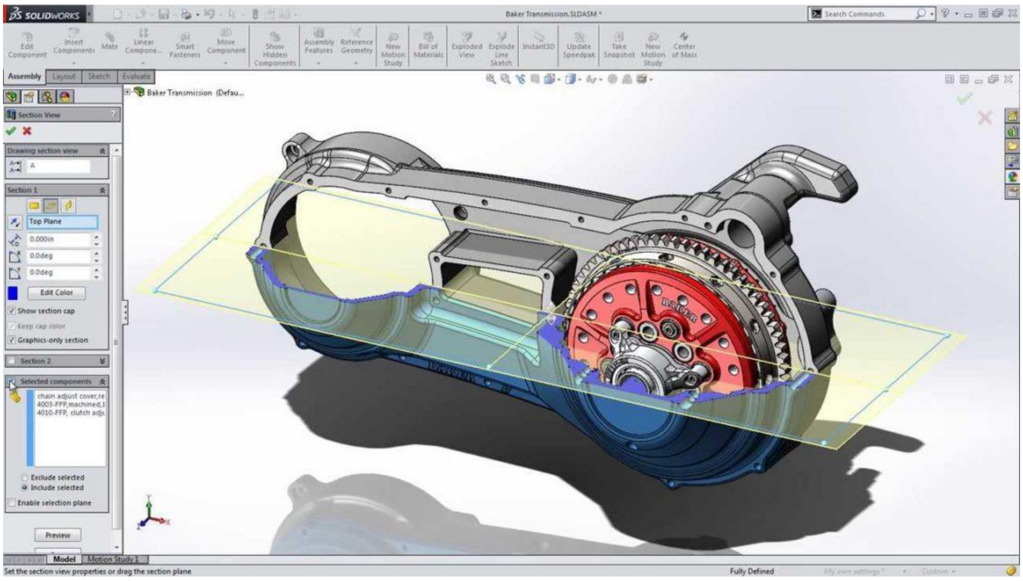

Figure 2.1. SolidWorks design (muhendisce.com, 2016)

Among the various operations offered by the program to users, the main ones and the details of these operations are as follows:

Sketcher

- Profile drawings
- Actions to be applied to profiles

Part Design

- Image adjustments
- Sketch-based applications
- Solid modeling
- Changing the coordinates of the solid model
- Sheet metal forming
- Surface forming processes
- Surface-based solid creation
- Application of the molding required for the manufacture of the parts

Assembly Design

- Assembly of parts

- Creation of constraints
- Movement of mechanisms
- Movement inhibitors in mechanisms
- Dependent movements in mechanisms
- Part call to assemblies with Toolbox
- Smart Mate fast track adding

Drafting (Preparation)

- Extraction of technical drawings
- Image creation
- Dimensioning
- Entering assembly numbers
- Shape and size tolerances

Analysis

- Linear stress analysis of a simple part
- Thermal analysis of a simple part
- Buckling analysis
- Optimization tests
- Testing the designed part under all kinds of boundary conditions

Simulation

- Identification of the connections of the simple mechanism
- Adding friction to connections
- Finding the thrust momentum values that should occur as a result of the collision
- Simulation of the mechanism

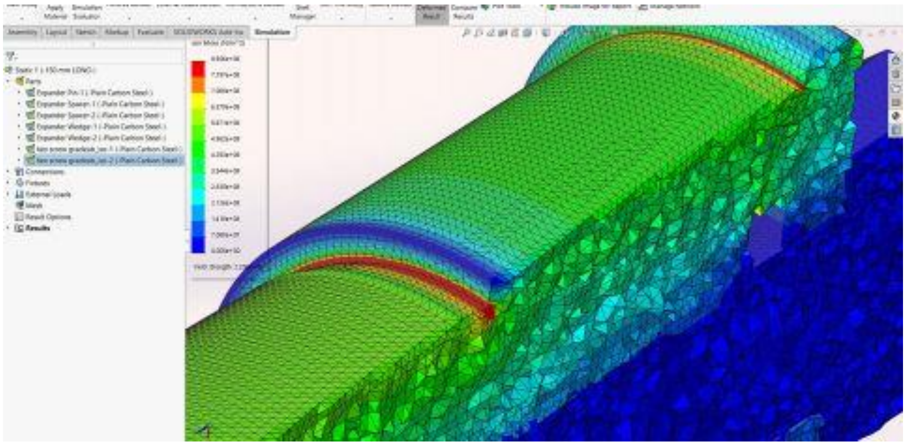

Figure 2.2. Solidworks analysis (Solidworks.com, 2021)

Solidworks Usage Areas

Fast and error-free assembly is achieved by using parametric approaches based on a feature in assembly construction and part modeling. During assembly, the connections of all parts with each other can be made up of relations such as parallelism, tangent and concentric, and the values can be determined in terms of relative distance. Thus, all assemblies are easily organized. Solidworks program commands, which have a user-friendly interface, are very easy and simple. The understanding of the SolidWorks program is based on the creation of complex three-dimensional geometric structures from simple drawings. In addition, with the SolidWorks program, which has the 3D Sketch feature, two-dimensional drawings such as lines, circles and triangles can be used even in three-dimensional drawing mode. Thus, two-dimensional drawings can be easily created on the three-dimensional coordinate plane.

Computer-aided design, computer-aided production, and computer-aided engineering technologies, especially used by people working in the field of machinery and molds; have an important place in the design and production world. SolidWorks, which is also preferred in different sectors, stands out in this technological universe.

SolidWorks is also a computer-aided engineering program. The part, whose solid model is prepared with the SolidWorks program, can be resized with simulations including finite element method and similar analyzes and strength analysis. Thus, engineering designs with high durability can be made with a low budget and material consumption.

SolidWorks is actively used in many engineering applications. The main ones of these engineering fields are as follows:

- Aviation and Space
- Automotive and Transportation Vehicles
- Consumer Products and Medical Products
- Processing Facilities
- Construction and Electronics
- Machinery Parts and Heavy Equipment
- HVAC and CFD Applications
- Energy Technologies
- Product Design, Mold and Tool Design

As a result, the entire process from start to finish can be run through SolidWorks, where it is possible to evaluate how the design will yield results in various variables. In addition, with the advanced program, vehicle designs are tested in a virtual environment, thus providing more control during and after the test.

2.1.2. ANSYS Software

ANSYS software is a computer-aided engineering program that allows analysis and simulations in engineering studies. The ANSYS program provides highly effective studies in many different engineering disciplines such as mechanics, heat transfer, structural analysis and computational fluid dynamics.

The ANSYS program, one of the most widely used CAE (Computer Aided Engineering) programs in the world, uses the finite element method. With the finite element method, complex geometries, which are very difficult to analyze in one piece, are divided into many small pieces and analyzed separately. By combining the analysis results of a finite number of elements, the final and closest analysis results are obtained.

ANSYS develops and markets engineering simulation software for use throughout the product life cycle. This software is used to determine how the products will perform in different conditions before building test products or before crash tests take place. For example, situations such as how any bridge will last after years of traffic or how to design a slide that is desired to be created using less material without sacrificing safety can be easily simulated thanks to ANSYS.

Most simulations in ANSYS software are performed using the ANSYS Workbench system, one of the company's main products. The modules in ANSYS Workbench work in harmony by connecting to each other, thus enabling multi-functional advanced analysis. The dimensions of the objects are defined and then the desired analyzes are started by adding weight, pressure, temperature and other physical properties. (Jay P. Pederson 2000)

ANSYS Usage Areas

The ANSYS program is frequently used in many areas of engineering. It provides analysis results in many subjects such as 3D design, electronics, flow, optics, materials science, semiconductors, structural analysis. To summarize the main areas of use from these topics,

- Automotive Industry
- Aviation and Space
- Electronics and Robotics
- Energy Technologies
- Heating and Cooling
- Production
- Ventilation

ANSYS is widely used in many other fields in addition to these fields with its various modules. The 3 basic modules of ANSYS, Structural, Fluent and Electromagnetics are the most used modules. The Structural module is used for the strength of materials, the Fluent module is used for flow analysis, and the Electromagnetics module is used for applications where magnetic fields occur.

2.1.3. Finite Element Analysis

Finite Element Analysis (FEA) is the simulation of any physical phenomena using the numerical technique called Finite Element Method (FEM). This method is used by engineers to optimize components during the design phase to reduce the number of physical prototypes and experiments and to develop better products.

It is necessary to use mathematics to measure and comprehensively understand physical phenomena such as structure and fluid behavior, thermal convection, wave propagation, growth of biological cells. These physical phenomena are explained mostly using the method of Partial Differential Equations. However, thanks to the advancing technology in recent years, many effective numerical techniques have been developed that enable computers to solve these equations. One of the most prominent techniques is Finite Element Analysis.

It should be known that the finite element analysis method only gives an approximate solution to the problems and is a numerical approach that is used to reach the real result of partial differential equations. In its simplest form, finite element analysis is a numerical method used to predict how a part or assembly behaves under different specified conditions and to observe its results. It is generally used in modern simulation software and helps R&D and design engineers to observe weak points in their designs. (SimScale (2016) | Finite Element Method)

Its main areas of use are:

- Mechanical - Civil - Automotive Engineering
- Fluid Flow
- Heat transfer
- Electromagnetic fields
- Soil Mechanics
- Static - Dynamic
- Acoustic
- Structural Analysis
- Biomechanics

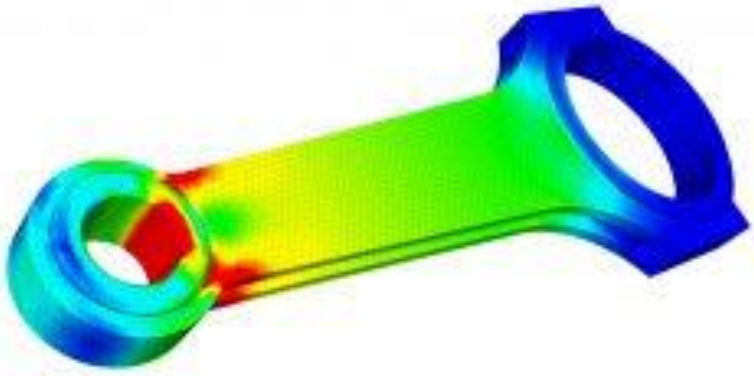

Figure 2.3. Result of a finite element analysis

2.1.3.1. Stress-Strain Analysis

The stress-strain analysis is an engineering discipline that uses various methods to determine stresses and strains in materials and structures subjected to forces. The term stress is a physical quantity that expresses the internal forces exerted on each other by neighboring particles of continuous material. The term strain is the measure of the deformation of the material. In other words, stress is the ratio of force to the area (S = F/A). Strain is the ratio of the change in length to the original length when subjected to some external force.

These analyzes are the most important type of analysis for mechanical, aerospace and civil engineers who are involved in the design of structures of various sizes such as bridges, aircraft and rockets, dams, tunnels, some mechanical parts. After the design, stress-strain analysis is used continuously in the maintenance of these structures and in investigating the causes of structural failures.

In engineering, stress-strain analysis is a tool rather than a goal. The main aim in making these analyzes is the design of structures that withstand certain loads using the minimum amount of material or meeting other optimality criteria. Stress-strain analysis can be performed with a combination of analytical mathematical modeling, experimental methods and classical mathematical techniques.

Stress-strain analysis can be performed by considering time-varying forces such as engine vibrations and a load of moving vehicles. In this case, the stresses and strains will also be functions of time and space (Wikipedia, Stress–Strain Analysis 2021).

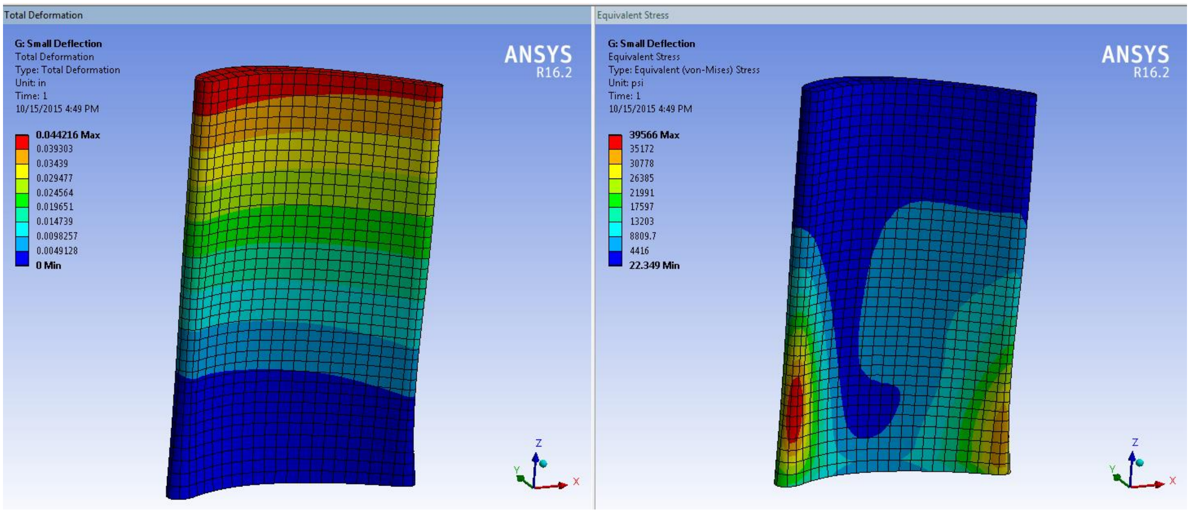

Figure 2.4. Stress-strain analysis (Özgün 2018, Solid Mechanics)

2.1.3.2. Fatigue Analysis

Machine elements are generally under the influence of varying loads and stresses. Although the loads acting on the elements are seen as static, sometimes the stresses occurring in the section can be variable. For example, the stresses created by the static load acting on a rotating shaft are completely variable.

In elements under the influence of variable stresses, the number of repetitions is more important than their maximum value. The cyclically varying stresses cause wear in the internal structure of the material. For this reason, the rupture event occurs well below the static limits. Changes in the internal structure of the material under the influence of varying stresses are called fatigue. The period of time that the elements last until they break is called life. The life of the elements is usually indicated by the number of cycles. The rupture in variable stresses begins at a point of discontinuity in the inner structure or outer surface. Around this point, the material fatigues and a crack occurs. Over time, this crack deepens, and eventually, the stress in the region outside the crack exceeds the strength limit, causing the elements to break suddenly. While most of the parts work very well at the beginning, after a certain period of time, depending on the number of cycles of the loading, parts are subject to fatigue damage and lose their functionality to a great extent or completely. The main purpose of fatigue analysis is to observe how many cycle the material can withstand during its life at the design stage.

Fatigue testing is a special form of mechanical testing performed by applying cyclic loading to a structure. Fatigue tests are used to predict fatigue life, observe crack data, identify critical locations, and make fatigue-safe structures fatigue-safe. The automobile and aviation sectors are areas where it is used intensively.

Fatigue analysis is a growing trend in assemblies and mechanical parts. Knowledge of stress analysis is important as it is the foundation of fatigue analysis. With the stress and strain information obtained through stress analysis, it is estimated how many life cycles the investigated component will withstand. Fatigue analyzes give the best results with the FEA method, but these tests can also be done manually. (Yuksel Chaush 2008)

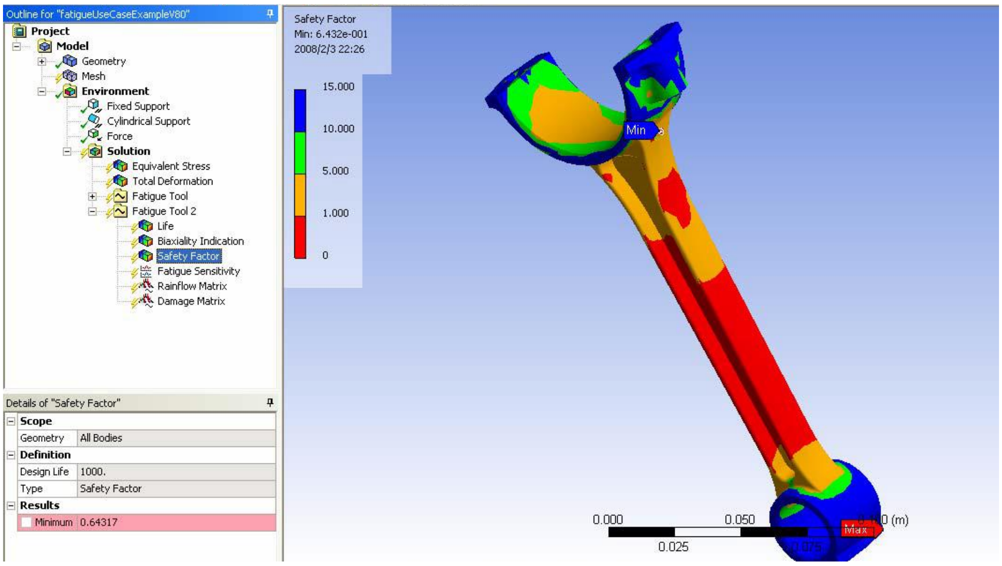

Figure 2.5. Fatigue analysis

2.2. Essential Parts of the Design

Solidworks was used while designing the car driver armrest. The main elements have been determined for the armrest design. These are the driver's seat, the mechanism handle and the frame of the armrest. While designing, they were primarily focused on. Our design is planned in two different structures. The mechanism that makes up the armrest and the parts, apparatus or tools that can be added as innovations.

Figure 2.6. Driver seat with armrest design

2.2.1. Driver's Seat

Since the driver's seat is out of the scope of the thesis, it was preferred to use it ready-made. The use of open-source design was preferred on the online site called Grabcad. A car seat design belonging to a user named Shailesh Pandey was used. (Shailesh Pandey 2014)

Figure 2.7. First version of Shailesh Pandey's drive seat design

It was used after a few changes and overlays on Shailesh Pandey's design.

Figure 2.8. Used version of Shailesh Pandey's driver seat design with the right corner view

Figure 2.9. Used version of Shailesh Pandey's driver seat design with the left corner view

2.2.2. Mechanism Handle

Part design for fixing the armrest fixed to the body of the chair at certain angles. First of all, our armrest with angle adjustment must be removable and attachable in order to be suitable for production. For this reason, it is larger than the mechanism, so it can be easily disassembled and mounted, the cover is made. The cover is fixed on the mechanism handle.

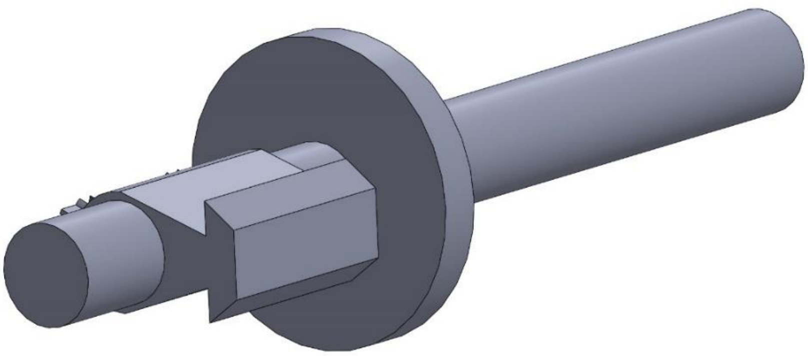

Figure 2.10. Mechanism handle with right corner view

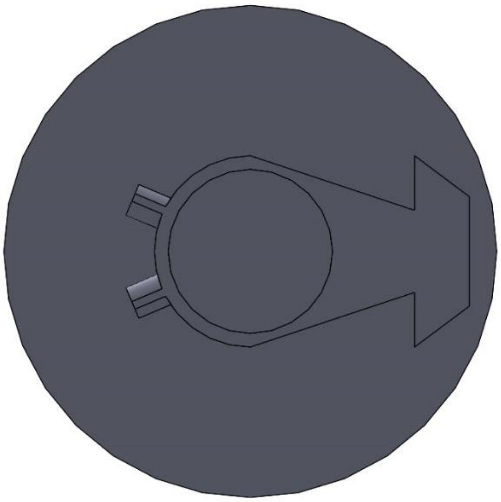

Figure 2.11. Mechanism handle with right corner view

The key part on the mechanism is the part that complements each other with the snap-on parts on the armrest. In the first meetings, it was planned more narrowly in design. However, it was later thickened to increase bearing capacity and extend durability.

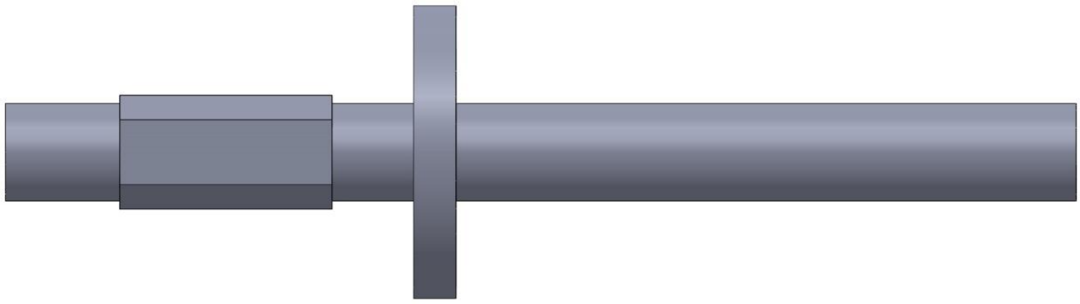

Figure 2.12. Mechanism handle with front view

The interlocking mechanism on the front and back individually is explained as follows. The design on the front is primarily designed for the armrest to move between certain angles. Thanks to this interlocking structure, a 90-degree range of motion are provided.

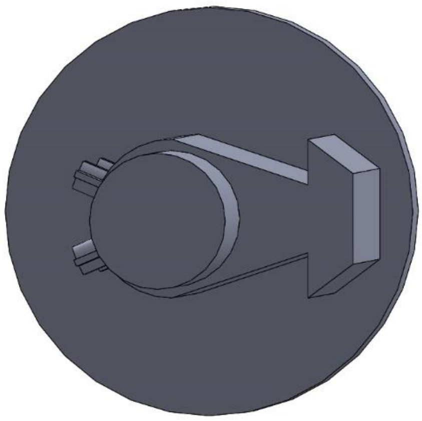

Figure 2.13. Mechanism handle with angle view

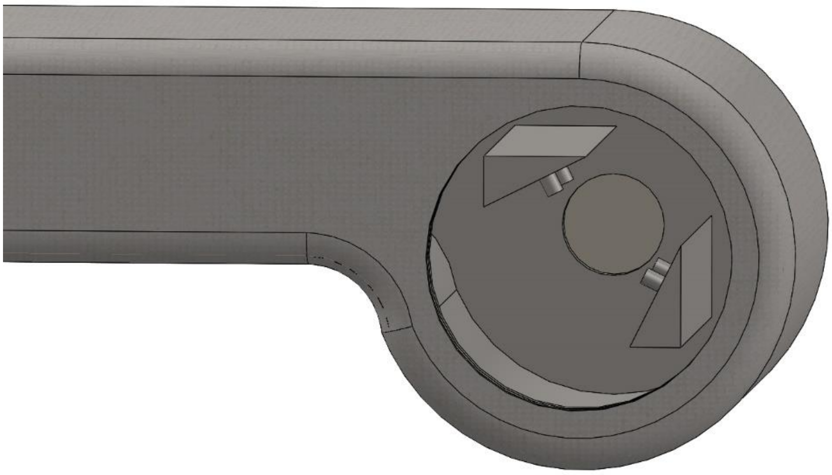

Figure 2.14. Armrest's joints for mechanism handle with angle view

In the meetings held, it was thought that the armrest would lose its position and move in sudden braking or sudden acceleration. For this reason, a design that prevents movement and stabilizes at desired angles is needed. Based on the need, female and male parts were made on the mechanism handle and the mechanism parts in the armrest, and fixing designs were produced in the position.

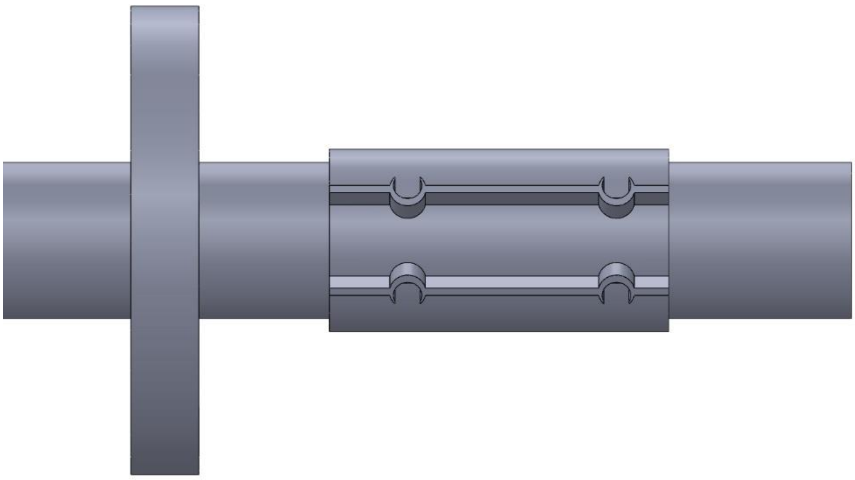

Figure 2.15. Mechanism’s back joints with back view

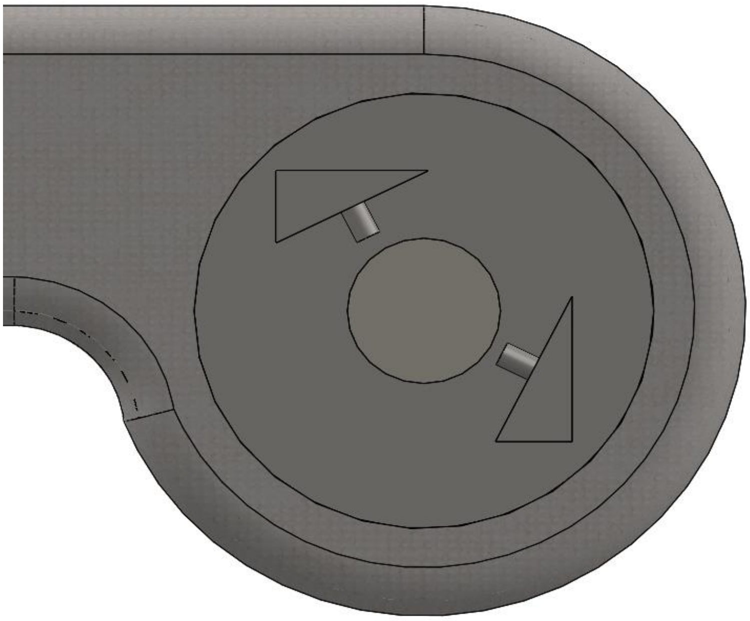

Figure 2.16. Armrest's joints for mechanism handle with right view

The protrusion on the front, on the other hand, aims to prevent the armrest from moving by ensuring that it is fixed on the body.

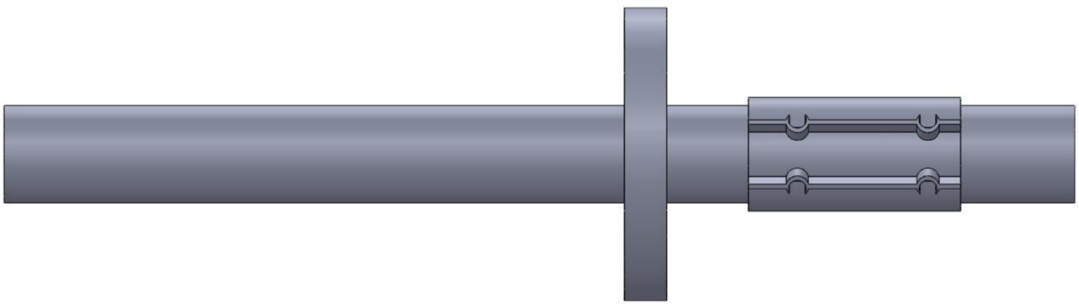

Figure 2.17. Mechanism handle with back view

2.2.3. Armrest

A design that does not differ much from the general designs and offers so many different innovations has been designed. This design, which has a phone storage area and interlocking parts with the mechanism handle, has three layers: its frame, foam cover and fabric cover. The most important of these is the frame. While its frame keeps the armrest structure afloat, it is also a part of the mechanism and contains the phone storage chamber. The armrest is ergonomically designed to provide comfort to people and increase driving pleasure.

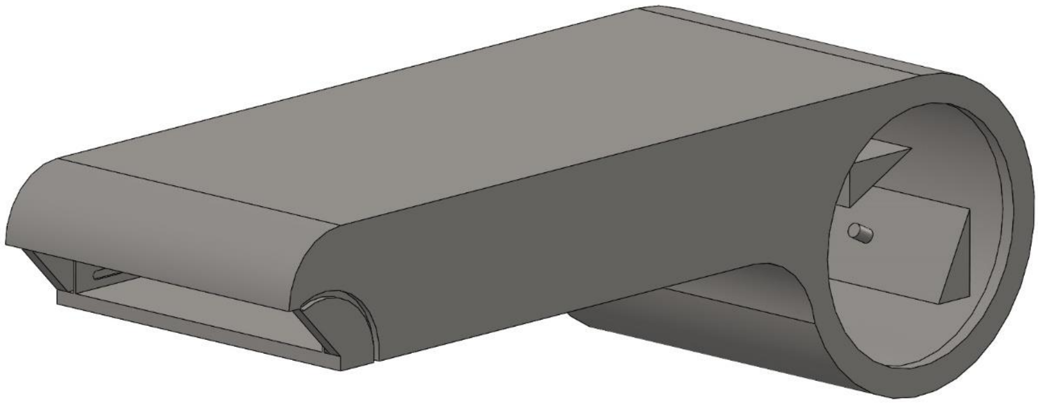

Figure 2.18. Armrest's frame with angle view

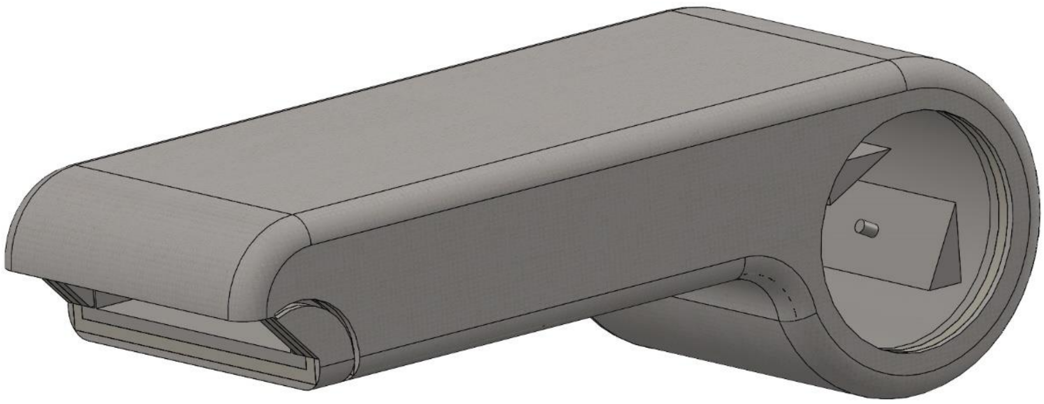

Figure 2.19. Armrest with angle view

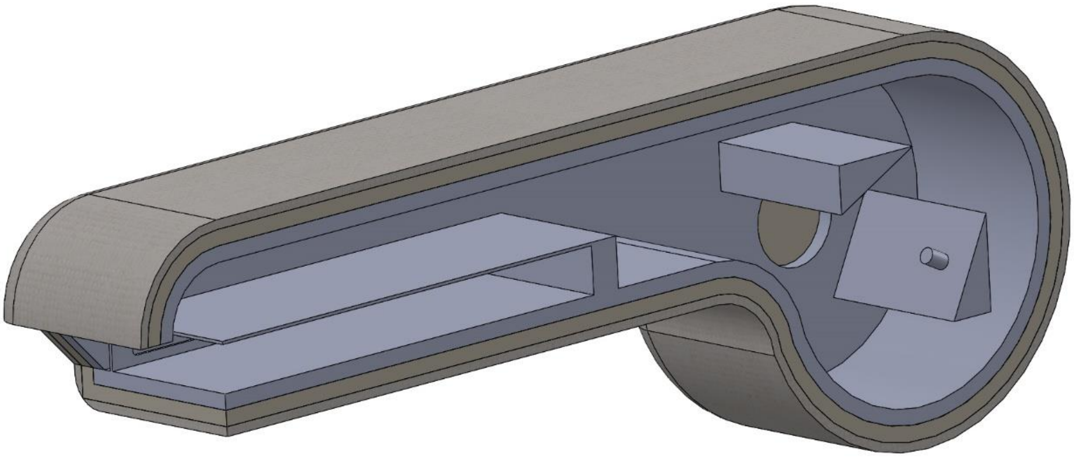

Figure 2.20. Armrest section view with single view

2.3. Mechanisms and Innovations of Design

2.3.1. Armrest Mechanism

The armrest mechanism is the most critical point of this design. Because if there is any problem, it is checked here first. Whether the designs we made for the armrest mechanism will carry the structure or not, this is the most important point. This design should both reduce the cost and be able to carry the load, its own frame weight, and also be applicable. These drawings should be made with these items in mind.

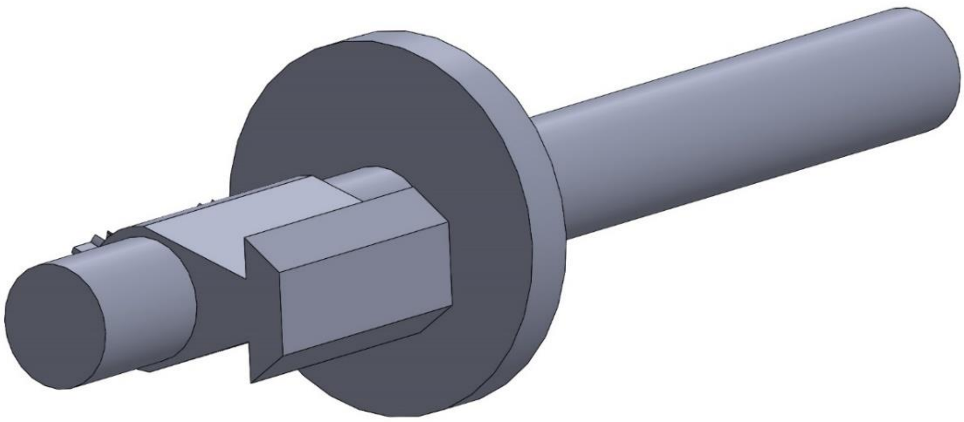

Figure 2.21. Mechanism handle with right corner view

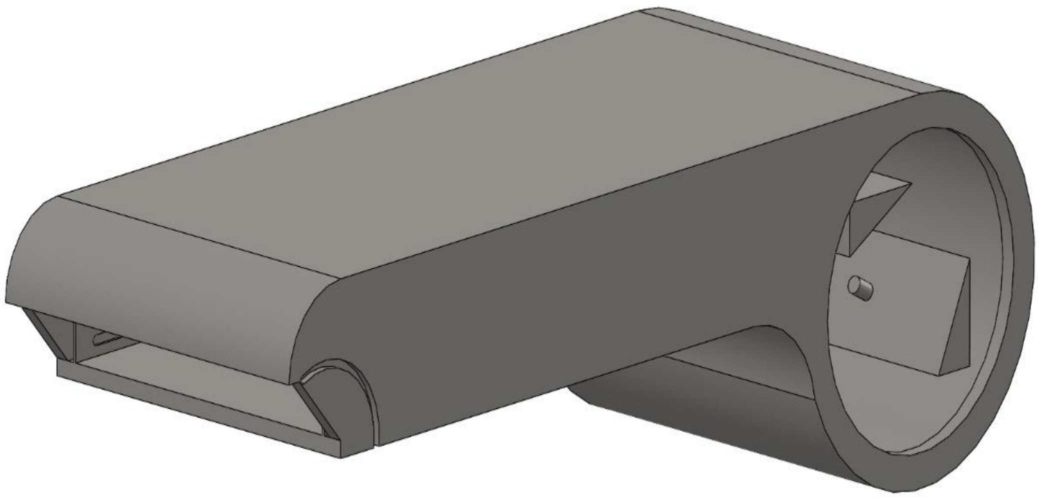

Figure 2.22. Armrest’s frame with single view

Our armrest mechanism has a stopper and is designed to be stable at 90 degrees angles. Firstly, in the horizontal position, that is, in the angle of use, and secondly, in the vertical standing angle, that is, it is lifted to reduce the footprint. In the horizontal stance, it provides ergonomically comfortable driving for people. It also contributes to the driver's health. The advantage of the vertical stance is that it takes up less space when we lift it, thus enabling the driver to use the empty space between him and the passenger on the right more comfortably. When a large space requirement arises, the purpose of bringing it to a vertical position is to bring the armrest to a vertical position and to ensure that that large area can be found.

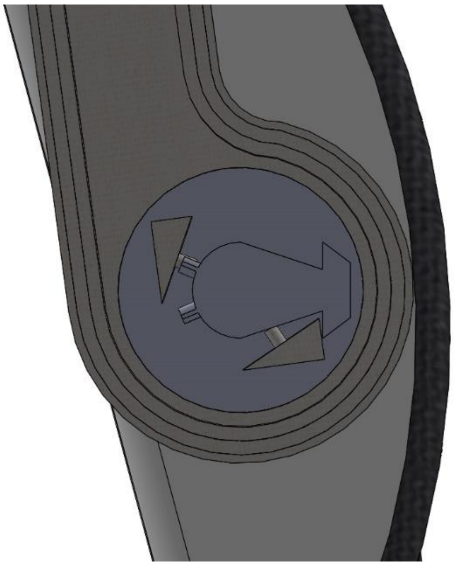

Figure 2.23. Mechanism of the armrest in the vertical position with section view

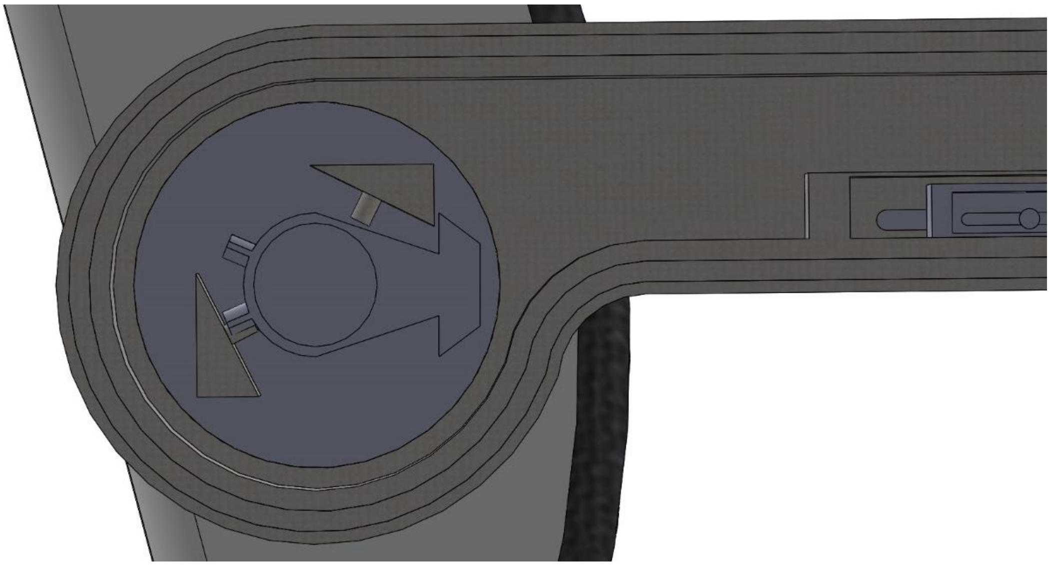

Figure 2.24. Mechanism of the armrest in the horizontal position with section view

This mechanism works thanks to the male and female parts on the mechanism handle and armrest parts. In this way, the armrest can move 90 degrees. Thanks to this mechanism, it will not make an upward angle change in the sudden acceleration that can be made in the horizontal position. Likewise, in the vertical position, it will not make a downward angle change in sudden brakes. It will stop at the desired position and state.

Figure 2.25. Armrest in the horizontal position with all design

Figure 2.26. Armrest in the vertical position with all design

Figure 2.27. All designs with exploded view

2.3.2. Phone Drawer Design

First of all, many things have been considered and discussed for innovation. In the meetings held, these have been that the cup holder, storage area or armrest can be rotated more on an axis and stored better. However, as a result of the meetings we held, they were abandoned because they were far from adding anything new or were already tried designs. Apart from these, another idea has been put forward. This idea has been to put phone storage space.

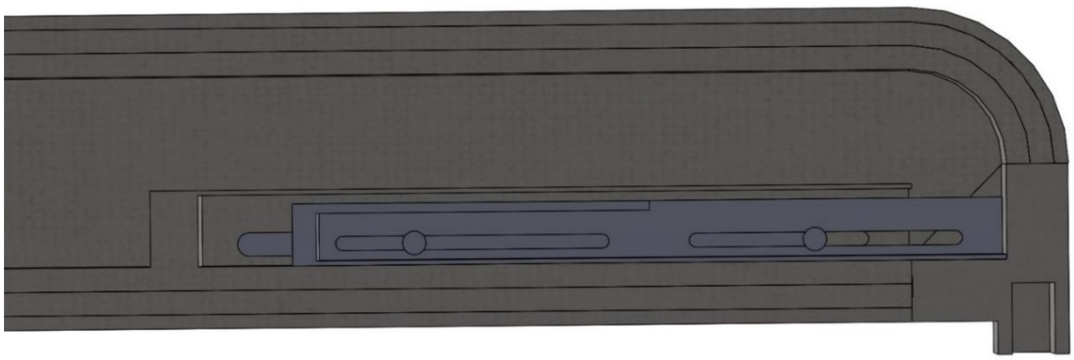

Figure 2.28. Closed phone drawer design section view

Thus, it is aimed both to be within reach of people in emergencies and to be kept away from attention and interest by being away from eye level. Thus, it is thought that both the speed of response to emergencies can be increased and the inattention in the driving process can be minimized.

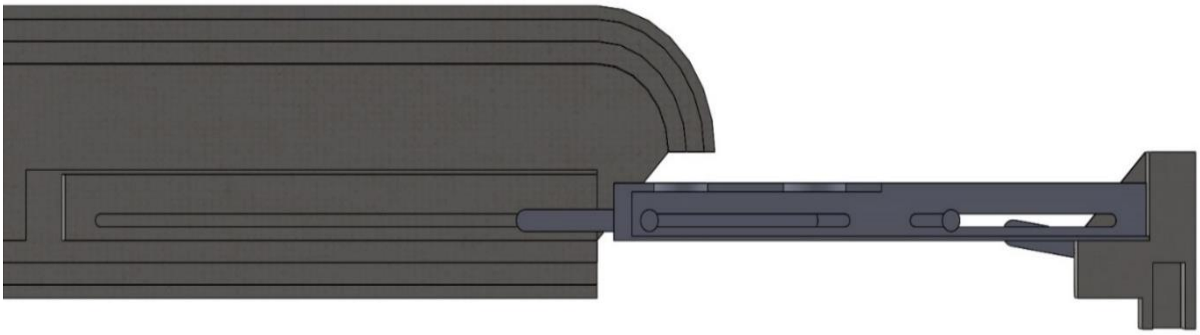

Figure 2.29. Open phone drawer design section view

It was discussed whether it would be more useful to have it on the driver's side, on the surface, or in the front of the armrest, in the meetings held before the phone storage drawer took its final form. As a result of these meetings, it was thought that the driver's side was on the surface and it could both force people ergonomically and disrupt the armrest design. For this reason, the front side was chosen as the part where the phone will be put in and taken out. Thus, the design of the armrest was preserved at a predictable level and it was aimed to enable people to reach the phone drawer more easily.

Figure 2.30. Open and angled phone drawer design with back corner view

The most important part of phone storage is the design of the drawer handles. Because if the phone storage area is not designed for use, it will be an unproducible project. The only ways it is suitable for use are that it is ergonomically suitable and accessible to people and that the phone or something else placed it is fully protected. Drawer handles are designed within this frame.

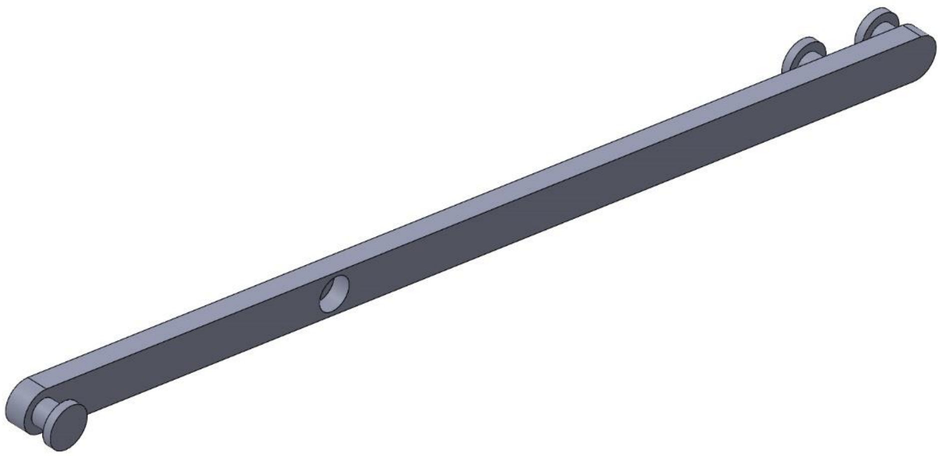

Figure 2.31. Drawer handles with angle view

Figure 2.32. Drawer handles with top view

First of all, an interior volume that is closed to all parts except the front was created. This volume is the slot of the handle of the phone. Drawer legs are required for the handle to move in this chamber. For this reason, paths were opened on both sides of the chamber in the direction of the drawer. In the same way, a similar way is opened on the phone handle. The handle is fixed in one direction thanks to 2 long handles on both sides. In order for this fixation to take place, the stabilizers moving on the way in the fixed chamber on the armrest consist of 2 parts, the reason for which is the information "When an infinite line passes from 1 point, a single line passes through 2 points". For this reason, even if the drawer is completely removed, the rails will not turn down due to gravity. The drawer will stay in the same direction as the armrest.

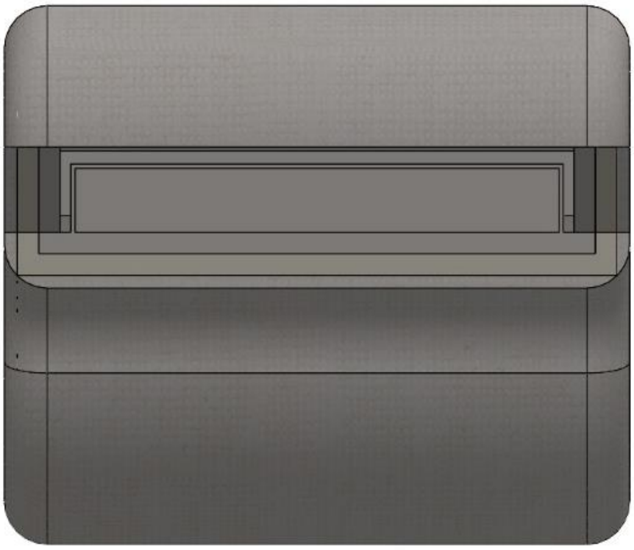

Figure 2.33. Armrest with front view

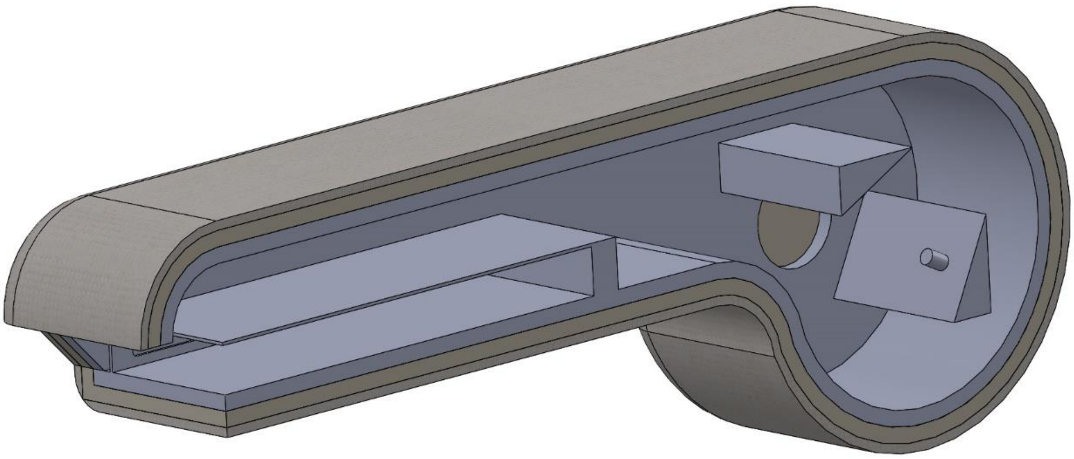

Figure 2.34. Armrest with section view

In addition, it was decided to add the angle handle used because the drawer face, which will face down in full direction due to gravity when the drawer is taken out, is dangerous because it can cause difficulties for instant use and the driver can hardly see the screen when it is in the open position. In addition to these, it is thought that problems such as the full turn of the drawer that comes out and thus damaging the product to be stored or the inability to use the product there at that time in full functionality may occur and prevent this. In this way, the armrest drawer will only be able to increase the angle it makes with the armrest up to a certain level. Thus, movements are restricted and controlled. This presentation ensures that the phone is both under the driver's hand and in the driver's field of vision.

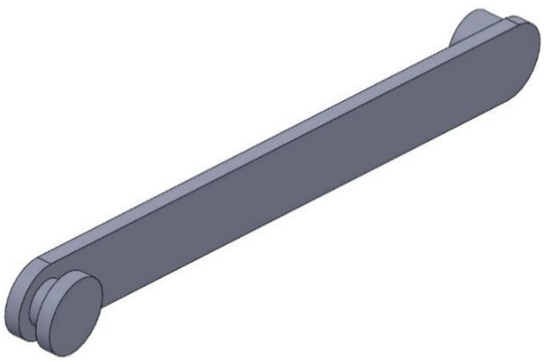

Figure 2.35. Angle handles with angle view

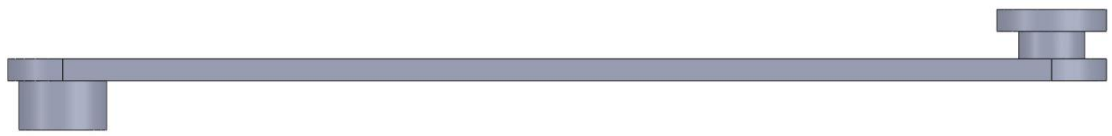

Figure 2.36. Angle handles with top view

Figure 2.37. Open single handle with all design's right view

The design of the phone holder, in which the phone is located, is considered as follows. Nowadays, people mostly use touch phones. For this reason, the most used parts of the screen, if not the whole screen, should be left open at the request of the people. Simple one-touch gestures such as answering the phone, viewing messages, or playing forward or changing music while listening to music require clear surfaces on the top surface of the handle to allow the driver to touch the touchscreen. For these reasons, the design was arranged. In this way, both design improvement, saving from the materials used and customer satisfaction are targeted.

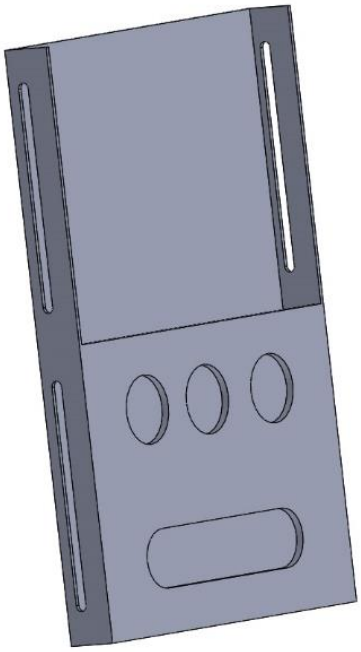

Figure 2.38. Phone holder with angle view

The cover part is normally a design that is planned to be cut from the armrest design. However, as a result of the discussions we had at our later meetings, it was thought that having a handle protrusion would be better for the cover design. It is aimed to add a plus in terms of both ergonomics and usability. By making the cover design like this, the driver's intervention in the storage area is facilitated, and the driver can easily do what he wants to do without distraction with this design. For this reason, the cover, which is considered continuing part of the armrest design, has changed a little with some changes. The outer cover of the cover is exactly the same as the armrest. Due to the lock design added to the design later, the design was later updated again. As a result of this update, a female slot has been drilled in the driver's side surface of the hatch. The male part, which is the fixed leg of the lock part, is associated here. In this way, the phone or any product protected in the chamber is protected.

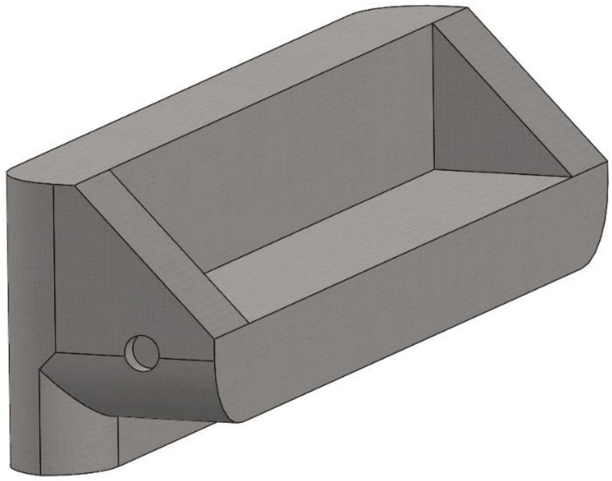

Figure 2.39. Phone drawer cover with left corner view

At the meetings we held at the end of these designs, it was discussed that when the armrest is in the used position, the drawer can be opened at the moment of sudden braking and the phone, or something placed there may be damaged or lost. In order to overcome this problem, a lock apparatus has been designed on the driver's side surface. Thus, unwanted accidents and complications are prevented.

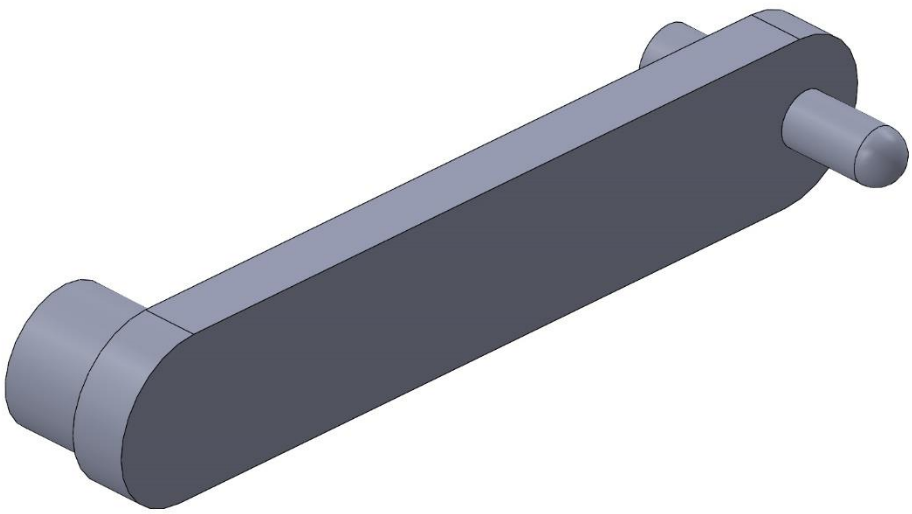

Figure 2.40. Lock apparatus with angle view

Figure 2.41. Lock apparatus with top view

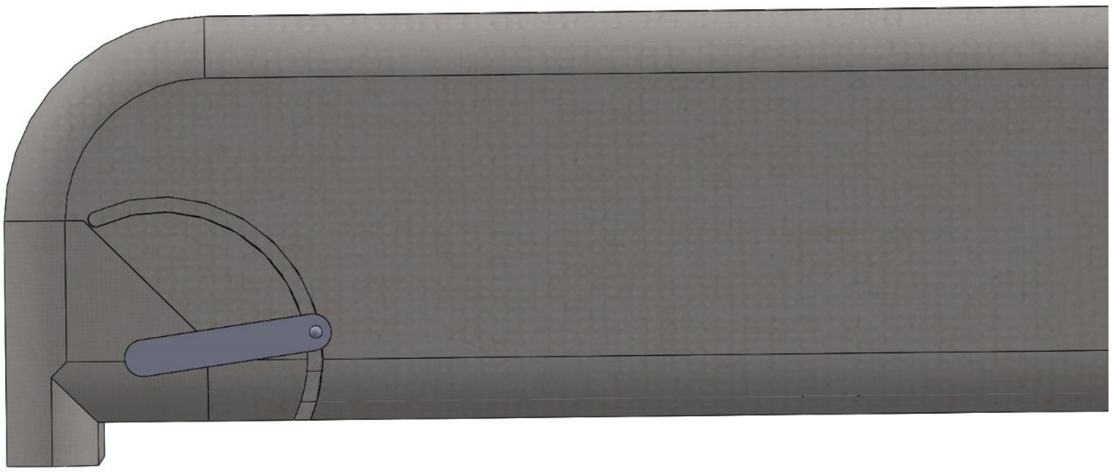

Figure 2.42. Cover and armrest locked with lock apparatus with right view

All these parts make up our armrest design with phone storage, step by step. All of them reveal a neat design as a whole.

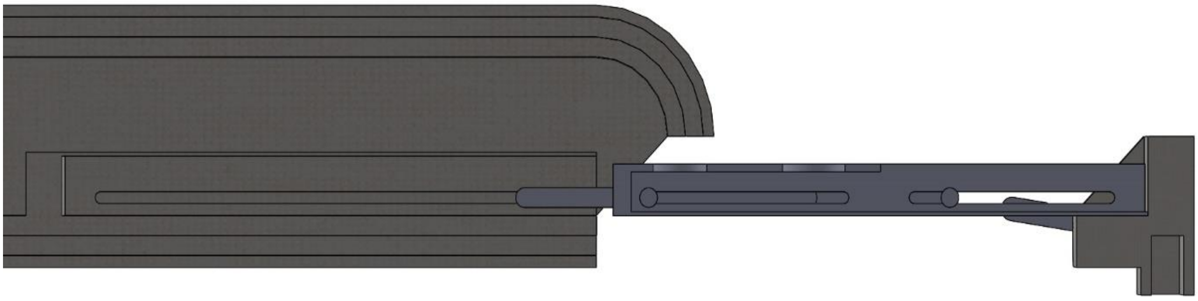

Figure 2.43. Open phone drawer design section view

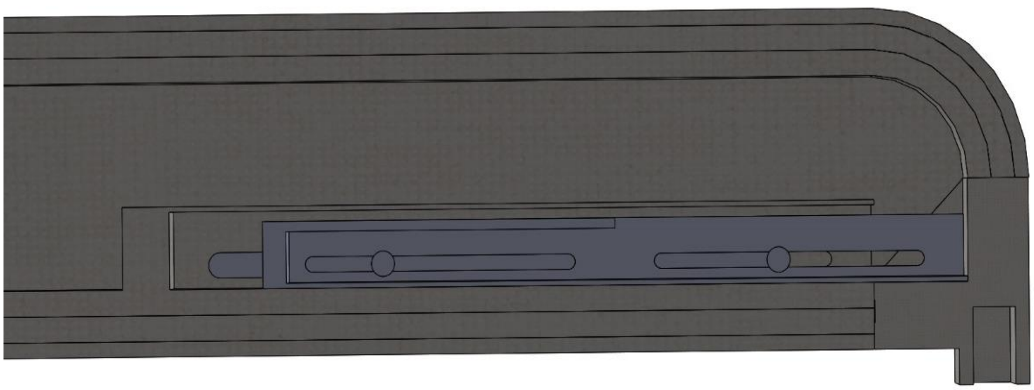

Figure 2.44. Closed phone drawer design section view

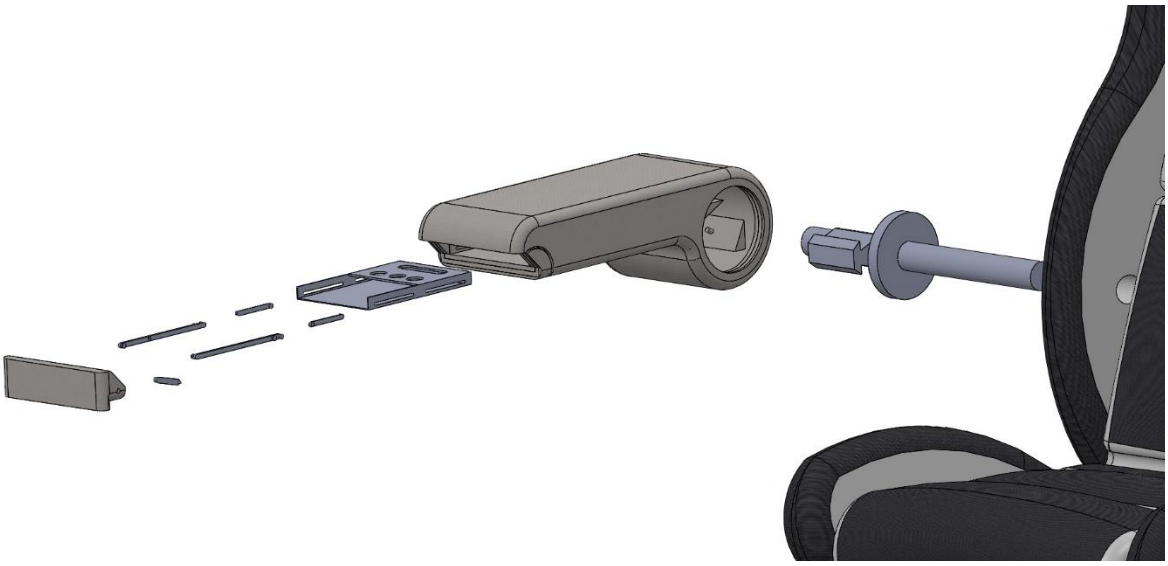

Figure 2.45. Phone drawer design with exploded view

All the above designs and mechanisms have formed our angle adjustable armrest design as a whole.

Figure 2.46. Armrest in vertical position with right view

Figure 2.47. Armrest in horizontal position with front view

Figure 2.48. Armrest design with open angle handle with angle view

Figure 2.49. Armrest design with exploded view

2.4. Material Selection

Material selection is of great importance at the design stage. Alternatives were considered to choose what material the armrest frame would consist of, and studies were conducted on three materials: Magnesium AZ31B Alloy, Structural Steel, and Aluminum, 6061, T6, wrought. The mechanical properties of these materials are summarized in Table 2.1 below.

Table 2.1. Mechanical Properties of Materials

Material	Density (ρ)	Yield Strength	Ultimate Strength	Poisson's Ratio (υ)
Magnesium, AZ31B Alloy	1.775 g/cm^3	154.9 MPa	239.9 MPa	0.305
Structural Steel	7.85 g/cm^3	250 MPa	460 MPa	0.300
Aluminum, 6061, T6, wrought	2.713 g/cm^3	259.2 MPa	313.1 MPa	0.330

The test for carrying the 800 N load required for the armrest was tested with the ANSYS program for three different materials. Here are each of the results for Magnesium AZ31B Alloy, Structural Steel and, Aluminum, 6061, T6, wrought materials respectively:

Magnesium AZ31B Alloy:

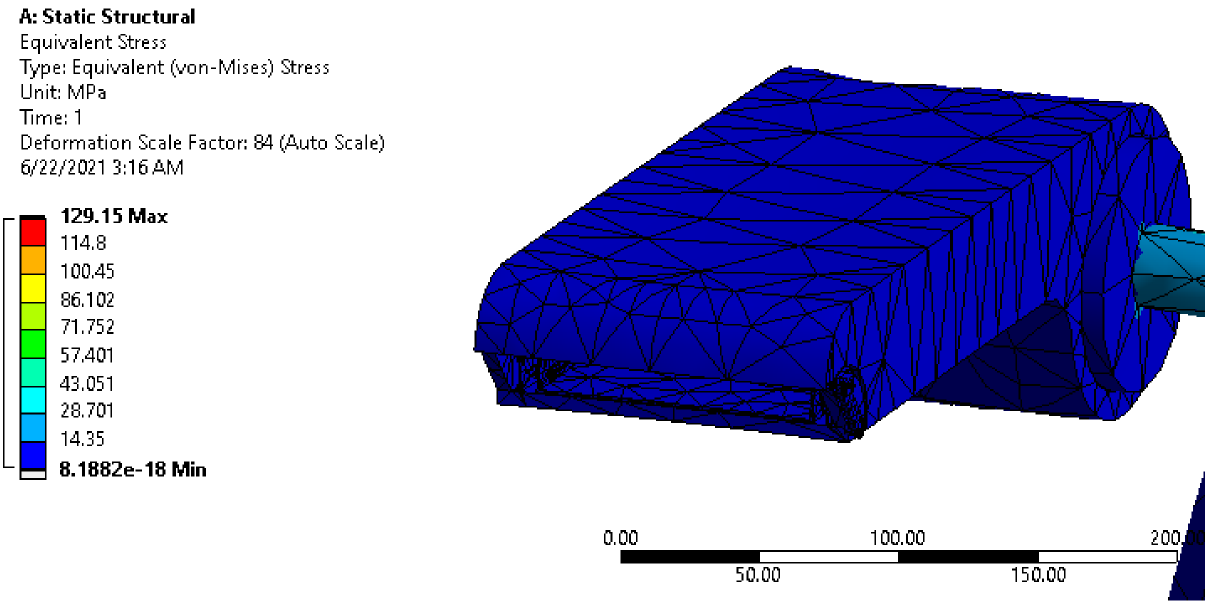

Figure 2.50. Magnesium AZ31B alloy equivalent stress

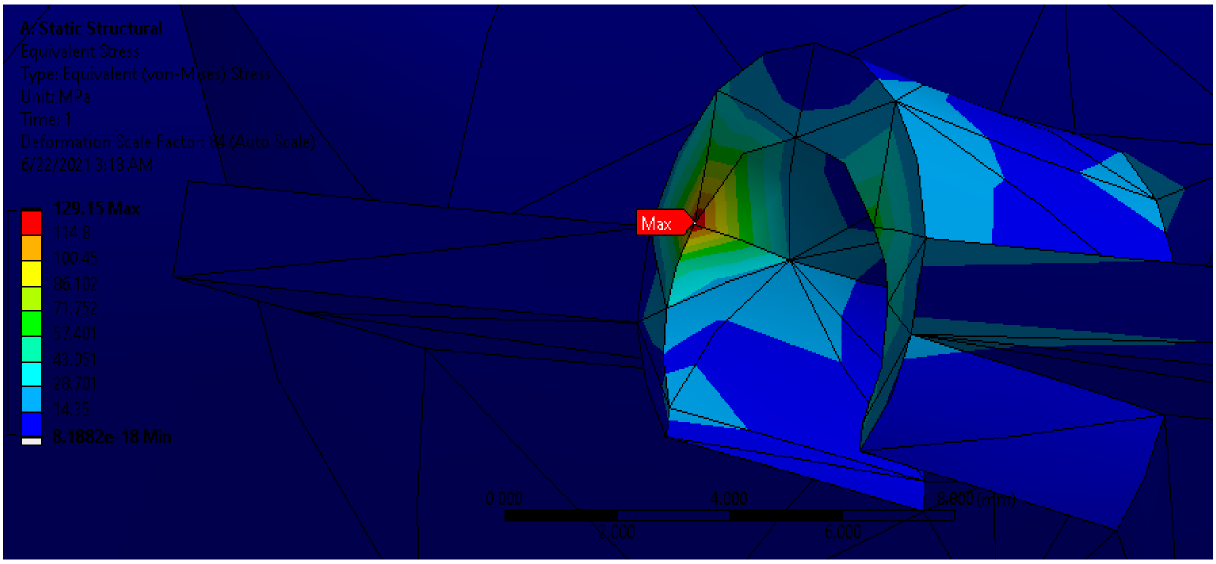

Figure 2.51. Magnesium AZ31B alloy equivalent stress

Structural Steel:

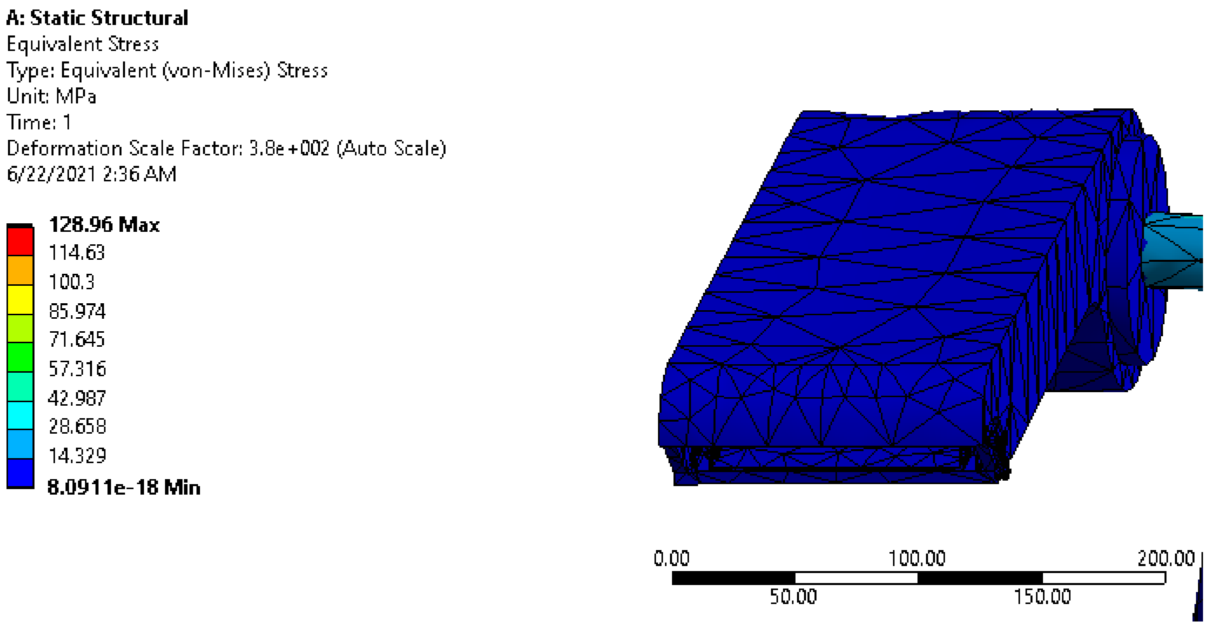

Figure 2.52. Structural steel equivalent stress

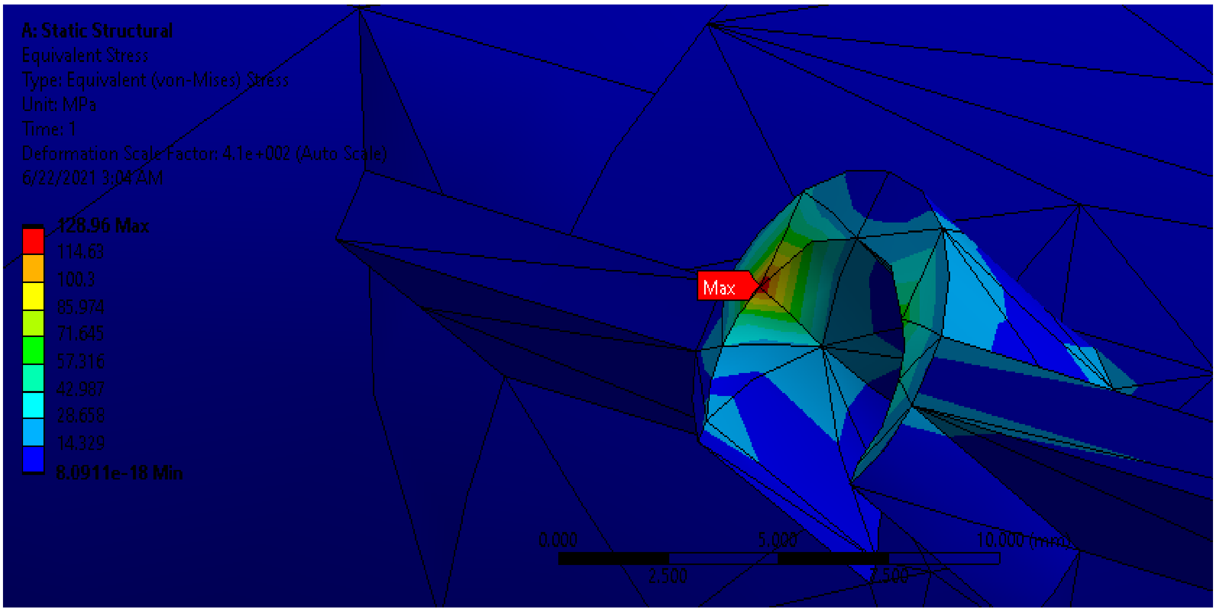

Figure 2.53. Structural steel equivalent stress

Aluminum, 6061, T6, Wrought:

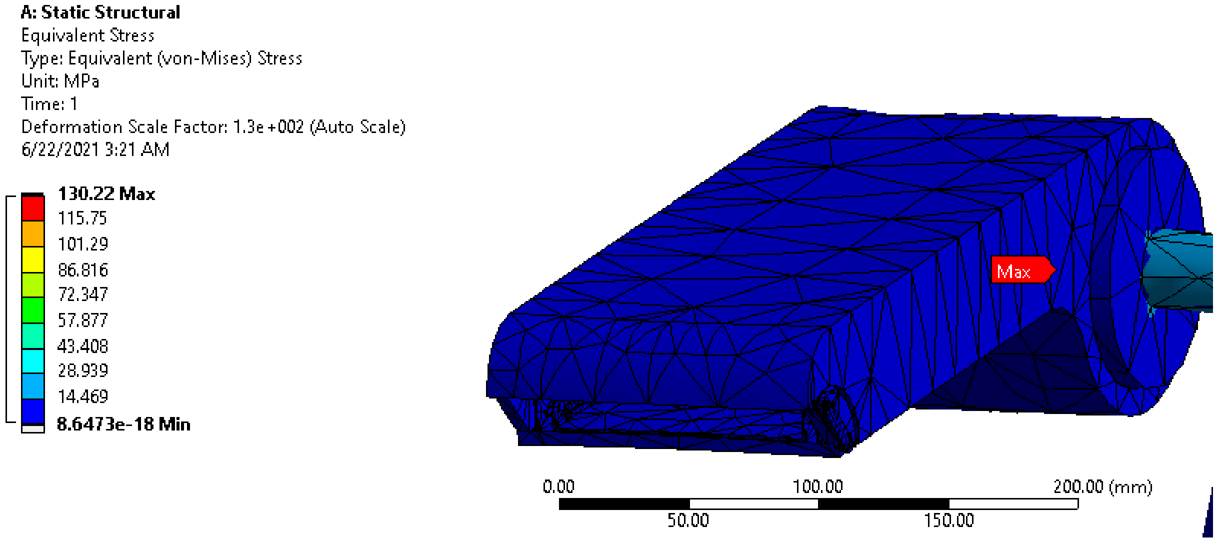

Figure 2.54. Aluminum, 6061, T6, wrought equivalent stress

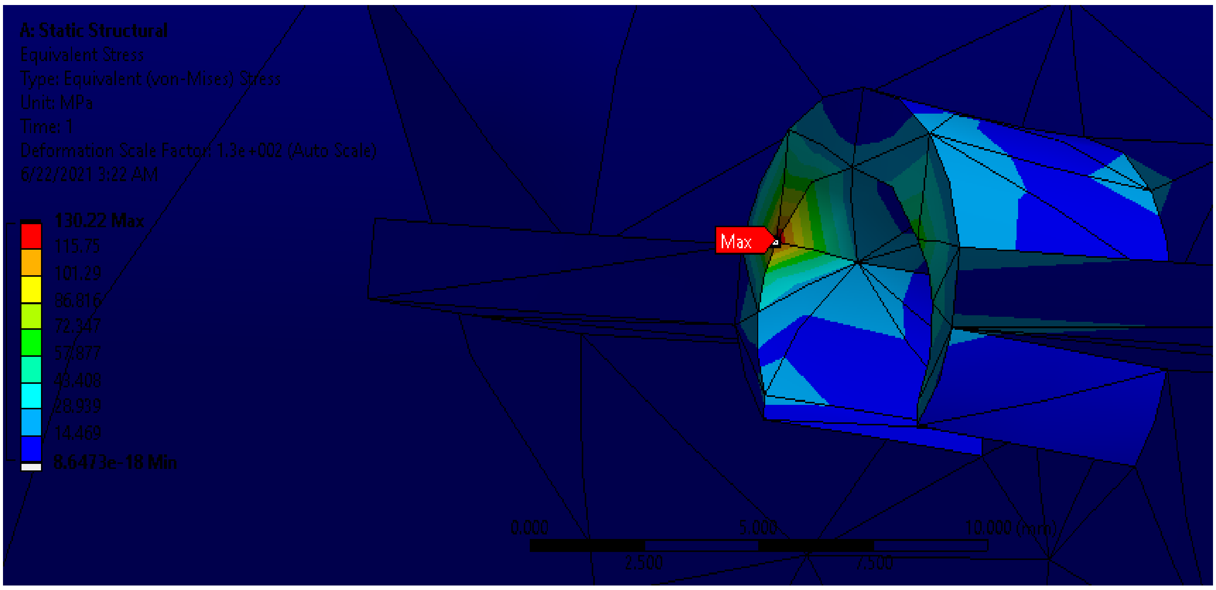

Figure 2.55. Aluminum, 6061, T6, wrought equivalent stress

When the equivalent (von-Mises) stress analysis results are evaluated with the Yield Stress in Table-1, the maximum equivalent (von-Mises) stress values of almost all three materials are the same and these values are around 129-130 MPa. Looking at the Yield Stress of the materials here, it is observed that Aluminum, Steel and Magnesium have values of 259.2 MPa, 250 MPa and 154.9 MPa, respectively. Considering these data, the use of Aluminum and Steel will be better in terms of the strength of the armrest. It is already known that the high mold costs of Magnesium make the use of this material difficult.

Cost and price are always essential factors to consider when making any product. Despite fluctuations in price, steel is typically less expensive than aluminum. Especially in the aviation industry, since the safety factor is much more important, more durable parts are preferred regardless of the cost in such cases. But in the automobile industry, keeping the cost low is more important. For these reasons, the design will continue by choosing Steel with a lower cost among Aluminum and Steel, which have almost the same Yield Stress values.

2.5. Test Requirements for Armrest

Although the necessary tests can be done on the computer, most of the tests done on the computer do not correspond to the life of the world one hundred percent. Therefore, after the computer tests are completed, the first prototype is prepared in the projects and tests are carried out with the prepared prototype. Thanks to these tests, errors in the design or mechanism are noticed before mass production. The tests carried out have standards and certain equipment.

Test Equipment are generally as follows:

- Test set-up to restrain the system under test on
- One 50 mm diam. and 200 mm stroke pneumatic cylinder
- An electro-pneumatic power unit to operate the cylinder.
- One electronic control load cell with 50 to 1500 N full-scale reading (accuracy 2%)
- A linear displacement transducer with travel ≥ 100 mm (accuracy 2%)
- One 100 mm hemispherical plunger
- One support for cylinder restrain.

Pre-test preparations

First, it is checked whether the armrest to be tested is working and the quality control document is prepared. After checking the armrest mechanism, the armrest is fixed as it is used in the vehicle. It is important for the test to be fixed in this way; it should be fixed in this way during the test as it is fixed in the vehicle. And those who load on the company's standards apply a certain load to a certain point. The only difference in horizontal and vertical tests is the direction of application of the force.

While testing

While performing the vertical load test, first of all, the measuring devices should be reset. For the load test, the pusher should be run for 30 seconds until it achieves a sitting load of 10 daN. Next, the load should be removed, and the instruments reset again. After reset, a gradually increasing load should be applied to the system, this load should be applied as 80 daN in vertical load tests. The armrest load should be lifted gradually. Meanwhile, the total and permanent deformation values should be recorded.

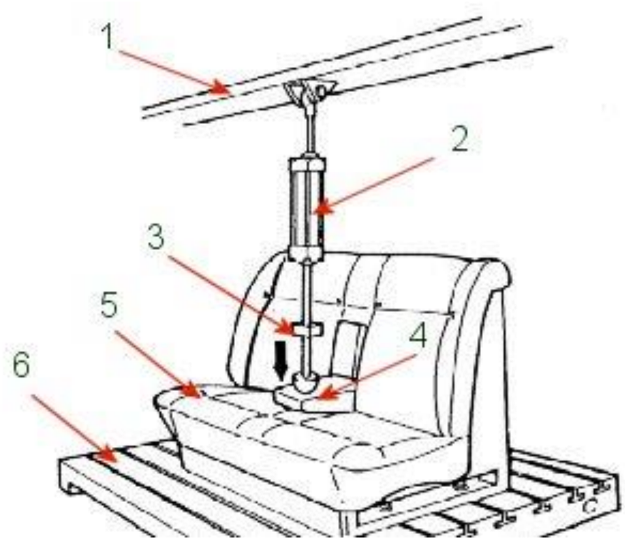

Figure 2.56. Test for armrest

The differences of the horizontal load test from the vertical load test are that the installation force for 30 s is 4 daN instead of 10 daN and the test force is 50 daN instead of 80 daN. Tests were made with these forces.

Interpret the following test results according to the standards of the armrest manufacturer. Computer tests are still not fully sufficient even today. These tests are therefore essential for the durability of an armrest.

3. RESULTS AND DISCUSSIONS

Analysis modeling has been done using ANSYS software and the purpose of the analysis is to control the strength of the designed front seat vehicle armrest. During the design phase, it was decided to use Structural Steel for the frame of the armrest. The sponge and plastic parts added to the armrest for factors such as aesthetics and comfort of use are not included in this analysis. Since it is structural analysis, the frame consisting of Structural Steel, which provides strength, is analyzed at this stage. During the analyzes, test-analysis values obtained from Martur company, which is collaborating in this study, were used. First of all, the general analysis of the armrest was made, and then the analysis of the phone compartment, which is the innovative aspect of the study, was completed.

3.1. General Armrest Analyses

In the test for the overall durability of the armrest, a vertical load of 800 N is applied to the armrest. An elongation of up to 8 mm and a permanent elongation of up to 1 mm are expected in this test. Armrests that meet these values or below are considered successful and production is started.

In order to apply this test, it was desired to create a distributed load in the ANSYS program and the Pressure value was obtained when the 800 N load was divided by the area affected by the applied load on the armrest surface. The upper surface area of the armrest was 280mm×130mm. When this process was done, a value of 0.021978 N/mm2 was obtained. This also equates to 0.021978 MPa. This Pressure value was entered in the Mechanical module of the ANSYS program. The vehicle seat to which the armrest is attached has been fixed from the bottom and back. The data obtained as a result of the analysis are as follows:

Equivalent (von-Mises) Stress:

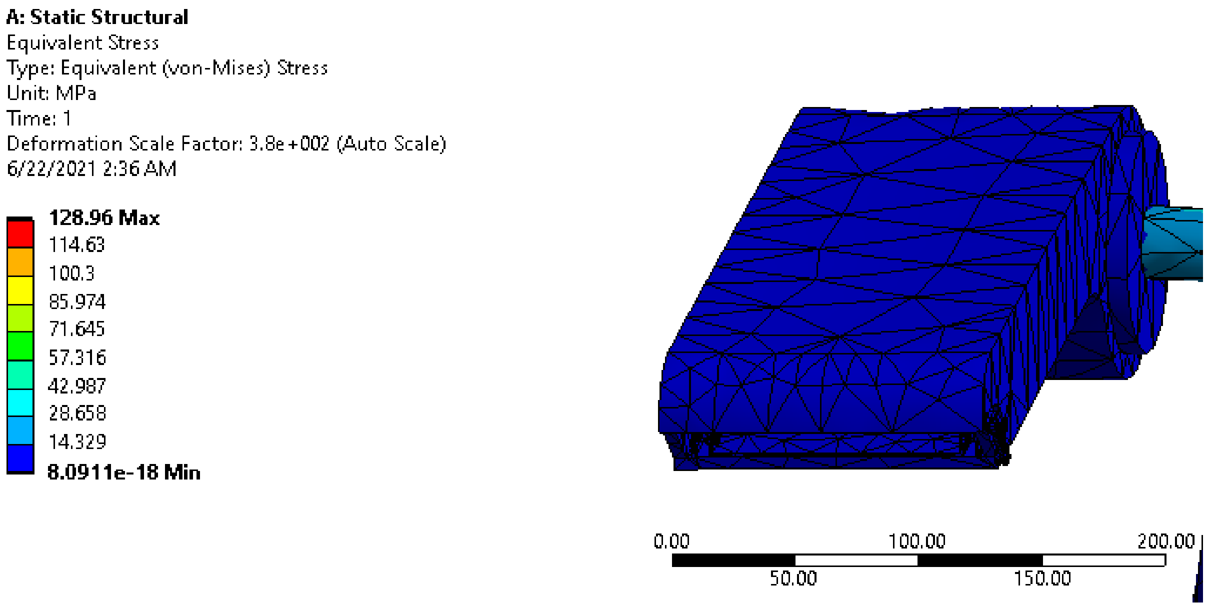

Figure 3.1. Equivalent (von-Mises) stress analysis-I

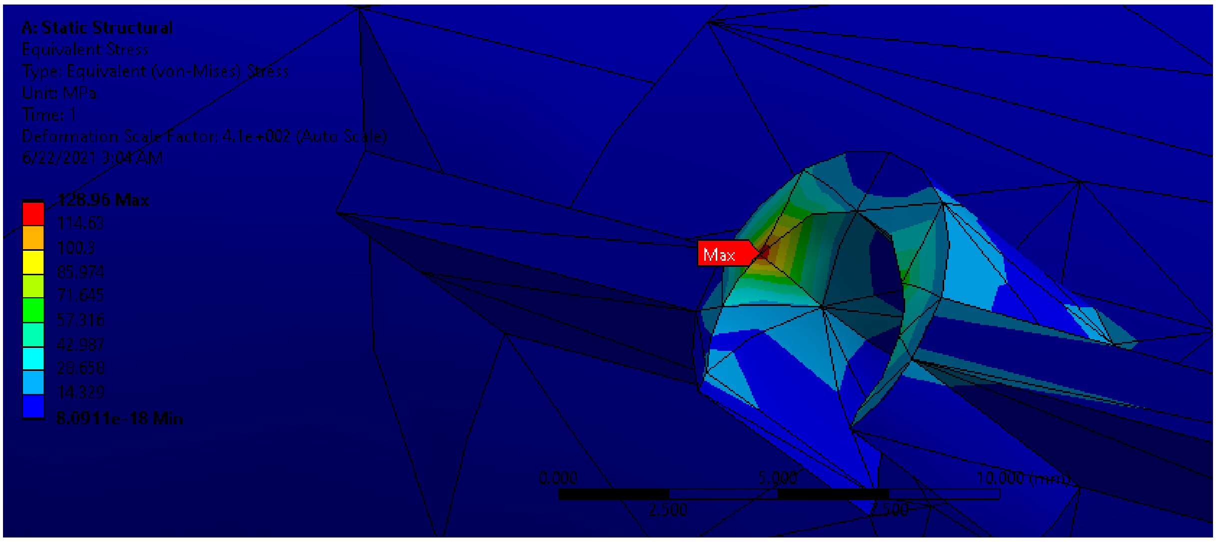

Figure 3.2. Equivalent (von-Mises) stress analysis-II

Equivalent Elastic Strain (ε):

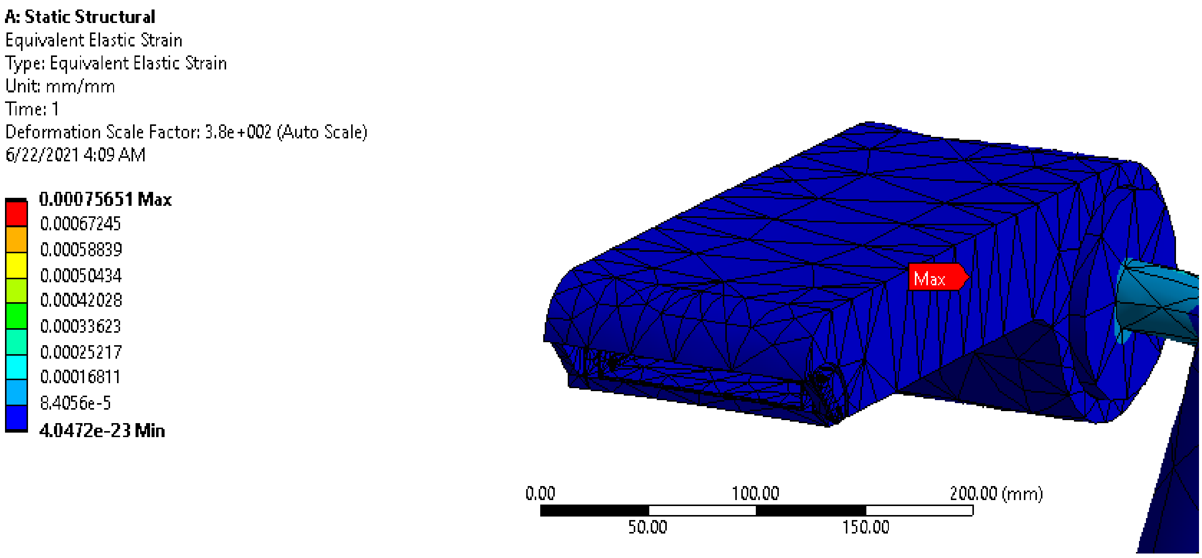

Figure 3.3. Equivalent elastic strain

Total Deformation:

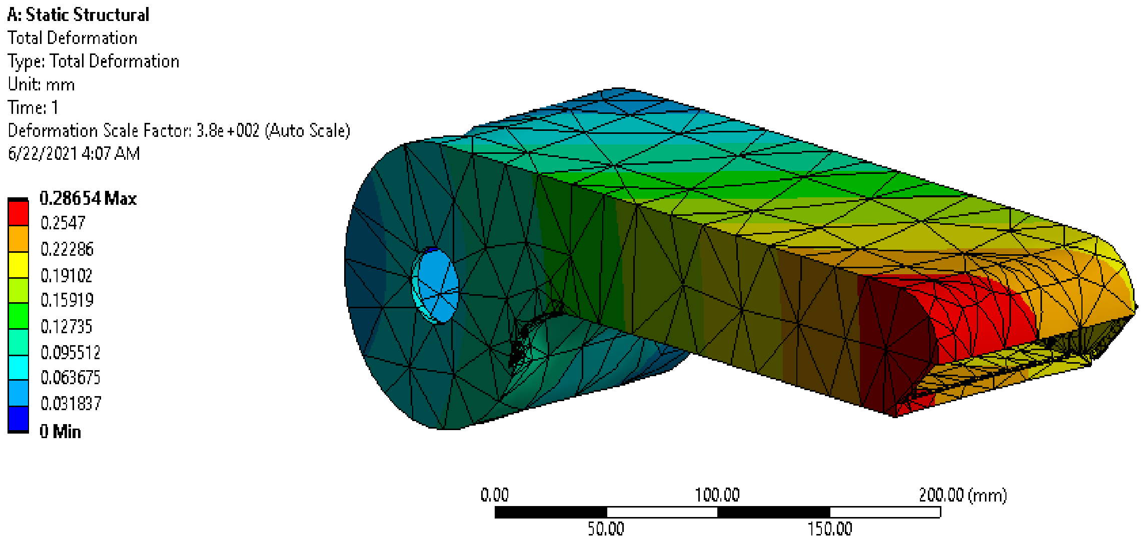

Figure 3.4. Total deformation

Fatigue-Life:

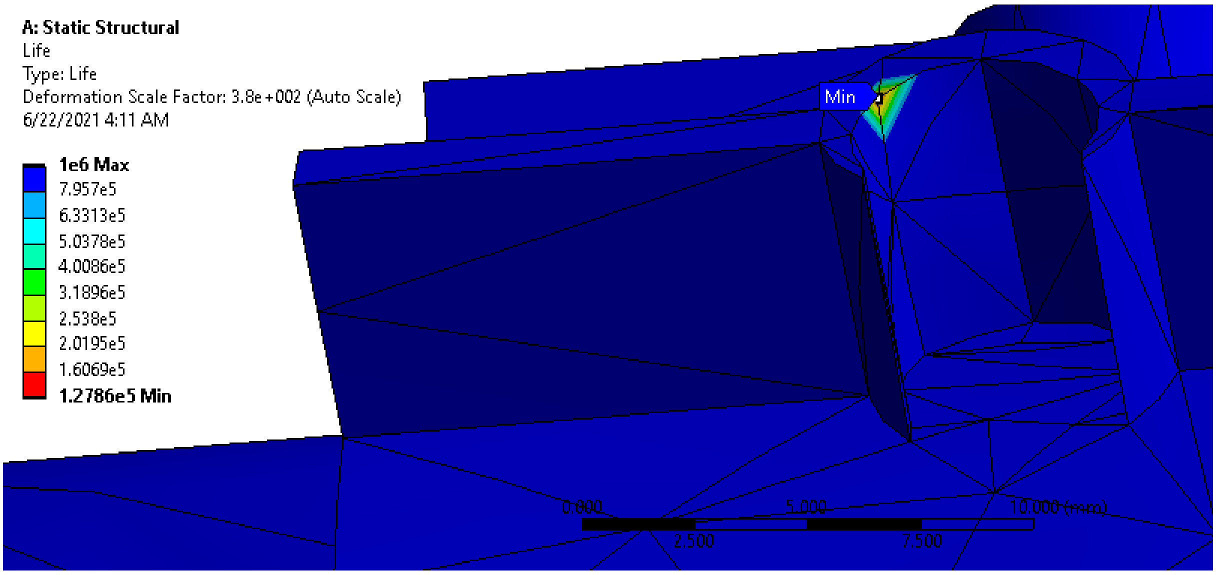

Figure 3.5. Fatigue-life

In the general analysis results for the designed armrest, it is seen that first of all, a maximum value of 128.96 MPa was obtained for the Equivalent (von-Mises) Stress result. The yield stress value of Structural Steel, which is the material used in the frame of the armrest, is 250 MPa. Therefore, the designed armrest passes this analysis successfully. Also, as a result of the Strain analysis, which is another analysis, it is seen that the maximum value of 0.00075651 mm/mm is obtained.

In the Life analysis results, 127,860 cycles were obtained as the minimum value. A minimum of 20,000 cycles is required for this test. Therefore, the designed armrest meets this requirement.

3.2. Armrest Phone Drawer Analyses

The results of the analyzes made for the phone drawer, which is the innovative aspect of the vehicle armrest designed in this study, are as follows:

Since there is no phone compartment in the vehicle armrests used so far, there is no test.

While performing these analyses, a load of 30 N was used, which is well above the average phone weight of 140-170 grams. Considering extreme situations, such a high load value is preferred.

In order to apply this analysis, it was desired to create a distributed load in the ANSYS program and the pressure value was obtained by dividing the 30 N load by the area affected by the load applied to the phone drawer of the armrest. The upper surface area of the armrest's telephone drawer was 145mm×100mm. When this process was done, a value of 0.00206897 N/mm^2 was obtained. This is also equal to 0.00206897 MPa. This Pressure value has been entered in the Mechanical module of the ANSYS program. The car seat, on which the armrest is attached, is fixed from below and behind. The data obtained as a result of the analysis are as follows:

Equivalent (von-Mises) Stress:

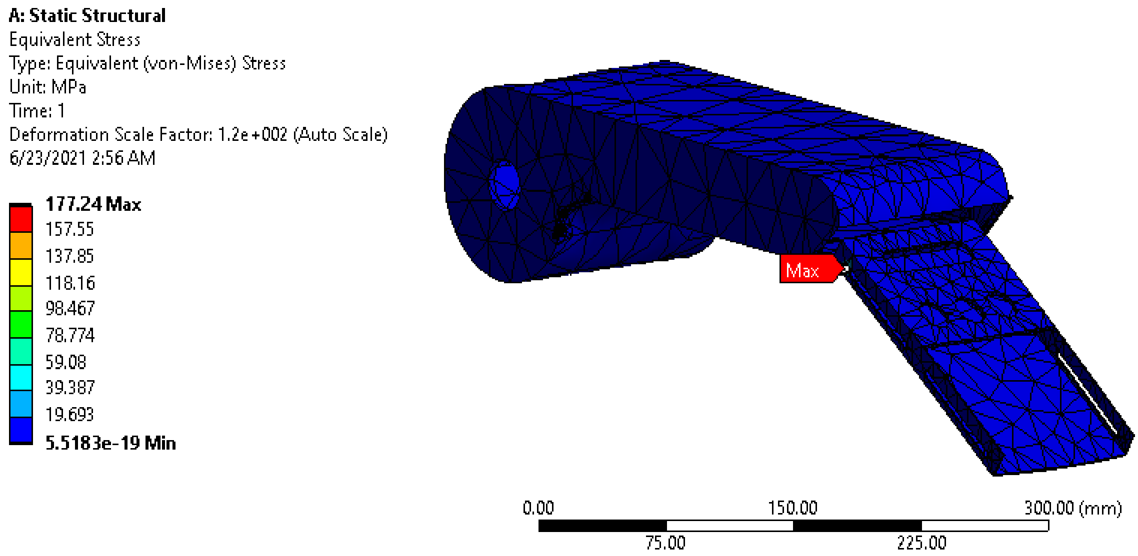

Figure 3.6. Equivalent (von-Mises) stress for the phone drawer-I

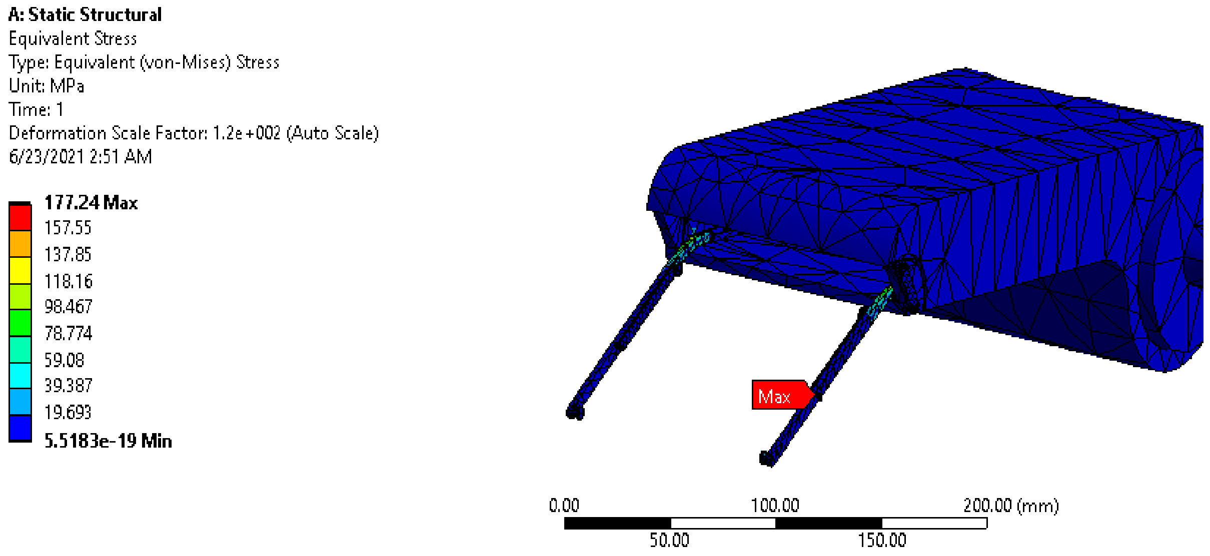

Figure 3.7. Equivalent (von-Mises) stress for the phone drawer-II

Equivalent Elastic Strain:

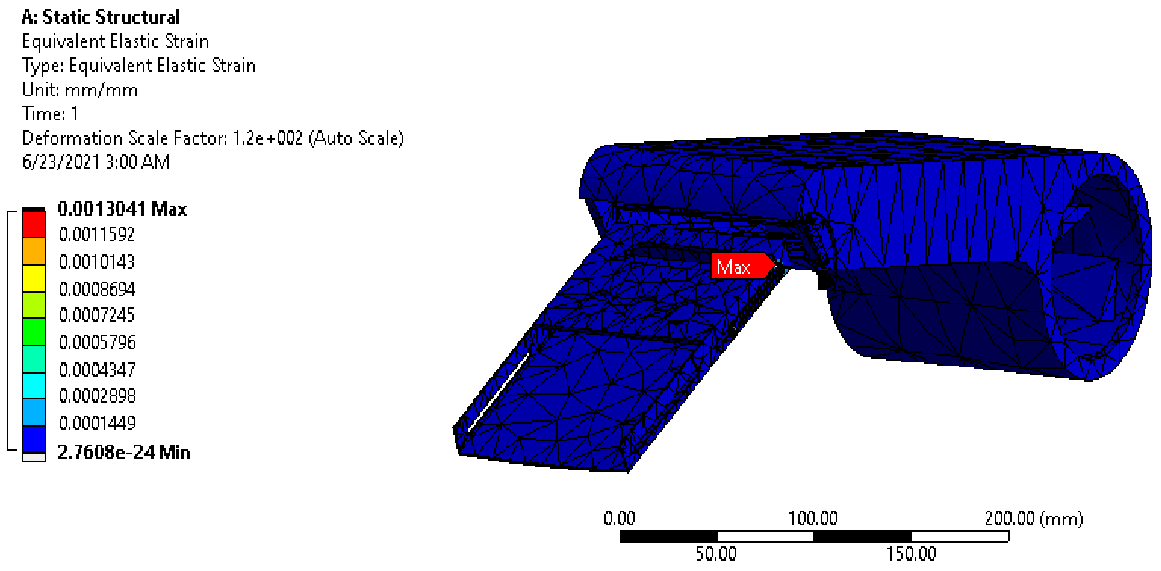

Figure 3.8. Equivalent elastic strain for the phone drawer

Total Deformation:

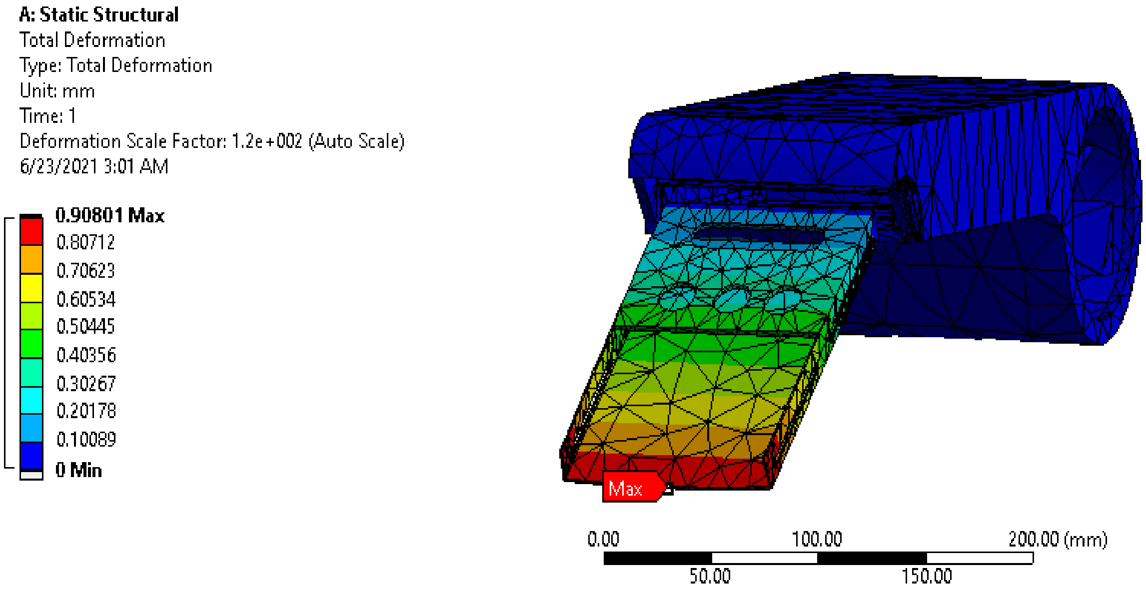

Figure 3.9. Total deformation for the phone drawer

Fatigue-Life:

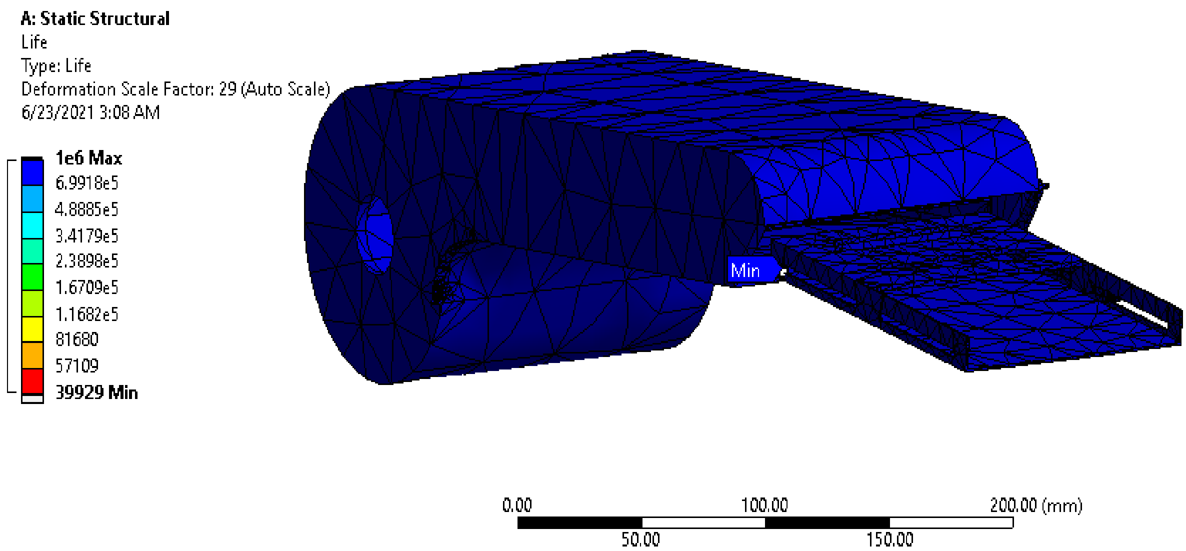

Figure 3.10. Life Analysis for the phone drawer

When the analysis results for the phone drawer, which is the innovative part of the designed armrest, are examined, it is seen that a maximum value of 177.24 MPa is obtained for the Equivalent (von-Mises) Stress result. As stated in the general analysis, the yield stress value of Structural Steel, which is the material used, is 250 MPa. For this reason, the phone drawer of the designed armrest successfully passes this analysis. Also, as a result of the Strain analysis, which is another analysis, it is seen that the maximum value of 0.0013041 mm/mm is obtained.

In the results of the life analysis, a result with a minimum of 127,860 cycles was obtained. Since there is no telephone drawer in a normal armrest, there is no cycle number for this part. Therefore, the minimum 20,000 cycle condition used in the general armrest analysis is also used here. The armrest designed under these conditions also meets this requirement.

4. EVALUATION OF THE CURRENT WORK FROM MUDEK PERSPECTIVE

4.1. Economic Analysis

The design is made up of three main parts in general terms. These are armrest, mechanism arm and phone drawer parts. The following tables show the economic cost calculation of these three main parts.

The cost analysis was made using the June 2021 exchange rate. (1.0 $=8.7 ₺)

4.1.1. Armrest

Table 4.1. Armrest cost analysis

Part	Fabric	Foam	Frame	Total
Material	Fabric	Foam	Structural Steel	-
Needed material per Part	0.33 m^2	0.31 m^2	5 kg	-
Unit price	1.5 $	2 $	0.85 $	-
Price	0.5 $	0.62 $	4.25 $	5.37 $=46.7 ₺

4.1.2. Handle

Table 4.2. Handle cost analysis

Part	Handle	Total
Material	Structural Steel	-
Needed material per part	2.5 kg	-
Unit price	0.85 $	-
Price	2.125 $	2.125 $=18.5 ₺

4.1.3. Phone Drawer Design

Table 4.3. Phone drawer design cost analysis

Part	Cover	Phone Holder	Total
Material	PVC Rigid	Structural Steel	-
Needed material per part	0.13 kg	0.3 kg	-
Unit price	1 $	0.85 $	-
Price	0.13 $	0.255 $	0.385 $= 3.35 ₺

As a result of the calculations, a cost amount of 46.7 ₺ for the armrest part, 18.5 ₺ for the mechanism handle and 3.35 ₺ for the phone drawer was obtained. The total cost was 68.55₺.

4.2. Real Life Conditions

A successful design has been realized in terms of daily life needs and user comfort. The design is suitable for daily living conditions with its features such as being able to move at 90 degrees, having a phone drawer section, ergonomic comfort of the driver and increasing the duration of driving pleasure. The fact that the dimensions of the design comply with the armrest dimensions of M1 class vehicles is another indication that it is suitable for real life conditions. It is seen from the results of the studies carried out in the analysis section that a design that is fully adapted to real life conditions has been realized in terms of meeting the armrest production test requirements.

4.3. Producibility

Manufacturability can be examined from three aspects. These are the economic, service and manufacturing aspects. First of all, when we evaluate it economically, it is clearly seen as a result of the economic analysis that the designed armchair is at a level that can compete with current market prices. From the service point of view, the fact that the created design is detachable provides great convenience in service. From the manufacturing side, the simplicity of the design facilitates the production, while the accessibility of the materials used facilitates the processes in terms of manufacturing.

4.4. Constraints

Since the design is for M1 class vehicles, the cockpit and front seating area is smaller than other vehicle types. For this reason, certain restrictions have occurred in the design phase of the designed armrest. These restrictions are as follows:

- The transverse width of the armrest,
- The length of the armrest,
- Designs according to the opening direction of the phone drawer,
- The situation when the phone drawer is open,

These limitations have limited the outer width dimensions of the designed armrest. The design was made within these limits. In addition to these, although it was thought to reduce the width during the design of the armrest, this request could not be realized due to the phone drawer.

5. CONCLUSION

5.1. Conclusion of the Project

In this study, car armrests that directly affect driver and passenger comfort were studied. The aim of the study was to design a driver's armrest from scratch and add an extra feature to the armrest that would provide convenience to the users. As a result of the brainstorms made in this direction, it was decided to add a phone drawer compartment to the armrest and work began. In this study, which was carried out on armrests suitable for M1 class vehicles, all stages from the first step to the last step of the armrest design were carried out carefully.

The design is based on two foundations. These are the phone drawer mechanism and the armrest movement mechanism. The phone drawer compartment is actually an innovation that can disrupt the structure and design of the armrest for M1 class vehicles. As a result of the meetings held and the different designs made, the desired design was made by keeping the structure of the armrest suitable and simple for M1 vehicle models and adding the desired innovation. As a result of a detailed investigation, the armrest movement mechanism is planned to be a mechanism with a stopper that moves at 90 degrees. The design, which was planned using SolidWorks, has improved day by day. During this design and thesis, a number of different methods were learned about the use of SolidWorks, while developing skills, as well as unknown about the program. Meanwhile, magnesium, aluminum and steel materials were evaluated from different aspects for material selection and the most suitable material was selected.

After the design stages, the design data taken from the SolidWorks program was transferred to the ANSYS program and the necessary analyzes were made. In this way, it was checked whether the test requirements were met. Stress, strain, deformation and life analyzes were performed and the results were presented.

Along with the analyzes and meetings held, many changes were made on the design. When stress and fatigue, which did not show sufficient resistance when necessary, did not reach a sufficient level in the analysis, the design was taken one step higher with different changes made in the design. In this way, it has been seen how designs can be taken to the next level by using the use of CAD and analysis together.

Continuous communication and exchange of ideas was ensured between students and advisors at every stage of the project. In this way, when there is any problem, problems are looked at from the perspective of many people, not one person. Thus, more accurate and more consistent decisions were made.

5.2. Recommendation for Further Works

For further works, studies can be made on improving the drawer mechanism of the design and replacing the materials used in the armrests with lighter materials. Thus, while providing convenience to the users and reducing the total weight of the vehicle, fuel will be saved in the long run.

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