ESCUELA TÉCNICA SUPERIOR DE INGENIERÍA (ICAI)

ELECTROMECHANICAL ENGINEERING DEGREE

Mechanics field

CRANE'S DESIGN AND MANUFACTURING PROCESS

Author: Loreto Rodríguez-Campra Hermoso

Director: Michal Vašíček

Madrid

June 2018

AUTORIZACIÓN PARA LA DIGITALIZACIÓN, DEPÓSITO Y DIVULGACIÓN EN RED DE PROYECTOS FIN DE GRADO, FIN DE MÁSTER, TESINAS O MEMORIAS DE BACHILLERATO

1º. Declaración de la autoría y acreditación de la misma.

El autor D. LORETO RODRÍGUEZ-CAMPRA HERMOSO

DECLARA ser el titular de los derechos de propiedad intelectual de la obra: "CRANE'S DESIGN AND MANUFACTURING PROCESS", que ésta es una obra original, y que ostenta la condición de autor en el sentido que otorga la Ley de Propiedad Intelectual.

2º. Objeto y fines de la cesión.

Con el fin de dar la máxima difusión a la obra citada a través del Repositorio institucional de la Universidad, el autor **CEDE** a la Universidad Pontificia Comillas, de forma gratuita y no exclusiva, por el máximo plazo legal y con ámbito universal, los derechos de digitalización, de archivo, de reproducción, de distribución y de comunicación pública, incluido el derecho de puesta a disposición electrónica, tal y como se describen en la Ley de Propiedad Intelectual. El derecho de transformación se cede a los únicos efectos de lo dispuesto en la letra a) del apartado siguiente.

3º. Condiciones de la cesión y acceso

Sin perjuicio de la titularidad de la obra, que sigue correspondiendo a su autor, la cesión de derechos contemplada en esta licencia habilita para:

a) Transformarla con el fin de adaptarla a cualquier tecnología que permita incorporarla a internet y hacerla accesible; incorporar metadatos para realizar el registro de la obra e incorporar "marcas de agua" o cualquier otro sistema de seguridad o de protección.
b) Reproducirla en un soporte digital para su incorporación a una base de datos electrónica, incluyendo el derecho de reproducir y almacenar la obra en servidores, a los efectos de garantizar su seguridad, conservación y preservar el formato.
c) Comunicarla, por defecto, a través de un archivo institucional abierto, accesible de modo libre y gratuito a través de internet.
d) Cualquier otra forma de acceso (restringido, embargado, cerrado) deberá solicitarse expresamente y obedecer a causas justificadas.
e) Asignar por defecto a estos trabajos una licencia Creative Commons.
f) Asignar por defecto a estos trabajos un HANDLE (URL *persistente)*.

4º. Derechos del autor.

El autor, en tanto que titular de una obra tiene derecho a:

a) Que la Universidad identifique claramente su nombre como autor de la misma
b) Comunicar y dar publicidad a la obra en la versión que ceda y en otras posteriores a través de cualquier medio.
c) Solicitar la retirada de la obra del repositorio por causa justificada.
d) Recibir notificación fehaciente de cualquier reclamación que puedan formular terceras personas en relación con la obra y, en particular, de reclamaciones relativas a los derechos de propiedad intelectual sobre ella.

5º. Deberes del autor.

El autor se compromete a:

a) Garantizar que el compromiso que adquiere mediante el presente escrito no infringe ningún derecho de terceros, ya sean de propiedad industrial, intelectual o cualquier otro.
b) Garantizar que el contenido de las obras no atenta contra los derechos al honor, a la intimidad y a la imagen de terceros.
c) Asumir toda reclamación o responsabilidad, incluyendo las indemnizaciones por daños, que pudieran ejercitarse contra la Universidad por terceros que vieran infringidos sus derechos e

intereses a causa de la cesión.

d) Asumir la responsabilidad en el caso de que las instituciones fueran condenadas por infracción de derechos derivada de las obras objeto de la cesión.

6º. Fines y funcionamiento del Repositorio Institucional.

La obra se pondrá a disposición de los usuarios para que hagan de ella un uso justo y respetuoso con los derechos del autor, según lo permitido por la legislación aplicable, y con fines de estudio, investigación, o cualquier otro fin lícito. Con dicha finalidad, la Universidad asume los siguientes deberes y se reserva las siguientes facultades:

- La Universidad informará a los usuarios del archivo sobre los usos permitidos, y no garantiza ni asume responsabilidad alguna por otras formas en que los usuarios hagan un uso posterior de las obras no conforme con la legislación vigente. El uso posterior, más allá de la copia privada, requerirá que se cite la fuente y se reconozca la autoría, que no se obtenga beneficio comercial, y que no se realicen obras derivadas.
- La Universidad no revisará el contenido de las obras, que en todo caso permanecerá bajo la responsabilidad exclusive del autor y no estará obligada a ejercitar acciones legales en nombre del autor en el supuesto de infracciones a derechos de propiedad intelectual derivados del depósito y archivo de las obras. El autor renuncia a cualquier reclamación frente a la Universidad por las formas no ajustadas a la legislación vigente en que los usuarios hagan uso de las obras.
- La Universidad adoptará las medidas necesarias para la preservación de la obra en un futuro.
- La Universidad se reserva la facultad de retirar la obra, previa notificación al autor, en supuestos suficientemente justificados, o en caso de reclamaciones de terceros.

Madrid, a 27 de Mayo de 2018

ACEPTA

Fdo...

Motivos para solicitar el acceso restringido, cerrado o embargado del trabajo en el Repositorio Institucional:

I declare, under my responsibility, that the Bachelor Thesis presented under the name:

...............CRANE'S DESIGN AND...............

...............MANUFACTURING PROCESS...............

in the Engineering ETS - ICAI of the "Universidad Pontificia Comillas" in the academic year ......2017/2018....... Is of my own authorship, original and unpublished and it has not been presented before to other intents.

The Project is not a plagiarism of another one, neither total not partially and the information que taken from other documents has been properly referenced.

Fdo.: Loreto Rodríguez-Campra Hermoso Fecha: 28./ 05./ 2018

Authorised the presentation of the bachelor thesis

THE DIRECTOR OF THE BACHELOR THESIS

Fdo.: Michal Vasicek Fecha: 31./ 5./ 2018

ESCUELA TÉCNICA SUPERIOR DE INGENIERÍA (ICAI)

ELECTROMECHANICAL ENGINEERING DEGREE

Mechanics field

CRANE'S DESIGN AND MANUFACTURING PROCESS

Author: Loreto Rodríguez-Campra Hermoso

Director: Michal Vašíček

Madrid

June 2018

CRANE’S DESIGN AND MANUFACTURING PROCESS

Autor: Rodríguez-Campra Hermoso, Loreto

Director: Vašíček, Michal

Entidad Colaboradora: ICAI - Universidad Pontificia Comillas

El equipo de Formula Student de la Czech Technical University de Praga necesita transportar el coche de carreras con el que competirá en la competición Formula SAE. El transporte se realiza mediante un camión que ya tienen. El problema es que no pueden simplemente meter el coche dentro del camión. Normalmente bastaría con una rampa para empujarlo al interior, pero la parte baja del coche está demasiado cerca del suelo y rozaría.

Este Trabajo Fin de Grado consiste en el diseño de una estructura con el objetivo de poner el coche del CTU Cartech (el quipo) dentro del camión. Cubrirá el diseño del marco de aluminio que soportará el peso del coche, la optimización del mismo mediante análisis con el programa CATIA V5 y la fabricación del mismo. Además, será necesario buscar un gancho del que poder colgar el coche y las vigas telescópicas que soportarán la estructura.

Por otro lado, también hace un recorrido por los pasos a seguir cuando se crea un producto. Primero, ha de identificarse una necesidad o un problema. Después, se discuten las posibles soluciones y se decide cuál es la más apropiada teniendo en cuenta las circunstancias. En este punto, se pasa a la optimización de la solución, y finalmente, la fabricación y producción.

En este Proyecto, no sólo tiene importancia el trabajo técnico, el estudio y el diseño, sino también el hecho de que gracias al proceso por el que se llegó al TFG y su realización han permitido el desarrollo de la capacidad de diseñar un producto conforme a las necesidades concretas de un grupo de personas, además de habilidades personales y comunicativas tan necesarias en un ingeniero.

CRANE’S DESIGN AND MANUFACTURING PROCESS

Author: Rodríguez-Campra Hermoso, Loreto

Director: Vašíček, Michal

Collaborating Entity: ICAI - Universidad Pontificia Comillas

The Formula Student team of the Czech Technical University in Prague needs to transport their racing car, the one which competes in the SAE competition. This transportation is made in a trailer that they already have. The problem is that they do not have a way of putting the car inside. The most logical solution would be a slope, but the bottom of the car is just too low.

This Bachelor Thesis consist of the design of a crane which objective is to put the CTU Cartech’s car inside the trailer that will carry it. It is going to go through the design of the aluminum frame that will lift the car, the optimization of that frame, as well as its manufacturing. Moreover, it will also be necessary to find the hook which will be used to lift the car and the telescopic legs that support the frame.

Besides, it goes all the way through the production of any product. First, a necessity has to be found. Then, we have to reach and discuss which solution is better. Later, this solution has to be studied and optimize. Finally, it has to be produced.

In this project, what is important is not only the design and technical work done, but also the fact that the author had the change to apply the theoretical knowledge she has acquired during her degree in the design and proposal of production of the device and the events that drove her to ending doing this bachelor thesis and the production of it has given the author the opportunity to test herself on another fundamental engineering skills as the ability of convincing that a project is valuable or the ability of working in a team and fulfill the necessities of others.

Index of Documents

DOCUMENT I. REPORT

DOCUMENT II. DRAWINGS

Synopsis

The Formula Student team of the Czech Technical University in Prague needs to transport their racing car, the one which competes in the SAE competition. This transportation is made in a trailer that they already have. The problem is that they do not have a way of putting the car inside. The most logical solution would be a slope, but the bottom of the car is just too low.

Apparently, this Bachelor Thesis just consist of the design of a crane which objective is to put the CTU Cartech's car inside the trailer that will carry it. It is going to go through the design of the aluminum frame that will lift the car, the optimization of that frame, as well as its manufacturing. Moreover, it will also be necessary to find the hook which will be used to lift the car and the telescopic legs that support the frame.

Besides, it goes all the way through the production of any product. First, a necessity has to be found. Then, we have to reach and discuss which solution is better. Later, this solution has to be studied and optimize. Finally, it has to be produced.

The point it is not that this problem existed and the author designed a solution. The point is: how did the author know that the team had this problem? Why is a Spanish Erasmus student giving an answer to a glitch of a Czech Formula Student team?

The author had the change to apply the theoretical knowledge she has acquired during her degree in the design and proposal of production of the device, but the events that drove her to ending doing this bachelor thesis and the production of it has given the author the opportunity to test herself on another fundamental engineering skills as the ability of convincing that a project is valuable or the ability of working in a team and fulfill the necessities of others.

This is really important because all of us engineers study the same, but it is working on something where we really learn.

Abstract

Formula SAE is a worldwide student competition where the target is to create the best racing car prototipe. Each university has its own team. CTU cartech is the team of the Czech Technical University in Prague and this bachelor thesis is essentially a colaboration with this project. It consist of the design and manufacturing process of a crane with the objective of placing the racing car into the trailer that is going to be used for its transportation. But how do actual motor-racing teams manage to transport their cars? And can we apply these technics or should we come up with an original solution?

Key words: crane, structure, design, teamwork, Formula Student SAE.

.

In the middle of difficulty
lies opportunity.
ALBERT EINSTEIN

It always seems impossible
until it's done.
NELSON MANDELA

Acknowledgments

First of all, thanks to the mix of unexpected circumstances that ended in me doing an Erasmus exchange year in Prague.

Second, warm thanks to the Formula Student team, the CTU cartech. They suggested me the topic of my bachelor thesis and let me work with them. Specially, I have to thank Lukas, the team captain, who has helped me with all the problems I was having in using a new program or designing the suitable crane. I am very grateful for their trust in my work.

Of course, thank you very much to Michal Vasicek, the director of this thesis, for his patience and guidance. Thank you for accepting to guide me in this bachelor thesis and being so easy-going, not only with all the bureaucratic problems that we have had, but also with the difficulties I have had with the project itself.

Then, thank you to Alberto of the ICAI International Office, Damian and Juan Norverto, the coordinator of the Bachelor Thesis in ICAI, who have been so understanding with our situation in the Czech Technical University and has helped as much as they could. Also, thank you to all the ICAI professors, without them I would not have the knowledge to develop this bachelor thesis.

Thank you very much to my family who has listened my problems and supported me in each crossroads.

Last but not least, a heartfelt thanks to Marta, my lovely roommate who has beared me the hole year, my Erasmus friends: Elia, Marta, Edu and company, Nacho, Danilo, Maxime, Manuela, Alba, the argentinian and the mexican crew, and the rest of friends that have made this a wonderful year in Prague, where I have grown much more than I could have ever imagined thanks to them. Also I have to name Rafa, my helpmate this year, the other ICAI student in Prague with whom I have solved every problem.

Thank you for making this Bachelor Thesis the reminder of a once in a lifetime experience.

DOCUMENT I

REPORT

Index

Index of figures

Acronyms

ICAI	Instituto Católico de Artes e Industrias
PFC	Proyecto Fin de Carrera
CTU	Czech Technical University
ČVUT	České Vysoké Učení Technické v Praze
CAD	Computer-Aided Design
CAE	Computer-Aided Engineering
CATIA	Computer-Aided Three dimensional Interactive Application
FEM	Finite Element Method
GTAW	Gas Tungsten-Arc Welding
TIG	Tungsten Inert Gas
GMAW	Gas Metal Arc Welding
MIG	Metal Inert Gas

PART I

REPORT

Chapter 1

First steps

This Bachelor Thesis consist of the design of a crane which objective is to put a Formula Student's car inside the trailer that will carry it. It goes all the way through the production of any product. First, a necessity has to be found. Then, we have to reach and discuss which solution is better. Later, this solution has to be studied and optimize. Finally, it has to be produced.

It is going to go through the design of the aluminium frame that will lift the car, the optimization of that frame, as well as it's manufacturing. Moreover, it will also be necessary to find the hook which will be used to lift the car and the telescopic legs that support the frame.

1.1. State of the art

Engineering has been described by the Engineers Council for Professional Development in the United States as the "creative application of scientific principles to design or develop structures, machines, apparatus or manufacturing processes, or works utilizing them singly or in combination".

But engineering is not only this, engineering is as ancient as time. Even in the stone age, people used their ingenuity to manufacture tools made out of the resources they had available: stones, branches, leather… They put things together like in a jigsaw puzzle. They created their own jigsaw puzzles to fulfil their needs. This is the essence of engineering, the capacity of look into the problems and create a way of tearing them up.

Besides, they share their knowledge field with scientist, but they are different. The scientist's objective is to know, while the engineers' is to do. While the scientists study the physical world, the engineer applies this knowledge to solve practical problems. These problems cannot be pre-selected, the engineer must solve them as they arise, trying to satisfy conflicting requirements. The solution given should be the most desirable one, taking all the factors into account. Of course, engineers' work is much easier thanks to the knowledge provided by scientists, ones' work is better with the others' and viceversa.

Problem solving is common to all engineering work [1]. Either if it requires mathematical calculus or common sense, if it is physical or economic, the most important matter is the process of creative synthesis and design, the way the engineer looks at the glitch in order to crack it in the most optimum and original way.

In ancient times, engineers, craftsmen and artists had the same goal, but they mainly proceeded by trial and error. Yet by combining fiddling with imagination they were able to create brilliant devices. In fact, the word "engineer" derives from the latin word *ingenium*, which means trick, a clever or special way of doing something. Nowadays there are many more resources and much more acquired knowledge, but it is very important to keep in mind the perspective. As long as the theoretical knowledge is basic and necessary, it is the way that you use it what makes the difference. A great engineer is not the one who knows everything, but the one who applies that knowledge in the best way.

For example, the romans are known for their outstanding engineering constructions. They built bridges, roads, tunnels and impressive aqueducts. These feats are a proof of their impressive engineering skills and ingenuity. Roman engineers took older ideas and inventions, improved them and innovate. New materials and techniques were developed, they led a revolution in the construction of bridges and aqueducts, they refined the existing weapons at the same time that they controlled the power of water. These engineering achievements produced wealth and prosperity, improving the roman standard of living and helping to maintain the dominance of Rome in Europe and the Mediterranean. [4]

This is a illustrative example of the function on an engineer and the magnitude of its work, but most crucial is to realize the importance of thinking out of the box. Engineers study a whole heap, they learn about mechanics, mathematics, physics, electricity… and during the process it is very important to learn how to mix those fields and use them to improve society and people's lives.

The problems an engineer has to solve vary in scale, difficulty and subject, but the steps that should be followed are the same. First, the situation should be analysed, and a plan of attack studied. In this way, the problem is reduced to a question which has to be answered. By reasoning from known principles or by other more imaginative means and methods, the question is answered, and a new design approached. This answer or design must always be checked, so the accuracy and adequacy of the solution to the original problem can be assured. Finally, the results should be clarified and reported in a suitable form.

However, as well as the principal function of an engineer is to solve problems, the whole process is important. First, an engineer should be able to detect problems, to know how to analyse what is happening. Second, is essential to listen at the people affected (considering it is not just a technical reparation) because maybe the ideal solution for you is not what they really need, so the engineer should be able to empathize and walk in their shoes. And finally, the solution should be executed or constructed, because having an idea is good, but it is useless if it is not brought to reality.

For this reason, there are all kinds of engineers each one specialist in their own field of knowledge. These fields of knowledge can be divided by the specific topic that they study: aerospace engineering, civil engineering, electrical engineering, mechanical engineering, software engineering… but they can also be divided by the part of the solving problems' process they work into. All of these engineers are as relevant as the others, because they need each other's work to succeed in their own. As it was said before, it is not only important to have the idea of how an issue can be solved, but also to set it in motion.

This bachelor thesis is not only a design of a crane and a suggestion of the manufacturing process. It is a way of putting in practice everything that was said here before. In fact it would not have been possible if all the steps hadn't been followed.

The topic of this bachelor thesis wasn't chosen because the author has special interest in cranes or structures, but because it was the problem that had to be solved. The CTU cartech team had the problem of putting their car into their trailer, and when I asked what topic can I choose so I can also help you, they told me this issue. Moreover, they are building the proposed solution at this instant, so it is not only an ideal solution, but an actual reality.

To start laying some options on the table, I looked at precedents of this problem, how do actual motor-racing teams manage to transport their cars?

Figure 19. Transportation truck of a F1 car, pinterest.

Figure 20. Modern transportation of a F1 car, [5].

Nowadays the transportation process is complex, long and it has to be carried out very carefully, paying attention to the details. Nine days before the race they start moving and packing components. The cars travel disassembled in wood containers, without spoilers and the rest of sensitive components that are packed independently. [5]

In the times when the Formula 1 was less advanced in technology, had less followers and less financial aids, the transportation system was more unsophisticated. The racing cars were transported in a trailer and the most common way of putting the car into it was using a slope, as it can be seen in Figure 19.

This last example is the one that applies more to our case, due to the CTU cartech budget and available resources. We seek for a simple and economic solution, so inspiration is more likely to be found in the way they transported the cars before, not now.

Figure 20. Car W196 and Mercedes Renntransporter, [7].

1.2. Incentives

Last September, I arrived at Prague to do an one-year exchange in the Czech Technical University. I was excited and scared about the year that was about to start and the only thing I was able to think was: “I have to make the most of this year, I will not have the opportunity to live this experience again.”

Having this feeling I arrived at the mechanical faculty (fakulta strojní), which happened to be my host faculty. The first thing I saw there were four Formula Student cars, exhibited as they were the best trophy. For the last two years, one of my main aspirations was to enter the ICAI Speed Club, but never had enough time. I was never entirely sure I wanted to join the club, as I am far from being an expert in motorbikes.

However, this all changed when I saw these racing cars. I felt this would be my last chance to accomplish my goal, and it had to be here, in Prague. It is ironic because I decided to take a step forward in the most unlikely situation: in a foreign country, the last year of my degree, in a university that I do not know and where the language spoken is no other but Czech.

But despite this, I was determined to join the team, it was my main purpose, although I knew it wouldn't be easy. So, I started looking for the team captain (Lukas) and getting in touch with the teachers.

Before entering the team, I had to do a task: to model a meat meal in the CAD program CATIA V5. Nevertheless, the only problem was that the instructions were in Czech and I had never used this program before, but despite all of it I managed to finally do it.

Little by little, what only was an objective (entering the team) became my passion. So, I decided to make the perfect duo; on one hand I would be doing my bachelor thesis and on the other hand I would be helping the people who I was working with by facing real problems and doing not only theorical projects but also practical ones.

Once I decided that, I got in touch with Lukas and the rest of the team. I realised that it was the perfect task for me, and their need to solve a problem ended being my bachelor thesis topic: 'the design and manufacturing process of a crane to lift the racing car and put it into the trailer used for its transportation'. But, what is it mainly about?

The Formula Student's team of the ČVUT (Czech Technical University) needed a way to put their competition car into the trailer that is going to be used to transport it. Until now, they could not use a slope because the bottom of the car is too close to the floor, so they had to lift the car by themselves and put it in the trailer. Furthermore, they had to take out the shock absorbers because they could be damaged in the transportation.

Imagine having to do this every time you have to transport the car anywhere. This problem is not only annoying for the people in the team, but also it is a waste of time. Furthermore, the shock absorbers and some other parts are very likely to be damaged in this procedure.

For these reasons, this structure should be done: to save time, efforts and avoid the breaking of the car's components. I was so glad that they trusted me for this, even if it is not a task as relevant as others.

At this point the only thing left to do was to find a supervisor for the Bachelor Thesis here, in the CTU of Prague. It was not so evident who to talk with, because of three facts: first, I had a very specific topic; second, I was an Erasmus student in Prague; and at least but not less, not every professor is interested in guiding a student that they would only know for several months. So, I was inclined to begin the search by speaking with the professors that I thought would be more interested in that field: the department of Automotive, Combustion engine and Railway engineering. So, I emailed the head of the department.

When everything seemed to be all right, I received the answer to the email sent. It was a polite way of telling me that they did not work with Erasmus and if they do, they will be really strict with me. At first, I was confused, but later I realised that was the perfect opportunity to develop my communicative and persuasive skills. As Albert Einstein said: 'Aptitude is made of 1% of talent and 99% of work.'. So I met with him. After an hour talking about my bachelor thesis, he accepted looking for a tutor for me. That is how Michal Vasicek ended up being this project director.

In conclusion, this bachelor thesis has brought me the opportunity not only to design and produce a crane but also to develop personal and intellectual skills. Moreover, the essence of this project is what is behind, what developing a project means: being part of a team, working in group, but also alone, facing difficulties, following instructions, being creative, being an engineer.

1.3. Bachelor Thesis' Objective

The object of study of this bachelor thesis is a crane, specifically designed for the car and trailer of the CTU's Formula Student team.

Its objective is, beyond covering a necessity, to go through all the steps of the production of a product, in this case a crane. From the conception of the product in response to a problem, to the manufacturing.

Specifically, it will cover the conceptualization of the idea, the design of the crane, the optimization of it and its production.

1.4. Working methodology

The steps followed for the realization of this thesis were:

1. Identify and recognise a necessity (lift and put the car into the trailer).
2. Discuss possible options and seek the best one.
3. Decide the specific solution of the problem
   (the crane: support structure with a hook to lift the car).
4. Design the structure.
5. Optimize the structure's model (CATIA V5 and structure analysis)
6. Design the telescopic legs which will support the frame.
7. Search for the rest of the elements of the crane: wheels and hook.
8. Production: build the structure and attach it to the trailer.

1.5. Resources used

- CATIA V5
- Knowledge of structural analysis and strength of materials
- Formula Student team's experience

Chapter 2

Design

This chapter will go through all the designing process of the crane, the problem that was intended to be solved and the process of the creation of a solution.

2.1. Problem

Every engineering design responds to a necessity or a handicap that you need to get rid of. In this case, the problem was the transportation of the CTU Formula Student's car, most specifically, the way of putting the car inside the track that carries it from one place to another.

Figure 1. Version FS.09 of the CTU Formula Student car

In the designing of their new racing car, the FS.10, the Formula Student's team had the objective of decreasing the center of gravity. In order to achieve it, they designed a new frame and monocoque to be able to put the engine lower. Moreover, they adjusted the pilot's position and designed a new tank. The new tank is really low, in fact the space between the car and the floor is actually 45 mm.

This means that it is not possible to use a ramp or slope to put the car into the trailer because it would have to be very long, and the trailer is not big enough to carry the car and the slope. For this reason, the only way they had to do it was lifting the two tones car by themselves.

2.2. Racing car

The new model's dimensions that are needed for the design are:

- Length: 2'93 m
- Width: 1'5 m
- Height: 1'2 m

It weights 200 kilograms.

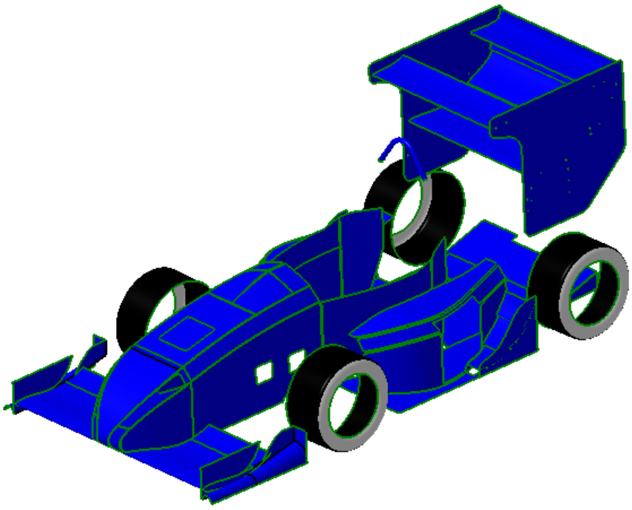


Figure 2. Surfaces of FS.10 car, CATIA V5

2.3. The trailer

The trailer that it is going to be used to transport this car is the one modelled in Figure 3. Its dimensions are:

- Ceiling-floor: 1'475 m
- Length: 3 m
- Width:1'5 m

The width has been measured taking in account the reinforces. The previous measure is the minimum width.

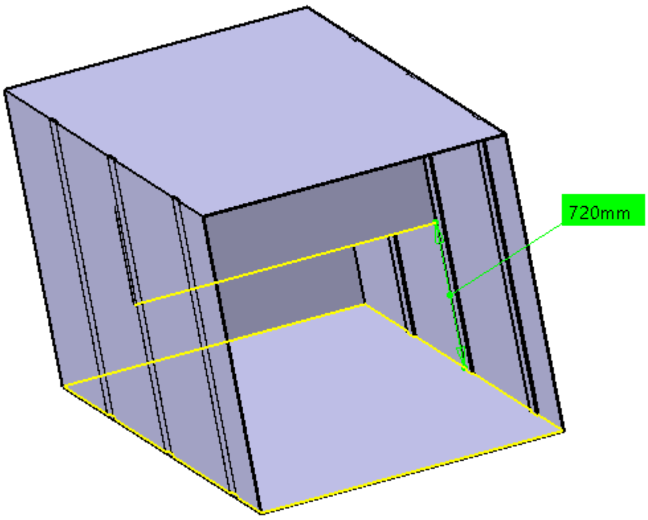


Figure 3. Trailer model, CATIA V5

2.4. Designing process

During the designing process, the most important thing was to adecuate the possible solutions to the circumstances of the problem and the situation. So the final design is the result of theoretical knowledge, previous experience of the team, budget and communication between the people involved.

2.4.1. First approach

The first step in the designing process should always be listening and be concious of what is the purpose of the device, what are the limitations of the design, but the most important thing is being aware of what do the people who are going to use it think.

The purpose has been explained above with detail (2.1. Problem).

The limitations are time, the budget, available resources and the fact that the team is made of engineering students not specialists.

Speaking about time, we had to have the final design in May, because in summer the races and the competition begin, so the device has to be installed and manufactured by this moment. This fact is relevant because it forces us to do a simple design, so it can be affordably to manufacture it in that time by one mechanical engineering student.

Speaking about the budget, it is also a relevant issue, due to the fact that in the Formula SAE competition (were the team participates and the car races) the marketing and business plan are taken in account.

Moreover, the available resources are the ones that the team is able to adquire by itself, buying it in stores that are able to deliver their products to us. So this limites the resources to the ones that can be found in Prague.

Last, but not less important, there is the fact that the designer, the author of this bachelor thesis, is a fourth year degree student of electromechanical engineering, the team captain, Lukáš Pakoň, is a master student of mechanical engineering and so is the one who is going to manufacture the device and put all the pieces together.

This considerations are very important, because as it was said before, engineering designs are a way of using our knowledge in an useful, suitable and original way.

2.4.2. First design

First, there was a meeting where the team made clear what they needed and how they needed the device. There was an inicial brainstorming where many ideas came up. Looking at all of them, the team said which one was more desirable for them, and the chosen structure was Figure 4.

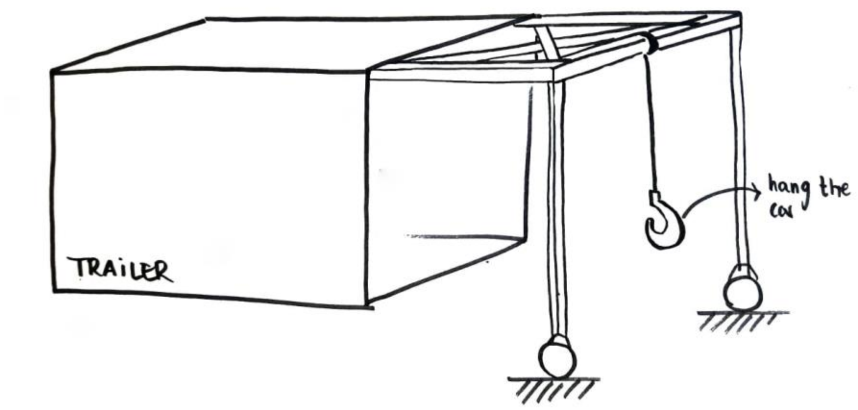


Figure 4. First design sketch.

The reasons of choosing this design were:

1. First, the device should be built into the trailer.

2. The principal structure has to be at the upper part of the trailer, because it is where there is more available space. Moreover, the most suitable way of lifting the car is to hang it with a hook from the chasis. The car would be hung from the curve part of the chasis that is above of the driver's head.

3. Third, it is easy to adquire the parts of this design and feasible to manufacture.

In operation, the car would be hung by the hook. Then, an elastic band will be used to avoid that the front part of the car swings. At last, the only thing left to do is push the structure into the trailer. The upper beams would be telescopic, by putting the principal beam into a bigger one attached to the trailer's ceiling. The legs with wheels would also be telescopic, so we are able to make them smaller and put them into the trailer as well.

2.4.3. Evolution of the design

Once the requirements were settled and what they needed was clear, the next step was studing if this structure was technically possible and improving it by making use of structures and strenght of materials' knowledge, along with the advice of university professors, .

The first mistake that had to be amended was the upper supporting beams, the cross between the two upper beams. The structure had to be pushed into the trailer and this is possible if the upper beams slide into two bigger beams attached to the trailer, but the cross-beams welded to the ones in the sides do not allow this to happen. For this reason, another support had to be found. It should be connected to the upper beams, but in a way that they could slide freely into the other ones.

Moreover, this cross protected the structure from bending if for example, the wind had blown wildly from one side to another of the structure with the car hanging from it.

To do both, solve the sliding problem and prevent the bending moment to curve the structure, instead of the cross-beams, there would be two others in the lateral part welded in the front part of the upper beam and in another parallel one. This last one would be supported by a rail attached to the trailer (Figure 5).

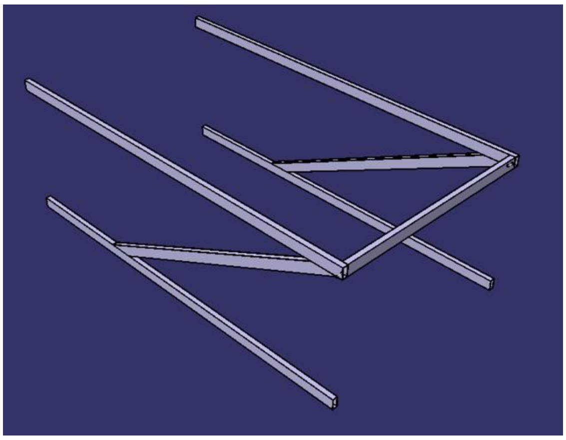


Figure 5. First structure model, CATIA V5

At this point, the design was quite adequate, so a model was done, working with CATIA V5. In addition, with this program it could be checked whether the model fitted into the trailer or not (Figure 6).

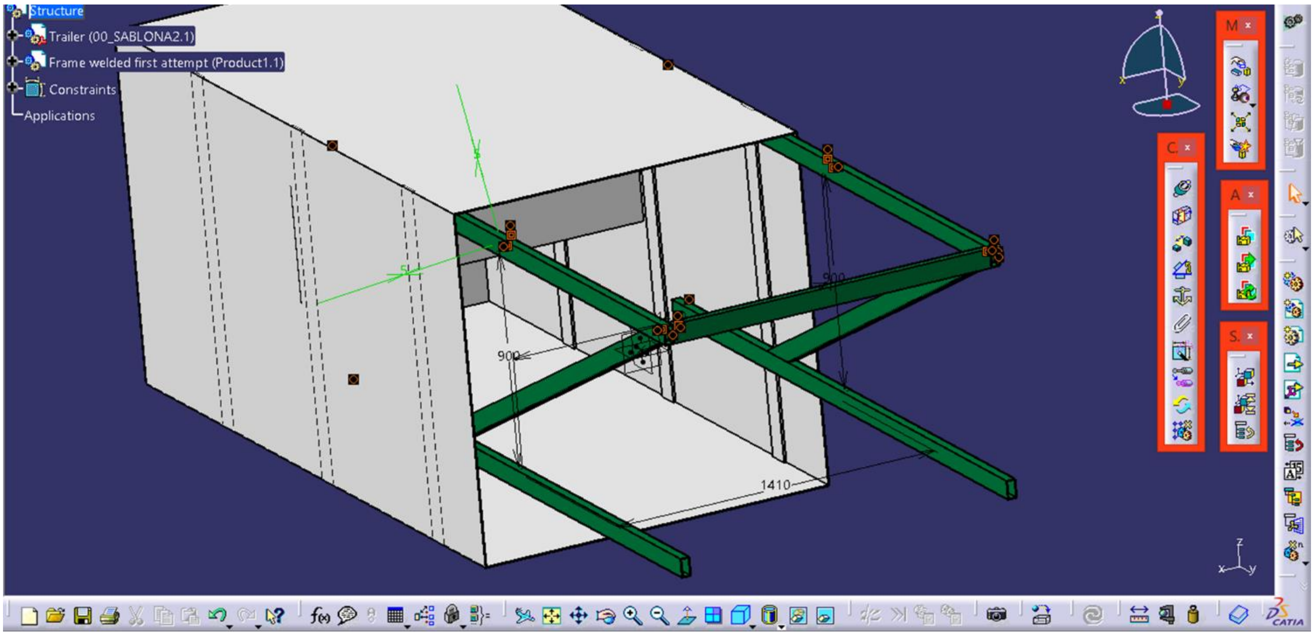
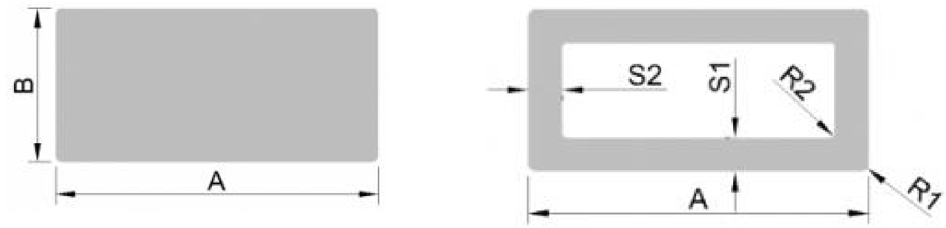


Figure 6. Assembly of the first structure and trailer model, CATIA V5.

Besides, due to a profesor's advise, the beams' profiles were also changed. At first, they were thought as rectangular-profile beams, but taking in account the weight that they were going to lift (200 kg) and the material of the beams (aluminium), it was not necessary this kind of profile. A rectangular beam with a gap in the middle is enough.



Figures 7 and 8. Rectangular profiles, [3].

After this first modifications based on structural knowledge and mechanical intuition, the structure was acceptable enough to say that next changes would be based in internal forces, displacement and Von Mises stress analysis results, carried out with CATIA V5.

2.5. Final design

After carrying out several analysis with the program CATIA V5 and changes in the beams' dimensions, profiles, in the structure… A definite design was accomplished. A design which was likely to manufacture, as light as possible so the trailer's walls are not damaged, and stiff enough to lift the 200 kg racing car. *Chapter 3 will go through all the analysis (frame, telescopic legs and support beams) and the improvement of the structure based on them.*

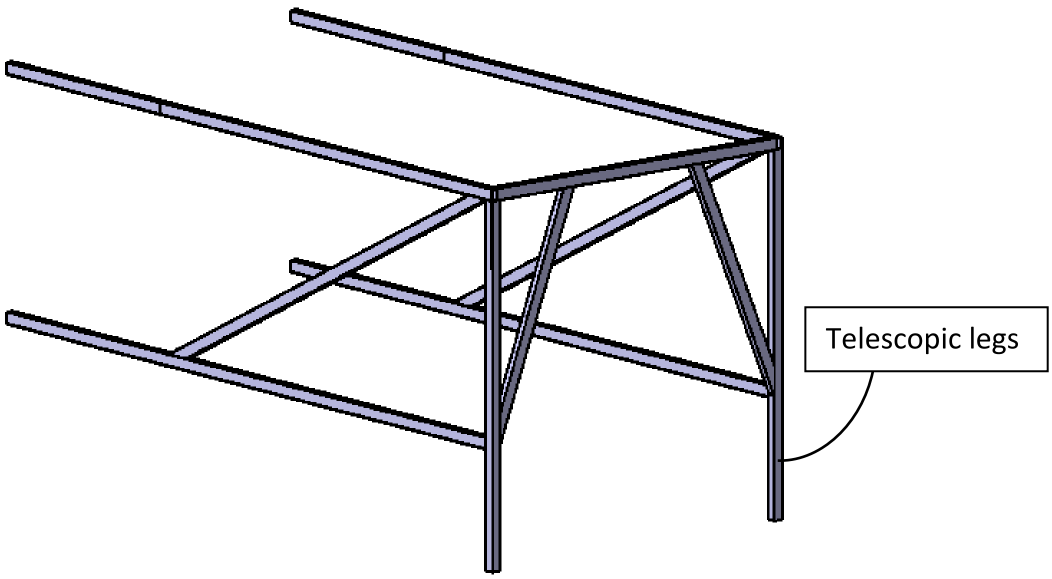


Figure 9. Final frame model, CATIA V5.

This final design consist of a frame of welded aluminum beams, more precisely aluminum EN AW 6060 T66; profile 50x30x3 mm, with two telescopic legs that support the main part of the weigh of the car and have wheels that allow us to move the structure back and forth. The upper beams of the structure slide into the gap of two bigger ones (60x40x3 mm) that are attached to the trailer's ceiling. The horizontal support beams slide on the upper face of two others (50x40x2'5 mm), also attached to the trailer, but to the lateral walls. In order to assure a smooth sliding of the beams, a substance called *iglidur* (*datasheet in Part II*) is applied in the touching surfaces. The weight of this frame is 25 kg.

The aluminum EN AW 6060 T66 has a density $\rho = 2'7$ g/cm^3, Poisson's ratio $\mu = 0.33$, Young's Modulus E = 68 GPa and specific heat capacity c = 900 J/kg-K. [11]

Moreover, after searching for telescopic legs and not finding anything suitable for our structure and our dimensions, the plan changed and they were finally designed and manufactured in the workshop as well. They are made of two beams, one bigger than the other, so the small one (30x30x4 mm) fits in the gap of the larger beam (40x40x4 mm) and slide into it. To fix the telescopic legs when the beams are rolled out, a mechanism was needed. It consist of two plates, with a spring in the middle (Figure 10).

The performance of the mechanism to fix the telescopic legs it simple. When the legs are inside the trailer, the beams should be one inside the gap of the other.

In this situation the elastic spring is compressed and the plates are enclosed by the inner walls of the bigger beam. In this way, when the structure is pulled out of the trailer, the inner beam slides out of the bigger one, but they should be fixed, so when the car is hung the telescopic legs are able to support the load. There are two lateral gaps at the end of the bigger beam, made specially for the circular pads in the plates, so they fit in the gaps and fix the telescopic legs' length.

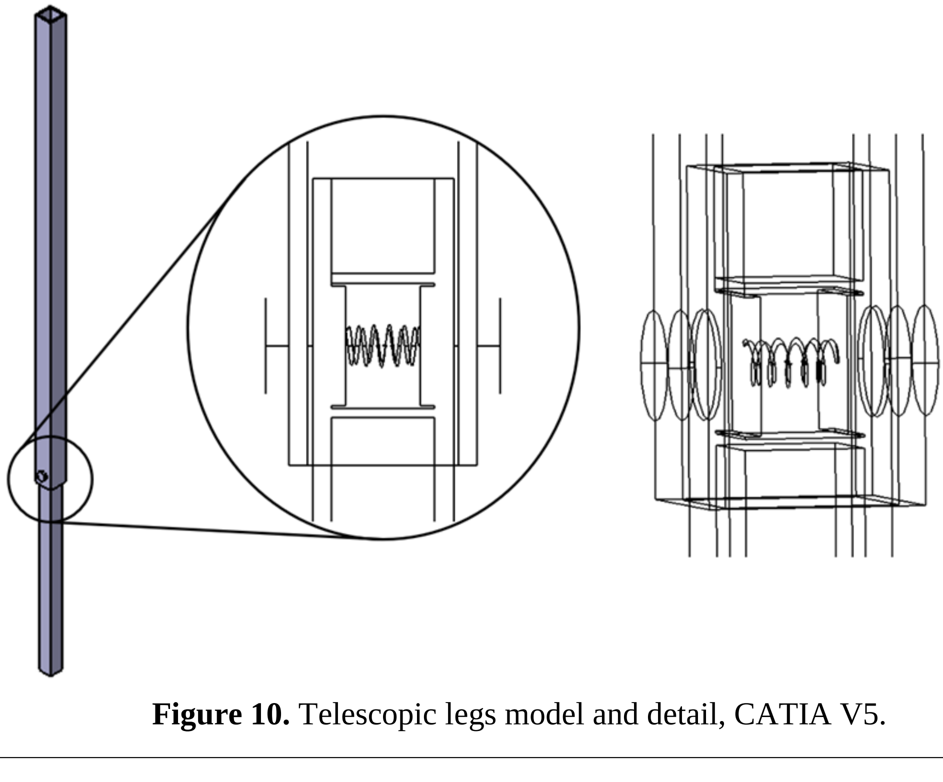


Figure 10. Telescopic legs model and detail, CATIA V5.

Besides, to avoid the displacement of the telescopic beams in the x direction (separation between them) an elastic band will be wrapped around them, at the bottom of the telescopic legs, to fix the distance between them.

Finally, there were only two details left: the wheels at the bottom of the telescopic legs and the hook where the car would be hung. This two parts were not designed nor manufactured in the workshop, but bought. *Datasheets in Part II*.

Chapter 3

Analysis

The previous chapter has gone through the designing process conceptually. This chapter will be focused on explaining and showing all the analysis done with the objective of testing the performance of the frame and the telescopic legs when a load it's applied, in particular, a 200 kg load equivalent to the racing car.

The CAE program which will be used is CATIA V5, developed by Dassault Systèmes. It was chosen because it is the program that the CTU cartech use, so there is no compatibility problems when they have to open the crane's model.

3.1. Frame analysis

The frame is the principal part of the device, it is the one that will suffer the most when the car is hung off it. For this reason, it must be the first part being analysed.

To do a good FEM analysis of the CAD model there are very important factors that should be determined: the boundary conditions, the mesh size, and the loads and the gravity force. This last factor is negligible compared with the effects of the load, but still we should take it into account to make a more exact analysis.

The boundary conditions are the way of modelling the surroundings of our device: the surfaces in contact with it, the kind of contact between them, the kind of unions between the parts of the device… It is very important to study them carefully, because the play a really important role in the analysis and the effects of the loads. Each device and each model has it's specific constraints, and so does the crane's model. Starting with the upper beams, they are slidding inside a hollowed beam, so that restrains all the displacements in all the surfaces that are in contact with it, except the one that allows them to go back and forth. As there is no attachment of one beam to another, the bending moments are not restrained. Secondly, looking at the horizontal support beams of the frame, we realize that they are only in contact with the beams under them, which bear their weight. This restrains only the z direction (up and down). In the third place there are the telescopic legs, which are not attached to the floor, so the restraint at the bottom of them (where the wheels will be) is not a clamp, it is a restriction of all the displacements, but not of the bending moments. The few first analysis have this mistake, the constraints considered as clamps are wrong.

The mesh size establishes how many points of the model are going to be analysed by the program. If it is bigger than it should, the results are not accurate. If it is very small, the computation time would be so long that maybe you do not even get to know the results. This is why it is important to choose a correct mesh size. There is not a correct value of mesh, only better or worse, so the way of determining the mesh size is comparing the analysis with previous ones, or by mesh refinement (start with a big mesh size and turn it smaller until the results are acceptable). According to previous analysis, a decent mesh size is 5 mm with 2 mm absolute sag.

Finally, the loads are the origin of the problem, the reason why the analysis should be made, so it is clear their importance. In the crane the only load acting will be the weight on the car hanging off the front beam, that it is 200 kg, as said before.

The analysis of the first structure (Figure 11) shows that it was a good idea to start with: the displacements are lower than 2 mm, so they are not bad. However, it can be observed that, while most of the deformation is in the front beam, the others have little or none deformation, so we can modify the profiles in order to distribute the load and make the structure lighter and stiffer.

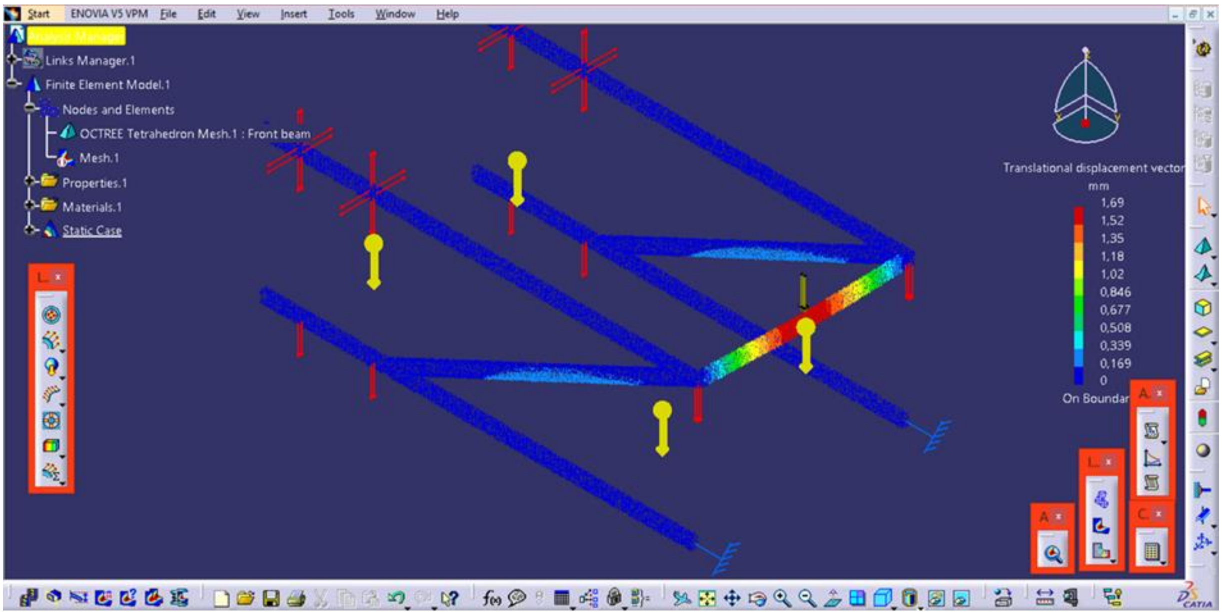


Figure 11. Analysis first frame model, CATIA V5.

First, the front beam was changed to a non-hollowed profile 70x30 mm and the others to 65x35x3 mm (Figure 12). With this changes we can notice that the improvement is very little, but if we change the front beam to 70x50 mm (Figure 13), it can be seen that the deformation is lower (1'03 mm) and closer to the optimal situation, and it is also more distributed among the beams. However, this structure is not lighter than the previous one, so the optimization process must go on.

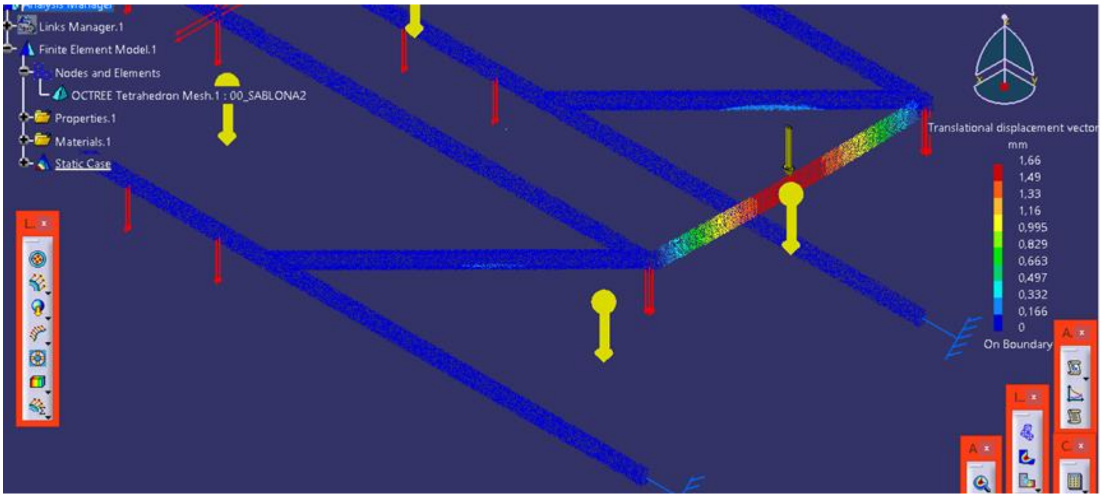


Figure 12. Analysis second frame model, CATIA V5.

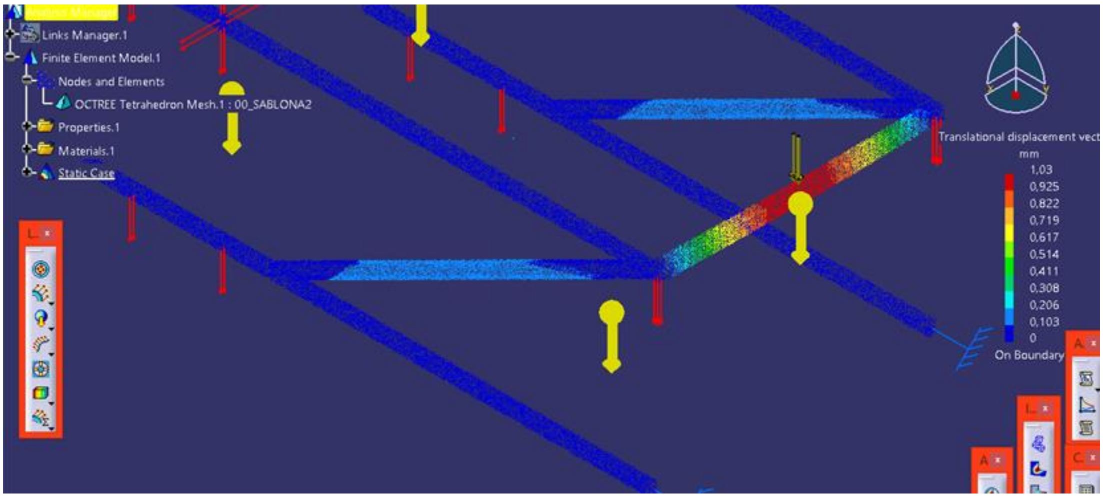


Figure 13. Analysis third frame model, CATIA V5.

Observing the results of the runned analysis, we can clearly see that the deformation mainly affects the front beam. Considering this fact, two supporting beams are added to the design: two beams welded to the front beam and to the telescopic legs, so they help managing the load charge.

At the same time that the reinforcements are added, the profiles of the beams are becoming smaller, taking in account that the load will not be concentrated in the front beam anymore. Starting with a profile 65x35x3 mm for all the beams and changing the dimensions, we arrive to the optimal structure (Figures 14 and 15). So the definite profile for the beams of the frame is 50x30x3 mm.

All the beams have been modelled with a 50x30x3 mm profile, except the telescopic legs' model beams, that have a 40x40x3 mm profile.

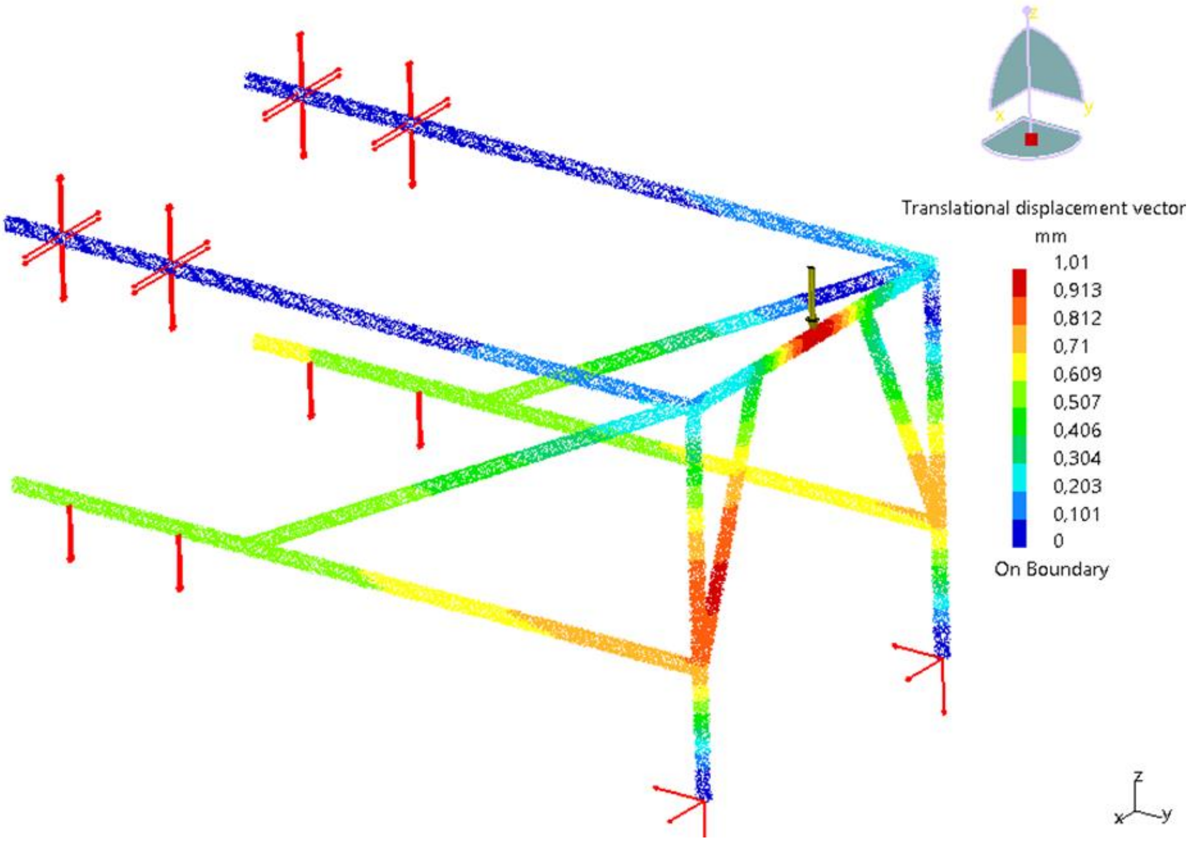


Figure 14. Displacement analysis final frame model, CATIA V5.

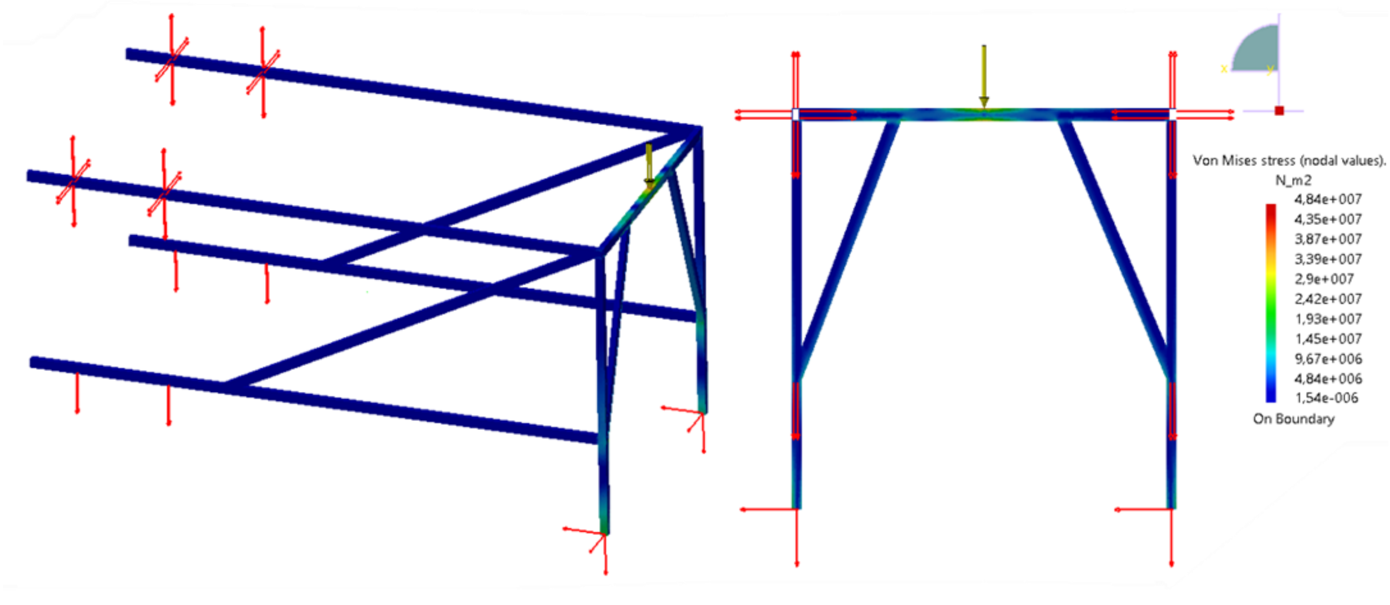


Figure 15. Von Mises stress analysis final frame model, CATIA V5.

The maximum acceptable stress is 85 MPa. It was established by applying a safety factor to the Yield Strength of this aluminum. The Yield Strength is 170 MPa and we wanted a safety factor around 2, which results in the value of 85 MPa.

The beams will be welded, so the material in the weld would be affected by the heat. Ductility would be lower, and so does the Yield Strength. For this reason, mechanical properties of heat-affected zones will have significant effect on the properties of the material, but they are unknown so some testing would be necessary.

From these last analysis we can conclude that this is the best solution for the situation that should be solved. The maximum Von Mises stress is around 50 MPa, that is below our acceptable limit. Moreover, the analysis shows how this configuration distributes better the load effects, so it is more unlikely for the frame to break. It can also be observed the places where it is possible that there is a failure in the future, so in upcoming inspections we know where to look for weaknesses. Besides, the maximum displacement is 1’01 mm that it is just the value we consider acceptable and the analysis also shows very clearly the state made before of the distribution of the load’s effect.

This solution includes a detail that was not mentioned before: to guarantee that the end of the telescopic legs has the x direction displacement restricted, an elastic band will be used. It will be wrapped around the end of both legs, so they do not separate with the effect of the load. The idea is ilutrated in Figure 22.

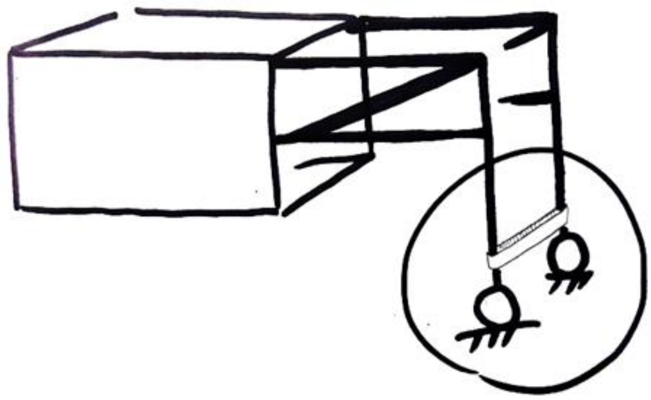


Figure 22. Elastic band sketch.

3.2. Telescopic legs analysis

As the telescopic legs play also a very important role in this structure, they should be designed and analysed carefully, because if they fail, the whole study of the frame is useless.

The telescopic legs’ design is described in Chapter 2, point 2.5.

The constraints that model the telescopic legs’ situation are: at the bottom a clamp (in this case we can consider it like this because the beam will be attached to the wheel, and it does not change much the effect in the beam to do this consideration), in the places where the legs are welded to a beam the effects are negligible, so there are no constraints needed.

The load acting on each of them is half the weight of the car: 100 kg, vertically and down.

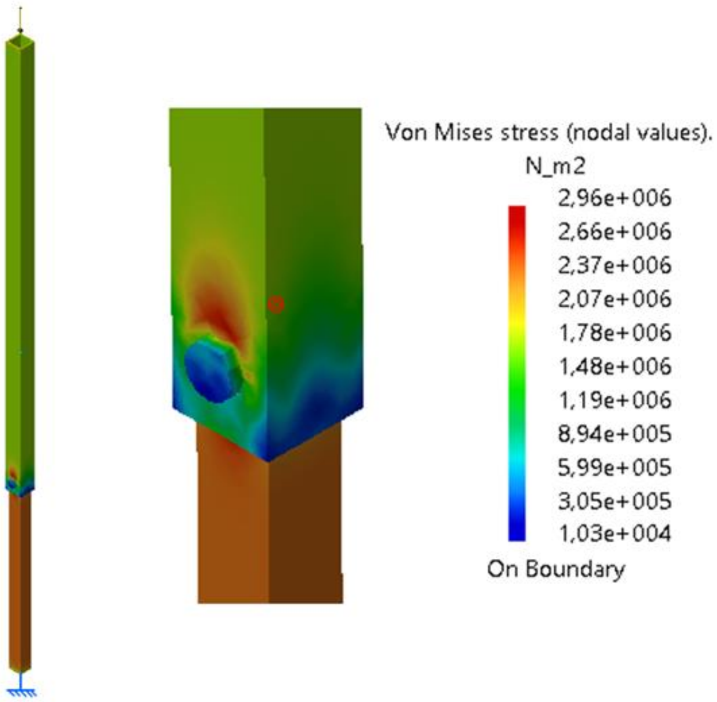


Figure 16. Von Mises stress analysis telescopic leg, CATIA V5.

3.3. Support beams analysis

Both the upper support beam and the “rail” one should be also dimensioned and analysed to make sure that the whole structure works. The analysis results can be seen in Figures 17 and 18.

The dimensions of the beams are: 60x40x3 mm the upper support beam and 50x40x2’5mm the “rail” beam.

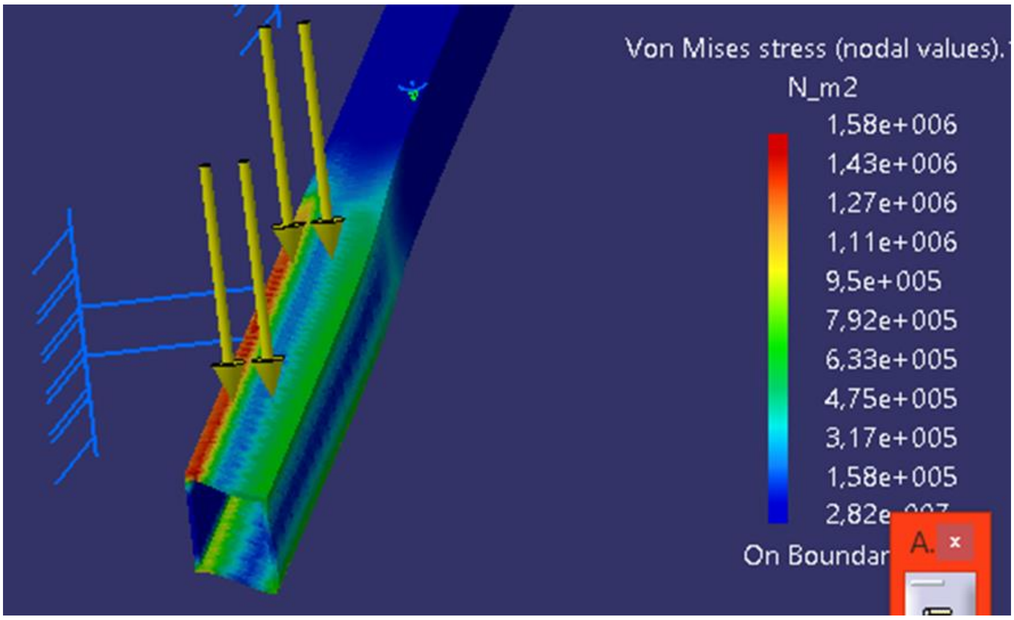


Figure 17. Von Mises stress analysis rail beam, CATIA V5.

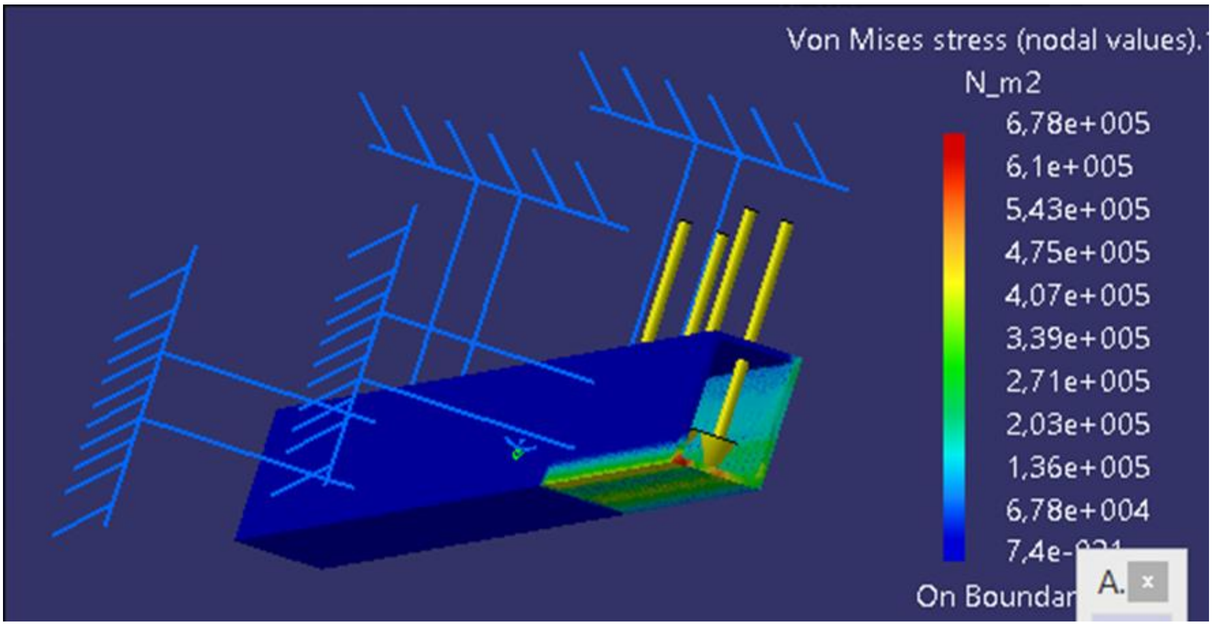


Figure 18. Von Mises stress analysis upper support beam, CATIA V5.

Chapter 4

Manufacture proposal

Manufacturing is the process of turning raw materials, components or parts into finished good that fulfills a customer's specifications or expectations. Manufactory normally employs a man-machine setup division of labor in a large scale production. [8]

4.1. Circumstances

According to the PART S Article 3, S3.2 – a, b of the 2017-18 Formula SAE® Rules – September 2, 2016 Rev A: "the business logic case may be used to identify how the team determined the trade-off between design for performance and design for manufacture and cost, hoe these requirements were considered in the overall concept and whether these were achieved in the final vehicle" and "the business logic case may be used to determine that the cost target was met for the same design solution and how cost was integrated into the overall concept and the iterative design process". In fact, the objective of the Cost and Manufacturing Event is to teach the participants that costs and budget are significant factors that must be considered in any engineering exercise, to make trade off decisions between content and cost based on the performance advantage of each part and assembly [6].

For these reasons, between others, the crane will be totally manufactured in the CTU's workshop by a member of the Formula Student's team. This decision have some manufacturing limitations in the welding technology that is available and in the quality of the brazing. First, the welding methods available at the university's workshop are: SMAW, GMAW, GTAW and SAW. Second, it has to be taken in account the welding knowledge of the member of the team who is going to manufacture the frame and the structure, as well as his ability in welding. In this case, he is very skilled, thus he is not a professional. For this special case, the resources and knowledge available are enough to manufacture the device faultlessly.

4.2. Assembly

The crane final design is shown in Figure 21.

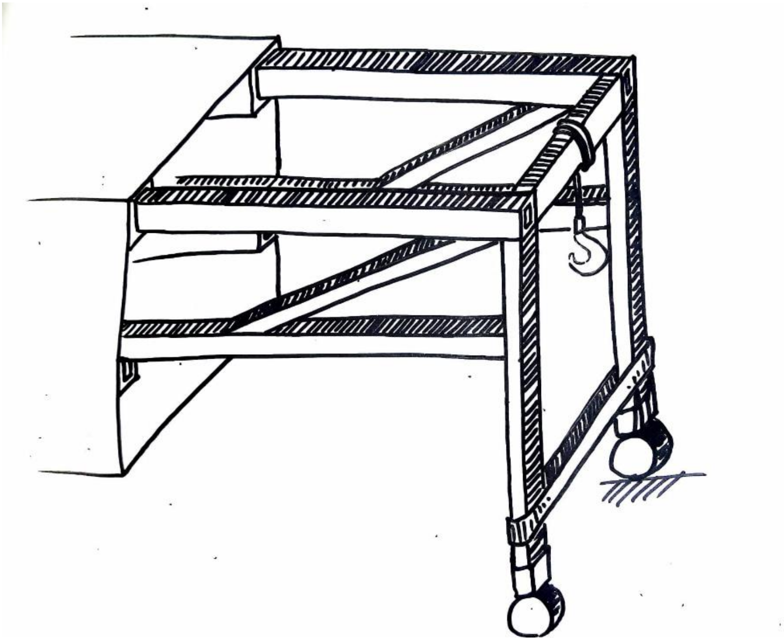


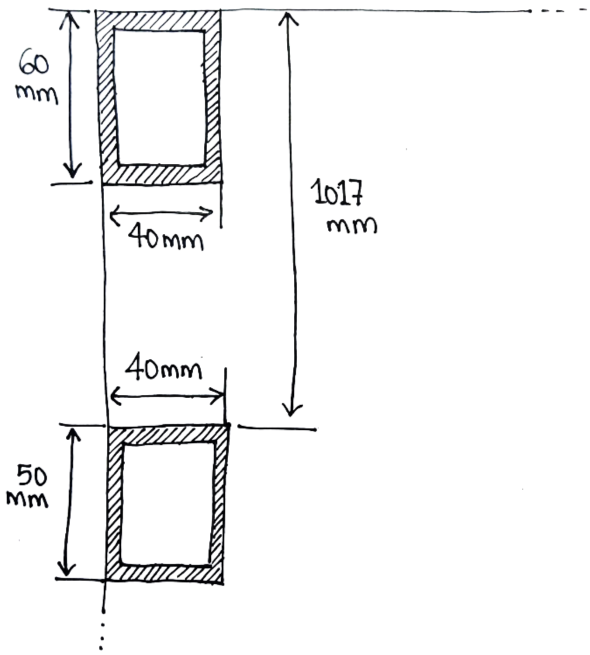
Figure 21. Crane final design sketch.

First, the aluminium frame must be manufactured. The beams are cutted in the ends according to the suitable welding position and the orientation of the beams. Then, they have to be welded so the structure is built as shown in Figure 9.

Second, the telescopic legs have to be assembled. In the first place, the mechanism responsible of fixing the telescopic legs' length should be constructed. It is made of two plates linked with a spring, that have also a rounded pad at the sides that will be in contact with the inner wall of the big beam (the opposite side of the spring). This parts will also be welded one to another. Moreover, the wheels have to be added at the end of both telescopic legs, to the smaller beam.

Third, the aluminium frame and the telescopic beams must be welded together to finally make up the whole structure. To finish this part of the crane, there is only one missing detail: the hook. But its assembly is not difficult, it just has to be setted in the middle of the front beam, where the racing car will be hung.

Needless to say that both the wheels and the hook do not need to be built because they are going to be bought.



Then, it is necessary to build the supports attached to the trailer. These supports consist of two 60x40x3 mm beams in the upper part and two 50x40x2’5 mm in the walls (Figure 23). These will also be constructed by a welding process.

Finally, the only step left is to apply the coating material that is used for a smoother beam-beam sliding and assemble the structure into the trailer.

Figure 21. Crane final design sketch.

4.3. Manufacture proposal

Aluminum, unlike steel, does not exhibit color when it arrives to its melting temperature. For this reason, when soldering aluminum with a torch, a flux should be used. It will melt as the temperature of the base metal reaches the suitable temperature. When welding with gas tungsten or gas metal arc, color is not as important bese the welding is completed before the area in the join melts.

Another special characteristic of aluminum is the aluminum oxide coating surface that appears when aluminum reactes with the os¡xygen in the air. The melting point of this substance is three times aluminum melting temperature. Moreover, it absorbs moisture, that causes porosity in the weld. To avoid it, it is necessary a slow cooling rate, so we give the aluminum time to expulse al the free hydrogen.

The aluminum the beams used in the crane is made of is 6XXX series. This alloys contain silicon and magnesium, which makes them heat treatable. They have medium strength and a good corrosion resistance.

Since aluminum is very likely to react with oxygen, almost always there is an oxide coating surface (bigger or smaller). This layer should be removed before the welding process. Using inert gases or flux is a big quantity prevents its forming.

Because of its high thermal conductivity, preheating is used when thicker parts have to be welded and procedures should use higher welding speed using high heat input. Two processes that fulfill this requirements are the gas tungsten arc and the gas metal arc.

Gas Tungsten-Arc Welding (GTAW = TIG) is more used to weld thinner sections of aluminum and aluminum alloys. Some precautions have to be taken: when manual welding the arc length should be short and equal to the electrode’s diameter, if the electrode touches the molten metal, it must be redressed and AC current must be used. One rules is that the arc legth should be equivalent to the diameter of the electorde. If the arc is broken, shrinkage cracks may occur resulting if a defective weld.

Gas Metal Arc Welding (MIG = GMAW) is used to weld thick parts of aluminum alloys. Argon or helium are the gases used, but argon gives to the weld better characteristics. [8]

Taking in account all these considerations, we can conclude that, theoretically, the best option for welding the aluminum beams of the structure is GMAW, because the thickness of the beams are greater than 1'6 mm. Moreover it is easier for welding in all positions because it does not use flux, but gas. And speaking about the gas, better a mix of Argon and Helium. With a 75-25 rate Argon-Helium we get the advantages of both gases, without the undesirable effects of each of them.

4.4. Final manufacturing method

In spite of the considerations made in the previous section, the selected welding method for the manufacture of the device is TIG, or GTAW (Gas Tungsten-Arc Welding), because is the one method of the ones that are available at the workshop that has better combination between accessibility and suitability.

Bibliography

[1] **Encyclopædia Britannica**, article "*Engineering*", contributor Ralph J. Smith, published on 5th October 2018. Last access date: 24/05/2018
https://www.britannica.com/technology/engineering

[2] **CTU Cartech** *webpage*. Last access date: 24/05/2018
http://cartech.cvut.cz/en/

[3] **ALUPA- Aluminium Pardubice**, *webpage*. Last access date: 24/05/2018
https://www.alupa.cz/hlinik/hlinikove-profily-EG00000101.html

[4] **Ancient History Encyclopedia**, article "*Roman Engineering*" by Victor Labate on 1st March 2016. Last access date: 26/05/2018
https://www.ancient.eu/Roman_Engineering/

[5] **Autobild.es**, article "*¿Sabes cómo viaja la F1 por el mundo? Pues con DHL*" by José Armando Gómez on 1st August 2012. Last access date: 26/05/2018
https://www.autobild.es/tecnica/como-viaja-la-f1-por-el-mundo-dhl-535

[6] **2017-18 Formula SAE® Rules** – September 2, 2016 Rev A.

[7] **Diario Motor** webpage, article "*Mercedes Renntransporter: el camión que transportaba las flechas de plata era igual de especial*" by Sergio Álvarez, 30th August 2015. Last access date: 27/05/2018
https://www.diariomotor.com/2015/08/30/mercedes-renntransporter-transporte-competicion/

[8] **Business Dictionary** webpage. Last acces date: 27/05/2018
www.businessdictionary.com

[9] **Weld Guru** webpage, blog entry "*Guide to aluminum welding*". Last access date: 27/05/2018

http://weldguru.com/aluminum-welding/

[10] **Lincoln Electric** webpage, "*A guide to Aluminum Welding*". Last acces date: 27/05/2018
https://www.lincolnelectric.com/en-us/support/welding-how-to/Pages/guide-aluminum-welding-detail.aspx

[11] **MakeItFrom** webpage. Last access date: 30/05/2018
https://www.makeitfrom.com/material-properties/6060-T66-Aluminum

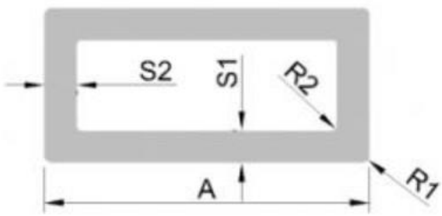
PART II

DATASHEETS

Beams Profiles ALUPA

https://www.alupa.cz/hlinik/hlinikove-ploche-a-ctvercove-tyce/kat-FG00000101.html

Název	A (mm)	B (mm)	C (mm)	S1 (mm)	S2 (mm)	R1 (mm)	Čís. prof.	Kg/m	sklad L (mm)*	Norma	Sklad	
Hliníkový jekl 50X30X3	50	30		3	3		923815	1,230	6000	EN 573-3 AW 6060 T66 EN 755-1,2,8	✔	
Hliníkový jekl 40X40X4	40	40		4	4		913054	1,550	6000	EN 573-3 AW 6060 T66 EN 755-1,2,8	✔	
Hliníkový jekl 30X30X4	30	30		4	4		916410	1,110	6000	EN 573-3 AW 6060 T66, EN 755-1,2,8	✘	
Hliníkový jekl 60X40X3	60	40		3	3		922515	1,500	6000	EN 573-3 AW 6060 T66 EN 755-1,2,8	✔	
Hliníkový jekl 50X40X2.5	50	40		2.5	2.5		923816	1,154	6000	EN 573-3 AW 6060 T66 EN 755-1,2,8	✔	



Řetězový kladkostroj ruční Scheppach CB 01

1 899 Kč s DPH

Centrální sklad:	**Skladem 1-2 ks**
Prodejna Litvínov:	**Není skladem**
Značka:	Scheppach
Kód produktu:	**4907401000**

SLUŽBA NAVÍC

Aby to pro Vás bylo co nejpohodlnější, tak si v případě reklamace zajistíme odvoz zboží sami a na naše náklady. Tím Vám ušetříme čas, starosti a výdaje.

Doporučené příslušenství

odebrat

Řetězový kladkostroj ruční Scheppach CB 01

DO KOŠÍKU

Cena	**1 899 Kč** s DPH
Hmotnost	9,5 kg
Max. nosnost	1000 kg
Minimální konstrukční výška	30 cm
Provedení	Ruční
Zdvih	3 m
Distribuce	CZ
Model	Scheppach CB 01
Rozměry stroje	250 x 180 x 170 mm

DŮM KOLEČEK

S námi jste v pohybu!

Transportní kolo L410.B44.081

Transportní kolo v pevné vidlici s uchycením na plotnu na čtyři šrouby

SKLADEM

iglidur® Tribo-Tape | Product range

For use in visible areas – iglidur® B160

Order key

Type	Dimensions [mm]		Options
B160 - T	- 005 -	0020 -	G
iglidur® material / Tape	Thickness	Width	Adhesive back

G = with adhesive back

Especially where the iglidur® Tribo-Tape is a visible part, the new black option now offers even more creative freedom. Furthermore the wear resistance compared to variants made of iglidur® A160 has been improved once again.

Tribo-Tape made from iglidur® B160 with adhesive back
Temperature –40 °C up to +90 °C

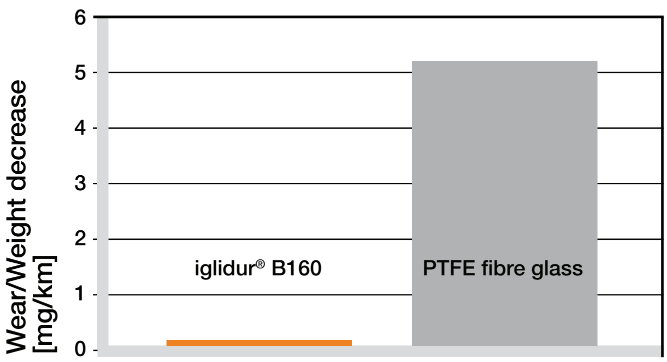
Dimensions [mm]

Thickness	Thickness tolerance	Width	Width tolerance	Part No.	Part No. with adhesive back[112)]
0.5	±0.1	20	±0.5	**B160-T-005-0020**	**B160-T-005-0020-G**
0.5	±0.1	50	±0.5	**B160-T-005-0050**	**B160-T-005-0050-G**
0.5	±0.1	100	±0.5	**B160-T-005-0100**	**B160-T-005-0100-G**
0.5	±0.1	500	±1.0	**B160-T-005-0500**	**B160-T-005-0500-G**

112) **Adhesive thickness tolerance: ±0.015 mm**

Individual widths upon request
Continuously from 20–500 mm

Cutting service
Design Tribo-Tape flexibly
▶ **www.igus.eu/custom-tape**

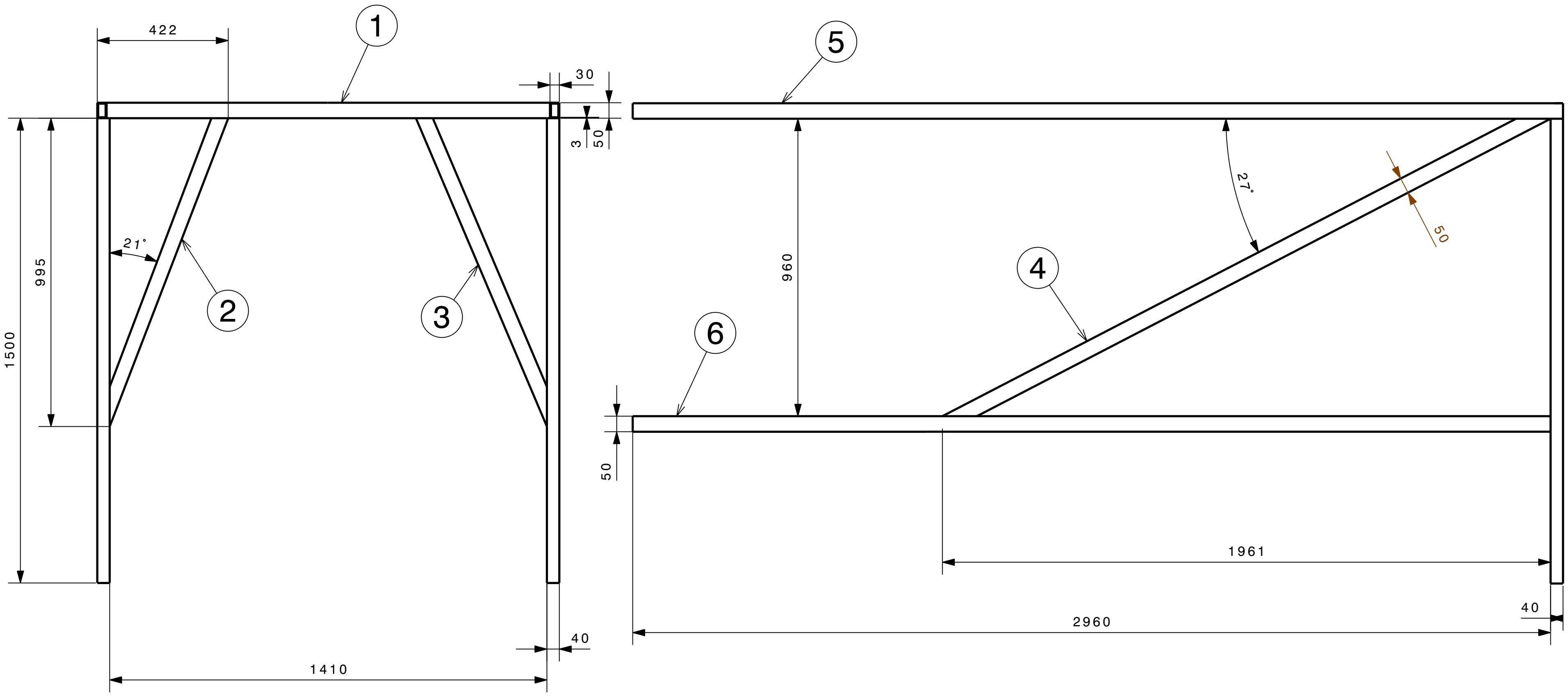


Linear wear against stainless steel pin (1.4305)
F = 10 N, v = 9,600 mm/min

DOCUMENT II

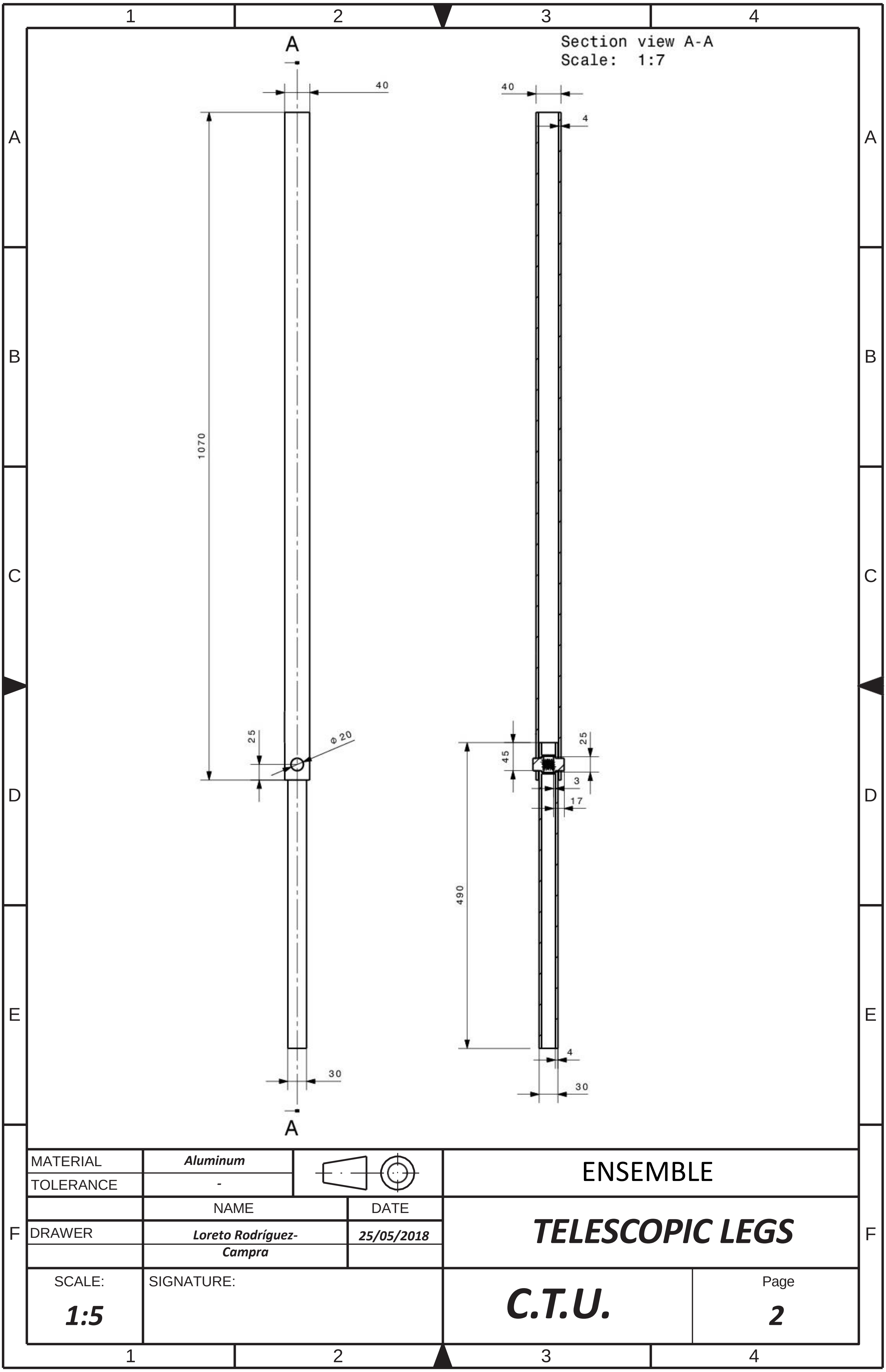
DRAWINGS

Drawings list



Beams 1-6 profile: 50x30x3 mm

MATERIAL	Aluminum		CRANE	
TOLERANCE	-			
	NAME	DATE	FRAME	
DRAWER	Loreto Rodríguez-Campra	25/05/18		
Scale 1:20	Signature		C.T.U. University	1 Page


A
Section view A-A
Scale: 1:7
40
40
4
1070
25
Φ 20
45
25
3
17
490
4
30
30
A
MATERIAL
Aluminum
TOLERANCE
-
ENSEMBLE
NAME
DATE
DRAWER
Loreto Rodríguez-Campra
25/05/2018
TELESCOPIC LEGS
SCALE:
1:5
SIGNATURE:
C.T.U.
Page
2