Bachelor Degree Project

UNIVERSITY
OF SKÖVDE

ENTRY/EXIT IMPROVED SEAT FOR A PASSENGER'S CAR

Sliding Seat for Volvo S80

Bachelor Degree Project in Mechanical Engineering
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Ana Huertas Dominguez
María del Pilar Pérez Bueno

Supervisor: Saeed Salimi
Examiner: Thomas Carlberger

Certificate of authenticity

This thesis work is submitted by Ana Huertas and Pilar Pérez to the University of Skövde as a bachelor degree thesis at the School of Technology and Society. We certified that all the material in this Bachelor degree project is our own work and the parts which are not, have been identified. It is significant to emphasize that our own work is mostly based on the knowledge acquired during the courses that we have gone through and it is also based on the notes collected from those courses.

Ana Huertas Domínguez

María del Pilar Pérez Bueno

Preface and Acknowledgements

We would like to thank Stephan Larsson, from Autoadapt company, for his valuable guidance and time which helped us in the development of this project. Thanks also Anna Syberfeldt, for giving us the opportunity to use the Volvo S80 car for taking measures.

We would like to give our thanks to Dr. Thomas Carlberger, our examiner, for guiding us and giving us advice every time we needed it; and to Saeed Salimi, our supervisor, for helping us during this semester. We will never forget either the unconditional support received from Ainhoa Goienetxea.

We want to make a special mention to Juan Cana because without his hardware support and patience, this project would not have come to the end. Last, but not least, we want to thank our grandparents and family for inspiring us to come up with the idea.

Abstract

This thesis work is focused on the design of a mechanism for the passenger's seat of a Volvo S80. This mechanism will facilitate the problems arised when somebody with limited mobility, either permanent or temporal, is entering or exiting the vehicle.

The main aim is to obtain an affordable device that enhances the life of those with reduced mobility, but paying special attention to those who do not receive any kind of economical help from the government. The idea is to be able to move the seat to the outside of the car so that one can seat with no special effort. Then, the mechanism, manually, performs the movements to bring it back to the inside. The concept of being manual is to avoid electronic devices that will surely increase the cost.

In this project, a possible design solution has been developed. A model was created with Autodesk Inventor 2012. The three basic positions of the mechanism were studied to determine the structural behavior of the product. For these studies, a load compensating the weight of a human was applied and the stresses and the deformation were analyzed by Finite Element Methods and the study was concluded when the safety factor was over 2.

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1 Introduction

This final thesis in mechanical engineering was developed by Ana Huertas and Pilar Pérez. It consists of the design of a mechanism for a car seat. The designed mechanism facilitates the entrance to the vehicle for people with reduced mobility. These people, who are not only disabled people but old people, people with temporary injuries, pregnant women or anyone else that in a circumstantial moment of life in which finds problems for some kind of body motion.

First of all, it is important to identify the problems that normal car seats cause for people with limited mobility. Subsequently, there was the investigation and the approach of the possible solutions. The selection of the simplest one came afterwards. The next step was to model the mechanism in 3D with Autodesk Inventor 2012 and selecting a material capable of supporting these stresses without plastic deformation or breakage. This program was used to design the proper mechanism which simulates the required movements and to do Finite Element Methods simulation. Once the maximum stresses were obtained, the safety factor was calculated and compared with the car criterion for safety factor. If the criterion is not fulfilled, the design has to be reevaluated on terms of materials and dimensions to improve the mechanism.

1.1 Identification of need and problem definition

Some of the problems found when going inside of a vehicle are the ones described below:

1. The pavement's step. For most people it means no special effort, but for a handicapped person it is in fact a big deal. In real life, the car is never completely flush to it. Anyone exiting the car has to cross the gap with the force of their arms. Figure 1 shows an illustration of this problem.

This makes problems for people with certain reduced mobility, not only for handicapped people. The usual way of doing it would be: stepping down into the gap and later up into the car. For these people it is a really big effort.

Figure 1. View of the pavement's step.

2. The car’s height. Taking as a reference the street’s floor level, a car seat is lower than a normal chair (this can be appreciated in Figure 2). This means that a person with reduced mobility has to drop down considerably in order to sit down. Later, the person has to stand up from an uncomfortable position for them.

Figure 2. Illustration of the height of a car; usually lower than a normal chair.

3. The door’s step. Most cars have some kind of step where the door closes; the place with the rubber band which makes the door close properly. In Figure 3 there is a visual explanation.

Usually, when a person with limited mobility wants to enter the vehicle has to perform several movements before being in the correct sitting position. These movements are explained below:

- The first thing to do is to sit on the seat with the legs outside the car.

- After that, the person has to rotate the body in order to put the legs inside the vehicle.

- Later, while the rotational movement is in course, he/she has to hold his/her legs over the top of the curb.

- Finally, they have to drop down at the same time they are raising a foot up to go over the step. This is quite complicated and they often hit their heads to the ceiling of the car. It is a difficult movement because it implies two movements at the same time.

Figure 3. Detailed view of the door's step.

4. Economical aspect. There are solutions already in the market that solve the problems explained above. The disadvantage found is that they are focused on handicapped people. As this kind of people may need the device for the rest of their life, there is not much attention regarding the price. All these devices suppose a big investment of money. This project will solve this.

5. Social aspect. In some countries the government funds these devices, so that handicapped do not have to worry about money. For anyone who has to pay the device himself/herself, the cost is sometimes as much as buying a new car. So they just prefer to deal with this problem in their daily routine or simply quit using the car, which maybe has considerable influences on their social life: a non necessary choice.

1.2 Purpose

The sliding seat is designed to solve the problems highlighted in 1.1.

The sliding mechanism is designed in a way that performs all the required movements for going inside a vehicle. This is with the purpose of avoiding any of the cases related to difficult situations mentioned before. This means that the person with limited mobility gets rid of the movements. With the sliding seat they just have to sit down and it is done!

The problem of the pavement's step is solved by letting the seat going outside of the vehicle. This prevents people from having to "jump" the gap. To solve the problem of the height of the car, the sliding seat is provided with a tilting movement too; anyone will be able to use the seat easily. An extractable foot rest has been installed to hold the legs during the process of exit and entrance.

Concerning about the price, the goal is to design a simple mechanism with the minimum number of components and economical material. Then, in this case, there is no need to worry about government's funds when the matter is to have a self-sufficient life.

1.3 Background

Bruno Independent Living Aids is an American corporation of accessibility products designed to enrich the life of those who have to deal with limited mobility. The company embraces all that is related with stair lifts, vertical platform lifts, vehicle lifts and turning automotive seating. Bruno’s company is a global dealer that sells all its devices through companies in Europe. For home accessibility products, they work internationally with the UK through the company Homeadapt. For automotive solutions, they count on the help of their Swedish partner AutoAdapt, based in Stenkullen, which is located between Skövde and Gothenburg.

Autoadapt is a pioneer company in car adaptation equipment. Over the years it has grown from a small cottage industry to a major high technologies operator. Autoadapt produces accessibility products to be used in cars by people with reduced mobility. One of their products is shown in Figure 1. More information can be found on www.autoadapt.com.

Figure 4. Tilda seat from Autoadapts company.

1.4 Method

Mechanical design comprises vast studies in which most engineering disciplines are involved. The ones concerning this project are mechanical engineering science, material science and the finite element method.

These are the four steps in the development of this seat:

1. The first step is the 3D modeling. To attain the most suitable design of the mechanism it is necessary to take into account the movement of the mechanism and the available space in the car. The number of parts ought to be reduced as much as possible, as well as weight and size. It is important to have always in mind that the purpose is to designing a standard device that can be placed on your car seat. The last step is designing the security system. It is compulsory having a lock system to fix the seat to the vehicle which has to withstand the impact of an accident too. Furthermore, the creation of an extra safety belt to guarantee that the person stays on the seat in order to avoid instability while the seat is making movements.

2. The second is step choosing appropriate materials. These should be as cheap and light as possible. However, it must meet the needed strength without jeopardizing the safety.

3. The third step is FEM analysis. Once the mechanism is selected, the stress of all the elements of the seat's mechanism will be calculated with the computer software called Autodesk Inventor 2012. Starting with 3D modeling, selecting the elements to study, choosing the most suitable size of mesh, applying the boundary conditions and the external forces that are supposed to be acting on the mechanism this analysis is carried out.

4. The next step is computing the safety factor. In this case, if there is a problem in the mechanism the life of the passenger is in risk. Therefore, a safety factor of 2 is required as a minimum.

5. The last step is modifying materials and geometry. If the results obtained from step 4 do not meet the safety factor criterion it is indispensable to make changes in the mechanism or the materials so that the mechanism fulfils the expectations.

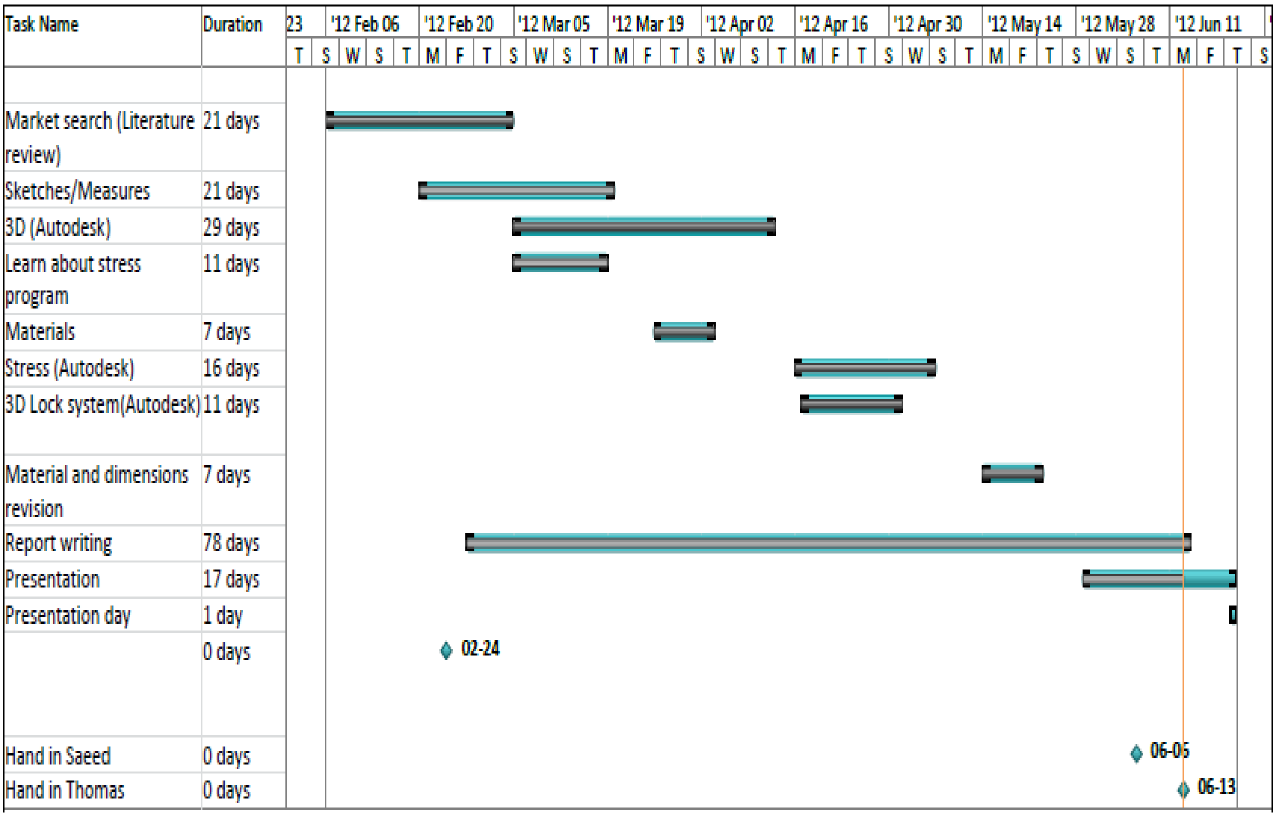
6. Future works. Knowing beforehand that this kind of projects take almost five years be completely finished, as Autoadapt said, before coming into the market, possible improvements, new calculations and suggestions were included in this project.

1.5 Limitations

The sliding seat mechanism is designed for a Volvo S80 seat. It has been necessary to focus on one specific brand and model of vehicle. Otherwise, it was necessary to collect many data about distances, measures and requirements of several kinds of cars to design a universal device. It is a fact that companies in the field of car adaptation have a specific department working full time studying all these parameters.

1.6 Project planning

Figure 5 is the Gantt chart of this thesis work.



Task Name	Duration
Market search (Literature review)	21 days
Sketches/Measures	21 days
3D (Autodesk)	29 days
Learn about stress program	11 days
Materials	7 days
Stress (Autodesk)	16 days
3D Lock system(Autodesk)	11 days
Material and dimensions revision	7 days
Report writing	78 days
Presentation	17 days
Presentation day	1 day
	0 days
Hand in Saeed	0 days
Hand in Thomas	0 days

Figure 5. Gantt Chart

2 Sliding seat mechanism

2.1 Aims

The aim of this project is to design a manual accessory that facilitates the entrance and the exit to a car for those challenged by limited mobility. Our major intent is to create a mechanism that, applied to the already existing seat in the car, must be able to perform all the required movements: going outside the car and back inside without being troublesome for the person sitting on it. The movements required can be seen in the sketches of Figure 6, Figure 7, Figure 8, Figure 9 and Figure 10.

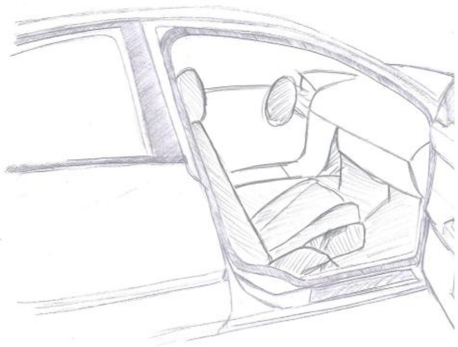


Figure 6. Position number 1: natural position of the seat.

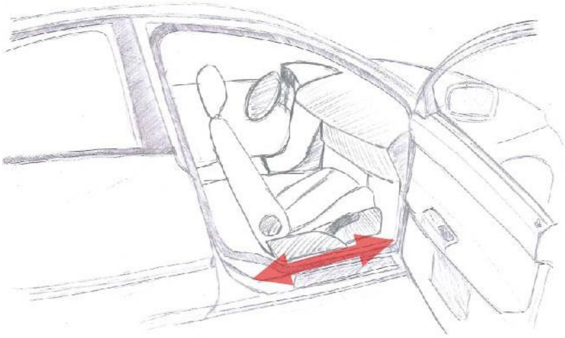


Figure 7. Position number 2: forward movement.

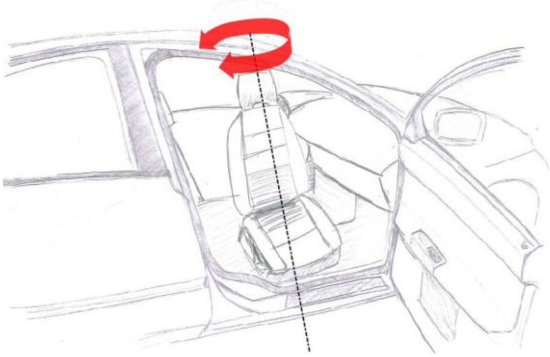


Figure 8. Position number 3: 90º rotation.

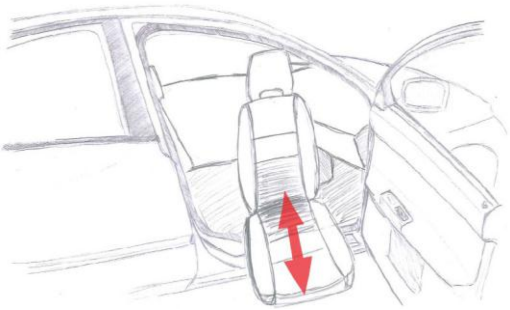


Figure 9. Position number 4: forward movement to the outside.

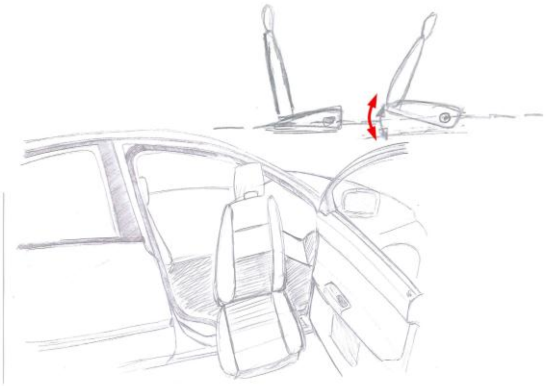


Figure 10. Position number 5: tilting movement.

The mechanism must deal with the appropriate distances and weights. However, what is most relevant is that the lock of the mechanism needs to pass safety tests, i.e. crash tests, without inconveniences.

The emphasis given on the manual use is due to the already commercialized sliding seats. The existing solutions on the market have two drawbacks: the price and the need of a specific seat. This seat is an automotive part, which increases its price. Hence, our aim is to create an affordable and efficient gadget that does not need the seat replacement.

2.2 Considerations in the design

Economization is the most important point in this project. Because of this, in order to avoid changing any original part of the car, the limits in size and space for the mechanism are the already existing rails of the car, the screws and nuts already in use, and the legs that fix it to the seat.

According to the measures took on a Volvo S80, the most critical point in the design of the sliding mechanism is the height of the seat. The distance between the seat and the ceiling of the car is narrow in comparison with the seat dimensions.

2.2.1 DFM

Design for Manufacturability (DFM) is a method, adopted by engineers when designing a new product. It is adopted to achieve the best properties through the most economical and affordable conditions during the process.

Each part of the sliding mechanism has been carefully selected according several aspects:

- The price of the raw materials.

- The difficulty and economical impact of the process to transform it into what is needed.
- The use of minimum special tools.
- The number of processes needed for the transformation.

All this selection is in order to minimize secondary operations. The complexity of future labor in reparations, the required mechanical properties and the stress analysis have been taken into account.

Lean system is integrated in this project. The basis of this system is the optimization of the manufacturing processes via errors detection and elimination. The foundations are the following:

- Do only what it is necessary, when it is necessary and in the amount that it is necessary, according to the needs of the customer.
- Quality is a must in the process. The worker has to indicate if there is risk of producing deficient parts. Furthermore, Poka-Yoke system avoids the manufacturing of deficient parts.
- Time required for the whole process must be the minimum. Considering from the extraction of the raw materials, to the time inverted in processing the parts.
- High rate of utilization of machines and labor. Once the investment is done, maximum profitability must be obtained, from machines and workers.
- Continuous improvement (Kaizen). The process is never perfect, there is always a way to improve it.

Poka-Yoke system is a Japanese method integrated in the lean system. It is an anti-failure method that works for humans. It consists of creating a visual need that can be detected easily if it is not fulfilled. In this project all the parts that have to be welded somehow are specified with and engraving in the exact place where it has to be welded. Furthermore, each part only fits in one specific engraving in order to avoid errors of position or place.

2.2.2 DFA

Design for Assembly method (DFA) is a methodology the main purpose of which is “product assembly simplification”. This is a worldwide extended system that offers great advantages.

The best and most noticeable effect of this method is cost reduction. The fact of minimizing material means less raw material, and fewer parts to assemble means less labor; these two facts are directly involved in the final price.

The number of pieces in the final result of the mechanism, when piecing it together to the car's seat, has been reduced by welding all the parts. These parts were allowed to be welded during the production process. The advantage is the less risk of delay in the production system if there are fewer pieces to be assembled in the assembly line. At the same time, the amount of waste produced is reduced considerably: if less material is used, fewer residues are obtained as a result.

In addition to this, the original joining screws and nuts that join the seat to the mechanism are still used in the new mechanism. These pieces are already a standardized design. Hexagonal head screws were used to fix the seat and rails to the sliding mechanism. Jame (1986:7.21) states about screws that "for ease of driving are the hexagonal head and…These are less susceptible to driver slippage and marred surfaces. They are generally lower in cost than types such as the hexagonal head socket."

2.2.3 DFE

Design for Environment (DFE) is a method that consists in taking into account the environmental impact of the final product, its materials, its production and the wastes that it produces.

The mechanism is mostly made of only one material in order to facilitate the recycling. This makes it easier to divide the mechanism in parts before throwing it to trash. The original seat and the rails are conserved. This implies less material used in the product and less waste generated. The sizes of the parts were reduced as much as possible with the objective of decreasing the fuel consumption. If the parts are small, they weigh less, and therefore, the vehicle fuel consumption is not severely affected.

In order to protect the environment, the materials of the package were chosen to be environmentally-friendly. The box is made from 100% recycled cardboard, and can be recycled again when it is considered necessary. The foam inside the box used to prevent potential damage to the mechanism when transported or stored, is not made of polystyrene. Polystyrene is derived from oil and not biodegradable. The production of this material is very polluting and the incineration produces toxic specks that pollute the air. The mechanism will remain protected thanks to EcoCradle, a natural light and resistant material obtained from crop waste. EcoCradle is biodegradable and renewable and it can even be used as compost for the garden. What is more, the ink used for printing the box is Water-Flex, which is water based ink that causes minimum impact on the environment.

2.3 Presentation of the product

The sliding seat consists of 92 pieces of which 42 are standard screws, nuts, washers and springs. The mechanism can be divided in 6 parts: the upper disc, the middle disc, the bottom disc, the lock system, the lever for the tilting movement and the foot rest. Figure 11 and Figure 12 illustrates the assembled mechanism in the natural position.

Figure 11. Isometric view of the assembly (front-top-left).

Figure 12. Isometric view of the assembly (back-bottom-right).

The three discs are basically a squared sheet of metal with the correspondent engravings for the pieces that are welded on each one. These engravings prevent any possible confusion of position and distance.

- Upper disc: Figure 13 and Figure 14 demonstrate the disc from different angles.

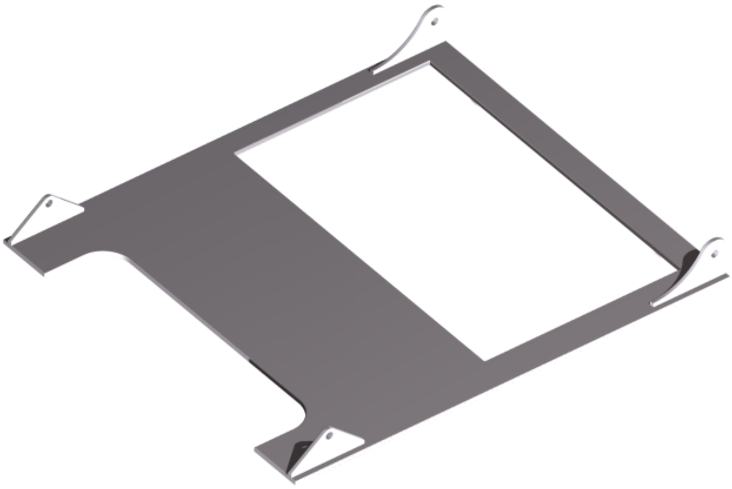


Figure 13. Isometric view (back-top-right)

Figure 14. Isometric view (front-bottom-right)

Figure 15 illustrates how this part takes care of the tilting movement.

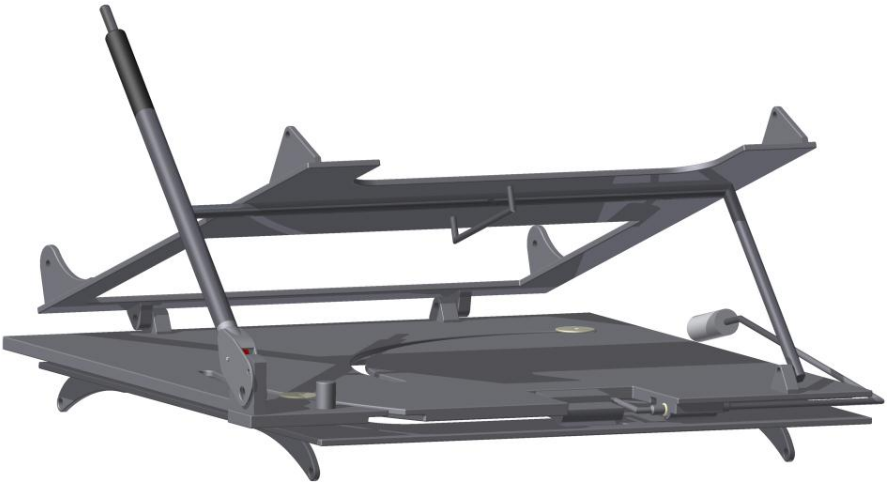


Figure 15. Isometric view of the mechanism with the tilting movement (front-top-left).

Four legs, which are fixed to the original seat of the car with the original screws, are welded on the top of the upper disc. According to the original seat, the ones on the front are different to the ones on the back (see Figure 16 and Figure 17).

Figure 16. Detailed view of the back leg.

Figure 17. Detailed view of the front leg.

In the front part of the bottom disc are welded two more legs. These legs are the ones in charge of the tilting movement. There is a screw inserted in each of them which acts as an axle (see Figure 18). In the middle of the disc there is also welded a U-shaped bar that constraints the angles that the disc raises up during the movement (see Figure 19).

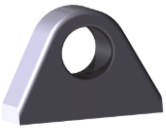


Figure 18. Detailed view of the leg for the axles for the tilting.

Figure 19. Detailed view of the restriction bar.

- Middle disc: Figure 20 and Figure 21 are detailed images of the disc.

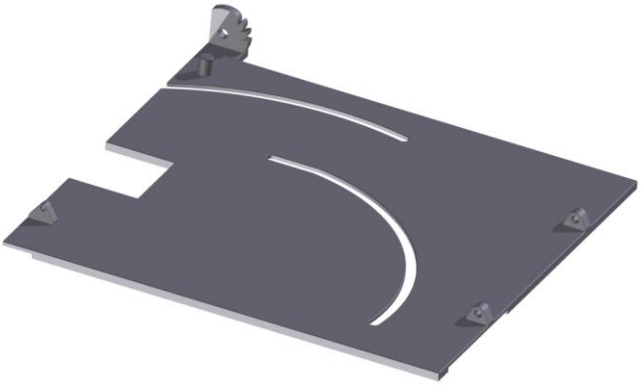


Figure 20. Isometric view (front-top-left).

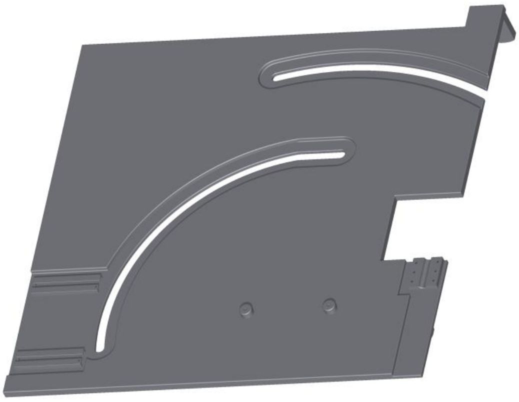


Figure 21. Isometric view (back-bottom-right).

This part is the one in charge of driving the seat outside of the vehicle (see Figure 22 and Figure 23). This disc is more exposed to stresses than the rest due to the fact that the tilting lever, the lock system and the foot rest are in direct contact with it.

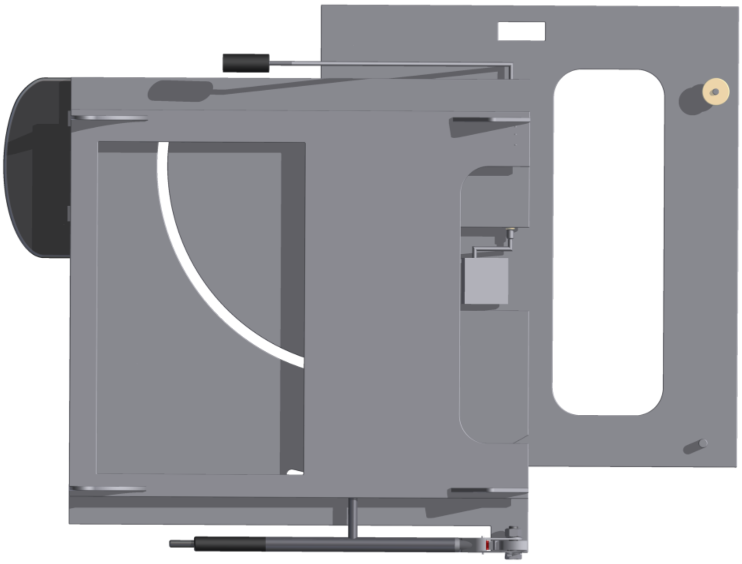


Figure 22. Superior view of the mechanism: outside position and foot rest out.

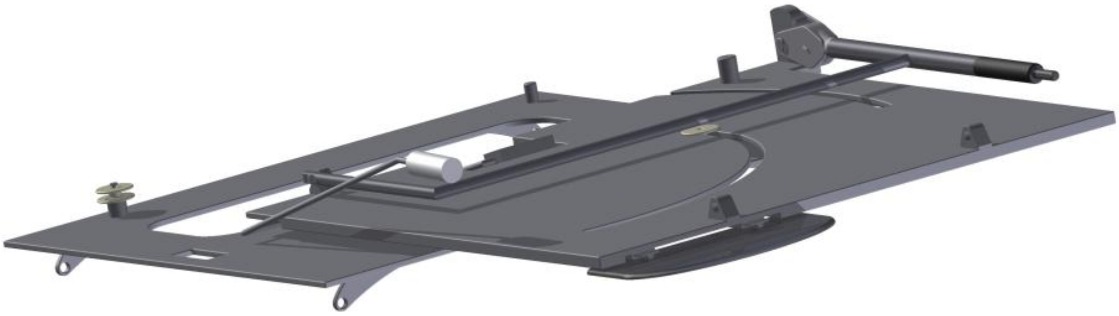


Figure 23. Mechanism in the outside position.

On a ledge and on the disc, a gear, which controls the descent of the tilting, is welded in the upper surface (see Figure 24). This ledge emerges from under the seat to a visible and reachable position. This is necessary in order not to place the gear under the seat, but next to it as closer as possible.

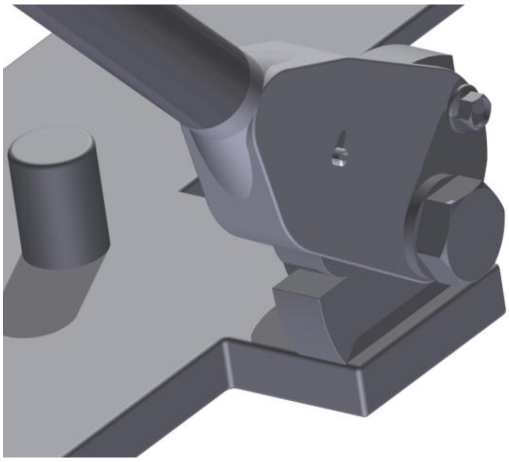


Figure 24. Detailed view of the ledge for the tilting lever.

On the upper face of the disc are also welded two legs. These are the legs in charge of the tilting that match with the ones in the upper disc. The tilting axles, which are screws, are inserted in these legs. Finally, in the upper back part is located another leg. In this case, in the leg is inserted the screw that acts as an axle for the tilting. The bar that is in contact with the upper disc to raise it rotates around this axle. See Figure 25.

Figure 25. View of the piece where the axle for the tilting lever is inserted.

If the disc is watched from below, it is possible to see two pivots welded in a strategically calculated position (see Figure 26). Each of these pivots contains a wheel inserted and fixed with a screw and washer joint, which slides along a rail in order to allow turning and forward motion (see Figure 27).

Figure 26. Detailed picture of the pivot.

Figure 27. View of the wheel.

The wheels can be separated in two parts to insert them in the tracks. They are connected with a blind screw and a washer to the respective disc (bottom or middle, depending on the case). The central connection of both parts is elliptical to avoid it turning on itself. The two parts can be seen in Figure 28 and in Figure 29.

Figure 28. View of bottom part of the wheel.

Figure 29. View of the upper part of the wheel.

Another piece, which is part of the lock system, is also located in this surface of the disc (see Figure 30).

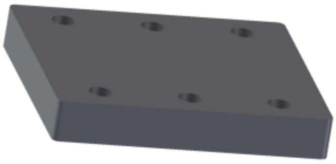


Figure 30. View of the piece of the lock system.

The rails that attach the foot rest to the disc are also welded in this surface as shown in Figure 31.

Figure 31. View of the tracks welded in middle disc.

- Bottom disc:

This is the disc that is connected to the rest of the vehicle. It will move only if the seat is raised with the original mechanism, for adapting the seat for each people height. Figure 32 and Figure 33 are detailed images of the disc.

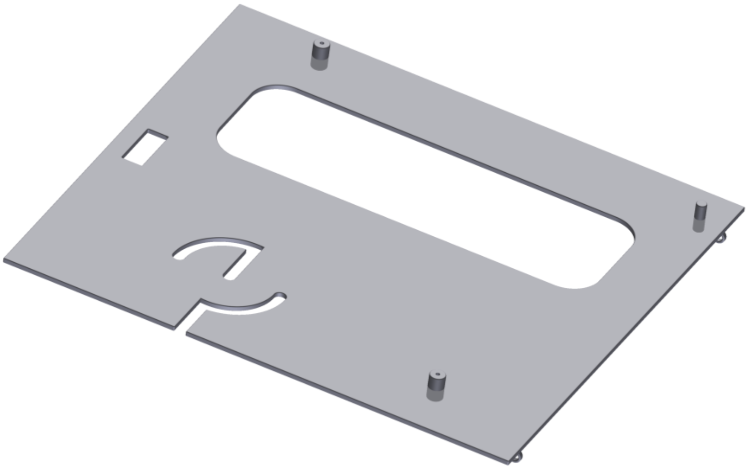


Figure 32. Isometric view (back-top-left).

Figure 33. Isometric view (front-bottom-right).

This disc contains the most special part of the whole sliding mechanism. The slots for making it turn and then slide outside are a solution specially developed for this project (see Figure 34). In these slots slide the wheels that are inserted on the pivots from the middle disc.

Figure 34. Detailed view of the slots.

Two pivots with a blind hole, similar to the ones on the upper disc, are welded on top of the bottom disc. The function of these pivots is to contain one wheel each. The wheels slide in the rails of the middle disc as can be seen in Figure 35 and in Figure 36.

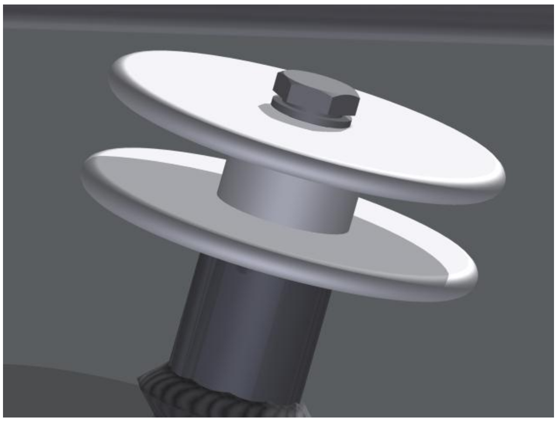


Figure 35. Detailed view of the assembly pivot-wheel.

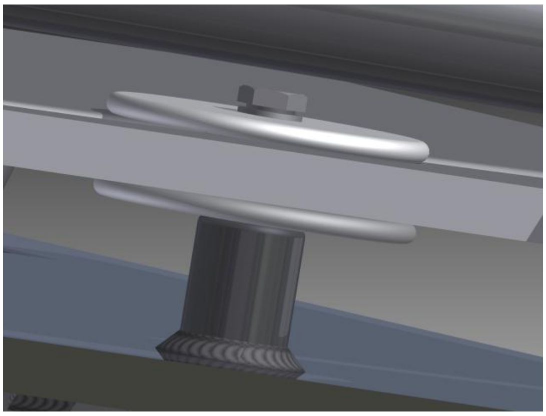


Figure 36. Detailed view of the assembly wheel-disc.

Taking a look from below it is easy to distinguish the four legs that fix the mechanism to the original rails of the car. In contrast to the legs on the upper disc, these are all equal. See Figure 37.

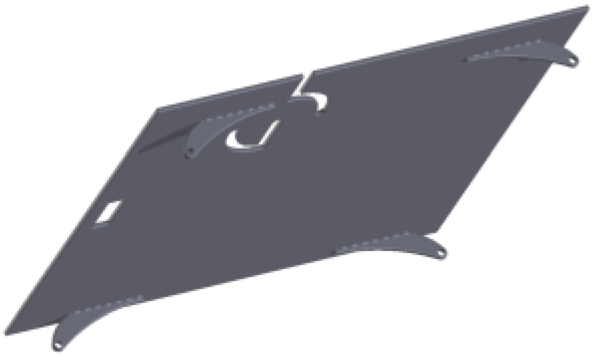


Figure 37. Detailed view of the leg that connects the mechanism with the original rails.

- Lock system: this is the most important part of the mechanism in terms of safety, because it is what prevents the mechanism to be activated during an accident. See Figure 38. If the system is acting, then it is impossible to move the mechanism.

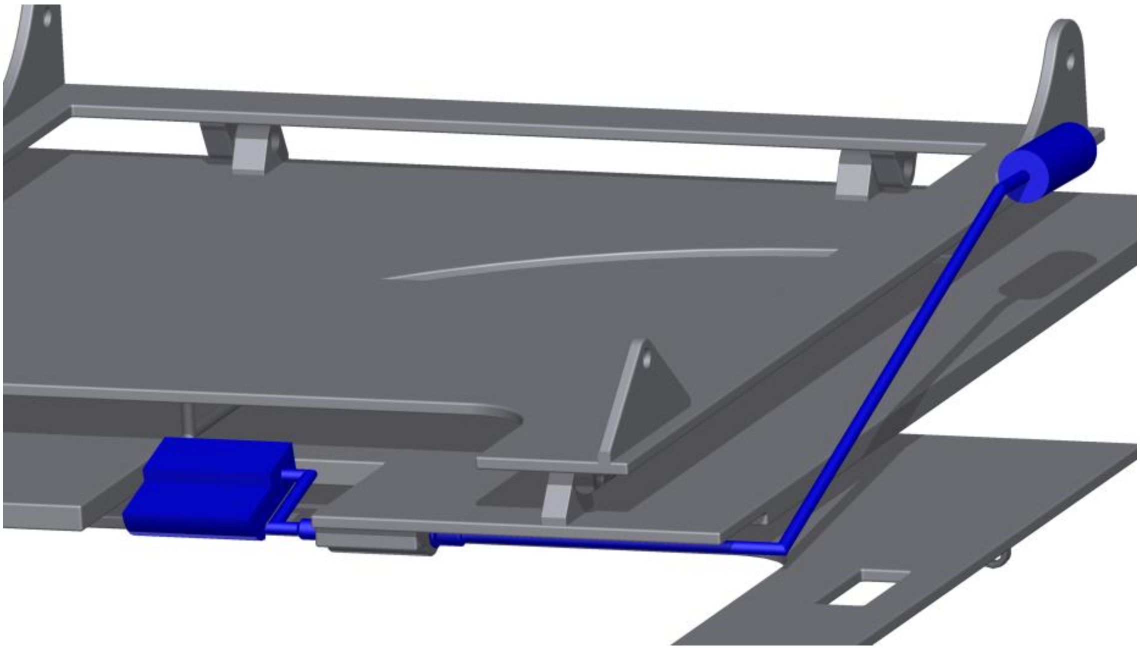


Figure 38. Lock system

The safety system contains a plastic handle, to be hand activated and deactivated when considered necessary (see Figure 39). This plastic handle is threaded into a metal lever which mainly causes the on and off position (see Figure 40).

Figure 39. Detailed view of the lock system handle.

Figure 40. Detailed view of the lock system lever.

The lock system lever is fixed in the middle disc with a piece that can be separated into 10 different components; six of these components are standard screws (see Figure 41). One of the remaining parts is in direct contact with the middle disc. This part has a hole for holding the lock system bar, but the bar is covered with a nylon piece that is separated in two in order to be able to assemble it (see Figure 42). The function of this nylon part is to reduce the friction between the lever and the piece that matches it to the middle disc. Finally, the three parts exposed are hold with a fourth part (see Figure 43), and the complete component fixed to the disc with the help of the screws.

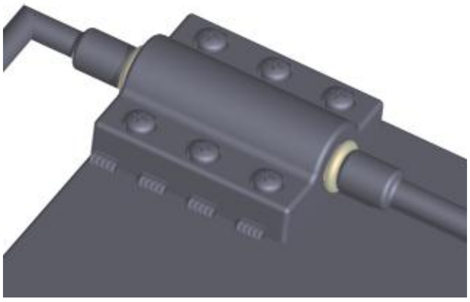


Figure 41. Detailed view of the component with the screws.

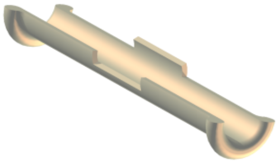


Figure 42. Detailed view of the nylon cover.

Figure 43. View of the part that covers the complete component.

The last part of the lock system is the piece that actually makes the sliding seat remain stuck. It is a small piece that fits in a hole made in the middle disc and that only leaves this position if the lock lever is activated. See Figure 44.

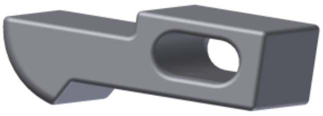


Figure 44. View of the lock system piece.

- Tilting lever: it is consists of 13 pieces. The function of this lever is very similar to a hand brake: it is easy to pull, but once it is in the upper position, it is necessary to push a button to bring it back to the horizontal position. In this case, the horizontal position is the natural position of the seat, and the raised position means that the tilting is activated. To avoid being activated by mistake or in an accident, it is provided with a simple lock system: the gear and the gear cover are connected with a screw that disables the movement of the whole lever. This screw is loosened with a simple twist; it does not need several twists. See Figure 45.

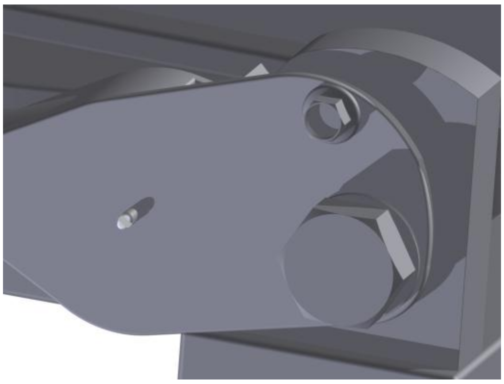


Figure 45. Detailed view of the lock for the tilting movement.

One of the pieces that forms part of the tilting lever is the gear mentioned former in the paragraph about middle disc. This is the gear that prevents the way back to the horizontal position (see Figure 46). The part that connects the gear with the rest of the lever is a cover (see Figure 47).

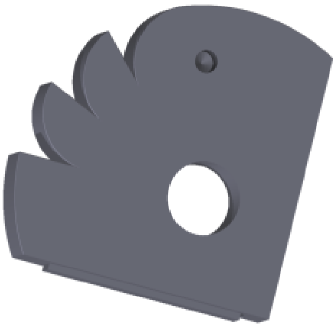


Figure 46. Detailed view of the gear of the tilting lever.

Figure 47. Detailed view of the gear cover.

The piece that lets the gear to control the movement is called "Movable Piece" (see Figure 48) and it is inserted in the gear cover with and standard piece shown in Figure 49.

Figure 48. Detailed view of the movable part.

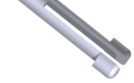


Figure 49. Detailed view of the standard axle for the movable part.

The movable part is activated with another piece from the interior of the lever (see Figure 50).

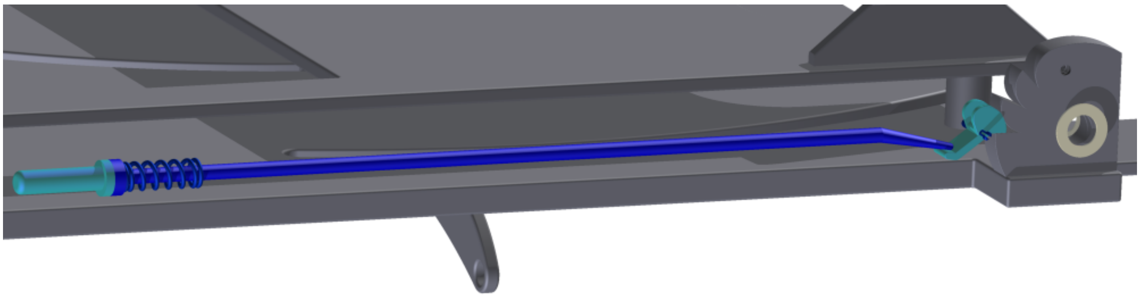


Figure 50. View of the interior part of the tilting lever.

The bar that lifts the seat when the tilting lever is pulled (see Figure 51) is welded to the part that covers all the components of the tilting lever. As can be seen on Figure 52 this exterior lever has an engraving for facilitating the process of welding.

Figure 51. Detailed view of the piece that raises the seat.

Figure 52. Detailed view of the engraving.

In the opposite end of the lever there is a button (see Figure 53), which is activated by the passenger to enable the tilting movement.

Figure 53. Detailed view of the button.

The button is inside a plastic cover (see Figure 54) that makes it comfortable to grip the tilting lever which at the same time holds the spring that holds the tilting lever in an inactivate position (see Figure 55).

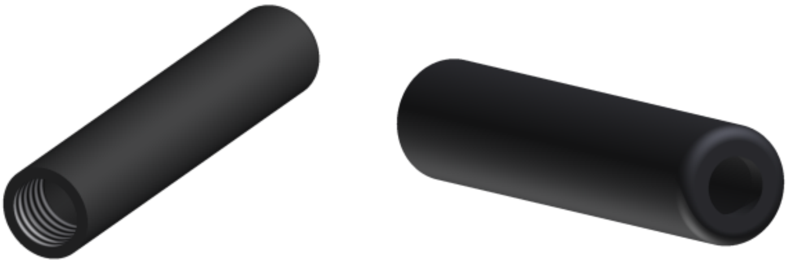


Figure 54. Detailed views of the plastic cover and the internal thread.

Figure 55. Detailed view of the spring.

The gear, the gear cover and the exterior of the lever are wrapped with a piece of leather that prevents injuries that could occur between the two first components. The exterior part of the lever is also covered in order to omit the need of painting any part of the mechanism. If these parts were not plastic, it would be necessary to paint them. This makes it nicer for the user when touching them. The leather has a hole to allow the tilting lock screw outside, and to prevent it from falling, there is a nut on the inner part of the leather that ensures completely the piece of leather stuck to the screw.

-Foot rest: there is an extractable foot rest that moves at the same time than the middle disc (see Figure 6.) Its function is to hold the legs while the movement is on course. The foot rest is activated by hand, as every component in the sliding seat. This disc is joined to the rails that are welded in middle disc with a pair of rails that match inside the others (see Figure 7).

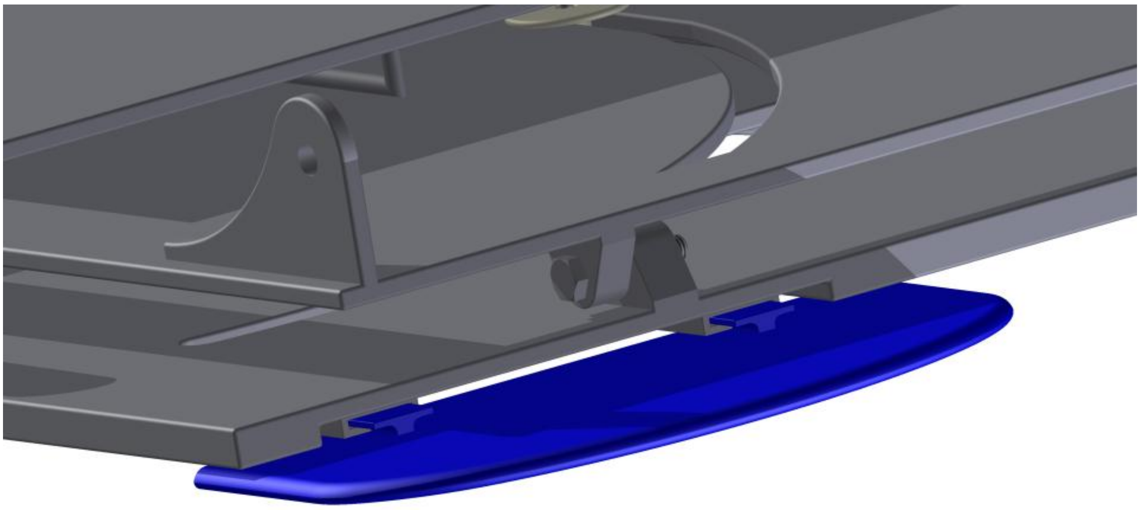


Figure 56. Detailed view of the assembly of the foot rest.

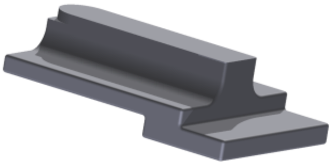


Figure 57. View of the interior rail.

In Figure 58 the engraving in the bottom surface to facilitate gripping is shown.

Figure 58. Isometric view of the foot rest (front-top-left).

3 Materials

3.1 Steel

Metals are one of the most widely used materials in engineering due to ductility, flexibility, luster, thermal, electrical and manufacturing characteristics. They also have the possibility of being turned into alloys for enhancing their qualities. By applying a heat treatment it is also possible to improve metal's qualities without changing any chemical composition. Common metals have the following characteristics:

- High stiffness. Stiffness is "the quality of being firm, hard or unable to bend"[1]. Tensile stress test is a standard method that has the objective of comparing one metal with another. It consists of subjecting a test-specimen to pure tensile stress. When a plastic deformation is observed, the applied tensile stress is considered the elastic limit of that material. The test-specimen has standardized dimensions in order to always have the same work section at the beginning of the test.

- High strength. Strength is "the ability to support a load without breaking"[1]. This quality is checked with the standard tensile test. In this case, the test-specimen is under pure tensile stress until it breaks. In that point, the stress which is applied is considered the maximum tensile stress that the material is able to resist.

- Hardness. It is the quality of being "solid, firm and rigid; not easily broken, bent or pierced" or "the resistance of a material to penetration by a pointed tool"[1]. The main systems of measurements of hardness are Rockwell and Brinell. These tests consist roughly in a penetration tool with a specific point which uses a specific load to create a mark in the material in study. Depending on the dimensions of the created mark, the material has a different value of hardness. Both are empirical.

- Toughness. Toughness is "the capacity of absorbing energy"[1]. It is measured in Joules per cubic metre. This property is not only dependent of the material; the ambiental conditions also affect it. Chiefly, low temperatures reduce the ductility, affecting seriously the toughness. Its values can be obtained with the Charpy notched-bar test. It consists in a pendulum that hits the bar with a determined speed. The energy that can be absorbed by the material is defined taking into account the weight of the pendulum, its speed and the deformation (or breakage) that is generated on the bar. In the case of this project, the toughness acquires a high relevance because this test is quite similar to the conditions of the mechanism: it is considered static except in the crash-case that can be consider as a punctual hit.

Metals are roughly divided in two groups: ferrous and non-ferrous. The ferrous have an iron base, and they can be subdivided in cast irons and steels. Most of the following

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[1] *Cambridge dictionary,* Cambridge university press 2001.

discussion is about steels. This is the material that fulfils better the requirements and in the most economic way.

As Groover (2011:317) explains “steel is an alloy of iron that contains carbon ranging by weight between 0.02% and 2.11%. It often includes other alloys ingredients, such as manganese, chromium, nickel, and/or molybdenum; but it is the carbon content that turns iron into steel.” Depending on the chemical composition it is possible to talk about five groups of steels:

- Plain carbon steels: they just contain small quantities of no-carbon alloying elements. The composition is about 0.4% manganese plus lesser amounts of silicon, phosphorus and sulphur. The American Iron and Steel Institute (AISI) and the Society of Automotive Engineering (SAE) define plain steel by means of a four-digit numeration: 10XX. In this code, number 10 means plain carbon steel and XX indicates the percent of carbon in hundredths of percentage points. Table 1 shows the classification of plain carbon depending on its carbon content:

Table 1. Plain carbon steels classification.

Name	Range of content Carbon	Common applications
Low carbon steel	Less than 0.20%	Automobile sheet-metal parts, plate steel for fabrication, railroad rails.
Medium carbon steel	0.20-0.50%	Machinery components, engineer parts.
High carbon steel	Greater than 0.50%	Springs, cutting tools, wear-resistant parts.

- Low alloy steels: they have the same chemical composition than plain carbons but the amount of non-carbon alloying elements is higher, resulting in a substantial modification of the properties. The total amount of alloying elements cannot be higher than the 5% of the total weight. They have better properties but heat treatments are often required to achieve them. The principal alloying ingredients and their benefits are contained in Table 2. The percentage of each element is variable depending of which quality needs to be highlighted.

Table 2. Principal alloying elements for low alloy steels.

Alloying element	Improvements
Chromium (Cr)	Strength, hardness, wear resistance, hot hardness. Corrosion resistance when alloyed considerable quantities.
Manganese (Mn)	Strength, hardness.
Molybdenum (Mo)	Toughness, strength.
Nickel (Ni)	Strength, toughness. Corrosion resistance when alloyed considerable quantities.
Vanadium (V)	Strength, toughness, wear resistance.

Weldability is the main disadvantage of this kind of steel. The research about low alloy steels, focused on solving this problem, resulted in the creation of the high-strength low-alloy steels (HSLA). They have better resistance against strength than plain carbon, but they conserve the formability and weldability.

- Stainless steels. They are highly alloyed steels. These materials guarantee the best resistance against corrosion. They contain high levels of Chromium (above 15%) whose free electrons generate an oxidizing atmosphere that avoids corrosion. Stainless steel is expensive in comparison with plain carbon or low alloy steel due to its difficult manufacturing process.

- Tool steels. They are used in extreme working conditions. They have high levels of alloying elements with the objective of improving the desired properties for the selected application. An example of this is the ability to harden, reduced distortion during heat treatment, hot hardness or enhanced toughness. Some tools can be made from other materials but, for a correct operation, for high-speed, hot-working, cold-work, water-hardening, shock resistant or casting tools, it is recommended the use a special tool steel.

- Special steels. They are alloyed with special elements in different amounts. They are really expensive and some of them are not environmental friendly. Its principal characteristic is that they possess unique processing features.

This mechanism takes advantage of the qualities of steel: high stiffness, high strength and toughness, which are the critical stresses or the critical conditions in this case. The discs, the legs and the levers are made from plain carbon steel because its properties fulfil the necessities with the lower cost. The welds are made of HSLA steel, particularly with ER 70S-6 mild steel, for improving the resistance.

3.1.1 Weldability

The mechanism contains some pieces that need to be joined. The considered options were a screw-nut joint and a welded union.

The screw-nut option is the one that makes the assembly easier because it just needs two number 8 spanners for a correct adjustment. This union permits the user to assemble the mechanism on his/her own, but it supposes an increase in the number of pieces and also in the weight of the mechanism. Two holes are needed in each leg in order to achieve a correct position and an adequate resistance to the stress. That implies eight more pieces in each leg: four washers, two screws and two nuts. That would mean thirty-two extra pieces, with the cost that it supposes and the inconvenience that such a high number of pieces hints at the DFA (design for assembly). The legs also need a flang, which needs to be drilled. That implies an increment in the material of the legs and also in the manufacturing process. It is possible to see these specifications in

Figure 59.

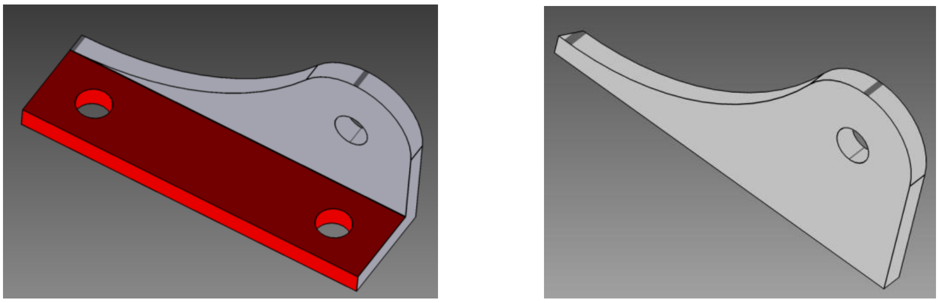


Figure 59. Leg designed for screw-nut union and the leg for welding.

The welded joint includes fewer pieces and less material. However, it implies the necessity of a skilled worker despite the cost that it incurs. Besides, the welded joint avoids the possibility of an easy disassembly. In contrast, it improves in a significant manner the flux of tensions, the behaviour against shear and the quantity of material needed. This is the selected process because of all the advantages previously described. Any well trained user could assemble the mechanism on his/her own. The only problem is that the process implies the disassembly of the original seat and of the electronic components. The final step is the reassembly of the seat, with the mechanism included. This could be an arduous task. It is going to be a customer’s choice but, assembling the mechanism on his/her own implies the risk of a not-correct assembly and the safety risk that it could have. For all this, the costumer could save money by assembling his/her own mechanism, but it is advisable to engage a skilled worker. In that way, the cost of the skilled worker in relation with the welding is decreased.

The ER 70S-6AWS (A5.18) carbon steel is the filler metal that takes advantage of these welding properties. One of these advantages is that it conserves almost the same properties as if the assembled pieces were one single piece. The intended application of weldability in this case allows the use of weldings. HAZ (Heat Affected Zone) properties of the base metal are unaffected in this situation, and it does not introduce detrimental discontinuities. Besides, it reduces the number of singular pieces, avoiding the use of screws, nuts and washers in the assembly. The high levels of alloying elements as Silica and Manganese, on the ER 70S-6, provide good welding properties. This permits an excellent deoxidation that provides the welding with extraordinary mechanical properties and magnificent radiographic quality. This is achieved in both, continuous and intermittent, fillet weldings. Due to the carbon percentage (0.07-0.15%C) it is unnecessary to treat them against cracking. This material has also less melting temperature than the base metal, what makes it possible to be welded. ER70S-6 is a copper-coated carbon steel is included in the group of mild steels. This material has a high tolerance to be rusted and milled. It is recommendable for fillet welding even in heavy equipment, in structural, automotive and general carbon steel production.

Welded joints cause stress concentration. External stresses appear when the service loads are applied. Also other internal (or residual) stresses show up due to the welding process. The absence of the perfect process of welding makes arise unequal thermal distribution or thermal gradients that change the volume of the welds. This causes some compression-tensile stresses in the zone. Paying attention to the features described previously, the welding process has to be made with discussion.

Arc welding is the selected process because of its price-quality ratio. The Gas Metal Arc Welding (GMAW) or MIG welding has high deposit efficiency (98%) and it is versatile (any position). It can deposit weld metal at a very high rate in any positions. It could be used manually or adapted to a robot. It is the cheapest process that fulfils all the requirements. The AISI recommends GMAW for plain carbon steels. The GMAW lets using it in small plate thickness. The ER 70S-6 requires CO_2 as shielding gas.

Using welded joints, the mechanism is produced from two simple sheets of metal 490x500 mm. These discs are cut and milled to ensure that the slots where the wheels are going to move and the legs, are in a correct position. In this way, the assembling process is simple and, at the same time, it can be installed in several cars. The user can do it just by changing the position of the legs, or even changing a leg. This situation depends on the model of the car and the dimensional necessities.

The morphology of the mechanism allows an easy welding of the components. The design has been made considering the welding necessities for the initial assembly and the subsequent maintenance, making it easy to access to the welding zone.

The welded joints have fillet form and T position due to the structure of the pieces that are going to be welded.

3.2 Nylon 6/6

The main purpose of this project is to reduce the cost of the final product as much as possible. Furthermore, it must fulfil the functionality and security requirements of the device.

As it is a movable mechanism, some frictional and rotational problems are presented. The wheels have to rotate at the same time that they are moving through the rails especially designed for the expected movement. It implies quite hard friction in the contact zone between wheel and track and also in the pin connection with the plate. The design considerations that have to be under control are the following:

- The viscosity of the lubricant (μ).
- The load per unit of projected bearing area (P).
- The speed (N).
- The bearing dimensions.

One of the most common issues in these cases is the use of bearings. By using bearings the pin connection problem could be solved. This solution would avoid the internal friction and also it omits the need of fixing the wheel to the support, but the dimensions of the pieces turns to be an obstacle.

The support has a smaller dimension than any standard bearing. This supposes that a special bearing would have to be designed for this application, which would increase the cost in an unacceptable manner. Another option could have been the change of the size of the support and make it larger. This choice would have involved, firstly a complete redesign of the mechanism and of the support, and secondly a redesign of the wheels and of the tracks. This last change would have been the most critical one, making the tracks larger could have implied a different flux of tension on the plate, which entails a worse distribution of the bending moment that could break the piece or make it works in an incorrect way.

All the friction problems of the device came from the wheels. Changing the material was the better solution. It will solve internal and external friction problems, respect the desired movement and also reduce the number of pieces. Only the wheel will be needed for a correct operation.

Analysing the work and environmental conditions, Nylon 6/6 was chosen attributable because of the mechanical properties that it offered.

Nylon 6/6 is commercialized from 1941. Nylon is a polymer obtained in the condensation of diamines and dicarboxilic acid. Sometimes it is reinforced with minerals and fibreglass. Due to its chemical composition with –NC-C=O chains it has a high fusion temperature and a good behaviour under tensile stress. Its properties can be conserved up to 150°C, but it is recommendable to avoid the use over 93°C. For the mechanism studied in this project, this will never happen. The work environment is the internal part of a car, which is supposed to be in comfortable temperatures for human use.

The most important applications of this homopolymer are in the mechanical engineering field. It is used in valves, bearings, levy, journal-bearings or gears. Besides all the advantages previously mentioned, nylon can work without lubricants. Furthermore, it is noiseless and it can be made in one piece, avoiding assemblies. It can be manufactured by injection. It is well-known in the automobile industry; it is used in the mechanism of doors, windows or tubes.

In conclusion, nylon 6/6 is selected for the wheels because it is light, noiseless, does not need lubrication, does not need maintenance and it avoids the friction and wear between the wheels and the pieces in contact with it.

3.3 ABS plastic

Acrylonitrile Butadiene Styrene plastic (ABS), is also known as engineering plastic. This name comprises a family of plastic materials whose main characteristic is strength, and heat and impact resistance. This group of materials gets the name of thermoplastics due to the three monomers that take part of its complex composition. It is possible to obtain a wide variety of grades depending on the amount present of each component.

Table 3 contains the general properties of each component:

Table 3. Component and properties.

Component and Percentage	Properties
Acrylonitrile (15-35%)	Chemical resistance. Fatigue resistance. Toughness and stiffness. Fusion resistance.
Butadiene (5-30%)	Ductility at low temperature. Impact resistance. Fusion resistance.
Styrene (40-60%)	Ease of processing (fluidity). Brightness. Toughness and stiffness.

Moreover, it is important to highlight the non toxicity. Some further information is that it is opaque, only if it is not very thin layer. ABS plastic can be presented in many colors, from dark to ivory, and it also admits the addition of pigments. All these properties make this plastic useful in industry in innumerable areas. For all the advantages mentioned previously, it is very used from automotive and electronic industry to toy industry (Lego).

Physical properties:

- Tensile strength: 40-50 MPa.
- Impact strength (Notched Impact Strength): 10-20 kJ/m^2.
- Thermal expansion coefficient: 70-90 x10 -6.
- Maximum temperature: 80-95 ºC.
- Density: 1.0-1.05 g/cm^3.

In this project this material has been used in the parts that need human contact. The button of the tilting lever, the piece that covers the button and the spring in the tilting lever, and the lock system, are made with this material. This material is softer and nicer.

3.4 Leather

This material has been used since Roman times. It consists of animal skin (usually from cows, sheeps, pigs…). This treated skin has the properties of strength and resilience that make it suitable for further manipulation. Over the years, it has been seen in many applications. Nowadays, it is usually artificial. It is possible to find leather in binding, upholstery or where it gets interesting for this project: interior of vehicles.

Synthetic materials are commonly used because they are wear resistant, easily cleanable and, at the same time, they match perfectly in terms of design. There is also a second use which is not related at all with beauty. If attention is paid to the gear lever of a vehicle, as an example, one can notice a small piece of artificial leather covering its base. In this place any other plastic piece would be difficult to set. This is because there is a need of extra flexibility in the zone. In this project, the leather has a similar function; it is used for covering the gear that activates the tilting disc. The purpose of covering it is in order to avoid injuries. If it is not covered, it might be easy to stuck any clothing on it, or even worse, fingers, as an example, while the lever is being activated. To avoid this, there is going to be a piece of artificial leather from the plastic handle to the gear. Regarding to aesthetics, the color of the leather can be selected to match the rest of the car.

There is no need to worry about the price being noticeably increased. Just a maximum of 30cm^2 are necessary for each piece, which is not big deal. Any other synthetic material can be used if there is a particular interest of not using real skin. These synthetic materials take advantage of the flexibility properties.

4 Manufacturing methods

The processes described in this chapter are the ones chosen as the most appropriate for developing the sliding seat mechanism. Each part of the gadget has been carefully designed to be as simple as possible and to require the lesser manufacturing processes to decrease the final cost.

4.1 Cutting

4.1.1 Sawing

This method is the most common method because it is very simple. This process, which consists of a turning cutting wheel, is used to cut all the bars in the mechanism. The wheel is provided with sharpen teeth that, when in contact with the bar due to the turning movement, divide the piece of material in two different parts with enough accuracy.

4.1.2 Gas cutting

This method is the cheapest for cutting sheets of metal. Because of this it is the best choice if accuracy does not play an important role. The base of this process is an oxygen jet acting in the piece to cut. Gas cutting is appropriate for materials that oxidize rapidly, and for carbon steel this process works perfectly.

During the process, the part to be cut is attacked by a very high temperature. Hence, right after, a jet of oxygen is directed in the specific area which it is desired to cut. This produces the oxidation of the metal. The oxidation is so fast that part of the material burns. This burning leaves a heat in the piece that melts the oxide produced and accelerates the preheating applied formerly. The metal already melted produces a slag, letting the oxygen jet act in a new part of the piece.

4.1.3 Laser cutting

This method is widely used for cutting carbon steels more accurately. It is able to produce complex shapes easily that through other methods would be costly and difficult. As there is no wear resistance tool-work piece, there is better precision. When the laser is acting, the metal is melted. This is the reason why the sheet is cut, but there is a small heat affected zone. There is no need to worry about warping, cut edges show virtually no distortion. Moreover, laser parameters can be automated and adjusted to necessities.

Three sheets with 5 and 10 mm thickness are bought, and then they are cut with the desired shape to form the three discs, as well as the pieces that are the same thickness.

4.2 Casting

Casting is a forming process without any removal of material. It is based on melting the materials that are going to be part of the final piece. It consists of a number of operations through which a mould with a specific shape is obtained. This mould can be expendable, semi-permanent or permanent; moreover, the moulds can be classified as simple or composite. Moulds are refractory and maintain their strength at high temperature because they have to endure the high temperatures of melted materials. Once the mould is ready, the mixture is poured inside and it is left to cool until the solidification is completed.

The most important advantage of this way of forming pieces is that it is easy and economical to create complex shapes that otherwise would be impossible to reproduce with alternative methods.

4.2.1 Metal-casting

This project will focus on permanent mould casting, also called hard mould casting. Die casting is the most appropriate method for the pieces of the mechanism that cannot be produced via machining processes. The process can be carried out in hot-chamber or in cold-chamber machines. It is the chosen method mainly because the mould can be used more than once (the casting can be removed easily from it). In addition to this, the result is a piece with a good surface finish, close dimensional tolerances as well as uniform and good mechanical properties.

For this mechanism, the pieces that are not expensive to be produced with this method are the ones that are not too large, too complex or too heavy, i.e., usually weighing less than 25 kg. The disadvantage is that the necessary installations are expensive. Dies are costly but, on the other hand, labor cost is inexpensive if the process is automated.

4.2.2 Plastic-casting

Nylon and acrylic thermoplastics let casting in different shapes with flexible or rigid moulds, depending on the complexity of the piece to produce. This method is the cheapest given that it is very simple; however, it is quite slow. During the process, all the elements are heated above the melting point in order to flow easily and then poured into the mould. This is the reason of the importance of the low viscosity of the polymer. The process is finished once the polymerization takes place at ambient pressure. This method is used for producing parts that require high resistance to abrasive wear.

4.3 Machining

4.3.1 Milling

This process is used to obtain complex profiles. A rotating cutting tool removes the material by moving along various axes with respect to the work piece in order to obtain the final shape. Engravings are made on the discs with this method with the purpose of clarifying the exact location of each component.

4.3.2 Drilling

This method consists of a rotational and almost cylindrical-shaped end-cutting tool that spins and creates holes when in touch with a piece of material. To obtain a satisfactory result, the spindle must rotate appropriately and be able to resist any side forces resulting from the drilling process. The result is a cylindrical hollow in the piece whose length and diameter may vary depending on the specific requirements.

Drilling is the most common machining process to make holes. It is also the most economical in terms of volume of metal removed and the cheapest method for cutting a hole in a solid. Irrespective of what the primary production is, holes have to be machined in pieces in order to enhance size, accuracy, straightness, geometry and tolerances of the previous process. Drilling takes place with a relative rotation between the work piece and the tool, with relative longitudinal feeding. The result is chips from excess material.

There are many methods for drilling. As no special treatment needs to be taken into account in the present project, general purpose drilling seems to be the best choice. Twist drills are usually composed of two flutes, which draw the hole. At the same time, these flutes guide the produced chips upward and also let the lubricant fluid inside. None of the pieces of the mechanism has very long drills in terms of depth. Furthermore, standard holes for standard screws, nuts and washers took priority in the project to special-sized ones. The aim of this is fulfilling its main objective of cost reduction. Twist drills range from 0.150 to 89 mm diameter, and they can be designed by fractional, millimeter, numerical or metric series. Their standard drill sizes are M2, M3, M6, M8 and M10, which are all the normalized sizes of holes present in the mechanism.

Table 4 and Table 5 show recommended operating parameters for producing holes in plain carbon steel with twist drills and feed rates for some kind of materials.

Table 4. Recommended operating parameters for producing holes in plain carbon steel with twist drills.

	Hardness		**Cutting tool material**	**Peripheral speed**		**Feed rate**	**Helix angle degree**	**Point angle degree**	**Point style**
	HB	**HR**		**m/min**	**(sfm)**				
To 0.25C	125-175	71-88 HRB	HSS	24	(80)	Y	25-35	118	Notched
To 0.50C	175-225	88-98 HRB	HSS	20	(65)	Y	25-35	118	Notched
To 0.90C	175-225	88-98 HRB	HSS	17	(55)	Y	25-35	118	Notched

Table 5. Feed rates for the materials listed in Table 4.

	Feed rate, mm/rev at a drill diameter of:				
	3.2 mm	6.4 mm	12.7 mm	19.1 mm	25.4 mm
Feed Rate Y	0.08	0.13	0.20	0.267	0.317

For small holes, i.e., the ones that range from 0.025 to 3.2 mm, there is a need for special machines, techniques, etc. that differ from conventional drilling. The speed of the spindle must be high. For the specific case of 2-mm holes, about 5000 rev/min is necessary. In this kind of drilling, the shavings are turned into metal powder.

4.3.3 Screw threading

The general purpose of this process is removing excess material from a piece. With this action it is possible to match two pieces that are compatible. This is a non-permanent joint; it can be assembled and disassembled as many times as needed. Regardless of the chosen process, a lathe and a piece of material are needed to carry it out. There is always a relative rotation and an axial movement.

It is possible to apply screw machining to any material that is available in bar form. When designing the parts, one has to have in mind that it is necessary that the threading does not terminate too close to a shoulder. It is important to consider the space needed for the tool. In tubular parts, it is necessary to take into account the thickness of the material, because if the piece is very slim, it may break during the process or even after it is already assembled.

4.3.4 External parts: single point threading

Threading is created in the piece with a turning movement of the part which rotates on a lathe, and a lineal movement of the tool, called die, in accordance with the total length of the thread. Depending on the shape of the cutting tool, many different shapes and angles are available. More than one single pass of the die is usually necessary in order to obtain more accuracy. Single point threading is not a very fast process, but it works for small production. If the rate of the productions needs to be increased, it should be noted that there are die-hard chasers, i.e., tools provided with more than one tooth and usually with four cutters.

All the external parts of this product have been produced with this method.

4.3.5 Internal parts: tapping

Internal threads can be produced with many different machining processes, but tapping gives precision and accuracy. A tap is a cylindrical-shaped cutting tool with cutting threads in the external part. When in contact with the piece, the excess material is removed, leaving the interior of the piece ready to be assembled with the convenient male thread. Taps are available with two, three or four flutes, but two-flute spiral taps are the most common. As Kalpakjian and Schmid (2006:716) state: “Multiple-spindle tapping heads are used extensively, particularly in the automotive industry where 30 to 40% of machining operations involve the tapping of holes.”

The process may take place by hand or with specialized machines such as drilling machines, lathes, automatic screw machines and vertical CNC milling machines. During the process, the tool is the part that takes control in the rotary and axial motion. In this process, it is obligatory to make a distinction between full-length holes and blind holes. In the case of having a blind hole with full depth, a bottoming tap or a plug tap is required. These two have a continuous cutting edge with almost no taper at the end.

4.3.6 Grinding

Grinding is an abrasive machining process that is usually the last step in the manufacturing process. It provides the maximum accuracy may required and it is also used for cutting. The process consists of a grinding wheel that is rotating in an axis and it is made up off a high number of grains of bonded abrasives oriented randomly and with irregular shapes. When the grains are in contact with the piece, remove the undesired excess of material. Grinding produces perfect surfaces in parts where slippery is a must.

4.3.7 Filing

Filling entails small removal of material from a surface, especially from corners or edges. This is the method to produce chamfers and fillets. The process is usually developed by hand for small production rate; it is also available automated for mass production. The cutters that execute the process are available in many different shapes as conical, spherical, cylindrical, etc. and work at high rotational speed removing small amounts of material.

Every single piece of the sliding mechanism has gone through this process. This system is a way of decreasing stress in the corners and edges of the parts. Furthermore, sometimes it is also necessary to smooth the relative motion between two parts.

Table 6 shows the machining processes that the parts of the mechanism need to undergo before becoming a final piece.

Table 6. Parts and machining processes.

METHODS / PARTS		Cutting			Casting		Machining						
									Screw threading				
	Standard	**Sawing**	**Gas**	**Laser**	**Metal**	**Plastic**	**Milling**	**Drilling**	**Single poimt**	**Tapping**	**Grinding**	**Filling**	**Welding**
DISCS													
Upper Disc			X	X			X					X	
Upper Leg Front			X					X				X	
Upper Leg back			X					X				X	
Tilting bar Displacement		X											X
Tilting Axle			X					X				X	
Screw M6	X												
Washer M6	X												
Middle Disc			X	X			X					X	
Pivot		X					X	X		X		X	
Wheels			X				X	X			X	X	
Screw M3x16	X												
Washer M3x16	X												
Tilting Bar Axis			X					X				X	
Bottom Disc			X	X			X					X	
Bottom leg			X					X				X	

METHODS / PARTS		Cutting			Casting		Machining						
									Screw threading				
	Standard	Sawing	Gas	Laser	Metal	Plastic	Milling	Drilling	Single point	Tapping	Grinding	Filling	Welding
TILTING SYSTEM													
Buttom		X					X					X	
Plastic handle		X					X	X		X		X	
Spring	X											X	
Exterior lever		X					X	X	X	X		X	
Interior lever		X					X					X	X
Gear cover			X		X			X	X			X	X
Gear				X				X				X	
Movable piece				X			X	X				X	
Axle Movable Piece	X												
Tilting Bar		X					X	X				X	X
Tilting Bar Axle			X					X				X	
Tilting Disc Axle			X					X				X	
Lock System Screw M4	X												
Support		X					X	X		X		X	

Pivot Bottom Disc													
Support Pivot Middle Disc		X					X	X		X		X	
Screw M10	X												
Washer M10	X												

METHODS / PARTS		Cutting			Casting		Machining						
									Screw threading				
	Standard	**Sawing**	**Gas**	**Laser**	**Metal**	**Plastic**	**Milling**	**Drilling**	**Single poimt**	**Tapping**	**Grinding**	**Filling**	**Welding**
FOOT REST													
Foot rest			X				X	X				X	
Exterior Rail Foot Rest		X						X		X		X	X
Interior Rail Foot Rest			X									X	X
Screw M1.8	X												

METHODS / PARTS	Standard	Cutting			Casting		Machining						Welding
		Sawing	Gas	Laser	Metal	Plastic	Milling	Drilling	Screw threading		Grinding	Filling	
									Single point	Tapping			
LOCK SYSTEM													
Lock Bar		X							X				X
Lock Handle		X						X		X		X	
Lock Fix Part			X				X	X				X	
Lock Middle part			X				X	X				X	
Lock Bottom part			X				X	X				X	
Nylon Bearing						X						X	
Screws M3	X												

5 FEM analysis

5.1 Theoretical basis of the software

The finite element analysis is based in the Finite Element Methods. This is the way of achieving the stresses and deformations that come with the applied forces and movements executed by the mechanism.

It is a method that consists in dividing a body into regions. Then, the behaviour of each region is studied instead of studying the complete body. Each of these regions is called element and the contact zones between them are called nodes. In this case, a 3D mesh is necessary. The tethraedical is the one used by the program by default. It is possible to select the average element size (as a fraction of bounding box length), the minimum element size (as a fraction of average size), the grading factor and the maximum turn angle. There is also the possibility of selecting whether to create curved mesh elements or not. Furthermore, one can choose as an assembly option if using part based measure for assembly mesh.

The finite element analysis (FEA) was made by the Stress interface of Autodesk Inventor 2012. The tool executes the calculus considering the previously used materials and dimensions of the pieces. The obtained results are independent of the temperature. This means that the program assumes that the deformation caused by the temperature is insignificant in comparison with the deformation caused by the stresses. This tool can only be used with a material whose properties respond to a linear behaviour. This means that the elastic limit of the material cannot be surpassed. This situation coincides with the case in this project.

Autodesk Inventor uses the von Mises stress in its calculations. An equivalent stress is calculated by the combination of the principal stresses. It combines the six components of the stresses in a uniaxial stress. The formulas below correspond to von Mises' theory:

$$\sigma'^2 = \frac{(\sigma_x - \sigma_y)^2 + (\sigma_y - \sigma_z)^2 + (\sigma_z - \sigma_x)^2 + 6({\tau_{xy}}^2 + {\tau_{yz}}^2 + {\tau_{xz}}^2)^2}{2}$$

$$\sigma'^2 = \frac{(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2}{2}$$

$$\sigma_1, \sigma_2, \sigma_3 = main\ stresses$$

$$\sigma_1 > \sigma_2 > \sigma_3$$

$$\sigma' = Von\ Misses\ equivalent\ stress$$

The appropriate boundary conditions need to be imposed. The eight legs that fix the mechanism to the seat and to the rails are considered as fixed. They could look like pin connections, but their positions avoid the movement so they have to be indicated as fixed connections.

Different contact conditions appear due to the relative motion between pieces. The program has a tool that directly implements the dynamic simulation into a FEA. The previously defined conditions are transformed into shear forces between pieces. For example, screws are considered as sliding- no separation contact conditions. The wheels moving in the rails, and the tilting bar moving along the bottom surface of the upper disc to raise the seat, are also selected as sliding-no separation.

5.2 FEM study

The applied external loads are the pressure that the human weight causes in the seat plus the weight of the seat. The gravity is also applied, so that the weight of the mechanism is used in the simulations. There are three different simulations depending on the position of the mechanism:

1. The seat in the normal position with the human weight, the seat weight and gravity acceleration applied.

2. The seat in the outside position with the human weight, the seat weight and gravity acceleration applied.

3. The seat in the outside position plus the tilting disc activated, with the human weight, the seat weight and gravity acceleration applied.

Before starting with the FEA, the pieces have to be completely defined in materials and dimensions. In this point, is possible to start with the FEA process:

1. The loads were indicated depending on the case in study. The human weight has been considered as 75 kilograms (EURON-CAP). The weight of the seat is considered as 25kg. That would mean that the applied force in the mechanism has a total value of 981 N.

2. The boundary conditions were defined. The legs of the bottom disc are completely fixed to the original rails of the car. They were imposed with fixed boundary conditions. The ones in the upper disc receive the loads directly. The upper legs are not associated to any boundary condition because locking the mechanism in the upper and in the bottom part implies to adulterate the results. The distortion overcomes because locking the eight legs is impossible to deform the mechanism.

3. The contact loads were checked. To avoid of any mistake that could appear because of any constraint misinterpret between the program interpretation and the engineer desires.

4. Mesh definition. This is a laborious and problematic task. The user has to find a balance between the desirable number of mesh elements and the computer capacity. The objective is to achieve the more realistic result. The larger the elements, the quicker the calculus is realized, but inaccurate results are obtained. Smaller sizes permit more accurate results. The problem of this is that it implies long running time for the computer.

The approach to handle the mentioned problem was to start with large sizes of elements to check if all the parameter worked correctly. Then the elements' size was reduced successively.

The convergence study was made by the specific tool Autodesk Inventor has. It permits an easy understanding of how FEM works. The convergence shows if the analysis is accurate or not. It has to have a value lower than the 5%. It means that the displacement in an element in a simulation and the displacement of the same element in another simulation with the size reduction do not differ more than the 5%.

5. Checking the points were the stress is minimum and re-evaluation the design by changing the dimensions.

6. Repeating the process from step 1 again and again. The end is reached when the dimensions of the pieces are reduced as much as possible but maintaining the safety necessities and also achieving a convergence less than the 10%.

6 Results

In all the studied positions there are different forces acting in the mechanism in different values and directions

A Dummy is the reference for the force of the weight acting in the mechanism from above. A male Dummy weights 75 kg and a female Dummy 50 kg. For the simulations the male is the one that has been selected because it supposes a bigger load.

6.1 Position 1

Normal position of the seat. In this position the mechanism is in a neutral position: lock activated, tilting disc and tilting bar in horizontal position, foot rest retracted and mechanism facing front.

The loads acting in this case are the weight of the person and the weight of the seat. When a person is sat, there is not a uniform distribution of the weight in the seat. The body is not positioned on the center of the seat so that the centroid is displaced to the back. It is given that the front part of the seat is supporting 30% of the considered load. That amount means 294.3 N. The remaining 70% is at the back of the seat, 686.7 N. These loads are applied in the legs of the upper disc (tilting disc). Each of the front legs supports 147.15N and each of the back legs 343.35 N.

The weight of the mechanism is used in the simulation. The total mass of the mechanism is 30.5775 kg. That implies an internal force of almost 300 N.

- Results:

  F1 = F2 = -147.15 N (z axis)

  F3 = F4 = -343.35 N (z axis)

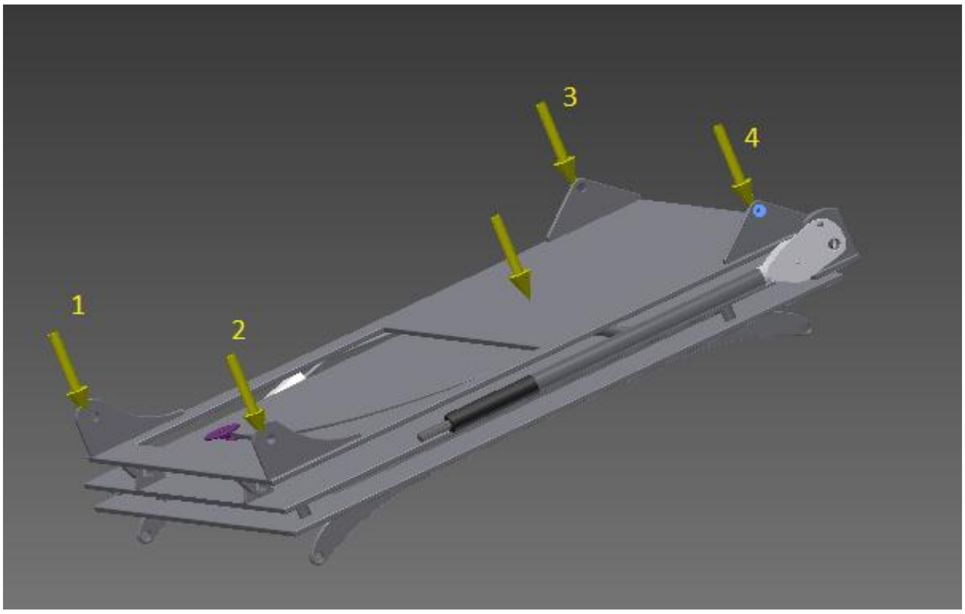


Figure 60. Loads applied in stress analysis.

Table 7 contains the parameters of the mesh.

Table 7. Mesh settings.

Avg. Element Size (fraction of model diameter)	0.1
Min. Element Size (fraction of avg. size)	0.2
Grading Factor	1.5
Max. Turn Angle	90 deg.
Create Curved Mesh Elements	Yes
Use part based measure for Assembly mesh	Yes

Table 8 moment on the bounded legs.

Table 8. Reaction Force and Moment on the four fixed legs.

Reaction Force		**Reaction Moment**	
Magnitude	**Component (X,Y,Z)**	**Magnitude**	**Component (X,Y,Z)**
1354.853 N	Rx = 0 N	80.625 N·m	Mx = -4.6398 N·m
	Ry = 0 N		My = 75.2022 N·m
	Rz = 1354.853 N		Mz = 27.8547 N·m

- Safety factor:

Minimum = 2.12

Figure 61 represents a visual value of the safety factor.

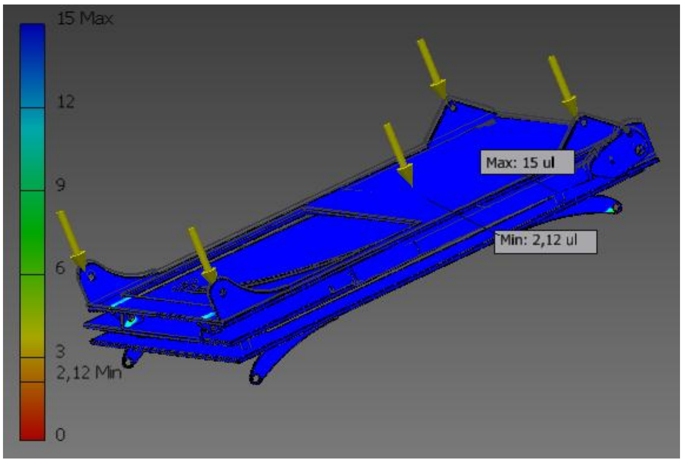


Figure 61. Safety factor.

- von Mises Stress (MPaMPa):

Maximum = 157.1 MPa

Figure 62 represents a visual value the stress obtained in von Mises.

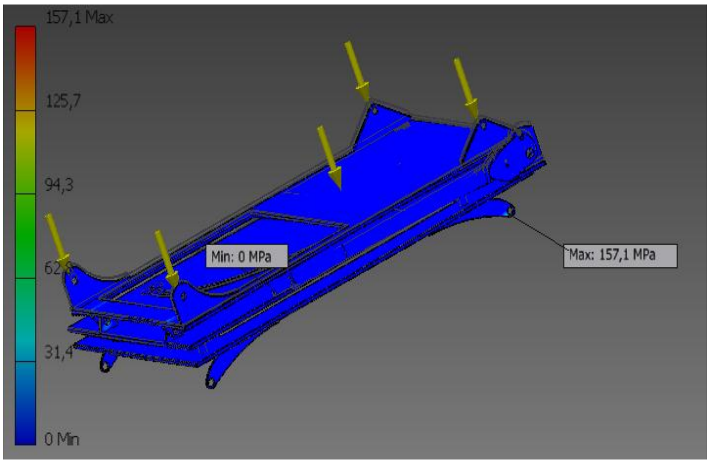


Figure 62. von Mises.

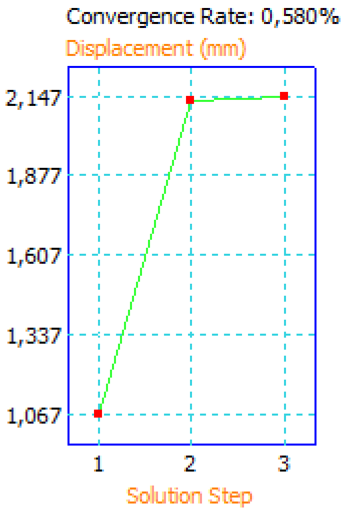
Table 9 contains the physical properties of the mechanism.

Table 9. Physical properties.

Mass	30.5735 Kg
Area	1288540 mm^2
Volume	3917030 mm^3
Center of Gravity	x = 5.95298 mm y = -8.24345 mm z = 18.9371 mm

Table 10 contains the values obtained in the convergence study in the critical point.

Table 10. Convergence results table and diagram.



Step	**Number of elements**	**Number of nodes**
1	186087	341610
2	189492	347375
Default mesh	192280	353301

6.2 Position 2

Outside position. The forces acting in this case have the same value and direction than in Position 1: weight of the person and the seat. The difference is the state in which the mechanism is located. For this study the lock system is deactivated and the middle disc is turned. That would mean that the seat is out of the car already.

- Results:
- F1 = F2 = -147.15 N (z axis)
- F3 = F4 = -343.35 N (z axis)

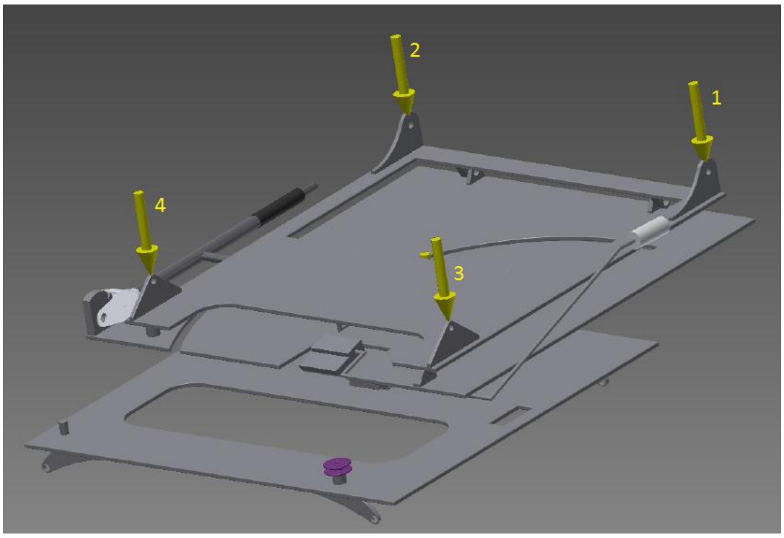


Figure 63. Loads applied in the stress analysis.

Table 11 contains the parameters of the mesh.

Table 11. Mesh settings.

Avg. Element Size (fraction of model diameter)	0.1
Min. Element Size (fraction of avg. size)	0.2
Grading Factor	1.5
Max. Turn Angle	90 deg.
Create Curved Mesh Elements	Yes
Use part based measure for Assembly mesh	Yes

Table 12 contains the reaction force and the moment on the bounded legs.

Table 12. Reaction Force and Moment on the fixed legs.

Reaction Force		**Reaction Moment**	
Magnitude	**Component (X,Y,Z)**	**Magnitude**	**Component (X,Y,Z)**
1531.08 N	Rx = 0 N	283.584 N·m	Mx = -275.973N·m
	Ry = 0 N		My = 796.235 N·m
	Rz = 1531.08 N		Mz = 2.4961 N·m

- Safety factor:

Minimum = 2.01

Figure 64. Safety factor.**Error! Reference source not found.** represents a visual value of the safety factor.

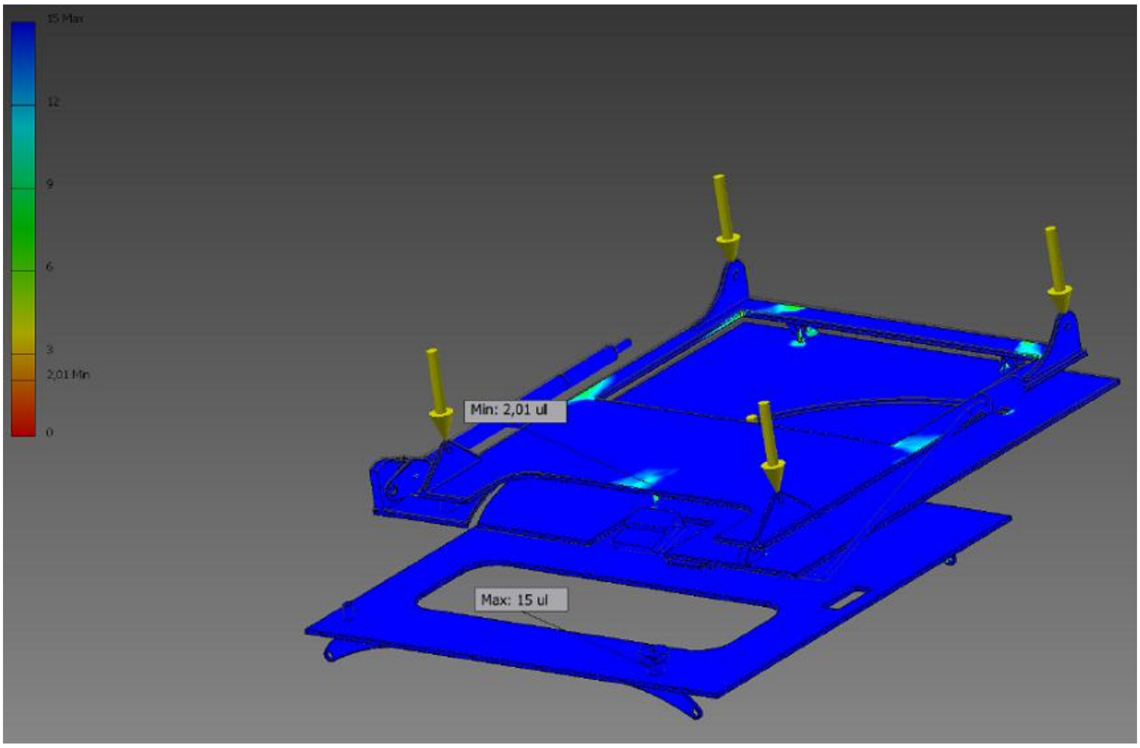


Figure 64. Safety factor.

- von Mises Stress (MPaMPa):

Maximum = 174.2 MPa

Figure 65 represents a visual value of the von Mises computed stresses.

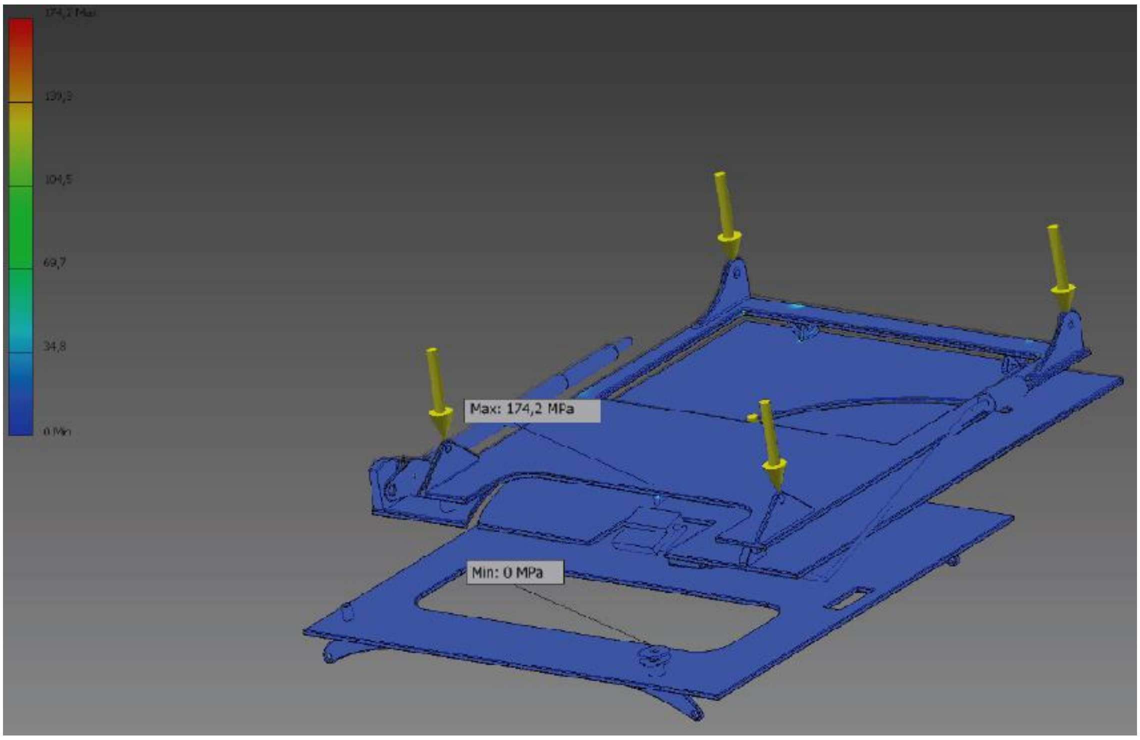


Figure 65. Von Mises

Figure 66 details the critical part, the U-shaped bar.

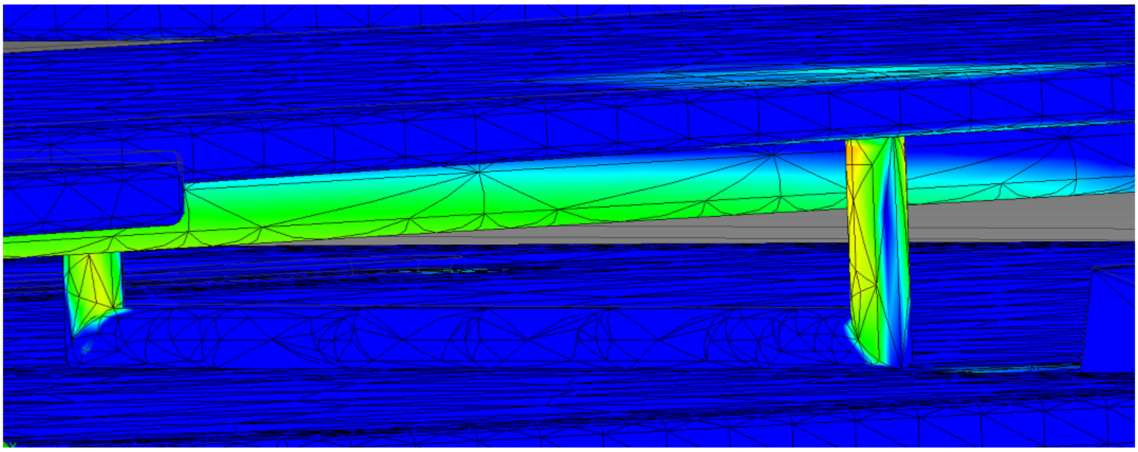


Figure 66. Safety factor distribution, U-bar.

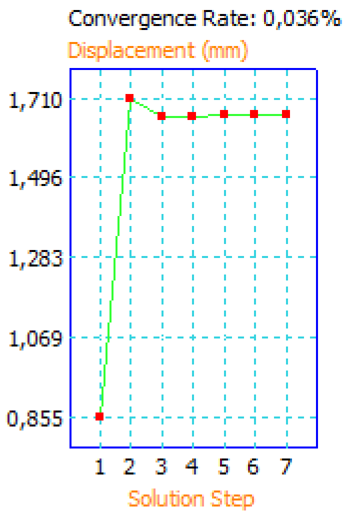
Table 13**Error! Reference source not found.** contains the physical properties of the mechanism.

Table 13. Physical properties.

Mass	30.5735 kg
Area	1288540 mm^2
Volume	3917030 mm^3
Center of Gravity	x = 46.8294 mm y = -177.358 mm z = 22.2667 mm

Table 14 contains the values obtained in the convergence study.

Table 14. Convergence results table and diagram.



Step	Number of elements	Number of nodes
1	141892	270929
2	144280	274825
3	145269	277135
4	146665	279336
5	147586	281005
Default mesh	148916	282842

6.3 Position 3

Outside position and tilting movement. In this case the simulation is made using the complete weight of the seat and the 40% of the human weight (75 kg). This is because in this position the feet are on the floor. Therefore, the seat is not supporting the complete weight of the body. The weight is distributed between the legs and the seat.

The screw that locks the movement of the lever is suppressed in this case. This is because the user has to loosen it before pulling the tilting bar and to the upper position. The screw for the lock system would not fall because it is attached with a nut to a piece of leather. The leather is covering almost all the length of the lever until the gear.

The front part of the seat considered to receive 30% of the considered load because the body is not positioned on the center of the seat so that the centroid is displaced to the back. This percentage means 161.865 N in the upper front legs. Hence, the remaining 70% produces a force of 377.685 N in the upper back legs.

- Results:

F1 = F2 = -80.9325 N (z axis)

F3 = F4 = -188.8425 N (z axis)

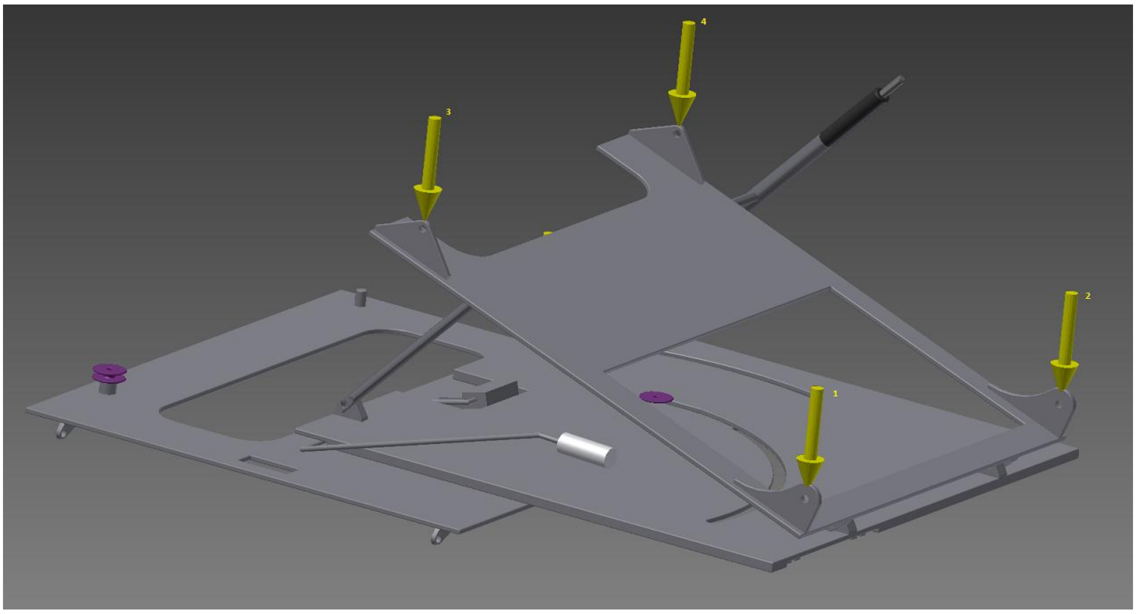


Figure 67. Loads applied in stress analysis.

Table 15 contains the parameters of the mesh.

Table 15. Mesh settings.

Avg. Element Size (fraction of model diameter)	0.1
Min. Element Size (fraction of avg. size)	0.2
Grading Factor	1.5
Max. Turn Angle	90 deg.
Create Curved Mesh Elements	Yes
Use part based measure for Assembly mesh	Yes

Table 16 contains the reaction force and the moment on the bounded legs.

Table 16. Reaction Force and Moment on the fixed legs.

Reaction Force		**Reaction Moment**	
Magnitude	**Component (X,Y,Z)**	**Magnitude**	**Component (X,Y,Z)**
1089.242 N	Rx = 0 N	240.0512 N·m	Mx = -233.6198 N·m
	Ry = 0 N		My = -55.1901 N·m
	Rz = 1089.242 N		Mz = 0 N·m

- Safety factor:

Minimum = 2.14

Figure 68. Safety factor. represents a visual value of the safety factor.

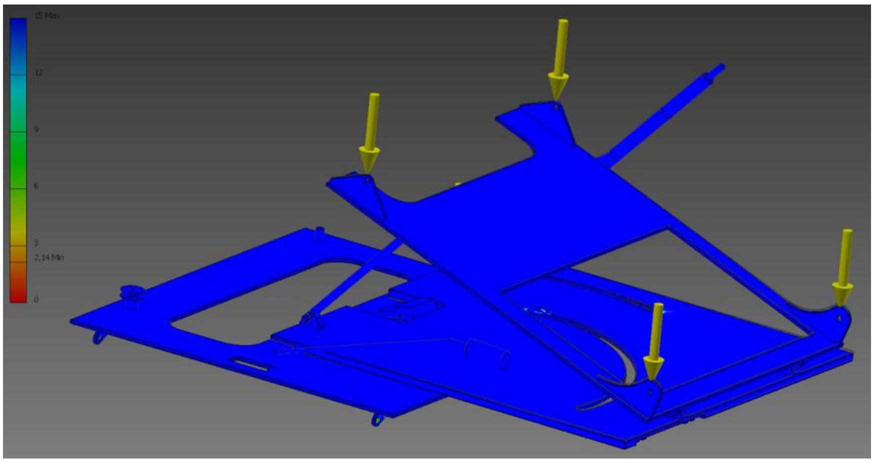


Figure 68. Safety factor.

MPaMaximum = 163.4 MPaMPa

Figure 69. von Mises.represents a visual value the computed von Mises stress.

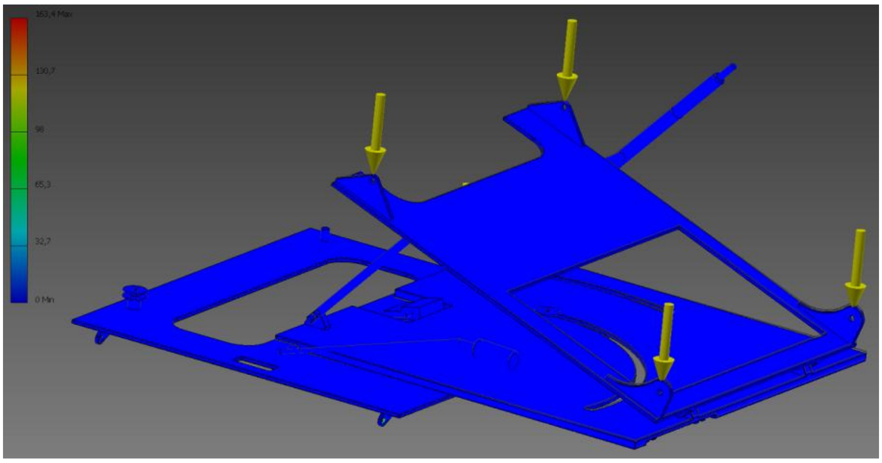


Figure 69. von Mises.

Figure 70 details the critical part, the gear cover.

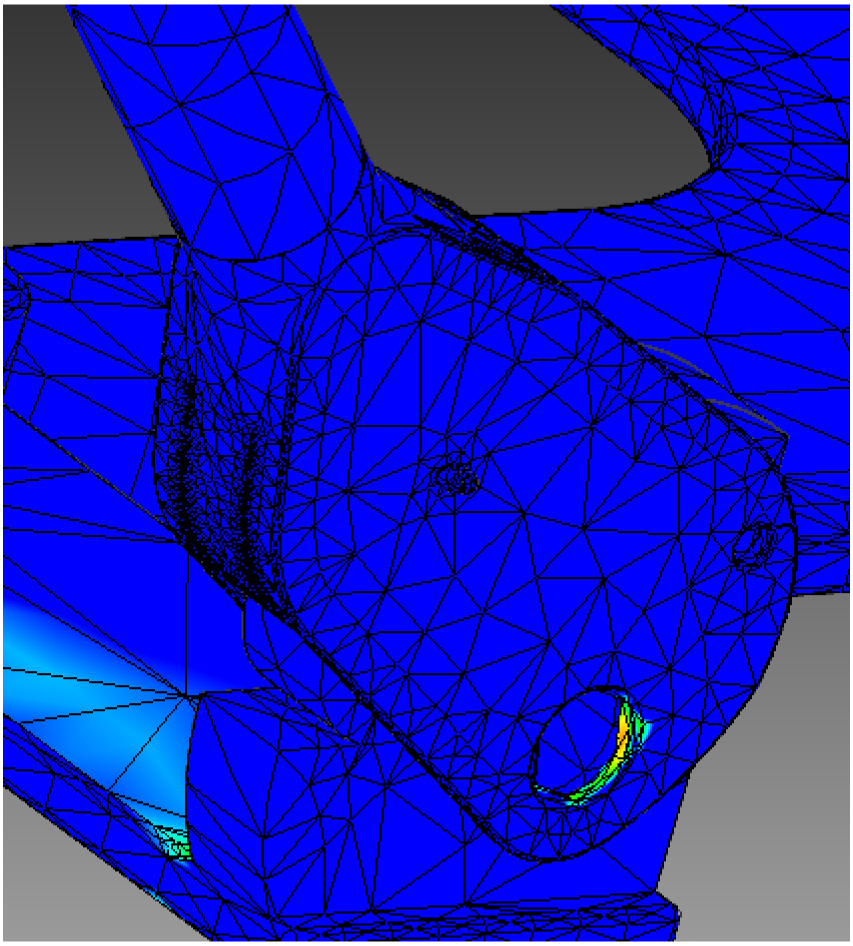


Figure 70. Safety factor distribution, gear cover.

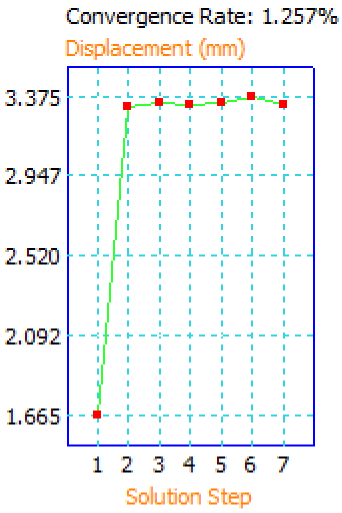
Table 17 contains the physical properties of the mechanism.

Table 17. Physical properties.

Mass	30.5735 kg
Area	1288540 mm^2
Volume	3917030 mm^3
Center of Gravity	x = 65.7873 mm y = -210.447 mm z = 34.6753 mm

Table 18 contains the values obtained in the convergence study.

Table 18. Convergence results table and diagram.



Step	Number of elements	Number of nodes
1	243218	431820
2	246130	436855
3	247163	438279
4	247172	438614
5	248318	440215
Default mesh	248396	438938

The analysis was executed starting with Position 1. In a first analysis, the displacements were excessive. The deformation of the discs was out of the range of a correct structural behavior. Two pivots were added in the critical points of deformation in order to minimize it. One was placed on the down disc and the other on the middle disc, one close to the gear. These pivots have the function of supporting the immediate upper part in a way they avoid it critical deformation. See Figure 71.

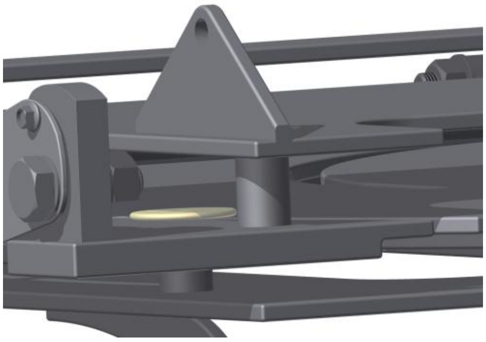


Figure 71. Detail of the pivots for support.

The following step was the position 2. This position is almost in cantilever (see Figure 72). Supporting the same loads the observed stresses were considerably higher. But any specific change on the pieces was required in this position.

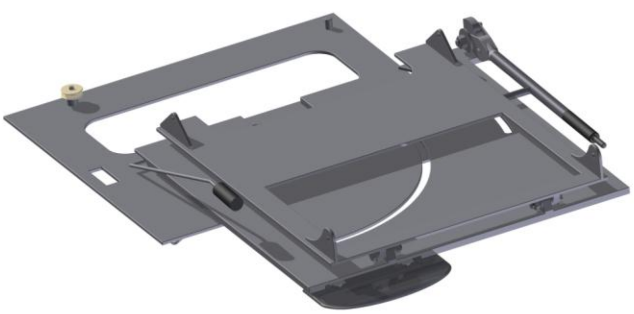


Figure 72. Cantilever position.

The last position in study was the position 3. As it was known from the beginning of the project, it was most critical one. Critical deformation was observed in the middle disc. The washers were changed for others with superior diameter for achieving a better distribution of pressure, but results were not positive. The decision was removing material from the upper disc. The purpose was minimizing the value of the loads. The external diameter of the pivots that support the wheels were broaden. Finally, the solution founded was a combination of the three explained previously. The result was an increment of the thickness of the middle disc from 5 mm to 10 mm. See Figure 73.

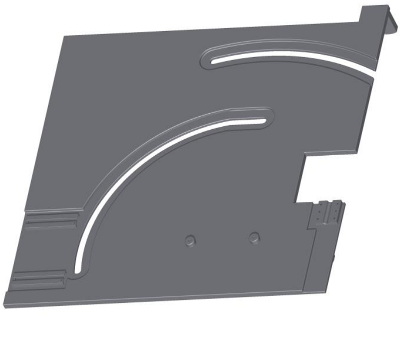


Figure 73. Thickness of the disc.

The three previous studies were made without convergence. Determined zones of the bottom disc were observed without noticing any bad working conditions. Taking advantage of this, some material was removed from the disc (see Figure 74), accepting a safety factor over 2, in any of the cases. The most favorable one was chosen.

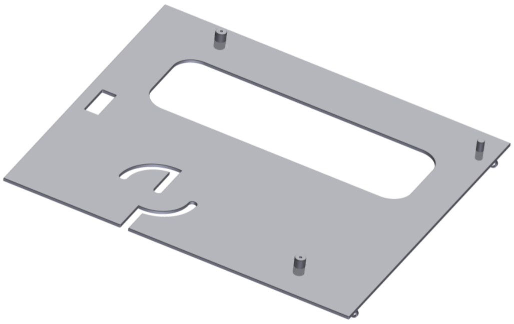


Figure 74. Detail of the removed material.

Once the mechanism fulfilled the expectations, the actual state of every component was adopted as the final result of the product. Convergence was studied in the whole structure of the mechanism. Accurate results were obtained with 5 steps. The limits imposed to the program were a better convergence than 5% or a maximum of 5 repetitions.

6.4 The footrest

The footrest has been simulated separately. This is because it could be used in any position independently of the others parts of the mechanism. The footrest just supports a percentage of the weight of the legs. The distribution of the legs weight between the feet and the surface of the legs that is sustained by the seat causes phenomenon. After several empirical tests, this weight is given a value of 7 Kg.

The two rails were limited with the boundary condition of fixed because they are welded to the middle disc.

- Results:

  F=68,67N

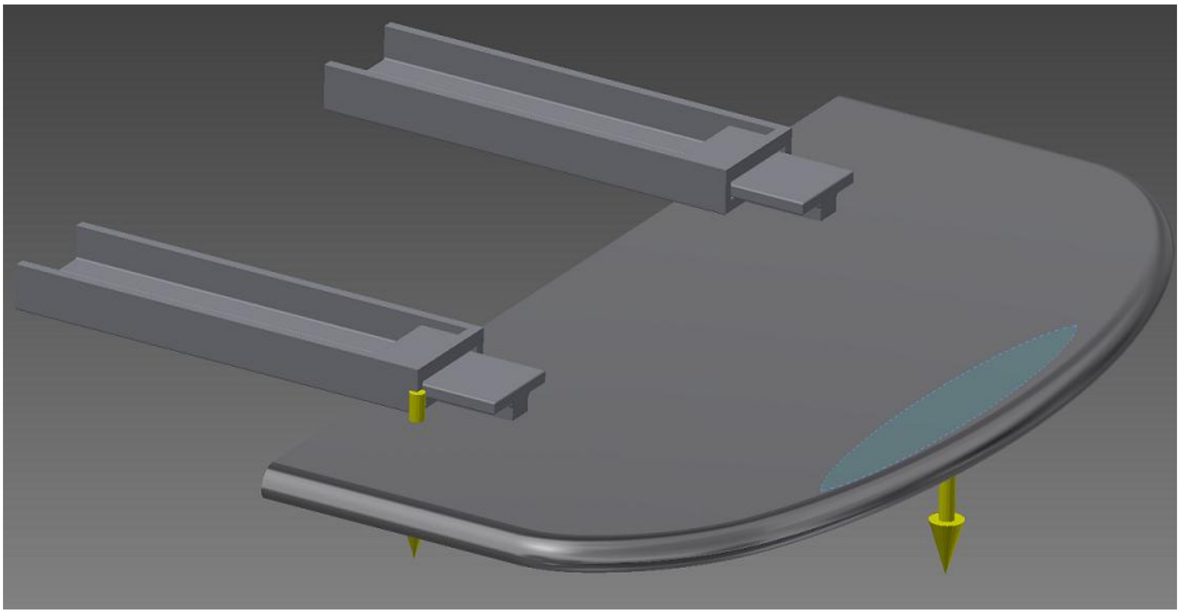


Figure 75. Loads applied in stress analysis.

Table 19 contains the parameters of the mesh.

Table 19. Mesh settings.

Avg. Element Size (fraction of model diameter)	0.1
Min. Element Size (fraction of avg. size)	0.2
Grading Factor	1.5
Max. Turn Angle	90 deg.
Create Curved Mesh Elements	Yes
Use part based measure for Assembly mesh	Yes

Table 20 contains the reaction force and the moment on the bounded rails.

Table 20. Reaction Force and Moment on the fixed legs.

Reaction Force		**Reaction Moment**	
Magnitude	**Component (X,Y,Z)**	**Magnitude**	**Component (X,Y,Z)**
70,095 N	Rx = 58,9498 N	4,38057 N·m	Mx = -3,74997 N·m
	Ry = 37,9253 N		My = 2,26236 N·m
	Rz = 0 N		Mz = 0,0940243 N·m

- Safety factor:

Minimum=2.35

Figure 76 represents a visual value of the safety factor.

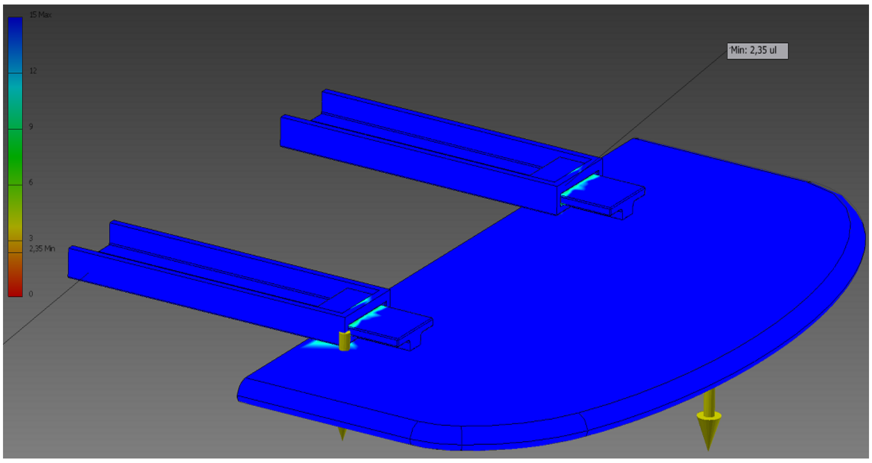


Figure 76. Safety factor.

- von Mises Stress (MPaMPa):

Maximum=148.7 MPaMPa

Figure 77 represents a visual value the stress obtained in von Mises.

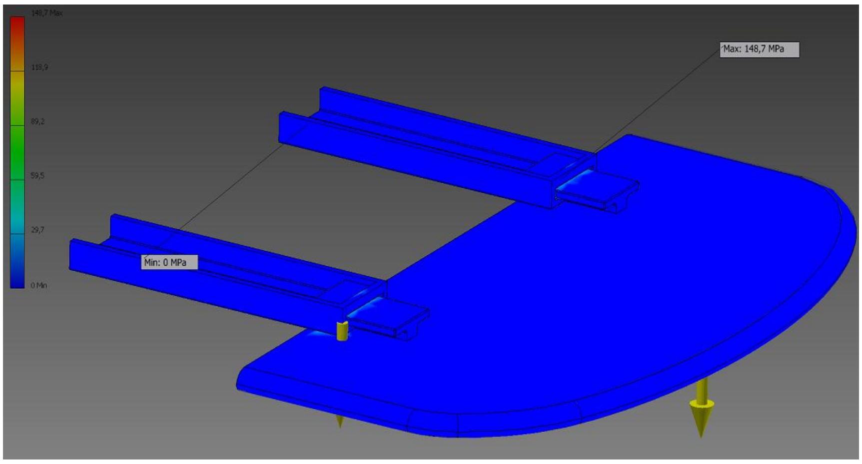


Figure 77. von Mises.

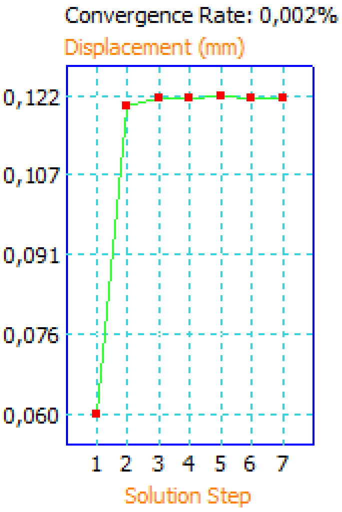
Table 21 contains the physical properties of the mechanism.

Table 21. Physical properties.

Mass	0.718696 kg
Area	48023.9 mm^2
Volume	91320.9 mm^3
Center of Gravity	x = 56.0566 mm y = -4.3076 mm z = 103,724 mm

Table 22 contains the values obtained in the convergence study.

Table 22. Convergence results table and diagram



Step	Number of elements	Number of nodes
1	43449	73365
2	47527	79635
3	50304	84207
4	52505	87791
5	54174	90476
Default mesh	56011	93473

7 Conclusions

Autodesk Inventor has been at the same time the best tool and the higher barrier of this project. It has given the opportunity of learning to use a professional program. The most important company in the world, when referring to car adaptation, uses this program in the development of their product. On the other hand, the project has been developed with the trial version of the program. This version looks like the original one and works like it except in the simulation environments. It does not permit to simulate correctly the screws and the welds. This has been the major handicap in this project.

The solutions proposed were considerably acceptable for the aims of this project. The results obtained from the study were favorable.

The critical parts are the four down legs, the middles disc and the pivots that support the wheels.

The FEM analysis shows that all the pieces support the expected stresses after the redesign process. With the foot rest simulation is possible to perceive how the stress concentration works. In the first position we can see that 100kg generate 157.1MPa in the mechanism. In the foot rest simulation we can see that 7kg generate 148.1MPa. This is because the load is in cantilever and also because the dimension of the critical piece are really small.

7.1 Future work

The visit to Autoadapt company was a guide in this project. The advice received from experts in the field was: “designing a nice extractable seat can take almost 5 years”. This means that there are many things that should be improved given the case that there were more time to work on the project.

- In the beginning, a waist seat belt was considered in order to make sure that the person in the seat is not going to fall while the seat is in motion. It has not been added in the final result of the product. Nevertheless, it might be interesting to consider the installation of one in the future.

- All the parts of the mechanism have been designed to be easily manufactured with the less expensive methods. Once the method is chosen, there are multiple ways of carrying out each process. The process selected depends on the material of the working tool, the kind of machine used, the way the machine works -if it is manual or automated-, and many other different possibilities that can be studied in more detail in order to find a better balance between price and accuracy.

- As it was explained at the beginning of this chapter, a precise study of the screws and the welds is one logical step which followed in this project. The safety factor permits to admit as correct the actual results. Anyways, these results can be improved with a further knowledge of the suffered stresses on the screws and the welds.

- Two simulations more could be made. Crash tests can be simulated by applying loads with the value of the force of the impact. The natural position with a front load applied simulates a frontal impact. The natural position with a lateral load applied simulates side impact. Frontal impact simulates two vehicles of approximately the same weight that collision when both are travelling at a speed of 55 km/h. It is considered that only 40% of the energy generated in the collision affects to the car seats (EURON-CAP). To simulate the crash, a force is applied with an object moving at 64 km/h. The missing speed is because it is considered that part of the energy is absorbed in the deformation. In the lateral study the speed of the impacting object is 50 km/h. Commonly, the lateral crash is simulated in the driver side of the car. A simulation program that permits the use of energetic data is necessary for these studies.

- A dynamic study could be developed in the future. The materials have been carefully selected in order to reduce as much as possible the wear. It could be interesting to know the exact value for the friction between different parts. In that case, those loads could be applied in the stress analysis.

- The prototype is another future development that should be carried out. With the aid of a 3D laser printer it is possible to get a clear and concise idea of how the mechanism would look like in real life. This system is much more realistic than the idea you can get from computer designing programs. Furthermore, as you are allowed to move the mechanism with your own hands, you are able to see if the movements are smooth enough. What is more, it is easy to identify any critical point in which the final product gets more difficult to slide. You can even check if the natural movement of the gadget implies any weird or difficult turning of the wrist that could be improved.

In addition to this, it is mandatory to consider safety tests. This may be one of the most important points to be carried out in a near future. The study would ensure that the mechanism is efficient and valid to be made in real life and not just let it stay as a 3D computer model. This is compulsory before this product gets to the industrial level of production. Some of the safety tests that the mechanism needs to pass are as follow:

- Fatigue test: the seat is overloaded and afterwards it is loaded to do the movements over and over until it breaks down.

- Vibration test: in this case it is possible to find that it has one or another requirement depending on the country where it is going to be used.

- Climate test: it would also be essential to prove that it deals perfectly with extreme weather conditions.

- Electromagnetic compatibility test: this one is required by The EU motor vehicle directive for any device installed in the car. In the case of a mechanism that is placed under a seat, the level of the test would not be too severe. This is because the mechanism does not play a role in driving the vehicle. This means that it is not a piece that is directly related to the motion of the vehicle, as the wheels of the steering wheel are.

- Static loads test: the mechanism is loaded until breakage.

This project is based on the creation of a mechanism for Volvo S80. Although, at the beginning, the idea was to create a universal device that could fit in the major number of cars. Given that the project ended up focusing on one specific vehicle, with an eye into the future, the joining pieces between the original rails and the car seat were designed to be easily adapted to other vehicles by just making some changes in the fixing pieces. If a more detailed study is developed, it is not complicated to reach a solution for most passenger cars in the market. In this way, becoming a universal device, the price would be reduced even more.

- It would also be interesting to develop a system which allows the user to set up his/her own sliding mechanism. If this was possible, the device could be available in any store. The costs would be reduced even more, taking into account that there is no need to take the vehicle to a mechanic to install the gadget.

To enhance the device even more, it would be worth finding an electronic driver motor that may do the complete sequence of movements. There is always the need of paying attention to the final price. It is mandatory to have in mind that this mechanism was designed with the purpose of making life easier for everyone, not just to the ones that receive economical help from the government, as disabled people are, but also for elderly and for people with long temporary injuries but it is possible to have this product in different price class.

To summarize, after examining the prototype and the crash test and comes the conclusion that the device is viable. If in addition to this, the mechanism is made it useful for most of the vehicles in the market, and if it were possible to find any powered unit to be adapted to the sliding seat, it would be possible to reach what is considered to be the highest level it could reach in terms of efficiency and price.

7.2 Sustainable development

7.2.1 Economical aspect

The cost, in comparison with the previous existing products, has been considerably decreased with the reduction of the number of parts and of the materials. The similar products that are already in the market costs about 7000€ and this one is approximately 2000€.

7.2.2 Social aspect

This project has been thought and designed in order to make easier the life of people with reduced mobility. It has been carefully designed to achieve the best comfort with the less cost. The product has been developed to help people with reduced mobility and to make them more involved with the rest of the society.

7.2.3 Environmental aspect

This project has been developed to have a minimum impact on the environment. The minimum use of materials has been achieved according to specifications. All the materials are recyclable and some parts can be removed and used again. The design of the parts was made in order to be produced with the lesser manufacturing methods and pollution.

7.3 Gains

- We have learnt and experienced to work independently (in our task level) but in a team, getting periodic meetings with our supervisor.

- Some research was carried out for the development of this project. The study was about what there is in the market nowadays. The best methodologies to adopt, the current problems, etc. were discovered.

- This project comprises broad knowledge in the mechanical field. The most suitable materials for the pieces and for the welding were chosen with the help of Science of Materials. The mechanism was designed with the knowledge acquired in the courses Machine’s Design and Mechanisms’ Theory. Manufacturing and Mechanical Technology were applied in the selection of the chosen methods for manufacturing. Business Management and Production Organization played a special role in the project. These two courses embrace from the final design of the pieces to the selection of the manufacturing methods. They are applied with the purpose to get the best value.

We have gone through a complete process of design (carried out in industry) which is our main field of study. This process contains different phases and studies in different areas (mechanical design, science of materials, mathematics, finite element method, manufacturing processes…). The study started by the identification of the need and defining the problems. It continued with an investigation about existing mechanisms that made similar movements as the needed ones. It kept on with a brainstorming about the possible combinations of those mechanisms. When the solution was founded, the 3D design with Autodesk Inventor 2012 started. The existing materials on the market and the manufacturing processes were studied while the 3D was in process. So that, when it was finished, the materials and manufacturing processes were imposed and the stress analyses began. Theses analyses took into account the finite element methods. The redesign process started when some results were collected. Some dimensions of the mechanism were changed. The product was considered as finished when all the simulations got a safety factor over 2.

- In this project, some problems are clearly exposed in the introduction. Many of them have been solved in rigorous detail. The solutions adopted are always connected to the principal objectives and at the same time, clearly and critically analyzed.

- This project has been developed until the expectations were covered within a time frame of 4 months. A solution has been given for the problems exposed, always having in mind that several improvements can be made. We have followed our designed project plan, however we had to reassess the plan several times but at the end we learnt how to make more realistic time schedule and have a cushion for each task to make it more flexible.

- The 3D computer designing program Pro-Engineer was used at the beginning in order to create the model, the simulation and to carry out the stress analysis. After being in contact with one of the most important companies in the field of car adaptation, the group took the choice of using Autodesk Inventor. Once the model was roughly designed, the mechanism was modified in several aspects such as material selection and dimensions. These adaptations have the aim of making it suitable to its application.

- Brainstorming has been used in different phases in this project. This method took place to reach the best choice for the final design of the mechanism, the manufacturing methods and for any decision. It has been essential in the development of the project the well-being of the users. Furthermore, the impact it may cause in the society and in the environment has been considered. Methods as design for manufacturability, for assembly and for environment (DFM, DFA and DFE) are the ones that lead this.

- Mechanical engineering is a wide field, so it is not strange that one manages better certain aspects and areas. In a team, members can complete themselves in perfect harmony. Having in mind that, although both parts have to participate and make decisions, there is always one who is more skilled in certain topics.

- The report of this project has been performed equally by the two members of the group, as the presentation will. Furthermore, this project offered the opportunity to be involved in different environments. At the beginning, there was a chance of visiting a related company to projects' field and to present the idea there. This way we got new ideas.

- The results obtained in the stress analysis with the software Autodesk Inventor were satisfactorily interpreted. A mechanism has been studied several times in order to obtain the one that fit the best in the framework regarding to the mechanical needs and limits. Changes on the materials and in the dimension of the pieces were made to adjust them to the requirements.

- The economical aspect is what encourages this project mostly. The project is focused on reducing the price of an already commercialized device. This product enhances the life of those with reduced mobility and it helps them to be more integrated in the society. Prices have been reduced getting rid of automated systems and selecting the most suitable materials, always regarding to the impact they may have in the environment, as it is shown in the chapter "DFE".

- This project includes a chapter where the need for further work is exposed. In the chapter “Future work” it is explained the necessity of applying in more detail many of the sciences used for developing this project.

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