UNIVERSIDAD DE VALLADOLID

ESCUELA DE INGENIERIAS INDUSTRIALES

GRADO EN INGENIERÍA MECÁNICA

DESIGN OF SAFE WEIGHTLIFTING BENCH

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Valladolid, Julio 2020.

TFG REALIZADO EN PROGRAMA DE INTERCAMBIO

TÍTULO:	Design of safe weightlifting bench
ALUMNO:	Rodrigo Castedo Hernández
FECHA:	17 junio 2020
CENTRO:	Faculty of Mechanics
UNIVERSIDAD:	Vilnius Gediminas Technical University
TUTOR:	Paulius Ragauskas

Cinco palabras claves que describen el TFG

Musculación, deporte, seguridad, diseño e innovación.

Resumen en español (máximo 150 palabras):

Diseño de un banco de press-banca más seguro con el fin de poder realizar la actividad deportiva sin el riesgo que conlleva que la barra, que en ocasiones pesa más de 100kg se quede en el pecho del deportista sin poder levantarla.

En el TFG se muestra el diseño realizado, los planos del dispositivo, un análisis de los bancos actuales y de alguna patente que tiene el mismo objetivo que este TFG, mecanizado de una de las piezas necesarias para el mecanismo del banco, parte económica, requisitos de seguridad y conclusiones.

Annotation

In this bachelor‘s degree final work was design a weightlifting bench with the particularity of being safer than the actual ones. The final goal of this device is avoiding some riskies in a common activity in every gym.

It consists on an structure where the mechanism of the bench is welded and also stops the barbell in case of an emergency.

Calculations part focus on the legs of the bench which are the risky part of the device, also on the lever and the strenght needed to activate the mechanism. Also on the technological part and economic calculations.

Keywords

Weightlifting, bench, sport, safety.

VILNIUS GEDIMINAS TECHNICAL UNIVERSITY
FACULTY OF MECHANICS
DEPARTMENT OF MECHANICAL AND MATERIAL ENGINEERING

Rodrigo, Castedo Hernández

DESIGN OF SAFE WEIGHTLIFTING BENCH

Bachelor's degree final work

Mechanical Engineering study programme, state code 612H33001
Machine design specialisation
Mechanical engineering study field

Vilnius, 2020

VILNIUS GEDIMINAS TECHNICAL UNIVERSITY

FACULTY OF MECHANICS
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APPROVED BY
Head of Department

(Signature)
Prof. Dr. Mindaugas Jurevičius
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2020-06-15
(Date)

Rodrigo, Castedo Hernández

DESIGN OF SAFE WEIGHTLIFTING BENCH

Bachelor's degree final work (project)

Mechanical Engineering study programme, state code 612H33001
Machine Design specialisation
Mechanical Engineering study field

Supervisor Dr. Paulius Ragauskas
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Vilnius, 2020

(the document of Declaration of Authorship in the Final Degree Project)

VILNIUS GEDIMINAS TECHNICAL UNIVERSITY

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DECLARATION OF AUTHORSHIP
IN THE FINAL DEGREE PROJECT

June 11, 2020

I declare that my Final Degree Project entitled "Design of safe weightlifting bench" is entirely my own work. The title was confirmed on March 12, 2020 by Faculty Dean's order No. 60me I have clearly signalled the presence of quoted or paraphrased material and referenced all sources.

I have acknowledged appropriately any assistance I have received by the following professionals/advisers: Dr. Paulius Ragauskas.

The academic supervisor of my Final Degree Project is Doctor Paulius Ragauskas.

No contribution of any other person was obtained, nor did I buy my Final Degree Project.

RODRIGO, CASTEDO HERNÁNDEZ

VILNIUS GEDIMINAS TECHNICAL UNIVERSITY
FACULTY OF MECHANICS
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2020.06.11
(Date)

Mechanical Engineering study field

Mechanical Engineering study programme, State Code 612H33001

Machine Design specialisation

OBJECTIVES FOR BACHELOR FINAL THESIS

2020.06.11...No. ..31......

Vilnius

For student: Rodrigo, Castedo Hernández.

(Name, Surname)

Final work (project) title: Design safer press bench for weightlifting.

Approved on ......12..........03............, 2020 by Dean's decree No. ...60me...
(day, Month) (year)

The Final work has to be completed by ....01.......05................, 2020..
(Day, Month) (Year)

THE OBJECTIVES:

Data:
The design of a press bench which helps people who are doing the exercice if they do not have enough strength to lift the bar by themselves. The bench will descend to the floor and the bar will be stopped by the structure so the person get rid of the bar that lies on his chest.

Explanatory note:
Introduction. Literature review. Calculations needed for the design of a construction. Description of construction and working principals. Technological design and calculation of one part. Operation instructions and safety requirements. Economical overview and calculations. Final conclusions. References

Drawings:
General view (1 sheet of A1); Assembly drawing (1 sheet of A1); Working drawings of parts (1 sheet of A1) Technological drafts of the part processing (0.5 sheet of A1); Economic indicator diagrams (0.5 sheet of A1).

Consultants of the final degree work (project): ....

....
(Title, Name, Surname)

Academic Supervisor .... Dr. Paulius Ragauskas
(Signature) (Title, Name, Surname)

Objectives accepted as a quidance for my Final work (project)

....
(Student's signature)

Rodrigo Castedo Hernández
(Student's Name, Surname)

...........11th of June 2020............
(Date)

Vilnius Gediminas Technical University
Mechanical faculty
Material engineering department

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Annotation

In this bachelor‘s degree final work was design a weightlifting bench with the particularity of being safer than the actual ones. The final goal of this device is avoiding some riskies in a common activity in every gym.

It consists on an structure where the mechanism of the bench is welded and also stops the barbell in case of an emergency.

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1 INTRODUCTION

This project is about the design of a gym's press bench that allows a person to complete an exercise in safety without the need of another person.

During the exercise, a person lies on his back on a bench with both feet on the floor and try to put the barbell (a bar with balanced changeable weights on its ends) over his chest and try to elevate it vertically perpendicularly with respect to the bench until the arms are completely extended as many times as the person wants, it can be a single repetition or even more than ten.

The barbell usually weights more than a hundred kilograms and could be dangerous if it rest on the chest of a person and even worse if it goes to the neck. That is why people should do this type of exercise in couples instead of alone.

Since the goal is to be able to perform the exercise without the need of another person, that is why the designed bench must have some system that allows to increase the distance between the barbell and the person and the better the easier it is to activate it by the weightlifter.

To achieve a satisfactory bench design it is necessary to pay attention to the parts of the assembly that are most at risk of plasticization. These ones would probably be the legs of the bench and also the lever used for activating the mechaism.

Apart of the calculation to know if the parts will plasticize it is also recommended to calculate how much the legs will move by elastic dispacement

It will be also neccesary to calculate the strenght needed to activate the mechanism and be sure that this value is not too high and everyone could push it.

Another calculation needed would be the velocity reached by the bench at the moment of colision with the shock absorber for knowing which shock absorber is the one who fits better.

This project will be also explained how a part will be machining and how worth the project is.

2 LITERATURE REVIEW

2.1 NON-SECURITY BENCHES

Usually in gyms there are only non-security benches. This could be no a problem because often there are more people around so in case of emergency someone will help the person in trouble.

Some of this non-security benches are the ones of the next figures.

Figure 2.1: Folding weightlifting bench

Most of the people who likes doing some weightlifting at home has a bench like the one of the figure (2.1). It is very light and easy to have it at home because you can fold it and keep it where you want.

Figure 2.2: Basic weightlifting bench

The figure (2.2) shows one of the most popular benches of the gyms. It is simple and cheap. In a gym, safety press bench is not as useful as one which will be used at home because there are people around you so in case of emergency the rest of the people could help you.

Figure 2.3: Weightlifting bench

The bench of the figure (2.3) is very similar to the second one (figure 2.2) but with a structure which helps to put the weights that are not being used.

2.2 TYPES OF SOLUTIONS

Diverse types of security solutions will be discussed on the following pages.

The different existing inventions will be divided into three groups:

A distinction will be made between the different types of benches that are used for weightlifting exercises.

Is not only a difference between security and non-security, also show the differences between security benches.

- Security barbells.
- Non-security benches.
- Security benches which stop the barbell at some point.
- Security benches which help to separate from the bar.

The following aspects will be taken into account in the analysis:

- How the safety device works.
- How the safety device allows the weightlifter to perform the exercise correctly.
- Price.
- Complexity of the bench.

2.2.1 SECURITY BARBELLS

The solutions people have done to improve the barbell making it safer have been basically design it with a different shape [1] [2] instead of using the straight one as is shown in the next figures (figures 2.4, 2.5 and 2.6)

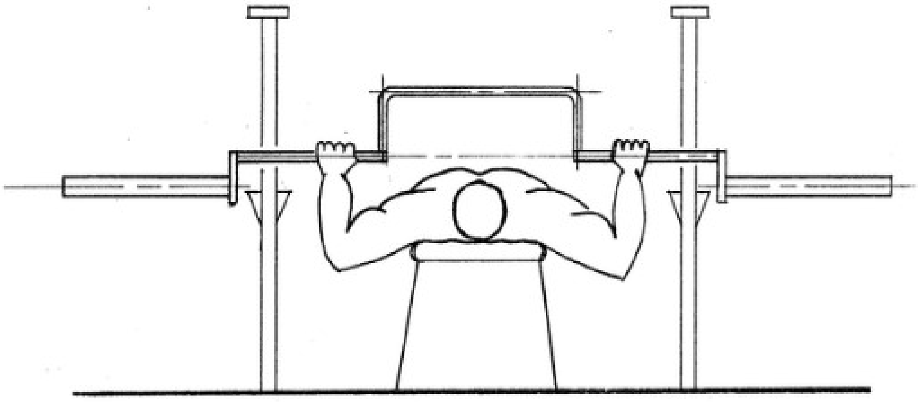


Figure 2.4: Barbell with chest hollow

This solution could be the simplest one and also the cheapest but no the best one. It allows the person to increase the length of movement which can improve the effectiveness of exercise but it not very effective in the scope of security.

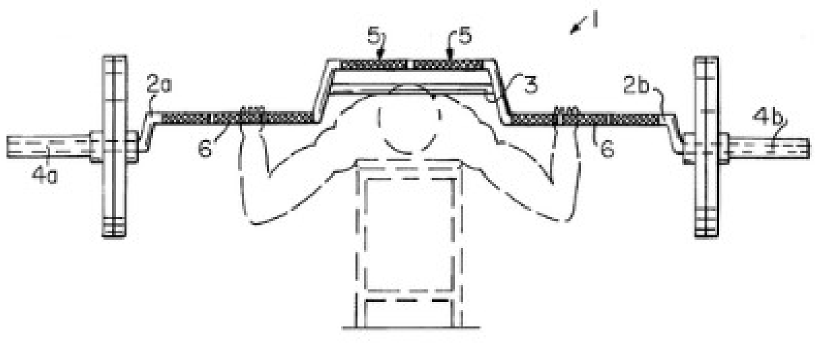


Figure 2.5: Barbell with chest hollow and extra bar for grabbing it by a second person

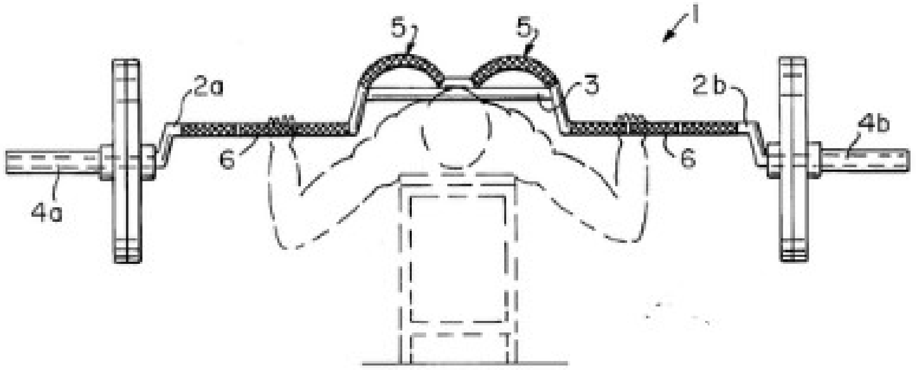


Figure 2.6: Barbell with chest hollow and extra bar with U-shape for grabbing it by a second person

The shape of the second and the third case is helpful in case of emergency because the people who help the one in trouble can grab the barbell when it rests on the chest of the person, easier than with the straight barbell.

In spite of everything, it's not a good way to solve the problem because the person can get trapped under the bar.

2.2.2 SECURITY BENCHES WHICH STOP THE BARBELL AT SOME POINT

Talking about security benches, the most common ones are the devices which stop the barbell at some point that was selected before the exercise.

Some of the structures for stopping the barbell could be welded and be part of the whole structure, others can be coupled to existing benches or they could even been simple structures that are placed on either side of the bench to hold the barbell.

Have security devices could be really useful and sometimes completely necessary, specially for people who train at home and gyms which opens 24 hours 7 days a week because in a lot of countries is possible to have a gym without staff, only the sports machines. If it is open the whole day, sometimes there is people alone so is not possible to ask someone for help.

Figure 2.7: Security bench

The figure (2.7) shows a bench more expensive than the previous ones but has a security device which is part of the original structure. The device is made by two bars and the height of them could be changed depending on the space the person will need to get rid of the barbell. The main problem of this type of security device is that it does not allow the person to do the exercise correctly because the barbell will not be close to the chest so the weightlifter can not do the movement as long as it should be.

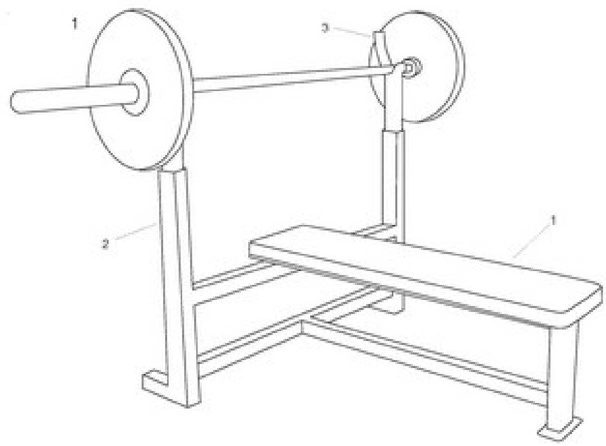


Figure 2.8: basic weightlifting bench

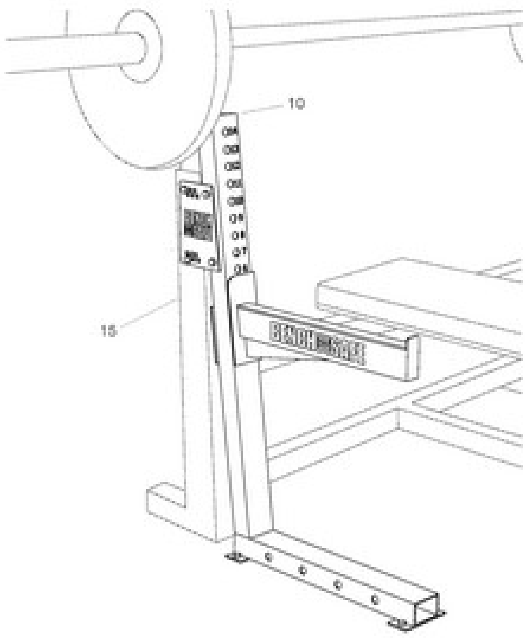


Figure 2.9: security device safety device to attach to the basic bench

There is another breakthrough that has been made on the issue of security [3], it is shown in the figures (2.8) and (2.9). The device consists of two equal structures, one on each side of the bench. It works the same as last case (figure 2.7), just two bars that would hold the barbell in case of accident but the problem is that the person has to choose where he wants the holding bars, if it is to high, the exercise is not going to be correctly but is safer or the opposite choice, if it is too low, the movement of the exercise would be perfect but in case of emergency could not be possible to get rid of the barbell.

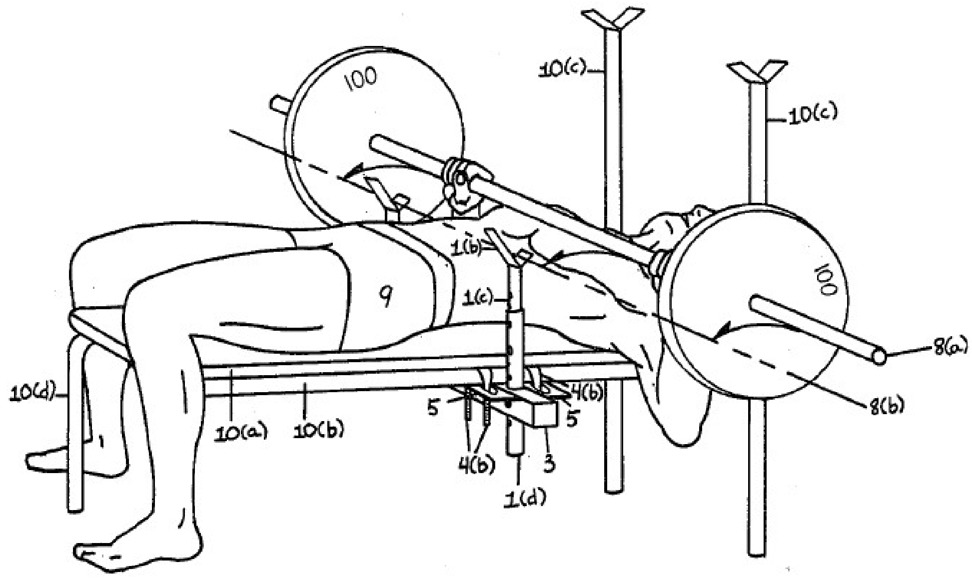


Figure 2.10: Security device attached to the bench

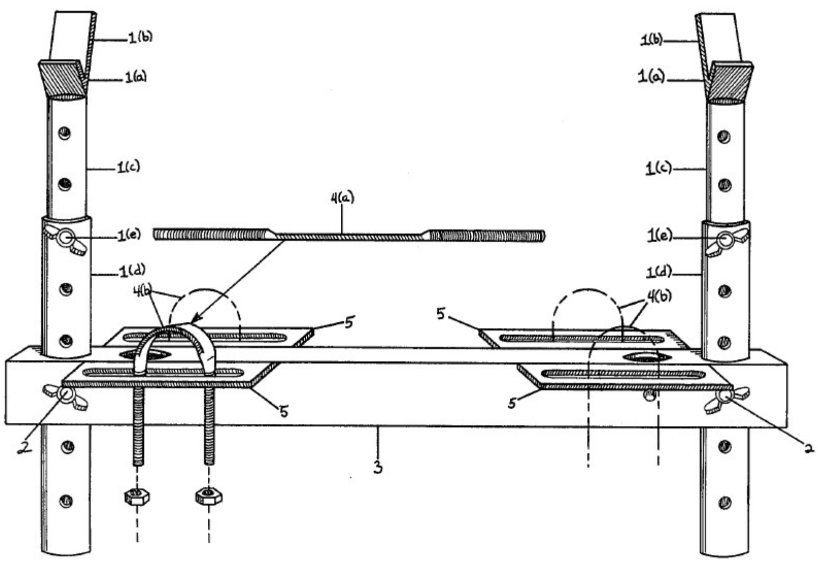


Figure 2.11: Scheme of the operation of the security device

The main advantage of this type of the devices (figures 2.9 and 2.10) that it is no necessary to buy a new press bench because the device can be attached to the bench by means of a screw system, so only a series of holes need to join the device to bench or even easier in case of the second one where no new holes are necessary.

The main disadvantage of the second device [4] (figure 2.10) is the impossibility of fixing it in the plane the person push the barbell because the arms would not have enough space to do the exercise properly. It could be a big problem because in case of emergency the person would have to push the barbell to the device and it is harder pushing weight out of the plane.

Is easy to know how the apparatus works looking at the figures 10 and 11. Basically the bench need to have two parallel bars under it to grab the four parts with the shape of an "U" (part 4(b) in the figures 2.10 and 2.11). That is another big disadvantage because it does not work for all benches.

In summary, this gadget could be very simple and maybe cheap but is not the best way to solve the problem.

Figure 2.12: Double simple support

The one of the figure (2.12) is the simplest solution, just two structures placed in both sides of the bench, far from the person so the weightlifter has enough space to move the arms and do the movement correctly. The problem is the same as the others before, shorten the length of movement and making it worse.

Figure 2.13: Guided barbell

Most of the gyms also have the type of barbell like the one of the figure (2.13).

The particular thing about this type of bars is that by rotating them, they can get hooked to the structure at the desired height.

Figure 2.14: Hook of the guided barbell

This is possible thanks to the hook seen in the figure (2.14). When the barbell rotates, the hook rotates too because the hook is welded to the barbell.

In the structure of figure (2.13) there are also two yellow devices, their function is make the exercise safer. They can be adjusted at the desired height and do not let the barbell descend.

So the hook and the yellow devices are advantages of this type of barbell.

It has a couple of disadvantages, one of them is the same as the fourth one (figure 2.7) because the yellow devices helps and stop the barbell but do not allow the person to get rid of it so in case of do not have enough strength to push the barbell, it will rest over the chest and there would not have the possibility of going to the neck but the space existing between the barbell and the chest of the person when the bar stops depends on the height he would chase before starting the exercise. Other disadvantage is the guide, the exercise is not as good as the one with the barbell free because the body works less.

2.2.3 SECURITY BENCHES WHICH HELP TO SEPARATE FROM THE BAR

This ones are the best option about security. Probably are the most expensive benches but also the safest ones.

In different ways, they help the person to get rid of the barbell and that is the objective of the project.

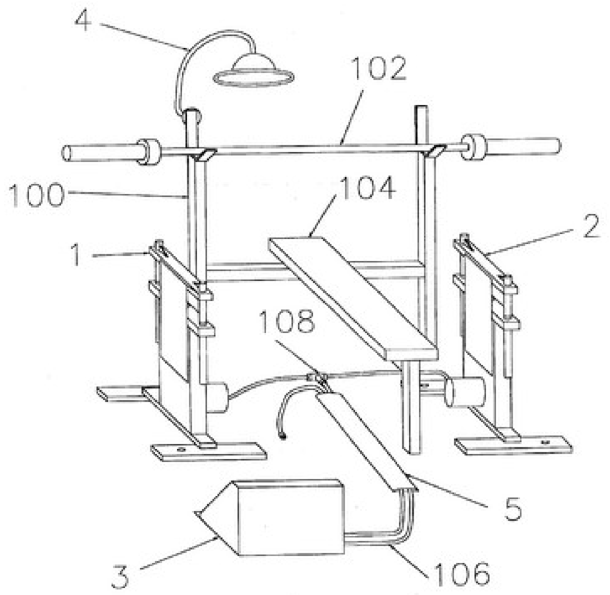


Figure 2.15: Hydraulic system of a security bench

It is interesting to see how the bench of the figure (2.15) works [5].

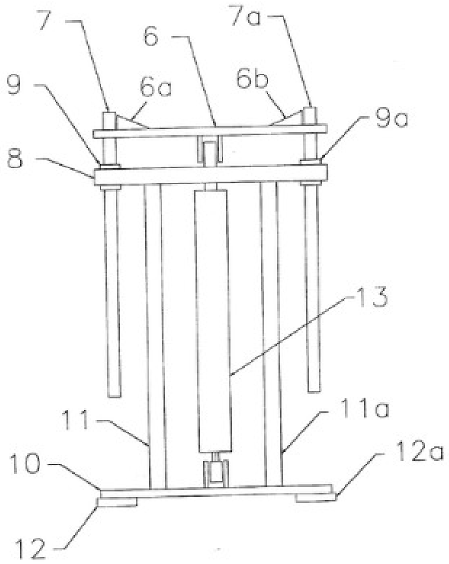


Figure 2.16: Structure of the support

It has an hydraulic system which is connected to two hydraulic cylinders one on each side of the bench. It has a structure similar to those mentioned above, specially to the figure (2.7). There is a small device with two pedals, "UP" and "DOWN". The cylinder does not move the bench, it is completely fixed to the rest of the structure, it elevates the bars that hold the barbell. The figure (2.16) shows easily how it works. Of course the structure has also two guided bars apart from the hydraulic cylinder.

This solution is one of the best. The main disadvantage is the complexity of the device and the price of it.

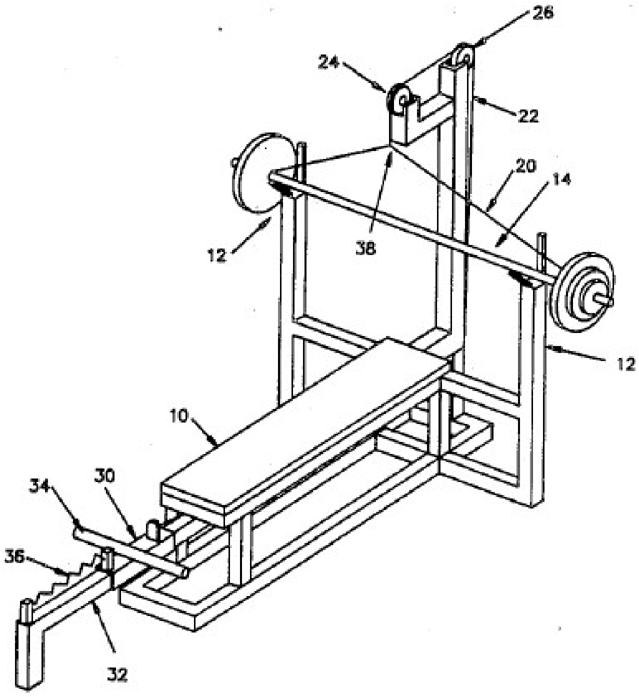


Figure 2.17: Security bench with cable

The bench which appears in the figure (2.17) is interesting to analyze [6]. The weight bar is attached to a cable system that incorporates a safety stop to prevent the barbell form crushing the chest of the user in case of accident.

The figures (2.18, 2.19, 2.20 and 2.21) shows exactly how it works step by step.

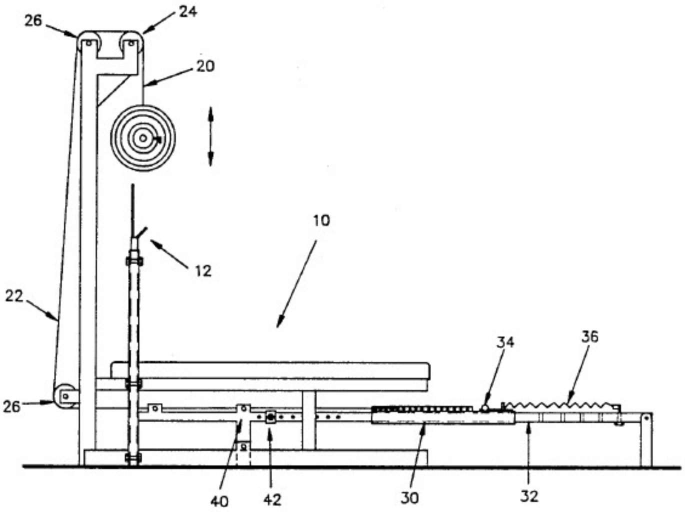


Figure 2.18: Schematic drawing of the bench

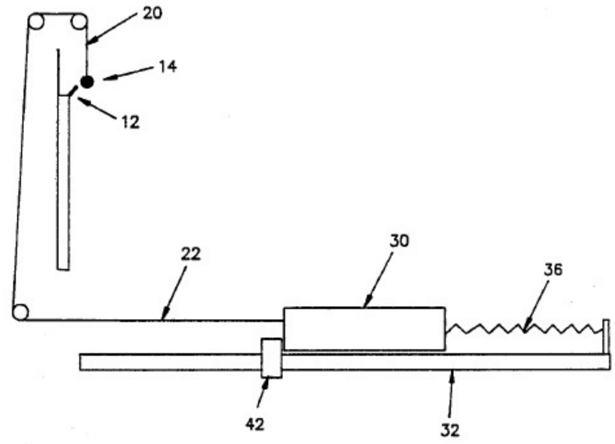


Figure 2.19: Step 1, barbell at the top

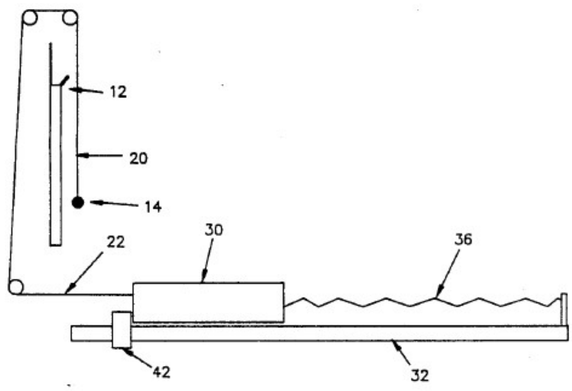


Figure 2.20: Step 2, barbell at the bottom

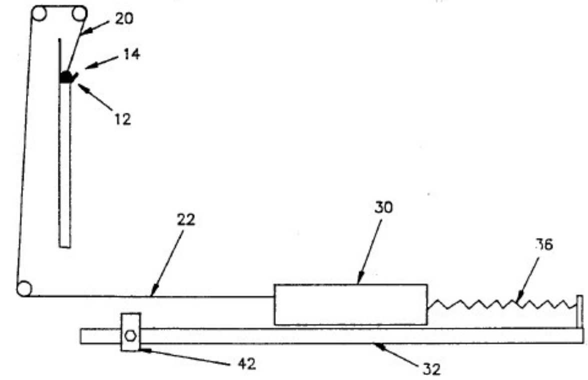


Figure 2.21: Step 3, barbell resting at the bar holder (after using the legs to help)

The security device is made by the cable that is connected to the part number 30 and also to the part number 34 because they are welded to each other. In case of emergency, the user must lift the feet from the ground and place them on the piece 34, so he can push with the legs and help himself because some of the strength needed is been doing with the legs instead of the full strength only with the chest and arms.

It also has a spring which connect the structure with the part 30 so when the weightlifter has his feet on the floor, the bar for the feet (Part 34) slides along the bar of the structure (Part 32) freely. Depends on how far the feet bar is from the bench could be dangerous because it can hit the knees of the user, usually the professional weightlifters do the exercise with the legs open (as many grades as they can) but with people who do not know the best way to do it could be a problem.

When the weight bar is on the top with the help of the legs it is necessary to push it to the barbell stand.

It also has another security device to stop the barbell. It works with a small piece fixed in one of the holes of the Part 32 which stops the part 30 and therefore also the cable and the barbell.

This solution is a very good idea, the only problem is the big it is. There are many advantages such as the simplicity of the mechanism and the ease it is for the user to use it.

One problem is not have enough strength on the legs to push the bar but usually is not a problem because most of the people have more strength in the legs than in the arms and chest so it should not be a problem.

The last security bench to talk about is the one of the figure 2.22 [7].

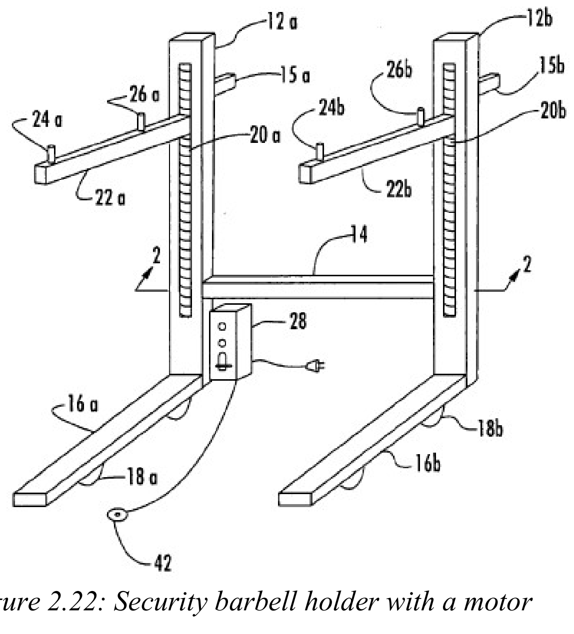


Figure 2.22: Security barbell holder with a motor

The structure is very similar to the figure (2.7) and (2.9) but the difference is the motor it has which elevate the bars that are holding the barbell so it lets enough space to the user to get rid of the bench.

In the figures (2.23) and (2.24) show the mechanism of the device which is not very complex, both parts are connected to elevate at the same time.

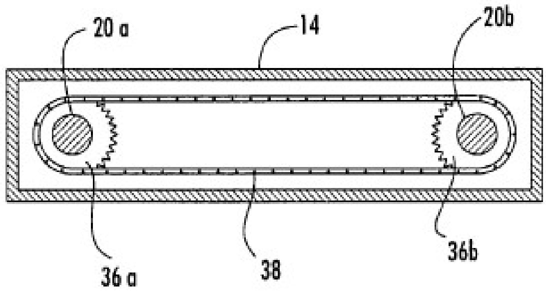


Figure 2.23: Schematic drawing of the motorized holder

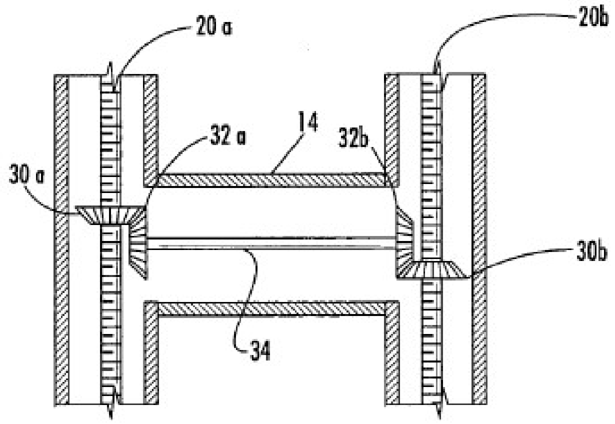


Figure 2.24: Schematic drawing of the motorized holder

This solves the problem of some of the previous invents that were only for stopping the barbell because the user can put the security bars at less high than his chest so the problem about the length of the movement would be solved and the weightlifter could do the exercise safe.

3 CALCULATIONS NEEDED FOR THE DESIGN OF A CONSTRUCTION

3.1 MAIN DECISIONS ABOUT THE DESIGN

There are a couple of features that need to be taken into account.

The first one is the dimensions of the bench (the place where the sport man will rest his back). The most popular dimensions are 1220mm of length and 340mm wide.

The necessity of having a wide structure in the part of the barbell to improve the stability of the bench.

To have enough free space for the feet, could be good having only one bar which connects the part of the head and the part of the feet instead of having two one, on each side which bother the person who is doing the exercise.

The lever should be in the middle plane of the weightlifting bench to be used easily with both feet.

The way the bench goes down it is also important. It could be completely vertical or in the case of the legs would not being articulated it would be a displacement and maybe it could be dangerous depending on where the barbell will be stopped, if the barbell is over the neck of the weightlifter and the movement displace the bench like the figure (3.1) shows could be dangerous because maybe the barbell can not pass over the chin and get stuck pressing the neck with fatal consequences. Because of this consequences the design will be with articulated legs and two vertical bars that will be the guides to obtain a vertical displacement for descending (fig.3.2).

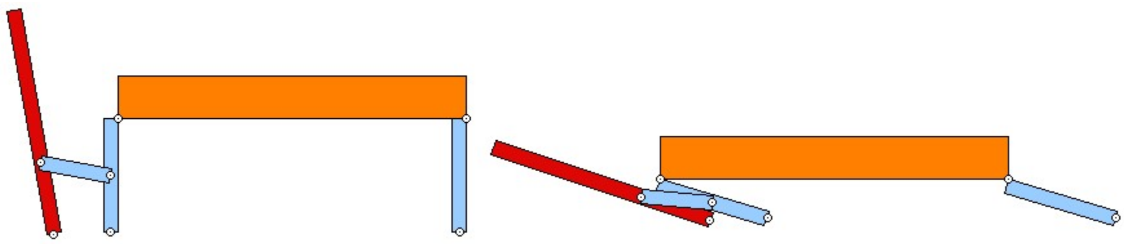


Figure 3.1: Basic drawing for descending the bench. Made with Working Model software

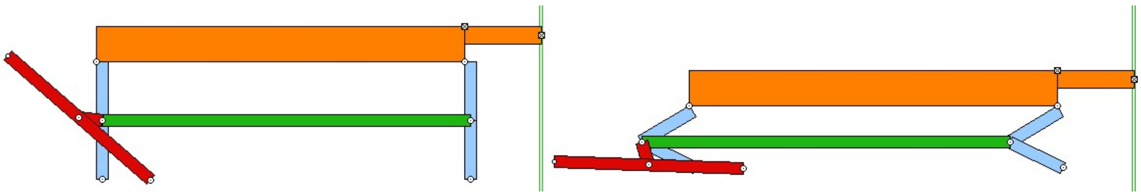


Figure 3.2: Basic drawing of another way for descending the bench. Made with Working Model software

After decide how the basic structure will be, the design of the weightlifting bench with Solidworks software is shown in the figures (3.3 and 3.4).

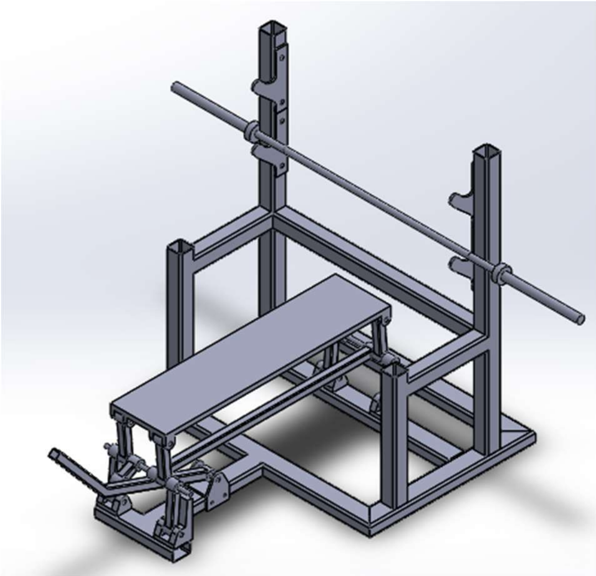


Figure 3.3: Basic design of the weightlifting bench with Solidworks software

Figure 3.4: Basic design of the weightlifting bench with Solidworks software

3.2 STRENGTH AT THE LEVER

[Reference: 9]

First strength to calculate is the one which is needed to push the lever to elevate the bench until the bench is on the top (point where legs are completely vertical).

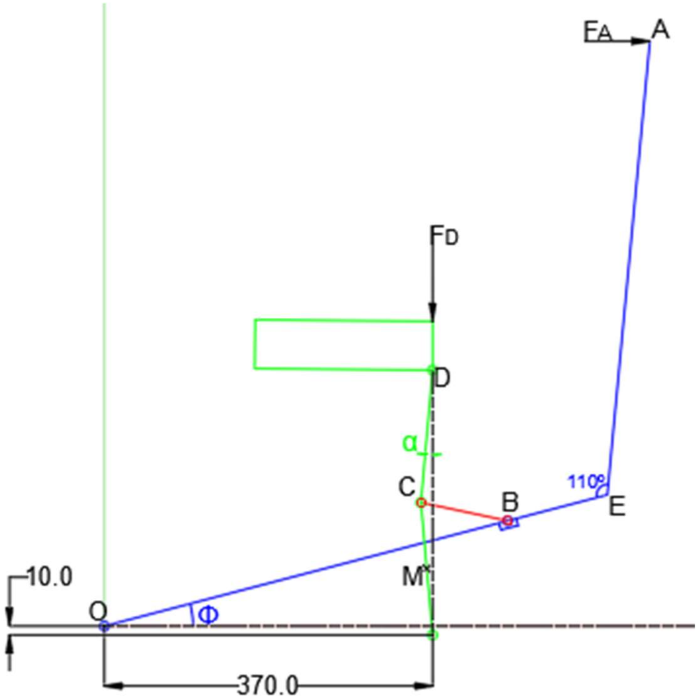


Figure 3.5: Sketch of the bar-structure. Drawn with AutoCAD software

The whole mechanism (figure 3.5) is divided in three parts, the blue one is the lever, on green are the legs and the bench and the last one is on red and is the bar which connects the lever with the articulation of the legs.

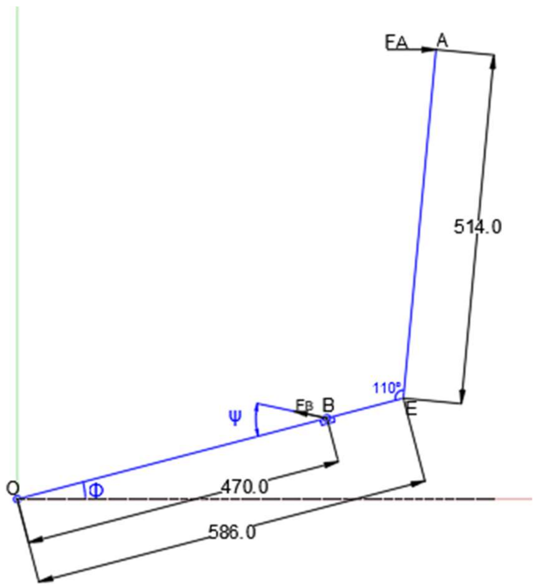


Figure 3.6: Sketch of the lever. Drawn with AutoCAD software

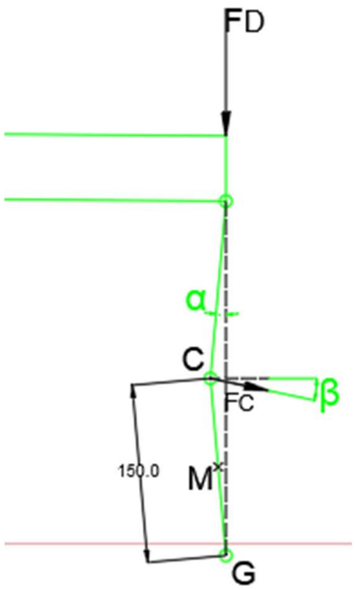


Figure 3.7: Sketch of the legs of the weightlifting bench. Drawn with AutoCAD software

Figure 3.8: Sketch of the bar which connects the lever and the articulation of the legs. Drawn with AutoCAD software

In the figures (3.6, 3.7 and 3.8) it is shown how the parts are and the dimensions of them.

The point "B" which takes place in the lever has an articulation so a rotation exist between the lever and the bar C-B.

The strength is done in the point A (the place where the powerlifter has to press the lever). It is necessary to know the strength needed because the weightlifting bench would not work if the person can not press the lever with enough strength.

The first thing to do is relate the mass which rests on the bench (barbell and body weight) with the strength the person has to do.

$$2l(1 - cos(\alpha)) \tag{3.1}$$

- l → Length of the leg.
- α → Angle between the leg and the vertical (30).

The equation 3.1 shows how much the bench will elevate until it would be on the top, basic trigonometry.

$$2 \cdot 150(1 - cos(5°)) = 1.14mm \tag{3.2}$$

$$\Sigma F = 0 \tag{3.3}$$

• F → Forces acting in a structure.

$$\Sigma M_0 = r_i \cdot F_i + r_j \cdot F_j \tag{3.4}$$

• M → Momentums acting in a structure.

Equilibrium equations (eq.3.3 and eq.3.4) will be used. The main important equation for us relating the two strengths we want to relate is the one of the momentum.

Equation 3.4 is used to calculate the exact force the weightlifter would have to do for keep the mechanism in equilibrium, if the strength increase, the lever will move forward so the safety weightlifting will start working.

$$\Sigma M_O = -F_A \cdot y_{OA} + F_{xB} \cdot y_{OB} + F_{yB} \cdot x_{OB} = 0 \tag{3.5}$$

• F_A → Force applied at the lever (it only has horizontal component).
• y_{OA} → Vertical distance between the origin "O" and the point "A" where the force F_A is applied.
• F_{xB} → Horizontal component of F_B (Force that actuate at "B")
• y_{OB} → Vertical distance between the origin "O" and the point "B" where the force F_B is applied.
• F_{yB} → Vertical component of F_B.
• x_{OB} → Horizontal distance between the origin and the point "B".

If the equilibrium formula (eq.3.4) is used at the lever, the resulting equation would be eq.3.5. Doing the momentum respect the point "O".

$$\Sigma M_M = -F_{xC} \cdot y_{CM} + F_{yC} \cdot x_{CM} - F_D \cdot x_{MD} = 0 \tag{3.6}$$

• M_M → Momentum respect the point "M" (point in the middle of the lower leg).
• F_{xC} → Horizontal component of F_C (force which actuate at "C")
• y_{CM} → Vertical distance between "C" (articulation between lower and upper legs) and "M".
• F_{yC} → Vertical component of F_C.
• x_{CM} → Horizontal distance between "C" and "M".
• F_D → Force applied in at point "B" (it depends of the weight that is over the weightlifting bench). It only has vertical component.
• x_{MD} → Horizontal distance between "M" and "D".

The value of F_D is calculated with the equation 3.7.

$$F_D = m \cdot g \tag{3.7}$$

• m → mass over the weightlifting bech, the weight of the person plus the weight of the bench plus the weight of the barbell.
• g → gravity value (9.81 N/kg)

The equilibrium equation (eq.3.4) it is also applied using as the centre a new point whose name is "M" because with the existing ones is not possible to relate both forces (F_D and F_C), so the new equation would be eq.3.6.

A bi-articulated bar only works with axil efforts so at the C-B bar the force at the articulation C will be the same as the one on the articulation B but with the opposite way (eq.3.8, eq.3.9 and eq.3.10).

$$F_B = -F_C \tag{3.8}$$

$$F_{xB} = -F_{xC} \tag{3.9}$$

$$F_{yB} = -F_{yC} \tag{3.10}$$

Replacing the above equations (eq.3.8, eq.3.9 and eq.3.10) in equation 3.6 we get the following formula (eq.3.11).

$$F_{xB} \cdot y_{CM} - F_{yB} \cdot x_{CM} - F_D \cdot x_{MD} = 0 \tag{3.11}$$

Now it is time to replace the distances and they are shown in the following equations (eq.3.12, eq.3.13, eq.3.14, eq.3.15, eq.3.16 and eq.3.17).

$$y_{OA} = \bar{O}E \cdot sin(\phi) + \bar{E}A \cdot sin(70 \circ + \phi) \tag{3.12}$$

• $\bar{O}E$ → Length of the lower bar of the lever.
• ϕ → Angle of the lower bar of the lever with the horizontal line.
• $\bar{E}A$ → Length of the upper bar of the lever.

$$y_{OB} = \bar{O}B \cdot sin(\phi) \tag{3.13}$$

• $\bar{O}B$ → Distance between the origin and the point "B" (where bar C-B and the lever connect)

$$x_{OB} = \bar{O}B \cdot cos(\phi) \quad (3.14)$$

$$y_{CM} = \frac{\bar{C}G}{2} \cdot cos(\alpha) \quad (3.15)$$

- $\bar{C}G$ → Length of the legs.

$$x_{CM} = \frac{\bar{C}G}{2} \cdot sin(\alpha) \quad (3.16)$$

$$x_{DM} = \frac{\bar{C}G}{2} \cdot sin(\alpha) \quad (3.17)$$

Replacing lengths the new equations will be the formulas 3.18 and 3.19.

$$-F_A(\bar{O}E \cdot sin(\phi) + \bar{E}A \cdot sin(70° + \phi)) + F_B \cdot cos(\beta) \cdot \bar{O}B \cdot sin(\phi) + \\ + F_B \cdot sin(\beta) \cdot \bar{O}B \cdot sin(\phi) = 0 \quad (3.18)$$

$$-F_D \cdot \frac{\bar{C}G}{2} \cdot sin(\alpha) + F_B \cdot \frac{\bar{C}G}{2}(cos(\beta) \cdot cos(\alpha) - sin(\beta) \cdot sin(\alpha)) \quad (3.19)$$

Now there is an equation system (eq.3.18 and eq.3.19) of two equations with three variables (F_A, F_B and F_D). Next step is isolate F_B (because the other two are the ones to relate), it is shown in equation 3.20.

$$F_B = \frac{F_A(\bar{O}E \cdot sin(\phi) + \bar{E}A \cdot sin(70° + \phi))}{\bar{O}B \cdot sin(\phi)(cos(\beta) + sin(\beta))} = \frac{F_D \cdot sin(\alpha)}{cos(\beta) \cdot cos(\alpha) - sin(\beta) \cdot sin(\alpha)} \quad (3.20)$$

When F_B is isolated in both equations it is possible to relate F_A and F_D and also isolate F_A (eq.3.21) because it make the calculus easier.

$$F_A = F_D \cdot \frac{sin(\alpha)\bar{O}B \cdot sin(\phi) \cdot (cos(\beta) + sin(\beta))}{(\bar{O}E \cdot sin(\phi) + \bar{E}A \cdot sin(70° + \phi)) \cdot (cos(\beta) \cdot cos(\alpha) - sin(\alpha) \cdot sin(\beta))} \quad (3.21)$$

Replacing the variables for the value in this case appear the next equation ()

$$F_A = 7848N \cdot \frac{sin(5°) \cdot 0.470m \cdot sin(14.64°) \cdot (cos(11.91°) + sin(11.91°))}{(0.58 \quad \cdot sin(14.64°) + 0.514m \cdot sin(70° + 14.64°)) \cdot (cos(11.91°) \cdot cos(5°) - sin(5°) \cdot sin(11.91°))} = 152.49N \quad (3.22)$$

The most unfavorable case is when the weight of the powerlifter is maximum (200kg) and the weight of the barbell is maximum too (600kg), (F_D=7848N) so the strength needed is (F_A=152.49N). The value of strength is small enough to be able to activate the mechanism easily by an adult person performing force exercises.

3.3 RESISTANCE OF THE LOWER LEGS

[Reference: 9]

Another part to analyze is the lower part of the legs (fig.3.9 and fig.3.10). In the figures it shown how high the support contact the leg, the length of the leg and also the direction of the force which is applied on the articulation of the leg.

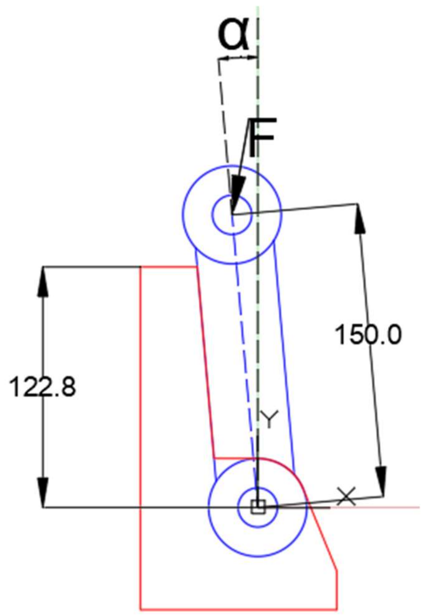


Figure 3.9: Drawing of the lower leg and the support. Drawn with AutoCAD software

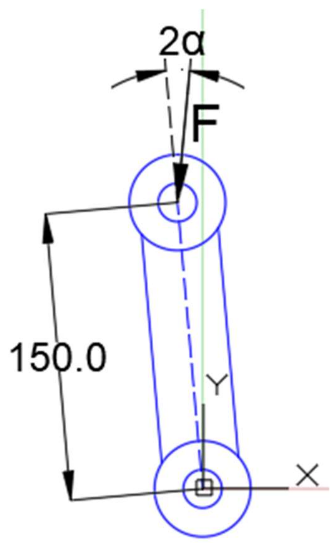


Figure 3.10: Drawing of the lower leg. Drawn with AutoCAD software

Doing a simplification, the bar will be analysed like a one dimension bar which is free on one end and it is completely fixed on the other. The length of the bar is the length between the centre of the articulation on the top and the high of the bar where it has not support (the top of the support).

To know which is the critical section it is necessary to calculate the diagrams of axial effort, shear effort and the bending moment. (figure 3.11)

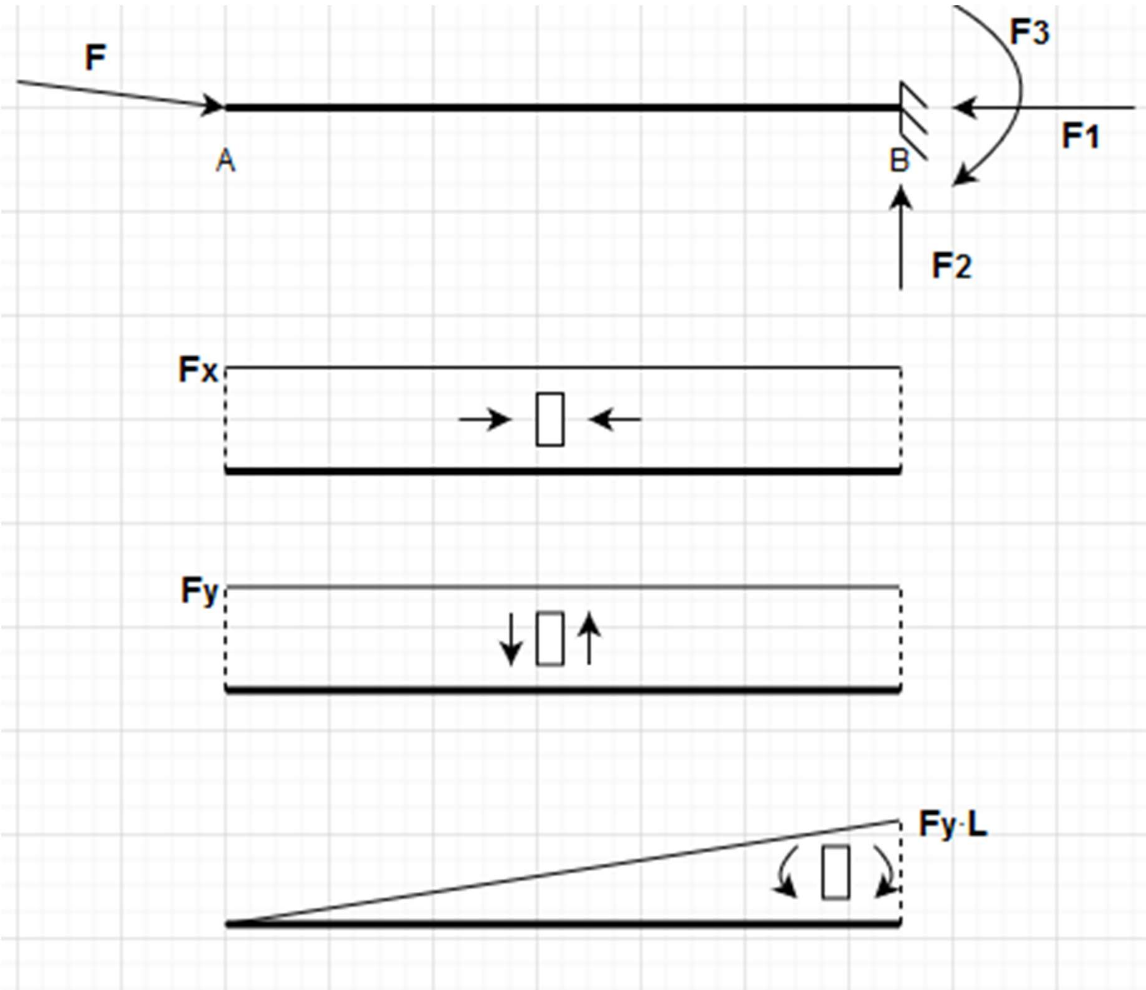


Figure 3.11: Diagrams of axial effort, shear effort and the bending moment of the bar. Drawn in draw.io website

The critical section is the one that is fixed because is the place where the bending moment is bigger and the other efforts are the same all along the bar.

It is easy to know the value of the forces (3.23) at the fixed face using the equilibrium equations (3.3 and 3.4).

$$F_1 = F_x; F_2 = F_y; F_3 = F_y \cdot L \tag{3.23}$$

• F_1 → Axial strength reaction at the fixed face.
• F_2 → Vertical strength reaction at the fixed face.
• F_3 → Momentum bending reaction at the fixed face.
• F_x → Horizontal component of the force which is applied at the free end of the bar.
• F_y → Vertical component of the force which is applied at the free end of the bar.
• L → Length of the portion of the bar that is been analysing.

Knowing the value of the reactions at the fixed section the next step is calculate the normal stress (eq.3.24) to know if the bar would not plastificate with the strength that would be applied.

$$\sigma_x = \frac{M}{I_z} \cdot y + \frac{N}{A} \quad (3.24)$$

• σ_x → Normal stress at the bar.
• M → Bending moment at one section of the bar.
• I_z → Moment of inertia of the section of the bar.
• y → vertical distance between the axis of the bar and the point of the section that is been analysing.
• N → Axial effort at the studied section.
• A → Area of the studied section.

$$\sigma_x = \frac{3000N \cdot sin(10°) \cdot 0.025m}{6.6cm^4} \cdot 0.020m + \frac{3000N \cdot cos(10°)}{2.9cm^2} = 14.13MPa \quad (3.25)$$

Applying equation (3.24) the normal stress of the leg is obtained and its value is σ_x=14.13 MPa.

The bar would not plasticize if the value of the normal stress is lower than the limit of the material (eq.3.26).

$$\sigma_x < S_x \quad (3.26)$$

The bar is made of AISI 304 steel whose elastic limit at 20 °C is 210 MPa which is higher than the maximum stress of the bar so it will not plasticize.

If the bar will not plasticize it would be convenient to know the displacements of the free end. This will be done with virtual forces work (eq.3.27)

$$\sum_f F \cdot \delta + \sum_{q(x)} \int_0^L q(x) \cdot \delta(x) \cdot dx = \sum_b \int_0^L [N\frac{n}{A \cdot E} + M_z\frac{m_z}{E \cdot I_z} + V_y\frac{v_y}{\frac{G \cdot A}{f}}]dx + \sum_F F \cdot \delta_Y \quad (3.27)$$

• n → Axil effort in the virtual problem.

• m $_z$ → Bending moment of the virtual problem
• v $_y$ → Shear effort in the virtual problem

The problem will be divided in two, one to know the vertical displacement and the other one to know the horizontal displacement.

Horizontal displacement

Let's start with the horizontal displacement, the diagram to calculate this displacement would be the one showed at the figure

Figure 3.12: Sketch to calculate horizontal displacement, real problem and virtual one. Drawn in draw.io website

Applying the formula of virtual forces, the resulting one is the equation

$$\delta_H = \int_0^L F \cdot cos(2\alpha) \frac{1}{E \cdot A} dx = F \cdot cos(2\alpha) \frac{L}{E \cdot A} \qquad (3.28)$$

• δ_H → Horizontal displacement of the free end of the bar.
• F → Force acting at the free section (fig.3.10).
• E → Young's modulus.

$$\delta_H = 3000N \cdot cos(2 \cdot 5°) \frac{0.025m}{200GPa \cdot 2.9cm^2} = 1.27 \cdot 10^{-}6m \qquad (3.29)$$

In this case the horizontal displacement is δ_H=0.0013mm.

Vertical displacement

The diagrams to calculate the vertical displacements are the ones shown at the figure(3.13)

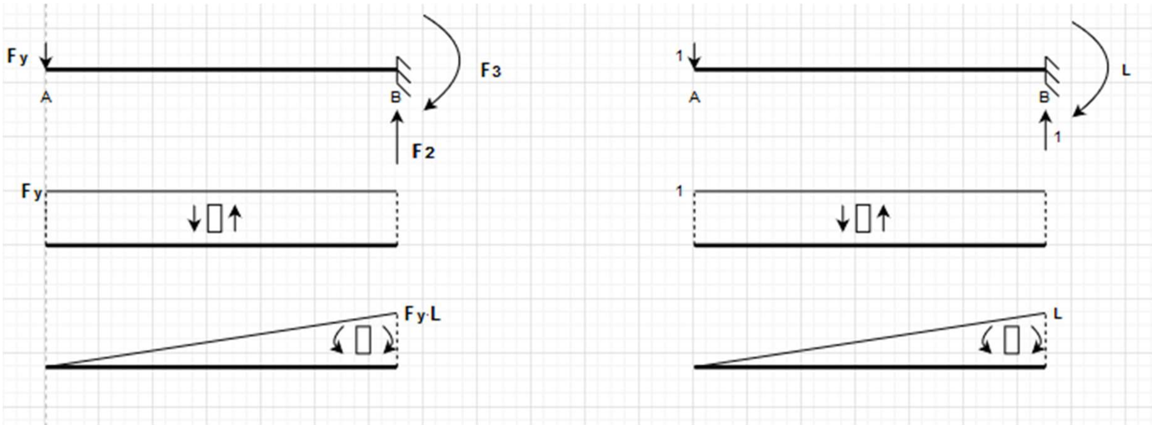


Figure 3.13: Sketch to calculate vertical displacement, real and virtual problems. Drawn in draw.io website

$$\delta_V = \int_0^L [F \cdot sin(2\alpha) \frac{1}{G \cdot A} + F \cdot sin(2\alpha) \cdot x \frac{x}{E \cdot I_z}] dx \qquad (3.30)$$

- δ_V → Vertical displacement of the free end of the bar.
- G → Shear modulus.

$$\delta_V = [F \cdot sin(2\alpha) \frac{x}{G \cdot A} + F \cdot sin(2\alpha) \frac{x^3}{3 \cdot E \cdot I_z}]_0^L \qquad (3.31)$$

$$\delta_V = F \cdot sin(2\alpha) \frac{L}{G \cdot A} + F \cdot sin(2\alpha) \frac{L^3}{3 \cdot E \cdot I_z} \qquad (3.32)$$

$$\delta_V = 3000N \cdot sin(2 \cdot 5°) \frac{0.025m}{86GPa \cdot 2.9cm^2} + 3000N \cdot sin(2 \cdot 5°) \frac{(0.025cm)^3}{3 \cdot 200GPa \cdot 6.6cm^4} = 7.28 \cdot 10^-9m \qquad (3.33)$$

In this case the vertical displacement is δ_V=7.28· $10^{-6}mm$

3.4 RESISTANCE OF THE UPPER LEGS

[Reference: 9]

The upper legs (fig.3.14) are bi-articulated bars so they only work at axil efforts.

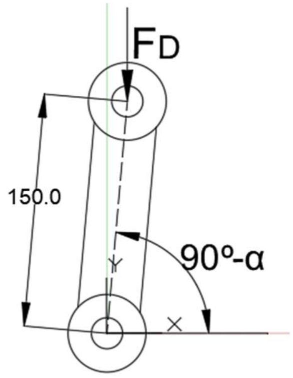


Figure 3.14: Upper leg drawing. Drawn with AutoCAD software

The efforts diagram of the upper bar is the one of the figure (3.15) where there is only axil diagram because is the only one different from zero.

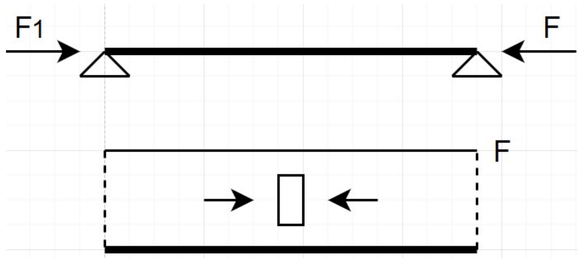


Figure 3.15: Upper leg diagram. Drawn in draw.io website

Watching the figure is easy to realize that both forces have the same value (eq.3.34).

$$F_1 = F \tag{3.34}$$

$$\sigma_x = \frac{3000N}{2.9cm^2} = 10.34MPa \tag{3.35}$$

The normal stress "σ_x" is calculated by eq.(3.24) but now the bending moment is zero so the value of normal stress is only affected by the axil effort. Because of the axil force, the bar suffer a normal stress of 10.34 MPa which is not high enough to care about because the bar will not suffer a permanent deformation.

3.5 RESISTANCE OF THE PEDAL OF THE LEVER

[Reference: 9]

It is important to know how the bar which is pushed to activate the mechanism will suffer plastizitation or not. The strength needed is already calculated.

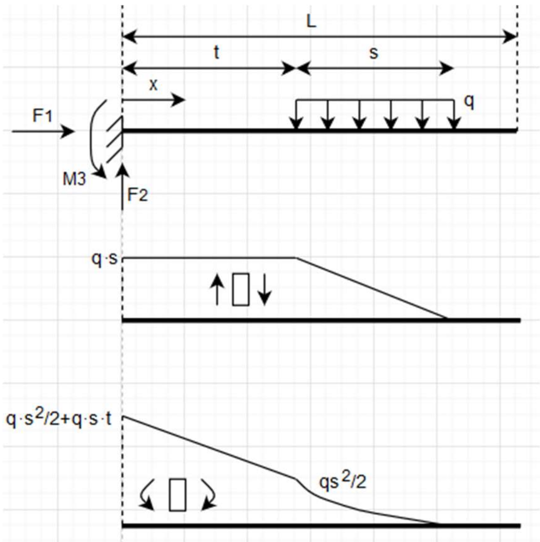


Figure 3.16: Effort diagrams of the pedal's lever. Drawn in draw.io website

The diagrams of the bar are shown in the figure (3.16). The critical section is the one fixed at the lever because the bending moment and the shear effort are maximum there.

Applying the equilibrium equations (eq.3.3 and eq.3.4) the reaction forces are calculated (eq.3.36)

$$F_1 = 0; F_2 = q \cdot s; M_3 = q \cdot s(t + \frac{s}{2}) \tag{3.36}$$

The formula of the bending moment and shear effort along the bar are:

- V(x)=V(0) if 0≤x≤t
- V(x)=V(t)-q(x-t) if t<x≤(t+s)
- V(x)=0 if (t+s)<x
- M(x)=M(0)-qÂ·sÂ·t if 0≤x≤t
- M(x)=M(t)+q($\frac{(x-t)^2}{2}$-s(x-t)) if t<x≤(t+s)
- M(x)=0 if (t+s)<x

The equation (3.24) will be used to calculate the maximum normal stress (it would be in the fixed face as it was said before).

The inertial moment "I_z" of a circle is (eq.3.37)

$$I_z = \frac{\pi \cdot r^4}{4} \tag{3.37}$$

$$A_{circle} = \pi \cdot r^2 \tag{3.38}$$

$$\sigma_x = \frac{\frac{1524.9\frac{N}{m}\cdot 0.1m}{\frac{\pi\cdot(0.0125m)^4}{4}}} \cdot 0.0125m = 99.41MPa \tag{3.39}$$

To calculate if the bar plastize the equation (3.24) will be used. Obtaining the value of σ_x=99.41 MPa so it will not plastize.

3.6 CHOOSE SHOCK ABSORBER

[Reference: 9]

In this section, the equations of the uniformly accelerated rectilinear movement (eq.3.40 and eq.3.41) will be used.

$$y(t) = y_0 + v_0 \cdot t + \frac{1}{2} \cdot a \cdot t^2 \tag{3.40}$$

$$v(t) = v_0 + a \cdot t \tag{3.41}$$

- y(t)→ height of the bench in a moment "t"
- y_0 → initial height of the bench (in this case is on the top)
- v_0 → initial velocity of the bench (in this case is zero)
- v(t)→ velocity of the bench in a moment "t"
- a→ acceleration of the bench (in this case is the gravity, a=-9.81m/s ^{2})
- t→ time passed since the start of the movement

$$0 = 0.214m + 0 + \frac{1}{2} \cdot -9.81\frac{m}{s^2} \cdot t^2 \tag{3.42}$$

$$t = 0.209s \tag{3.43}$$

The time of the move is 0.209 seconds (eq.3.43). Replacing the time in the equation (3.41) the final velocity could be calculated.

$$v(0.209) = 0 - 9.81\frac{m}{s^2} \cdot 0.209s = -2.05\frac{m}{s} \tag{3.44}$$

Knowing the distance between the top of the movement and the end (where is stopped by the shock absorber) is possible to calculate the velocity that the bench has when it contacts with the shock absorber.

Doing the calculations, the velocity is v=2.05m/s so the next step is looking for a shock absorber which fits in our case. The one that fits more is the WCB-080-080. It is designed for resist 0.6kNm when the velocity of the impact is 2m/s (similar to the one previously calculated).

The energy which is needed to absorb is easily calculated by the formula of the kinetic energy (eq.3.45)

$$E_k = \frac{1}{2} m \cdot v^2 \tag{3.45}$$

- E_k → Kinetic energy of the body.
- m→ Mass of the body.

The mass in this case will be the weight of the powerlifter and also the weight of the bench (75.9kg). The maximum weight of a powerlifter could be 200kg (the most unfavourable case).

$$E_k = \frac{1}{2}(75.9kg + 200kg) \cdot (2.05\frac{m}{s})^2 = 579.73Nm \tag{3.46}$$

In this case, the kinetic energy is 0.580kNm so the shock absorber fits perfectly.

3.7 RETAINING RINGS SELECTION

[Reference: 8]

Selected ring is Retaining ring 20x1.2 DIN 471 (figure 3.17).

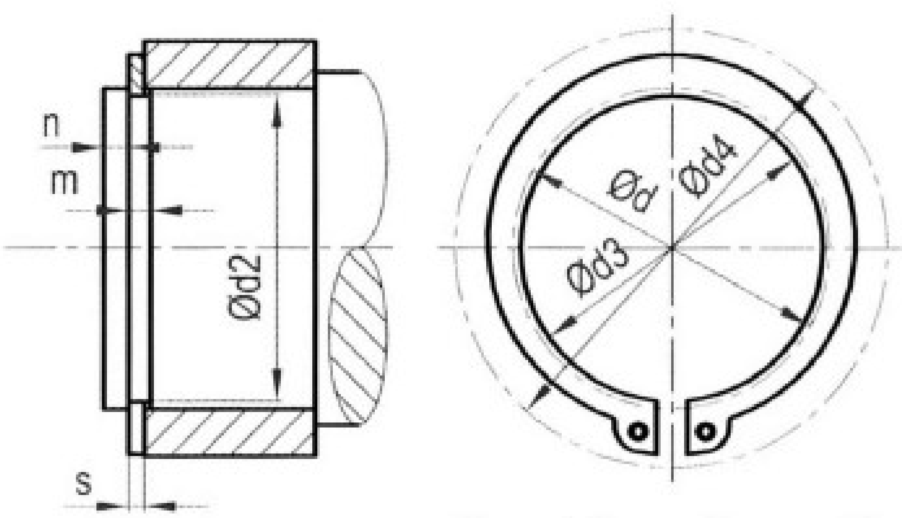


Figure 3.17: Retaining ring 20x1.2 DIN 471

Table 3.1: Retaining rings DIN 471

ϕAXIS	**RING**		**GROOVE**			**d_4**
D	s	d_3	d_2	m	n	
20	1.2	18.5	19	1.3	1.5	28.4

4 DESCRIPTION OF THE TECHNOLOGICAL PROCESS OF THE PART AND REGIMES OF MACHINING

[Reference: 15, 16]

The piece whose construction is to be detailed is the one that joins the lever with the base and houses the axis of rotation of the lever. This one was chosen because it could be de most difficult one to be created because of his geometry.

First of all, the mill turning machine chosen is the HAAS VF-2 (figure 4.1), the main characteristics are shown in the tables (4.1) and table (4.2)

Table 4.1: Main characteristics of the mill turning machine. Data obtained from the haas website

TRAVELS		**SPINDLE**		**TABLE**	
X Axis	762 mm	Max Rating	22.4 kW	Length	914 mm
Y Axis	406 mm	Max Speed	8100 rpm	Width	356 mm
Z Axis	508 mm	Max Torque	122 Nm @ 2000 rpm	T-slot Width	16 mm
Spindle Nose to Table (max)	610 mm	Drive System	Inline Direct-Drive	T-Slot Center Distance	125 mm
Spindle Nose to table (min)	102	Taper	CT or BT 40	Number of Std T-Slots	3
Cooling	Liquid Cooled	Max Weight on table	1361 kg		

Table 4.2: Main characteristics of the mill turning machine. Data obtained from the haas website

FEDERATES		**AXIS MOTORS**	
Max Cutting	16.5 m/min	Max Thrust X	11.343 kN
Rapids on X	25.4 m/min	Max Thrust Y	11.343 kN
Rapids on Y	25.4 m/min	Max Thrust Z	18.683 kN
Rapids on Z	25.4 m/min		

Figure 4.1: HAAS VF-2, Mill turning machine. Figure taken from Haas website.

For doing it, the stock will be from the steel AISI 1213 because it is a really good steel for being mechanized and its dimensions are X:120mm; Y:150mm; Z:120mm. (fig.4.2.a)

The operation will be divided in 5 steps.

1. In this step, the three holes of one side will be done as shown in the figure (4.2.b) and figure (4.2.c)

The tool used for this operation is ISO 870-1700-17L20-3 (fig.4.3) and ISO 870-1700-17-PM 4334 (fig.4.4) for the two holes of diameter 17 and ISO 870-2300-23L25-8 (fig.4.5) and ISO 870-2300-23-PM 4334 (fig.4.6) for the hole of diameter 23.

2. The second step is basically the same as the previous one but in the opposite face of the part. After that, all the holes would be done.

The tools are the same than the step one.

3. Now it is time to do the pocket which let us connect this part to the base. In the figure (4.2.d) is shown the toolpath that the tool will follow.

The tool for this operation is ISO 490-050A32-14L (fig. 4.7)

4. The fourth step is design for mechanizing the shape of the triangle (fig.4.2.e). For this step and for the next one is necessary to create a rectangular prism that will be placed inside the pocket made in the third step, this helps the part not be bended while is being fixed in the machine.

The tool for this operation and also for the next one is ISO 2P370-1905-PB 1740 (fig.4.9)

5. In the fifth and last step, the space where the lever will be placed is created as shown in the figure (4.2.f) and figure (4.2.g).

In this step two tools are used, one is the same one than in the fourth step and the other one is a shoulder mill (ISO R390-040B32-17H, figure 56 and ISO R390-17 04 16M-PH 4330, figure 4.11)

After all the previous steps the part will be ready to work.

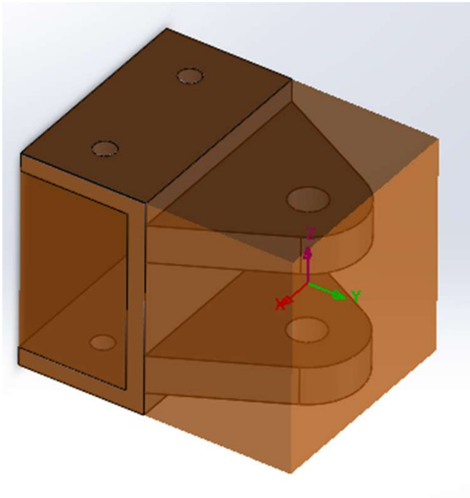


Figure 4.2.a: Initial stock

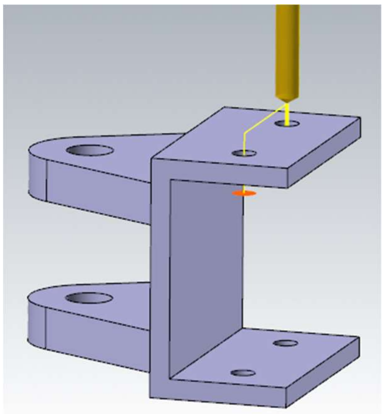


Figure 4.2.b: Drill of diameter 17 of the first step. Figure obtained in MasterCam software

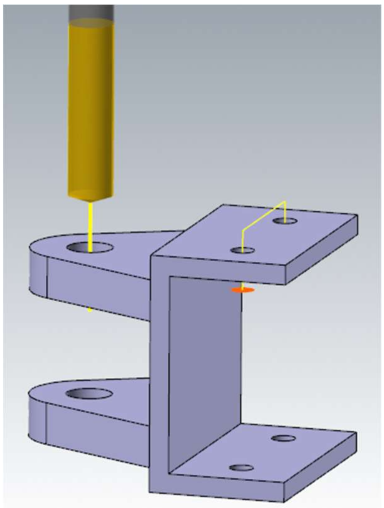


Figure 4.2.c: Drill of diameter 23 of the first step. Figure obtained in MasterCam software

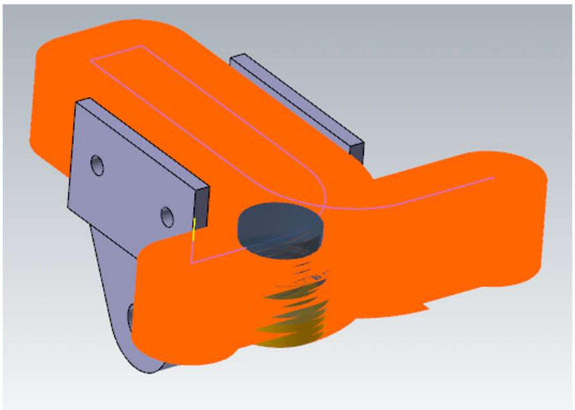


Figure 4.2.d: Toolpath of the third step. Figure obtained in MasterCam software

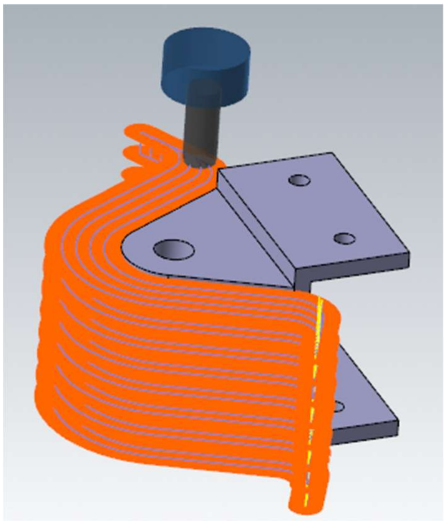


Figure 4.2.e: Toolpath of the fourth step. Figure obtained in MasterCam software

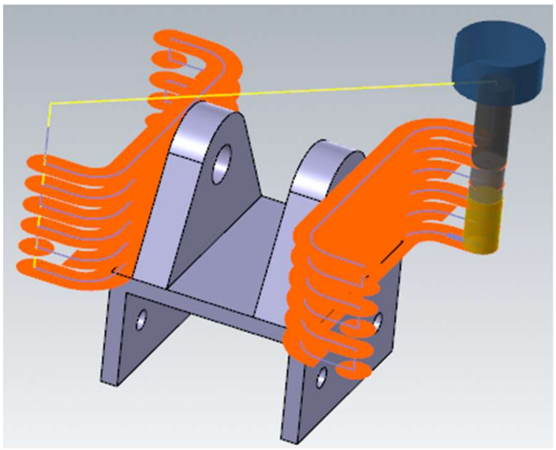


Figure 4.2.f: Flat end mill toolpath of the fifth step. Figure obtained in MasterCam software

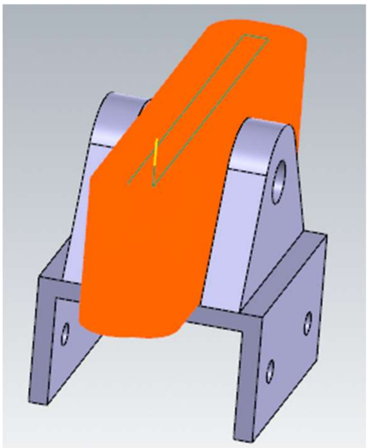
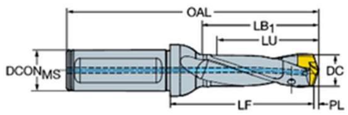


Figure 4.2.g: Shoulder mill toolpath of the fifth step. Figure obtained in MasterCam software

Table 4.3: Data of machining process

Manufacturing sheet									
Part name:	Lever support			Machine:		HAAS VF-2			
Part material:	AISI/SAE 1213			n max =		8100 rpm			
Stock:	120x118x150			P max =		22.4 kW			
Clamping device:	Parallel jaw for milling machine			T max =		122 Nm			
Nr.	**1**			**Operation: Drilling diam17**					
T1	Insert:	870-1700-17-PM 4334							
	Tool:	870-1700-17L20-3							
Pos 1	Vc	Fn	n	Vf	PPC	MMC	FFF	Depth	t
	(m/min)	(mm)	(rpm)	(mm/min)	(kW)	(Nm)	(N)	(mm)	(s)
	143	0.328	2680	877	11	39.1	3630	50	11.4
Nr.	**2**			**Operation: Drilling diam23**					
T2	Insert:	870-2300-23-PM 4334							
	Tool:	870-2300-23L25-3							
Pos 1	Vc	Fn	n	Vf	PPC	MMC	FFF	Depth	t
	(m/min)	(mm)	(rpm)	(mm/min)	(kW)	(Nm)	(N)	(mm)	(s)
	143	0.328	1980	648	14.8	71.6	4900	50	5.3
Nr.	**3**			**Operation: Drilling diam17**					
T1	Insert:	870-1700-17-PM 4334							
	Tool:	870-1700-17L20-3							
Pos 2	Vc	Fn	n	Vf	PPC	MMC	FFF	Depth	t
	(m/min)	(mm)	(rpm)	(mm/min)	(kW)	(Nm)	(N)	(mm)	(s)
	143	0.328	2680	877	11	39.1	3630	50	11.4

Nr.	**4**	**Operation: Drilling diam23**									
T2	Insert:	870-2300-23-PM 4334									
	Tool:	870-2300-23L25-3									
Pos 2	Vc	Fn	n	Vf	PPC	MMC	FFF	Depth	t		
	(m/min)	(mm)	(rpm)	(mm/min)	(kW)	(Nm)	(N)	(mm)	(s)		
	143	0.328	1980	648	14.8	71.6	4900	50	5.3		
Nr.	**5**	**Operation: Slot width 100**									
T3	Insert:	490R-140408M-PH 4330									
	Tool:	490-050A32-14M									
Pos 3	Vc	Fz	n	Vfm	Ae	Ap	NOPAE	NOPAP	QQ	PPC	t
	(m/min)	(mm)	(rpm)	(mm/min)	(mm)	(mm)	Nº. Pas. Ae dir.	Nº. Pas. Ap dir.	(cm3/min)	(kw)	(s)
	393	0.17	2500	1710	33.33	8.57	3	7	487	21.2	211
Nr.	**6**	**Operation: Triangular contour**									
T4											
	Tool:	2P370-1905-PB 1740									
Pos 4	Vc	Fz	n	Vfm	Ae	Ap	NOPAE	NOPAP	QQ	PPC	t
	(m/min)	(mm)	(rpm)	(mm/min)	(mm)	(mm)	Nº. Pas. Ae dir.	Nº. Pas. Ap dir.	(cm3/min)	(kw)	(s)
	423	0.13	5395	2870	8	15	4	8	396	19.4	274
Nr.	**7**	**Operation: Lateral contour 1**									
T4											
	Tool:	2P370-1905-PB 1740									
Pos 5	Vc	Fz	n	Vfm	Ae	Ap	NOPAE	NOPAP	QQ	PPC	t
	(m/min)	(mm)	(rpm)	(mm/min)	(mm)	(mm)	Nº. Pas. Ae dir.	Nº. Pas. Ap dir.	(cm3/min)	(kw)	(s)
	421	0.12	5100	1000	11.5	15	1	6	69.58	20.3	41
Nr.	**8**	**Operation: Lateral contour 2**									
T4											
	Tool:	2P370-1905-PB 1740									
Pos 5	Vc	Fz	n	Vfm	Ae	Ap	NOPAE	NOPAP	QQ	PPC	t
	(m/min)	(mm)	(rpm)	(mm/min)	(mm)	(mm)	Nº. Pas. Ae dir.	Nº. Pas. Ap dir.	(cm3/min)	(kw)	(s)
	421	0.12	5100	1000	11.5	15	1	6	69.58	20.3	41
Nr.	**9**	**Operation: Middle slot width 53**									
T5	Insert:	R390-17 04 16M-PH 4340									
	Tool:	R390-040B32-17H									
Pos 5	Vc	Fz	n	Vfm	Ae	Ap	NOPAE	NOPAP	QQ	PPC	t
	(m/min)	(mm)	(rpm)	(mm/min)	(mm)	(mm)	Nº. Pas. Ae dir.	Nº. Pas. Ap dir.	(cm3/min)	(kw)	(s)
	301	0.2	2400	1440	26.5	13.33	2	6	509	20.8	437

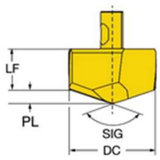


Generic representation

Datos del producto

Diámetro mínimo de corte (DCN) **17 mm**	Diámetro máximo de corte (DCX) **17,99 mm**
Parte 2 de identificadores de acoplamiento de elemento de corte (CUTINTMASTER) **CoroDrill 870-1790-17-PM**	Tolerancia de agujero alcanzable (TCHA) **H9**
Longitud utilizable (LU) **56,71 mm**	Relación de diámetro de longitud utilizable (ULDR) **3,168**
Dirección de la máquina en acoplamiento adaptador (ADINTMS) **Cylindrical shank (ISO9766 drill shank) -metric: 20**	Código de modelo de entrada de refrigerante (CNSC) **1: axial concentric entry**
Presión de refrigerante (CP) **10 bar**	Diámetro de conexión (DCON) **20 mm**
Longitud de punta (PL) **2,73 mm**	Longitud total (OAL) **126 mm**
Longitud funcional (LF1) **73,27 mm**	Longitud del cuerpo (LB1) **59 mm**
Velocidad de giro máxima (RPMX) **30000 1/min**	Peso del elemento (WT) **0,201 kg**
Sensor embedded property (SEP) **0**	Par (TQ) **1,2 Nm**
Estado de ciclo de vida (LCS) **A la venta**	ID de paquete de emisión (RELEASEPACK) **12.1**

Figure 4.3: ISO 870-1700-17L20-3. Figure taken from Sandvik coroplus website



Generic representation

Datos del producto

Clasificación de material, nivel 1 (TMC1ISO) P M K N S	Tamaño y forma de plaquita (CUTINTSIZESHAPE) **CoroDrill 870 -size 17**
Número de filos (CEDC) **1**	Diámetro de corte (DC) **17 mm**
Tolerancia de agujero alcanzable (TCHA) **H9**	Ángulo de punta (SIG) **142 deg**
Mano (HAND) **R**	Calidad (GRADE) **4334**
Sustrato (SUBSTRATE) **HC**	Recubrimiento (COATING) **PVD TIALN**
Longitud de punta (PL) **2,58 mm**	Rectificaciones máximas (NORGMX) **0**
Longitud funcional (LF) **8,02 mm**	Peso del elemento (WT) **0,011 kg**
Sensor embedded property (SEP) **0**	Estado de ciclo de vida (LCS) **A la venta**
ID de paquete de emisión (RELEASEPACK) **18.2**	

Valores iniciales

P — fn **0.33 mm/r(0.2-0.48)** vc **110 m/min(140-80)**	N — fn **0.35 mm/r(0.26-0.45)** vc **210 m/min(250-160)**

Figure 4.4: ISO 870-1700-17-PM 4334. Figure taken from Sandvik coroplus website

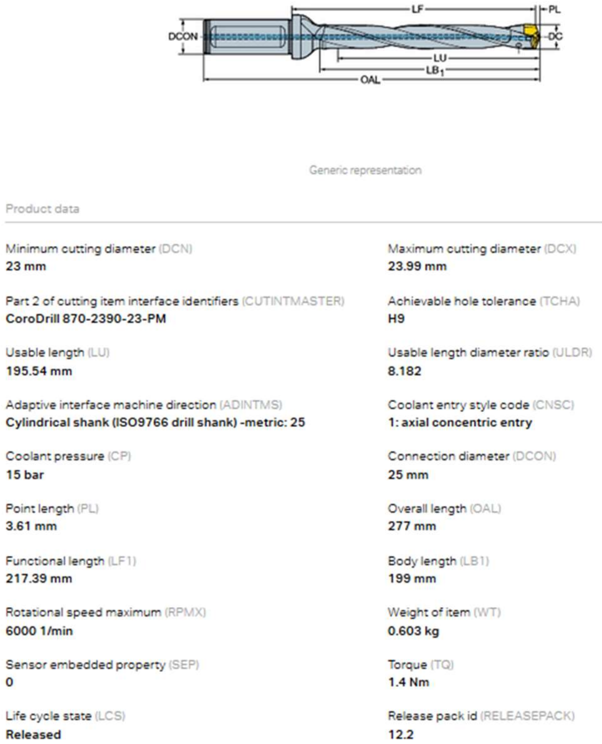


Figure 4.5: ISO 870-2300-23L25-8. Figure taken from Sandvik coroplus website

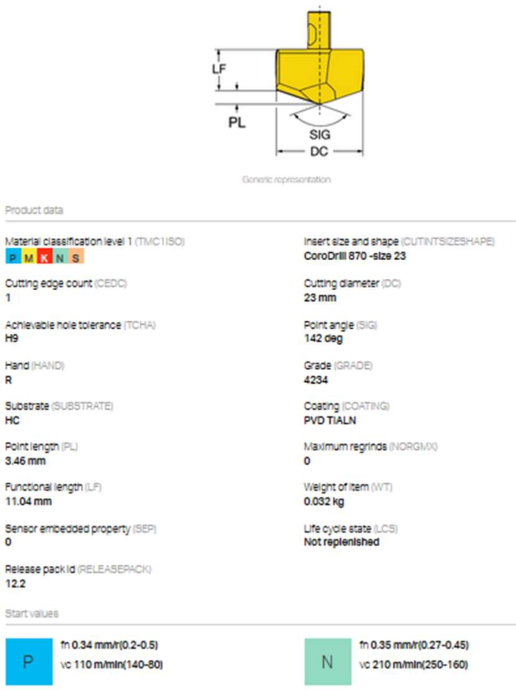
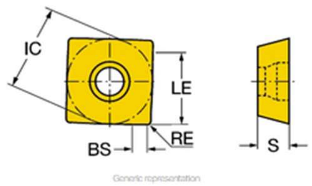


Figure 4.6: ISO 870-2300-23-PM 4334. Figure taken from Sandvik coroplus website

Product data

Cutting diameter (DC) **50 mm**	Cutting item count (CICTTOT) **3**
Cutting item count (CICT) **3**	Part 2 of cutting item interface identifiers (CUTINTMASTER) **CoroMill 490 -size 14 (490R-1404..)**
Depth of cut maximum (APMXPFW) **10 mm**	Centre cutting capability (CCC) **false**
Depth of cut maximum (APMXFFW) **10 mm**	Maximum ramping angle (RMPXFFW) **0 deg**
Maximum plunge depth (AZ) **0 mm**	Cutting pitch differential (CPDF) **true**
Peripheral effective cutting edge count (ZEFP) **3**	Adaptive interface machine direction (ADINTMS) **Cylindrical shank without clamping features -metric: 32.0**
Hand (HAND) **R**	Damping property (DPC) **false**
Coolant entry style code (CNSC) **1: axial concentric entry**	Coolant pressure (CP) **10 bar**
Connection diameter (DCON) **32 mm**	Functional length (LF) **120 mm**
Torque (TQ) **3 Nm**	Body material code (BMC) **Steel**
Rotational speed maximum (RPMX) **13700 1/min**	Weight of item (WT) **0.834 kg**
Sensor embedded property (SEP) **0**	Life cycle state (LCS) **Released**
Release pack id (RELEASEPACK) **10.1**	

Figure 4.7: ISO 490-050A32-14L. Figure taken from Sandvik coroplus website



Datos del producto

Clasificación de material, nivel 1 (TMC1ISO) **P K**	Tamaño y forma de plaquita (CUTINTSIZESHAPE) **CoroMill 490 -1404**
Número de filos (CEDC) **4**	Diámetro de círculo inscrito (IC) **13,8 mm**
Código de forma de plaquita (SC) **S**	Longitud efectiva del filo (LE) **10,3 mm**
Longitud filo Wiper (BS) **2 mm**	Radio de punta (RE) **0.8 mm**
Ángulo de filo principal (KRINS) **90 deg**	Mano (HAND) **R**
Calidad (GRADE) **4330**	Sustrato (SUBSTRATE) **HC**
Recubrimiento (COATING) **CVD TICN+AL2O3+TIN**	Grosor de plaquita (S) **3,9 mm**
Peso del elemento (WT) **0,008 kg**	Profundidad de corte máxima (APMX) **10 mm**
Sensor embedded property (SEP) **0**	Estado de ciclo de vida (LCS) **A la venta**
ID de paquete de emisión (RELEASEPACK) **18.2**	

Valores iniciales

Figure 4.8: ISO 490R-140408M-PH 4330. Figure taken from Sandvik coroplus website

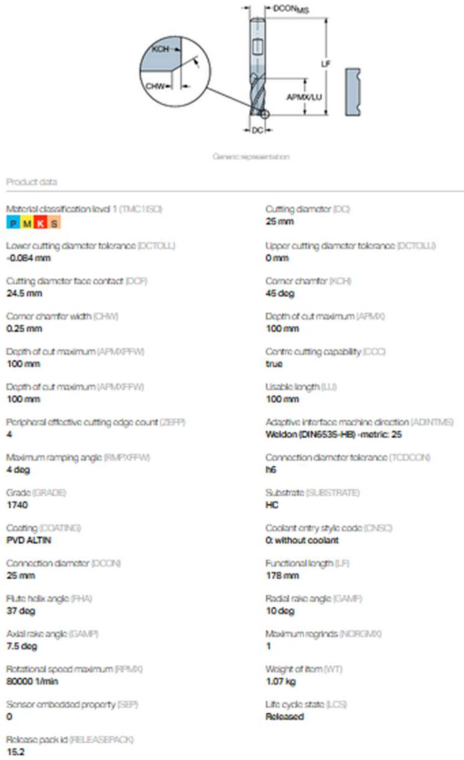


Figure 4.9: ISO 2P370-1905-PB 1740. Figure taken from Sandvik coroplus website

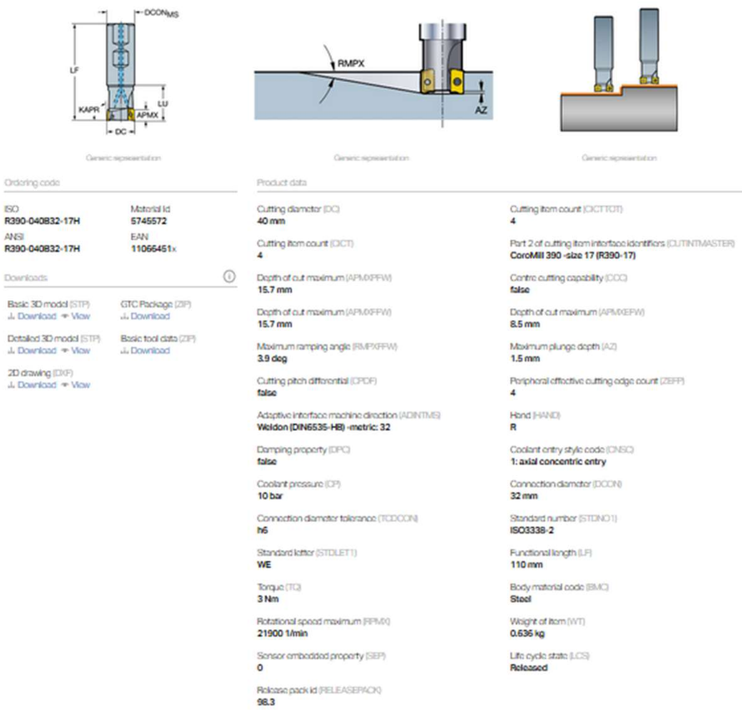


Figure 4.10: ISO R390-040B32-17H. Figure taken from Sandvik coroplus website

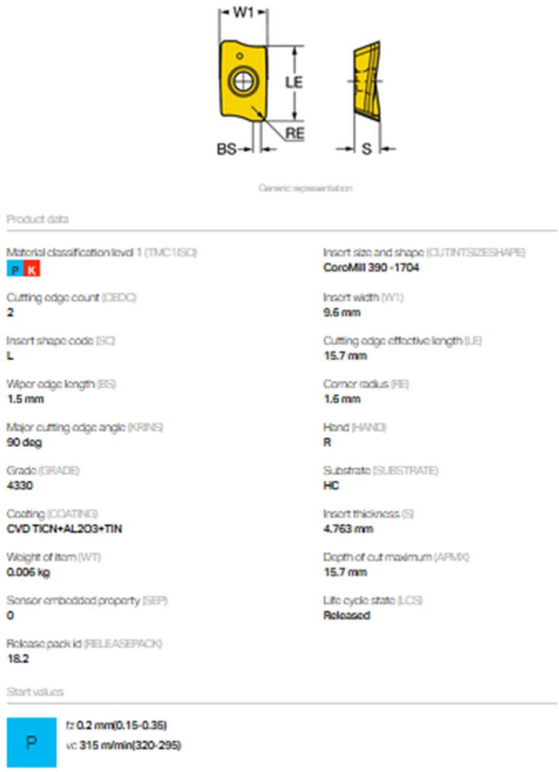


Figure 4.11: ISO R390-17 04 16M-PH 4330. Figure taken from Sandvik coroplus website

All the figures of the tools have been taken from the website of sandvik (sandvik coroplus toolguide).

5 SAFETY AND ENVIRONMENTAL REQUIREMENTS

5.1 SAFETY REQUIREMENTS

• **Use:**

How to use the weightlifting bench is very easy. It is similar to a normal one so everyone who has already tried a normal one will know how to do it, the main difference is how to activate the mechanism.

The machine is suitable for everyone whose height is bigger than 1.30 metres and has enough strength on the legs to push the lever. The strength needed (already calculated) is F_A=152.49N=15.54kg. This strength is the one needed when over the bench there are 800kg but usually the strength needed would be much lower so most of the people would be able to activate the mechanism.

The mechanism is activate with the lever, the necessary strength is small enough for anyone to easily activate the mechanism. While the lever is pushing, the bench start the small elevation until it reach the top because while it is using the lower legs made an angle of 5 degrees with the vertical. Once the bench reach the top, it is not necessary to continue pushing because the equilibrium point have been passed. At this moment, the barbell will rest in the lateral structure of the weightlifting bench while the bench will continue descending until the person has enough space to get rid of the barbell.

The exercise can only be developed when the bench is up as it is not designed to be performed in its lower position and this could damage the machine and disable it.

• **Space needed next to the machine:**

When the machine is being used, make certain that no one is next to the lever because it could be dangerous to be hit with the end of it because of the velocity it has while descending.

• **Maximum weight:**

The design allows 800kg over the bench (person weight plus barbell weight).

5.2 ENVIRONMENTAL REQUIREMENTS

• **Manufacturing:**

The manufacturing should be done as close as possible to the place it will be placed to decrease the distance of transportation and avoiding the pollution generated by the vehicles.

• **Dismantling, demolition and disposal:**

When the weightlifting bench is broken and can not be repaired or no longer be used, it has to be scrapped in an appropriate manner.

6 ECONOMICAL OVERVIEW

6.1 PROJECT COST CALCULATION

In this section it is calculated the cost of producing one unit of the product purpose of this project, including the design of it and also manufacturing and construction.

Table 6.1: Standard parts cost

Nr.	Item	Standard	Note	Q.	Price (Eur.)	Sum (Eur.)
1	Hexagon head bolt M16x2x140 steel grade A	ISO 4014		2	3.10	6.20
2	Hexagon head bolt M16x2x120 steel grade A	ISO 4014		8	3.10	24.80
3	Hexagon head bolt M10x1.5x45 steel grade A	ISO 4014		6	3.00	18.00
4	Hexagon nut M16x14.1 steel grade A	ISO 4032		10	0.30	3.00
5	Hexagon nut M10x8.4	ISO 4032		6	0.30	1.80
6	Plain washer M16 steel grade A normal series	ISO 7089		10	0.15	1.50
7	Plain washer M10 steel grade A normal series	ISO 7089		6	0.15	0.90
8	Retaining Ring 20x1.2	DIN 471		25	1.75	43.75
					Sum:	99.95

Table 6.2: Catalogue parts cost

Nr.	Item	Material	Note	Q.	Price (Eur.)	Sum (Eur.)
1	PUR Puffer WCB-080-080			1	33.00	34.60
2	Plastic bushing flaged ASTEPBF 2023-21-5	Plastic		60	0.45	27.00
					Sum:	61.60

Table 6.3: Stock parts cost

Nr.	Item	Material	Note	Q.	Price (Eur.)	Sum (Eur.)
1	Cold forming profile	Steel AISI 304 Norm.	Section 120x60.4 mm	1.56 m	17 Eur/m	26.52
2	Cold forming profile	Steel AISI 304 Norm.	Section 100x60.4 mm	4.94 m	15 Eur/m	74.10
3	Cold forming profile	Steel AISI 304 Norm.	Section 80.4 mm	6.2 m	11 Eur/m	68.20
4	Cold forming profile	Steel AISI 304 Norm.	Section 40.2 mm	3.67 m	7 Eur/m	25.69
5	Rectangular rod	Steel AISI 1213 Norm.	Section 120x120 mm	1.10 m	6.5 Eur/m	7.15
6	Rectangular rod	Steel AISI 1213 Norm.	Section 70x150 mm	0.25 m	6.00 Eur/m	1.5
7	Bar	Steel AISI 304 Norm.	$\phi 20$	1.87 m	11.37 Eur./m	21.30
8	Bar	Steel AISI 304 Norm.	$\phi 25$	0.54 m	15.93 Eur./m	8.60
9	Bar	Steel AISI 304 Norm.	$\phi 40$	0.94 m	39.89 Eur./m	37.50
10	Plate	Steel 1213	t=10mm	0.43 m^2	15 Eur/m^2	6.45
11	Mattress	EVA Padding	1.22 m x 0.34 m x 0.05 m	1	35	35
12	Bar	Steel AISI 1213 Norm.	$\phi 60$	0.10 m	85.32 Eur./m	8.53
					Sum:	320.54

The cost of all the supplies is 482.09 Eur.
The price os transportation is approximately 10% of the price of the supplies. (eq.6.1)

$$P_T = P_S \cdot 0.1 = 48.21 Eur. \tag{6.1}$$

- P_T → Price of transportation.
- P_S → Price of supplies.

The total cost of supplies is the sum of transportation cost and supplies cost. (eq.6.2)

$$C_s = P_S + P_T = 530.30 Eur. \tag{6.2}$$

- C_s →Total cost of supplies.

The equipment required to manufacture is going to be hired for two weeks. The tools and consumables which are purchased are not hired for just two weeks. The approximate cost in two weeks of the equipment are in table (6.4).

$$D_t = \frac{P_t}{2year \ \cdot 12\frac{mon}{year}} = \frac{250}{2years \cdot 12\frac{mont}{year}} = 10.42Eur \tag{6.3}$$

- D_t → Depreciation cost
- P_t → Purchased cost

Table 6.4: Equipment

Nr.	Equipment hiring (including transportation)	Price (Eur./year)
1	CNC machining center: HAAS VF-2	800.00
2	Water jet cutting center: ESAB Hydrocut LX 400029	1500.00
3	Welding center: ESAB Railtrac 1000	500.00
4	Inspection tools and instruments	1000.00
	Equipment purchasing (including transportation)	
5	Tools and consumables	250.00
6	Tools depreciation	10.42
	Sum:	4060.42

The approximate prices of manufacturing tasks for the design are shown in the table (6.5). Painting is carried out by sub-contractors.

Table 6.5: Manufacturing tasks

Nr.	Task	Price (Eur.)
1	Milling	400
2	Water jet cutting	1500
3	Drilling	300
4	Painting	150
	Sum:	2350

Consumables needed for the well performing are in the table (6.6).

Table 6.6: Consumables

Nr.	Item	Price (Eur.)
1	Cylinder lubricant	50
	Sum:	50

Construction works: For designing and assembling the entire structure a designer, an engineer, a technician, a miller and a welding technician. The cost of these professionals is in the table (6.7)

Table 6.7: Wages

Nr.	Function	Hourly wage (Eur.)	Daily working hours (h)	Monthly wages (Eur.)
1	Designer	24	8	1920
2	Constructor	16	8	1280
3	Manager	16	8	1280
4	Mill technician	10	8	800
5	Welding technician	13	8	1040
			Total:	6320
			Tax 24%:	1516.80
			Total:	7836.8

Preparation of the work place: Before start the manufacturing of a new product is needed to to prepare the workplace. This cost is shown in the table (6.8).

Table 6.8: Preparation of workplace costs

Nr.	Item	Price (Eur.)
1	Coordination costs	600
2	Workshop tuning	950
3	Machines tuning	80
4	Personal protective equipment	500
5	Unanticipated additional costs	2500
	Sum:	4630

The entire cost of the project consist of:

- Standard, catalogue and stock part prices (tab.6.1, tab.6.2 and tab.6.3)
- Equipment hiring costs (tab.6.4)
- Manufacturing tasks cost (tab.6.5)
- Consumables cost (tab.6.6)
- Wages (tab.6.7)
- Preparation of workplace cost (tab.6.8)

The total cost of the project is: (eq.6.4)

$$C = 530.30 + 4060.42 + 2350.00 + 50.00 + 7836.8 + 4630 = 19457.52 Eur. \quad (6.4)$$

• C→ Total cost of the project

The net profit of the project will be more or less the 20% of the total cost: (eq.6.5)

$$N = C \cdot 0.20 = 3891.51 Eur. \quad (6.5)$$

The market price of the product will be: (eq.6.6)

$$P = C + N = 23349.03 Eur. \quad (6.6)$$

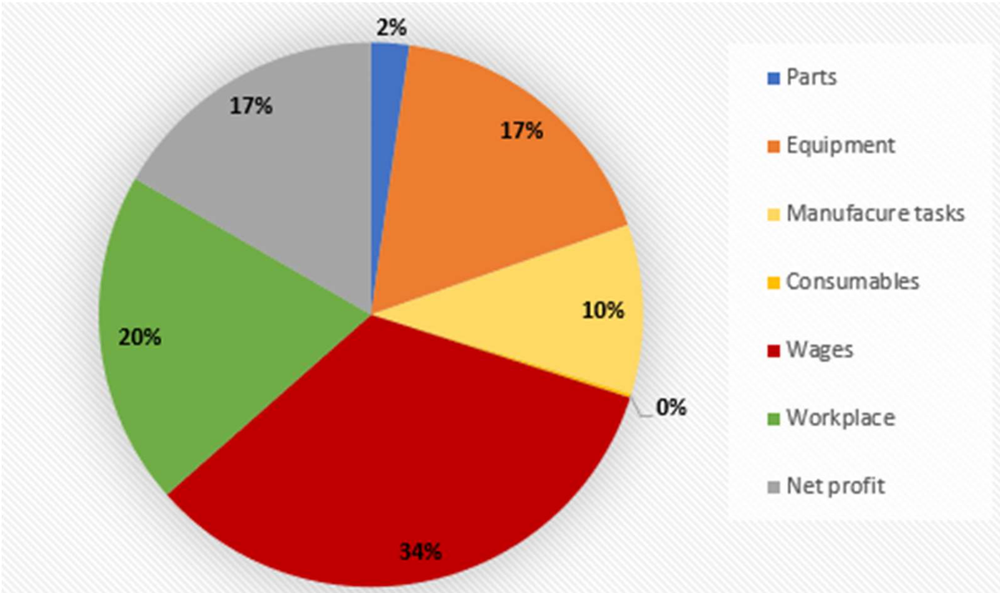


Figure 6.1: Manufacturing cost graphic

6.2 BREAK-EVEN POINT CALCULATION

To calculate break-even point, the equation (6.7) will be used.

$$Break-even\ Point = \frac{Fixedcostsperperiod}{Productprice-variablecost} \quad (6.7)$$

$$Break-even\ Point = \frac{4060.42+7836.80+46}{23349.03-(99.95+32\ \ .54+6\ \ .60+2350+50)} = 0.808 \quad (6.7)$$

In the period of time chosen (two weeks) less than 1 machine has to be produced which means that 21 devices has to be built in a year.

6.3 PAYBACK PERIOD

To calculate the payback period is necessary to do an estimation of the initial investment (machines needed, the place where the manufacturing will be done…)

Adding all the facts, the initial investment is around 90.000 euros.
Also is needed the earning before interest and taxes, calculated by the equation (6.8).

$$EBIT = Price - Variable\ costs - Fixed\ costs \quad (6.8)$$

$$EBIT = 23349.03 - (99.95 + 320.54 + 61.60 + 2350 + 50) - 4060.42 + 7836.80 + 4630 = 3939.72€/2weeks \quad (6.9)$$

The profit of the first year will be:

$$3939.72 \frac{€}{2\ weeks} \cdot 52 \frac{weeks}{year} = 102432.72 \frac{€}{year} \quad (6.10)$$

The payback period will be in the first year.

$$\frac{90000\ €}{102432.72\ €/year} = 0.88\ years = 10.54\ months \quad (6.10)$$

Figure 6.2: Graphic of the payback period

In one year the device start being worth which it is not a long period of time.

7 FINAL CONCLUSIONS

1. The idea of this project is improving the security of a common activity in every sport centre. It is not a high-risky activity but depending on the person who is developing it could be dangerous. That is why every improve in the field of safety is welcome.
2. There are similar ideas with the same goal than this one, the main difference with them is that the others need a pneumatic or hydraulic circuit, electric motor or other devices which can fail increasing the unexpected costs of the machine and also the accident risk.
3. This one only depends on the strength of the person who is developing the activity and this strength is not high (152.49N, 15.54kg) so the probability of failure is lower than the other patents.
4. The most risky parts were studied and the results showed that they are not going to break, the maximum stress is 14.13MPa. Some of the elastic displacements were also studied and they were very small, the displacements of the articulation between upper and lower legs are very small, the value of the vertical displacement is about 7.28nm and the horizontal one is 1.27µm so they are not a problem while the device is being used.
5. The shock absorber chosen is the one whose properties fits better to the requirements (velocity at the colision moment is 2m/s and the energy absorbed is 0.6kNm).
6. About the economic field, the price 23349€ is quite high even for a big gym but the prices could decrease doing a closer studio of the materials. For a particular person the price is high and depending how much the device will be used and how much he appreciates his own safety could be worth for him.

REFERENCES

Patents:

[1] Martin H Nielsen. “Stepped weightlifting bar”. CA 2088542. Aug. 2, 1994.
[2] Jr. Eston Bullard. “Chest exercise apparatus”. U.S. pat. 6010439. Jan. 4, 2000
[3] Matthew Klan. “Bench Press Safety Device”. AU 5668842. Oct. 27, 2017.
[4] Milnar James B. “Bench Press safety rest”. U.S. pat. 4411425. Oct. 25, 1983.
[5] Kevin Capizzo. “Self-spotting bench press apparatus for progressive lift distance training”. U.S. pat. 0114277. June 19, 2003.
[6] Karl A. Zimmer. “Weightlifting machine for safe free-bar bench press exercising”. U.S. pat. 4875676. July 18,1988.
[7] Wasim Andrews. “Weightlifting spotting device”. U.S. pat. 0072750. Mar. 29, 2007.

Textbooks:

[8] Jesus Félez, Mª Luisa Martinez. Ingeniería gráfica y diseño. Síntesis.
[9] Jose Antonio Garrido Garcia, Antonio María Foces Mediavilla. Resistencia de Materiales. 1ª Reimpresión. Universidad de Valladolid 1996, 530p.

Interactive, electronic publications, catalogues and manuals:

[10] Gorilla Sports, professional gym equipment for everyone. [seen 2020-04-05]. Access from internet. https://www.gorillasports.co.uk/weight-bench-adjustable-barbell-rack-white
[11] Telju fitness, catalogue of products shock line. Product 4SH070/0 PRESS BENCH. [seen 2020-04-05]. Access from internet. https://teljufitness.com/catalogo-telju/4sh070-0-press-bench/
[12] Deport trainer, catalogue of gym machines. Product BANCO PRESS DE BANCA PLANO PLATINUM RS-H5 12. [seen 2020-05-10]. Access from internet. https://www.deportrainer.com/pecho/653-banco-press-de-banca-plano-platinum-rs-h5-12.html
[13] ScSPORTS. Product Langhantelständer. [seen 2020-05-11]. Access from https://www.scsports.de/langhantelstaender-weiss.html
[14] Pro-gym. Catalogue of musculation machines. Product Multipower con Contrapesos - Smith Machine I Pro-Series. [seen 2020-05-10]. Access from internet. https://www.progym.es/mutlipower-de-discos-guiada-i-pro-series.html
[15] Haas cnc. Catalogue of vertical mill machines. Machine VF-2. [seen 2020-05-14]. Access from internet. https://www.haascnc.com/machines/vertical-mills/vf-series/models/small/vf-2.html
[16] Sandvick Coromant. CoroPlus Toolguide. [seen 2020-05-06]. Access from internet. https://www.sandvik.coromant.com/es-es/products/pages/toolguide.aspx

[17] Ingemecanica. Profile record. [seen 2020-05-07]. Access from internet. https://ingemecanica.com/tutoriales/prontuariodeperfiles.html#huecocuadrado

Software:

Working Model 2D. 2D Dynamic Motion Simulation. Design Simulation Technologies
Solidworks 2019 Students version. Dassault systems.
AutoCAD. Autodesk.
CoroGuide 2.0. Tools recommendation software. Sandvik Coromant
Mastercam 2020 Demo. Cam software.
TeXstudio. Free text editor.
Microsoft Word, Excel.

ANNEXES

CROSS SECTION PROPERTIES

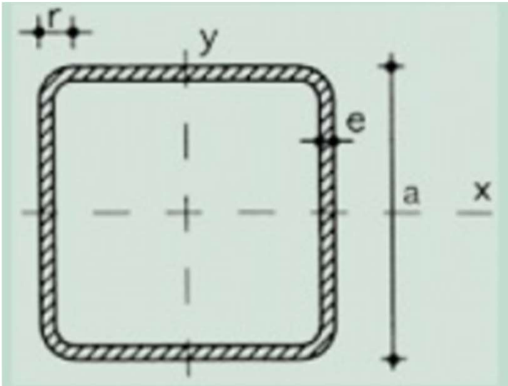


Figure 8.1: Square cross section

Table 8.1: Square sections. Data obtained from ingemecanica.com webpage

Section	Dimensions				Section terms						Weight
	a(mm)	e(mm)	r(mm)	u(mm)	A(cm^2)	S(cm^3)	I(cm^4)	W(cm^3)	i(cm)	I_t(cm^4)	p(kp/m)
#40.2	40	2	5	151	2.90	2.04	6.60	3.40	1.53	11.3	2.28
#80.4	80	4	10	303	11.60	16.30	108.80	27.20	3.06	180.0	9.11

- r → Radius of the corners.
- u → Perimeter.
- A → Section area.
- S → Static moment of half section, respect the axis X or Y.
- I → Inertia moment of the section, respect the axis X or Y.
- W=2l:d → Resistance modulus of the section, respect the axis X or Y.
- i=$\sqrt{I:A}$ → Radius of rotation of the section, respect the axis X or Y.
- I_t → Torsion modulus of the section.

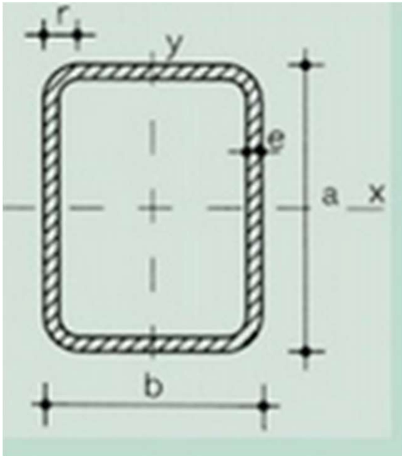


Figure 8.2: Rectangular cross section

Table 8.2: Rectangular sections. Data obtained from ingemecanica.com webpage

Section	Dimensions					Section terms										Weight	
	a (mm)	b (mm)	e (mm)	r (mm)	u (mm)	A (cm^2)	S_x (cm^3)	I_x (cm^4)	W_x (cm^3)	i_x (cm)	S_y (cm^3)	I_y (cm^4)	W_y (cm^3)	i_y (cm)	I_t (cm^4)	p(kp/m)
100x60.4	100	60	4	10	303	11.60	18.70	149.0	29.80	3.58	13.10	67.40	22.50	2.41	156.0	9.11
120x60.4	120	60	4	10	343	13.20	24.90	236.0	39.30	4.22	15.40	80.0	26.70	2.46	201.0	10.37

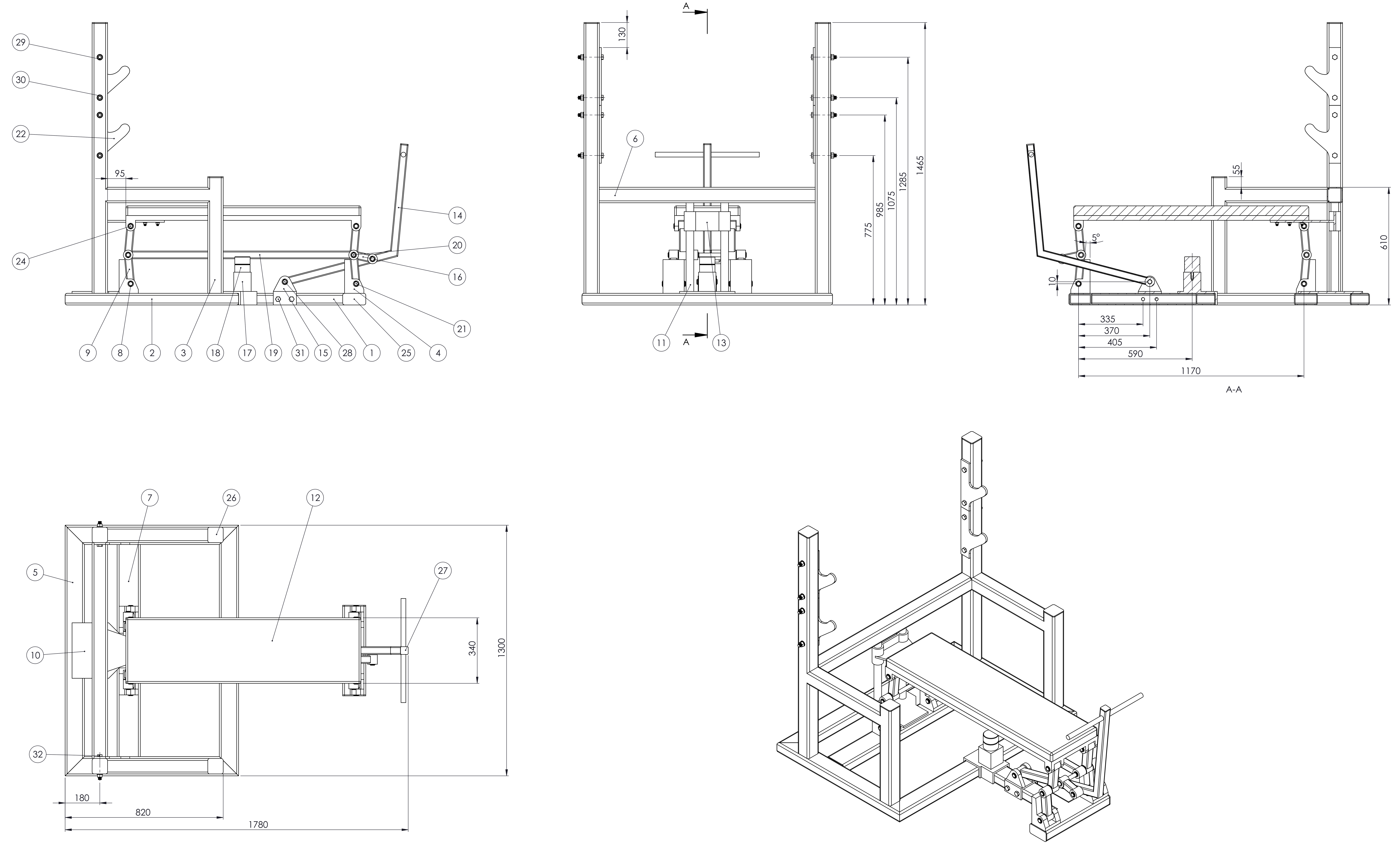
- r → Radius of the corners.
- u → Perimeter.
- A → Section area.
- S_x → Static moment of half section, respect the axis X.
- I_x → Inertia moment of the section, respect the axis X.
- W=2l $_x$:a → Resistance modulus of the section, respect the axis Y.
- $i_x=\sqrt{Ix:A}$ → Radius of rotation of the section, respect the axis X.
- S_y → Static moment of half section, respect the axis Y.
- I_y → Inertia moment of the section, respect the axis Y.
- W=2l $_y$:b → Resistance modulus of the section, respect the axis Y.
- $i_y=\sqrt{Iy:A}$ → Radius of rotation of the section, respect the axis Y.
- I_t → Torsion modulus of the section.

FORMAT	ZONE	POSITION	MARKING	NAME	STANDARD PARTS	QTY.	REMARK
				DOCUMENTATION			
A1			MBP20.60.01.02.001 AD	ASSEMBLY DRAWING			
				PARTS			
		1		Front part of the lower structure		1	
		2		Side part of the lower structure		2	
		3		Side part of the upper structure		2	
		4		Leg support		4	
		5		Back part of the lower structure		1	
		6		Back part of the upper structure		1	
		7		Bar of back supports		1	
		8		Plastic bushings FLAGED ASTEPBF_2023-21-5	X	60	
A4		9	MBP20.60.01.02.003	Leg		8	
A4		10	MBP20.60.01.02.006	Support of guides		1	
		11		Guides cylinders		2	
A4		12	MBP20.60.01.02.001	Bench		1	
A4		13	MBP20.60.01.02.002	Connection between bench and guides		1	
A4		14	MBP20.60.01.02.004	Lever		1	
A4		15	MBP20.60.01.02.007	Lever support		1	
		16		Connection lever-axis		1	
		17		Shock absorber support		1	
		18		PUR puffer	X	1	
		19		Connection between front and back axis		1	
A4		20	MBP20.60.01.02.005	Axis between legs		2	
		21		Axis leg-support		4	
		22		Barbell holder		4	
		23		Circlip for shafts normal_din471-10x1.2	X	25	
A4		24	MBP20.60.01.02.008	Axis bench-legs		4	
		25		cover 120x60		2	
		26		cover 80x80		4	
		27		cover 40x40		1	
		28		Axis of the lever		1	
		29		Hex nut style 1grade a_iso	X	10	
		30		Plain washer normal grade a_iso	X	10	
		31		hex bolt grade ab_iso	X	2	
		32		hex bolt grade ab_iso_120	X	8	
		33		hex bolt grade ab_isoM10-1	X	6	
		34		plain washer normal grade a_isoM10	X	6	
		35		hex nut style 1 gradeab_isoM10-1	X	6	
		36		mattress		1	

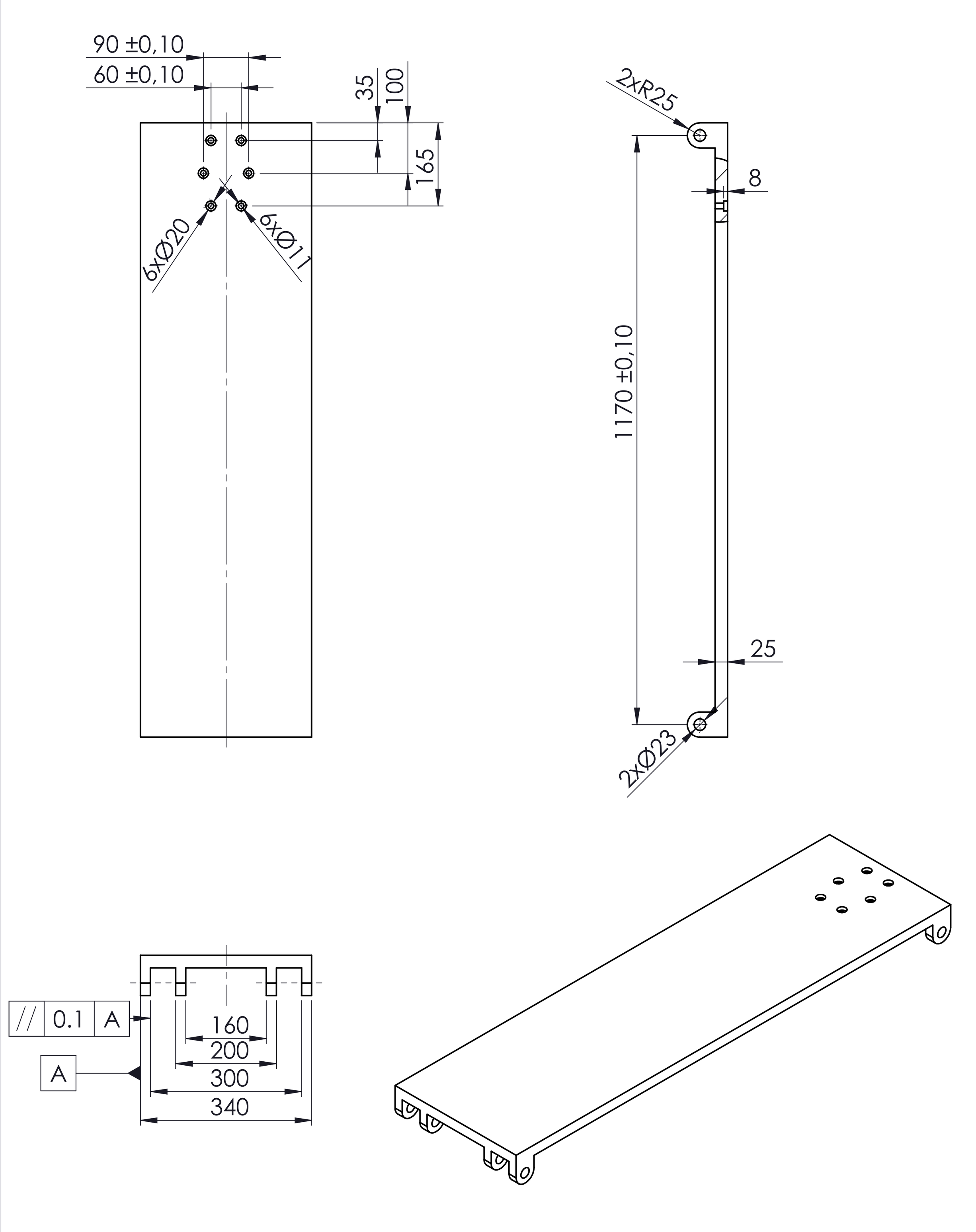
Case no.	Additional information	Material	Scale

Resp. department	Consultant	Document type	Status of the document
Dept. of Mech.		TABLE	Educational

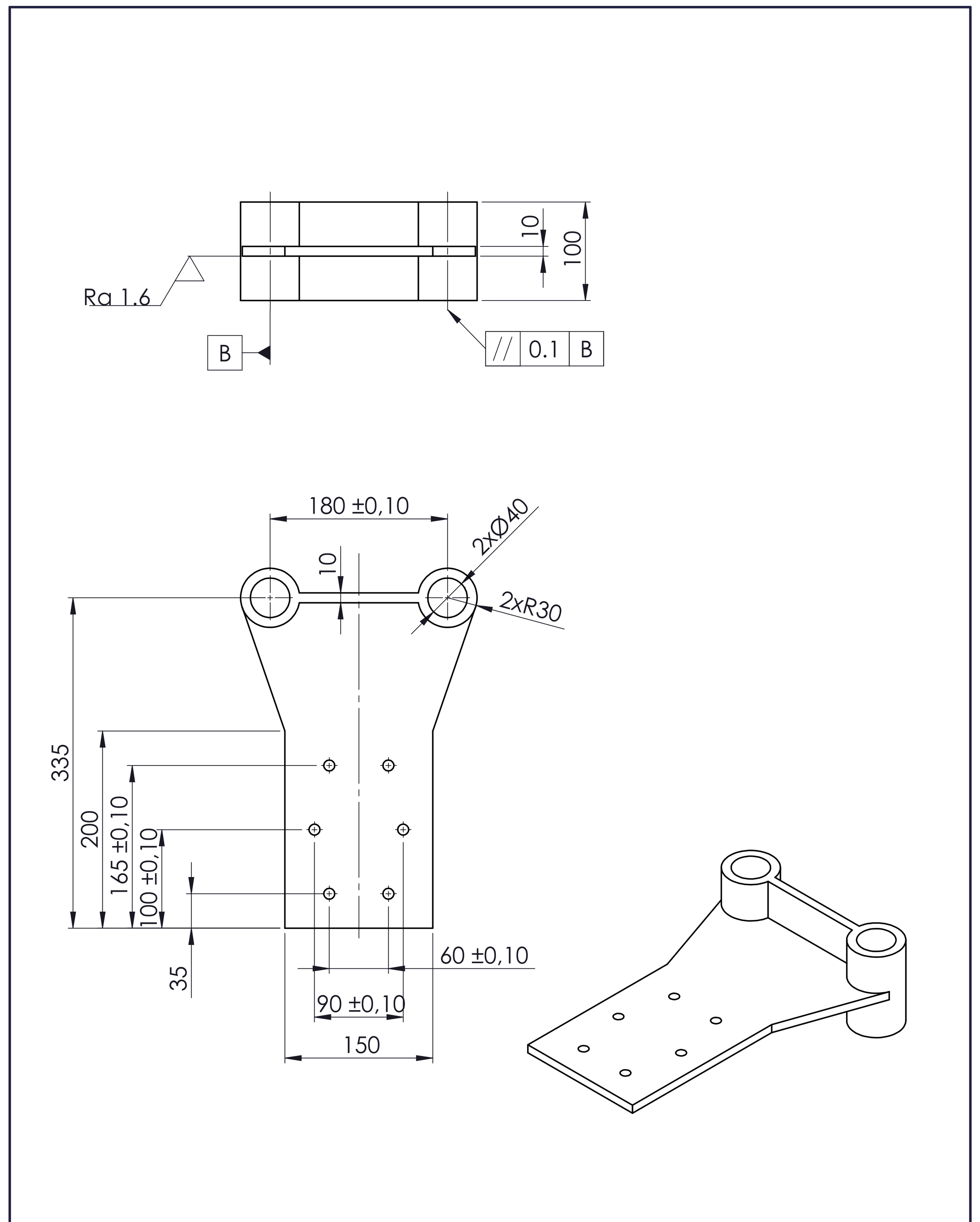
Owner	Compiled by	Title	Drawing nº
VGTU MPfuc-16	Rodrigo Castedo	Bill of materials	MPfuc
	Checked: Paulius Ragauskas		Release: A; Date: 15/05/2020; Lang.: en; Page:



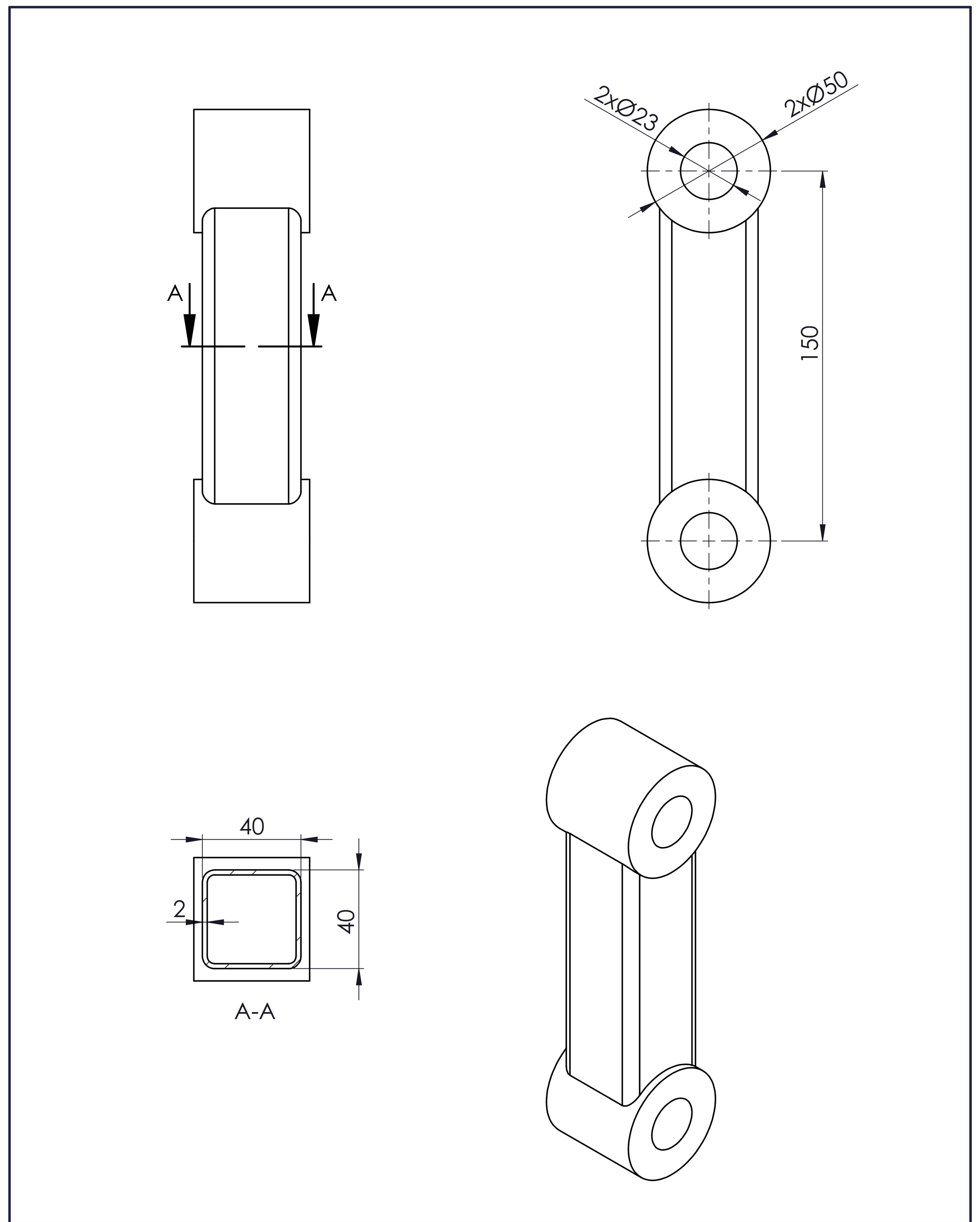
	Case No.	Additional Information	Material	Scale 1:10
Resp. Dep. Dprt. of Mech.	Consultant	Document type DRAWING		Document Status Educational
Owner VGTU MPfuc-16	Compiled by Rodrigo Castedo Checked Paulius Ragauskas	Title Assembly		Bookmark MBP 20.60.01.02.001 AD Relase A, Date 18/05/2020, Lang en, Page 2/12



Case no. | Additional information | Material: STEEL AISI 1213 | Scale: 1:10
Resp. department: Dept. of Mech | Consultant | Document type: DRAWING PART | Status of the document: Educational
Owner: VGTU MPfuc-16 | Compiled by: Rodrigo Castedo | Checked: Paulius Ragauskas | Title: Bench | Drawing nº: MBP20 60 01 02 001 | Release: A | Date: 15/05/2020 | Lang.: en | Page: 3/12



Case no. | Additional information | Material: STEEL AISI 304 | Scale: 1:5
Resp. department: Dprt. of Mech. | Consultant | Document type: DRAWING PART | Status of the document: Educational
Owner: VGTU MPfuc-16 | Compiled by: Rodrigo Castedo | Checked: Paulius Ragauskas | Title: Connection between bench and guides | Drawing nº: MBP 20 60 01 02 002 | Release: A | Date: 15/05/2020 | Lang.: en | Page: 4/12



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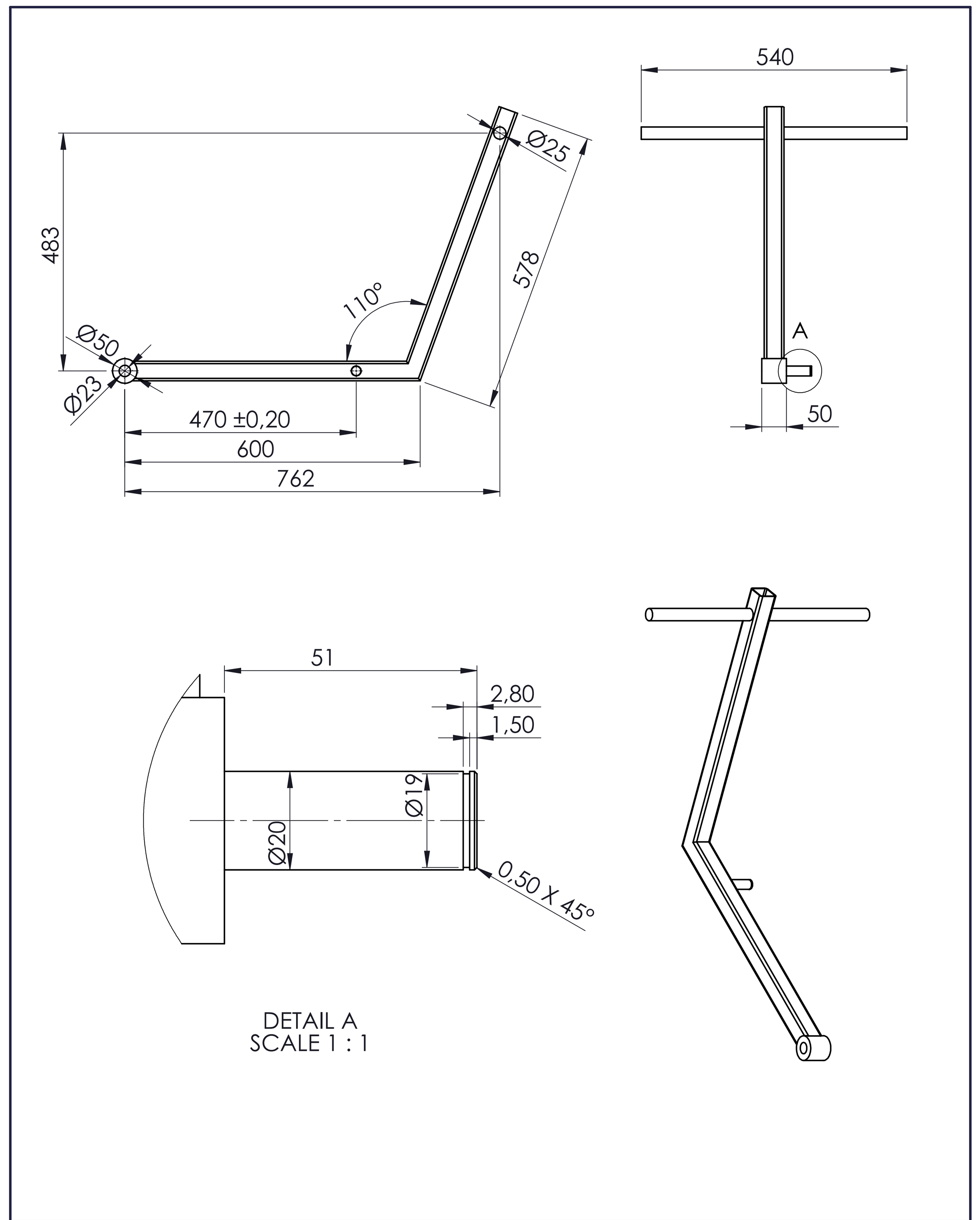
Resp. department: Dept. of Mech. | Consultant | Document type: DRAWING PART | Status of the document: Educational
Owner: VGTU MPfuc-16 | Compiled by: Rodrigo Castedo | Checked: Paulius Ragauskas | Title: Leg | Drawing nº: MBP 20 60 01 02 003 | Release: A | Date: 15/05/2020 | Lang.: en | Page: 5/12



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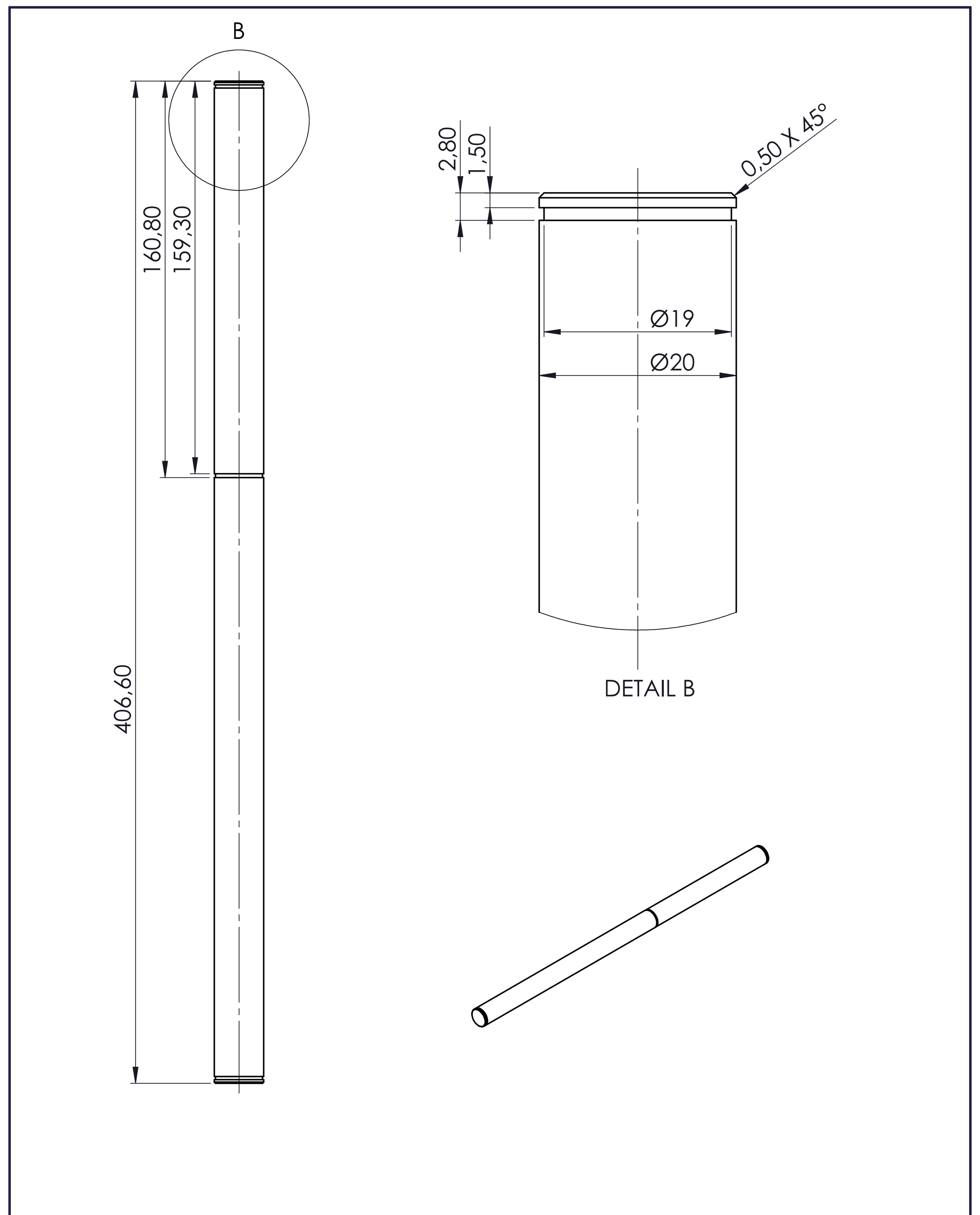
Resp. department: Dept. of Mech. | Consultant | Document type: DRAWING PART | Status of the document: Educational
Owner: VGTU MPfuc-16 | Compiled by: Rodrigo Castedo | Checked: Paulius Ragauskas | Title: Lever | Drawing nº: MBP 20 60 01 02 004 | Release: A | Date: 15/05/2020 | Lang.: en | Page: 6/12



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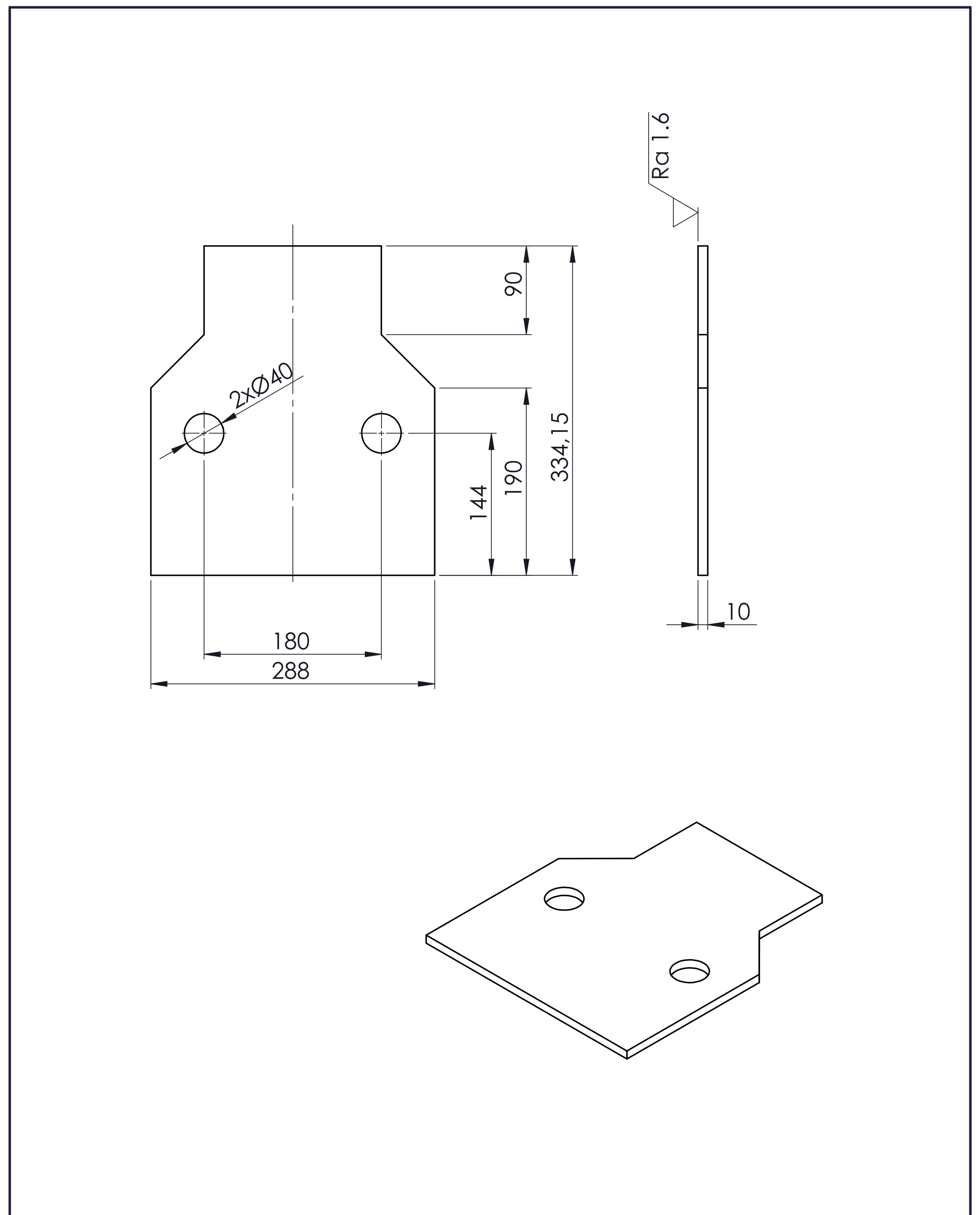
Resp. department: Dept. of Mech. | Consultant | Document type: DRAWING PART | Status of the document: Educational
Owner: VGTU MPfuc-16 | Compiled by: Rodrigo Castedo | Title: Long axis | Drawing nº: MBP 20 60 01 02 005



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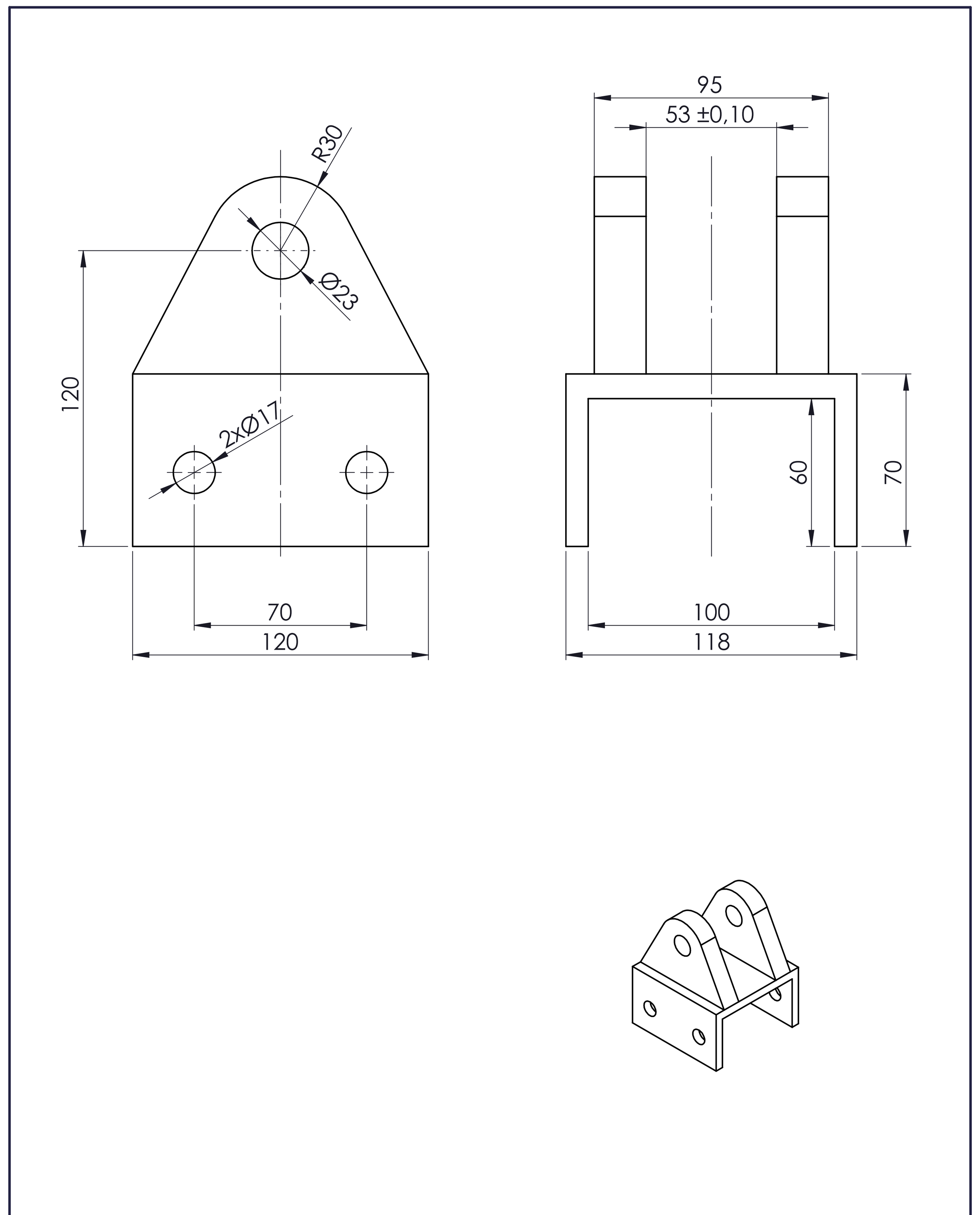
Resp. department: Dprt. of Mech. | Consultant | Document type: DRAWING PART | Status of the document: Educational
Owner: VGTU MPfuc-16 | Compiled by: Rodrigo Castedo | Title: Connection between bench and guides | Drawing nº: MBP 20 60 01 02 006 | Release: A | Lang.: en | Page: 8/12



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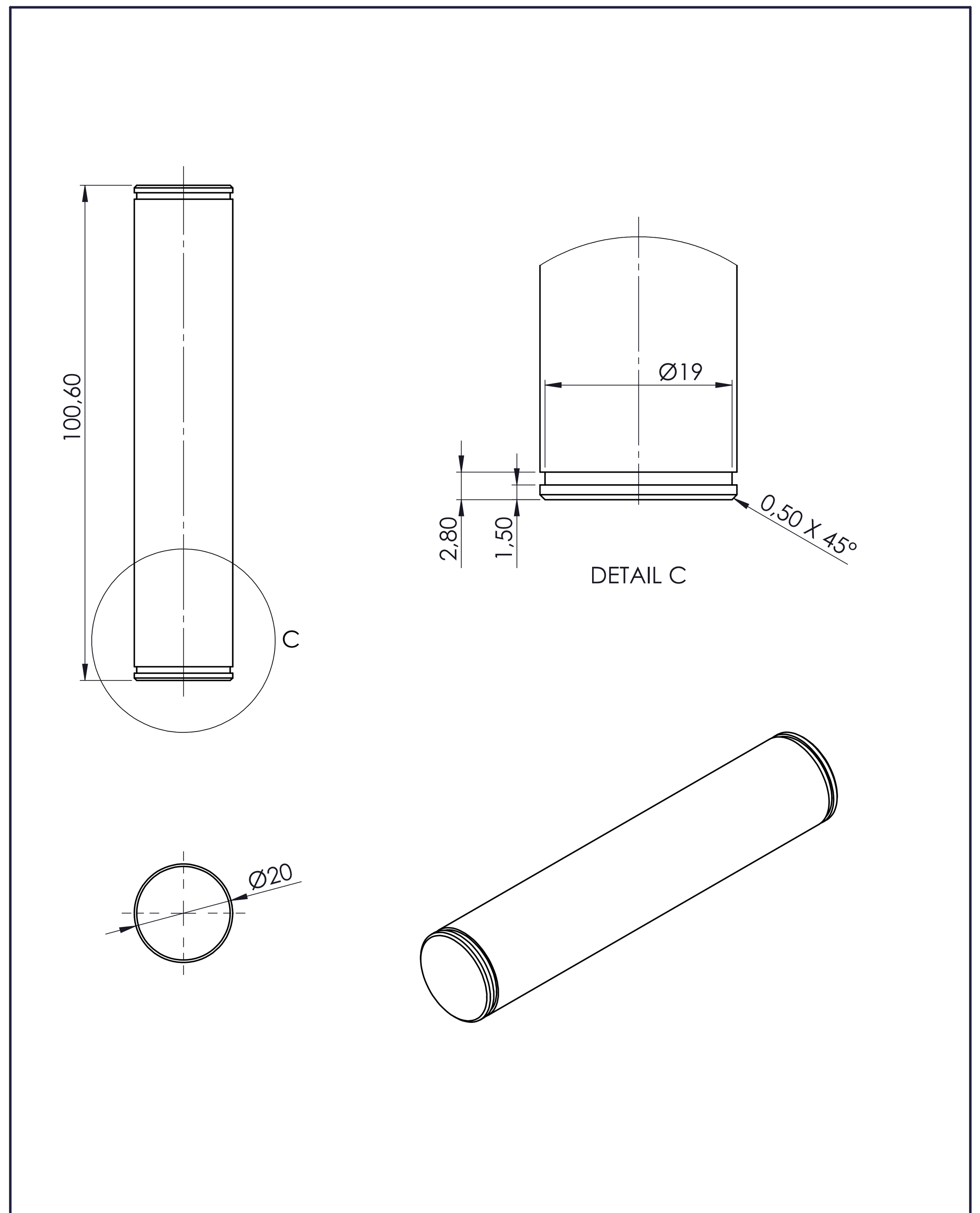

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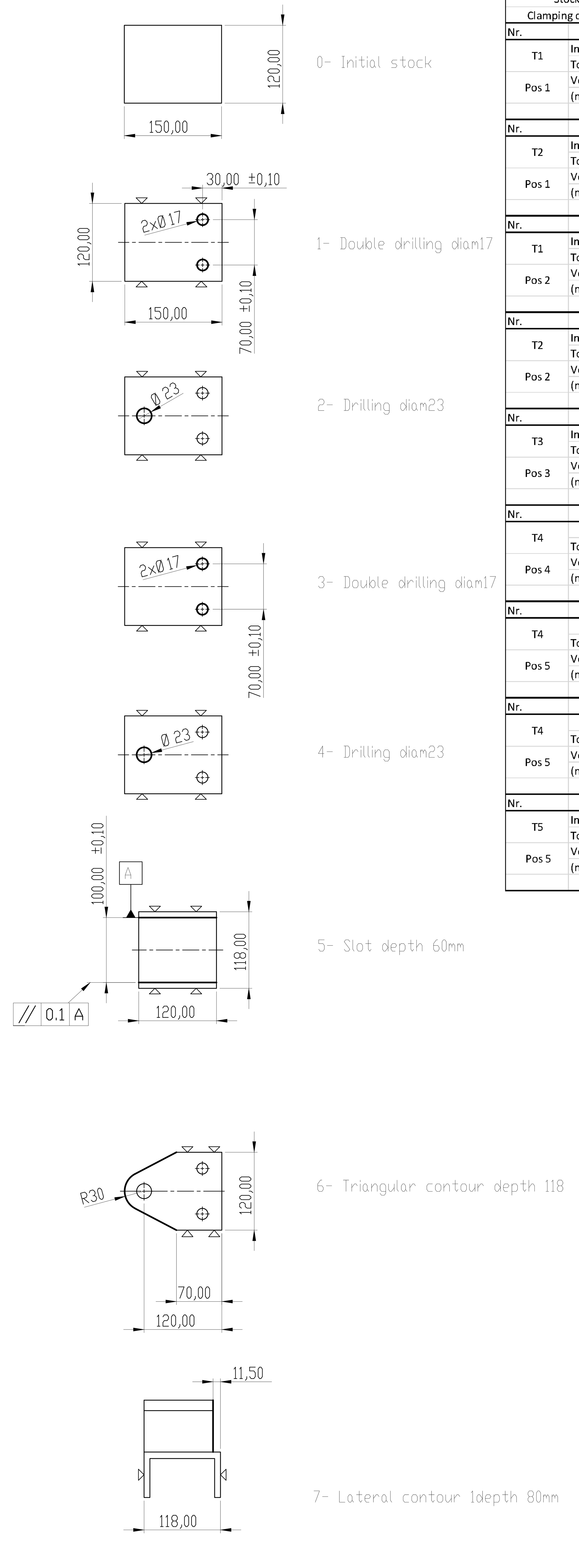
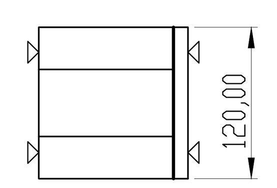
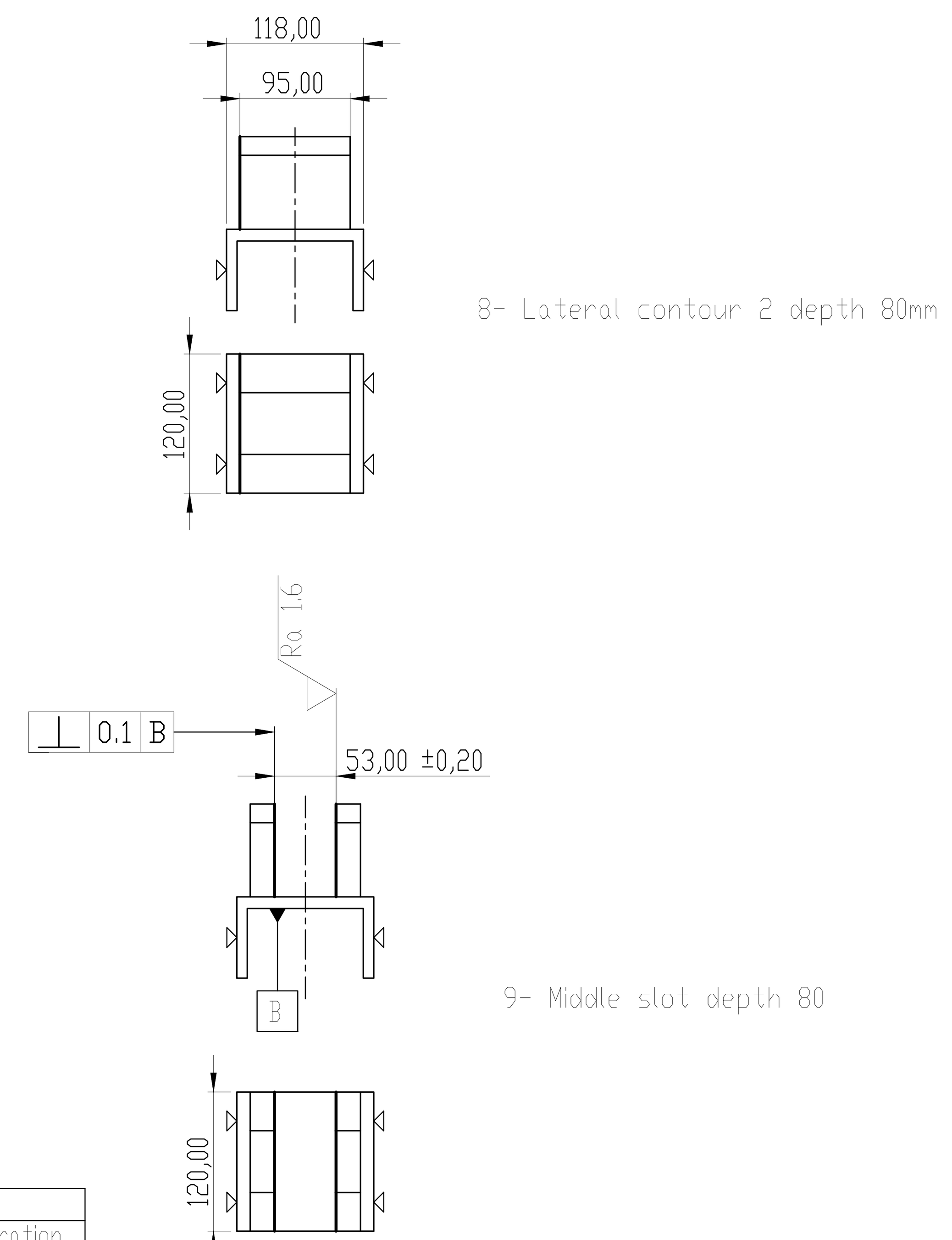


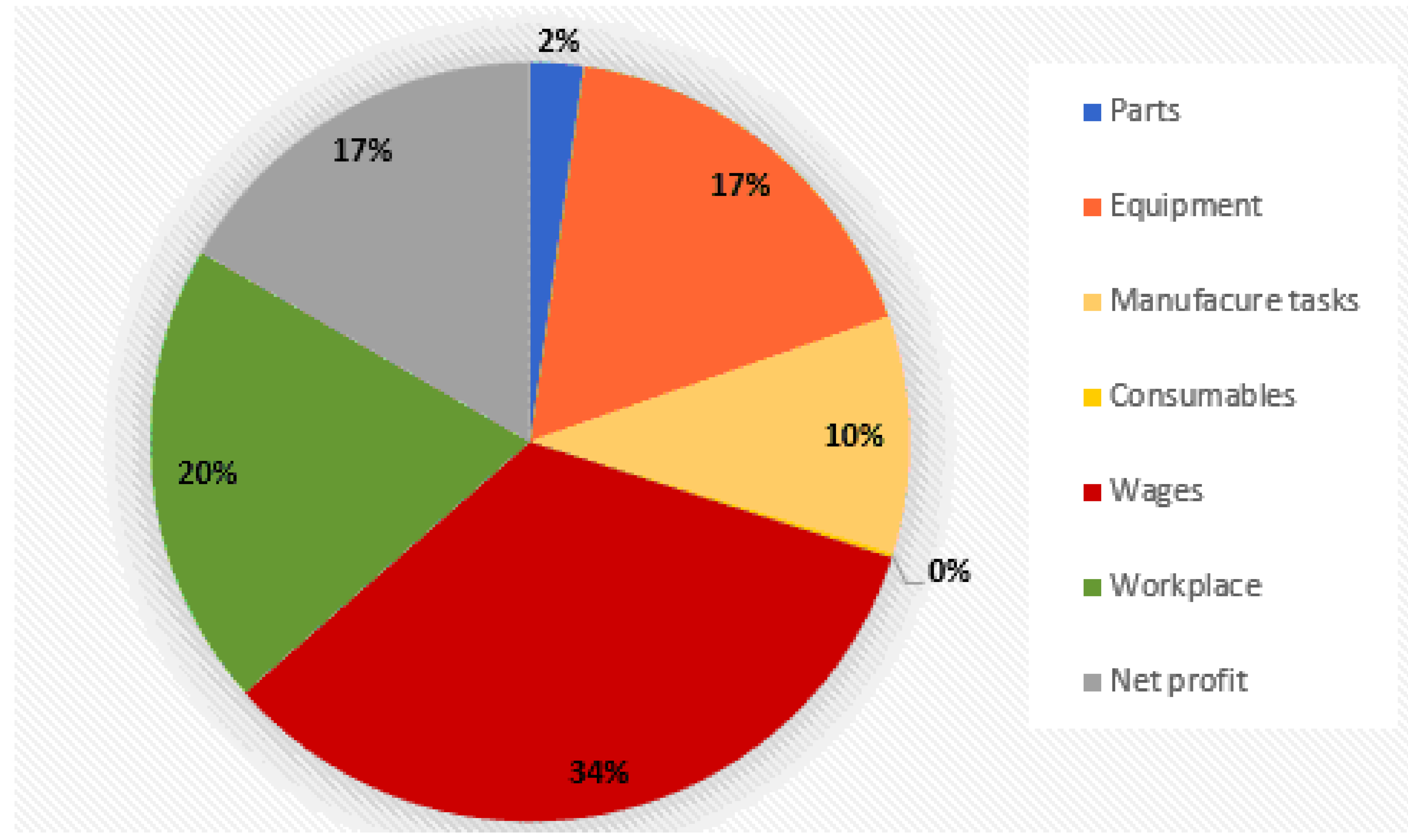


Manufacturing sheet											
Part name:		Lever support			Machine:	HAAS VF-2					
Part material:		AISI/SAE 1213			n max =	8100 rpm					
Stock:		120x118x150			P max =	22.4 kW					
Clamping device:		Parallel jaw for milling machine			T max =	122 Nm					
Nr.	1	Operation: Drilling diam17									
T1	Insert:	870-1700-17-PM 4334									
	Tool:	870-1700-17L20-3									
Pos 1	Vc	Fn	n	Vf	PPC	MMC	FFF	Depth	t		
	(m/min)	(mm)	(rpm)	(mm/min)	(kW)	(Nm)	(N)	(mm)	(s)		
	143	0.328	2680	877	11	39.1	3630	50	11.4		
Nr.	2	Operation: Drilling diam23									
T2	Insert:	870-2300-23-PM 4334									
	Tool:	870-2300-23L25-3									
Pos 1	Vc	Fn	n	Vf	PPC	MMC	FFF	Depth	t		
	(m/min)	(mm)	(rpm)	(mm/min)	(kW)	(Nm)	(N)	(mm)	(s)		
	143	0.328	1980	648	14.8	71.6	4900	50	5.3		
Nr.	3	Operation: Drilling diam17									
T1	Insert:	870-1700-17-PM 4334									
	Tool:	870-1700-17L20-3									
Pos 2	Vc	Fn	n	Vf	PPC	MMC	FFF	Depth	t		
	(m/min)	(mm)	(rpm)	(mm/min)	(kW)	(Nm)	(N)	(mm)	(s)		
	143	0.328	2680	877	11	39.1	3630	50	11.4		
Nr.	4	Operation: Drilling diam23									
T2	Insert:	870-2300-23-PM 4334									
	Tool:	870-2300-23L25-3									
Pos 2	Vc	Fn	n	Vf	PPC	MMC	FFF	Depth	t		
	(m/min)	(mm)	(rpm)	(mm/min)	(kW)	(Nm)	(N)	(mm)	(s)		
	143	0.328	1980	648	14.8	71.6	4900	50	5.3		
Nr.	5	Operation: Slot width 100									
T3	Insert:	490R-140408M-PH 4330									
	Tool:	490-050A32-14M									
Pos 3	Vc	Fz	n	Vfm	Ae	Ap	NOPAE	NOPAP	QQ	PPC	t
	(m/min)	(mm)	(rpm)	(mm/min)	(mm)	(mm)	Nu. Pas. Ae c	Nu. Pas. Ap c	(cm3/min)	(kw)	(s)
	393	0.17	2500	1710	33.33	8.57	3	7	487	21.2	211
Nr.	6	Operation: Triangular contour									
T4											
	Tool:	2P370-1905-PB 1740									
Pos 4	Vc	Fz	n	Vfm	Ae	Ap	NOPAE	NOPAP	QQ	PPC	t
	(m/min)	(mm)	(rpm)	(mm/min)	(mm)	(mm)	Nu. Pas. Ae c	Nu. Pas. Ap c	(cm3/min)	(kw)	(s)
	423	0.13	5395	2870	8	15	4	8	396	19.4	274
Nr.	7	Operation: Lateral contour 1									
T4											
	Tool:	2P370-1905-PB 1740									
Pos 5	Vc	Fz	n	Vfm	Ae	Ap	NOPAE	NOPAP	QQ	PPC	t
	(m/min)	(mm)	(rpm)	(mm/min)	(mm)	(mm)	Nu. Pas. Ae c	Nu. Pas. Ap c	(cm3/min)	(kw)	(s)
	421	0.12	5100	1000	11.5	15	1	6	69.58	20.3	41
Nr.	8	Operation: Lateral contour 2									
T4											
	Tool:	2P370-1905-PB 1740									
Pos 5	Vc	Fz	n	Vfm	Ae	Ap	NOPAE	NOPAP	QQ	PPC	t
	(m/min)	(mm)	(rpm)	(mm/min)	(mm)	(mm)	Nu. Pas. Ae c	Nu. Pas. Ap c	(cm3/min)	(kw)	(s)
	421	0.12	5100	1000	11.5	15	1	6	69.58	20.3	41
Nr.	9	Operation: Middle slot width 53									
T5	Insert:	R390-17 04 16M-PH 4340									
	Tool:	R390-040B32-17H									
Pos 5	Vc	Fz	n	Vfm	Ae	Ap	NOPAE	NOPAP	QQ	PPC	t
	(m/min)	(mm)	(rpm)	(mm/min)	(mm)	(mm)	Nu. Pas. Ae c	Nu. Pas. Ap c	(cm3/min)	(kw)	(s)
	301	0.2	2400	1440	26.5	13.33	2	6	509	20.8	437



Tools used		
Nr.	Designation	Operation
1	870-1700-17L20-3 & 870-1700-17-PM 4334	1,3
2	870-2300-23L25-3 & 870-2300-23-PM 4334	2,4
3	490-050A32-14M & 490R-140408M-PH 4330	5
4	2P370-1905-PB 1740	6,7,8
5	R390-040B32-17H & R390-17 04 16M-PH 4340	9

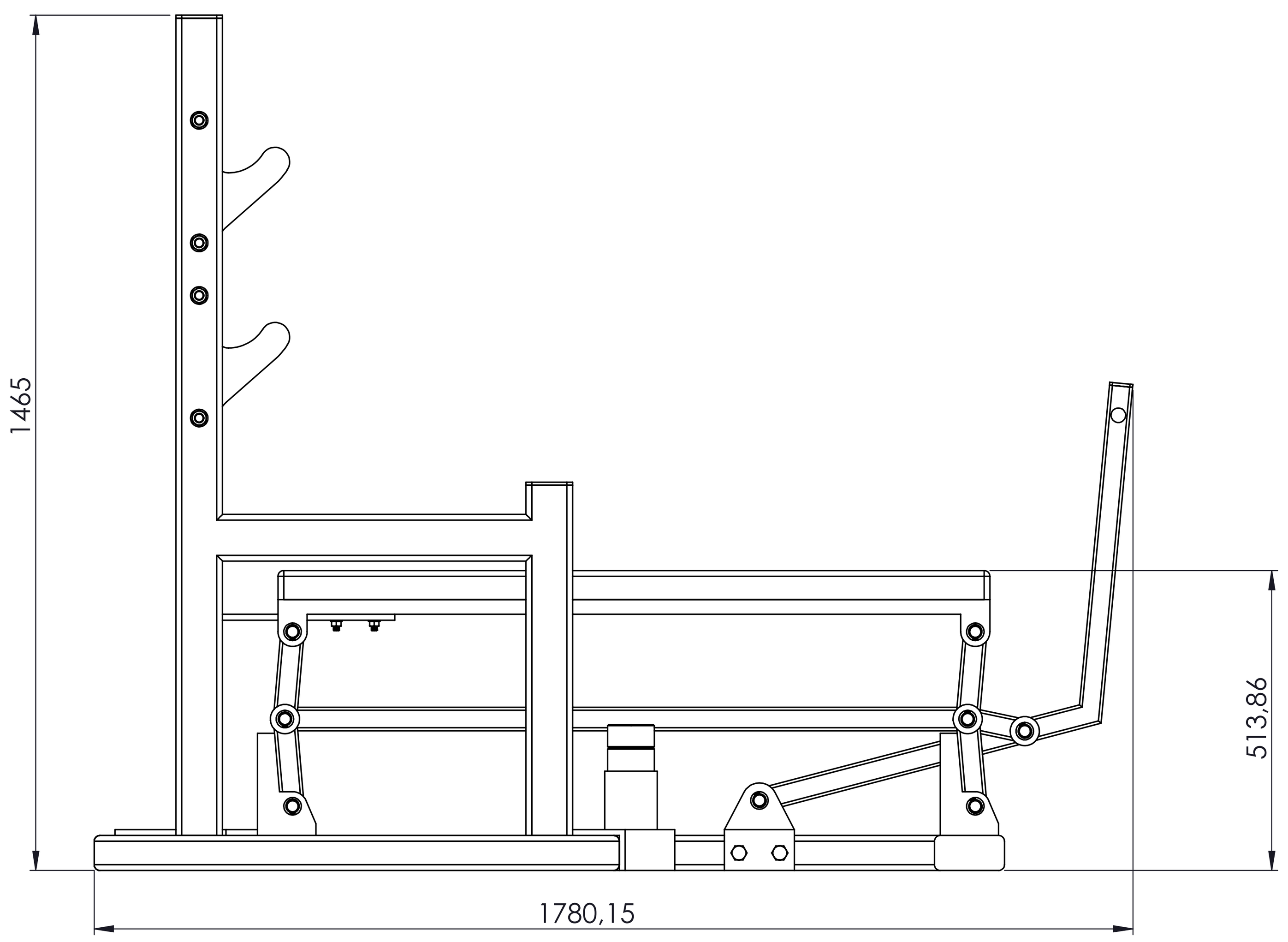
Reference Nº.	Other information:	Material: Steel AISI 1213			Scale: 1:5		
Responsibility:	Consulted by:	Document type: Technological process			Document status: Educational		
Owner: VGTU MPfuc-16	Drawn by: Rodrigo Castedo	Title: Technological process of the support of the lever	Drawing Nº. MPfuc-16.04.001				
	Checked by: Paulius Ragauskas		Rev.	Date: 22/05/2020	Lang. En	Sheet: 11/12	

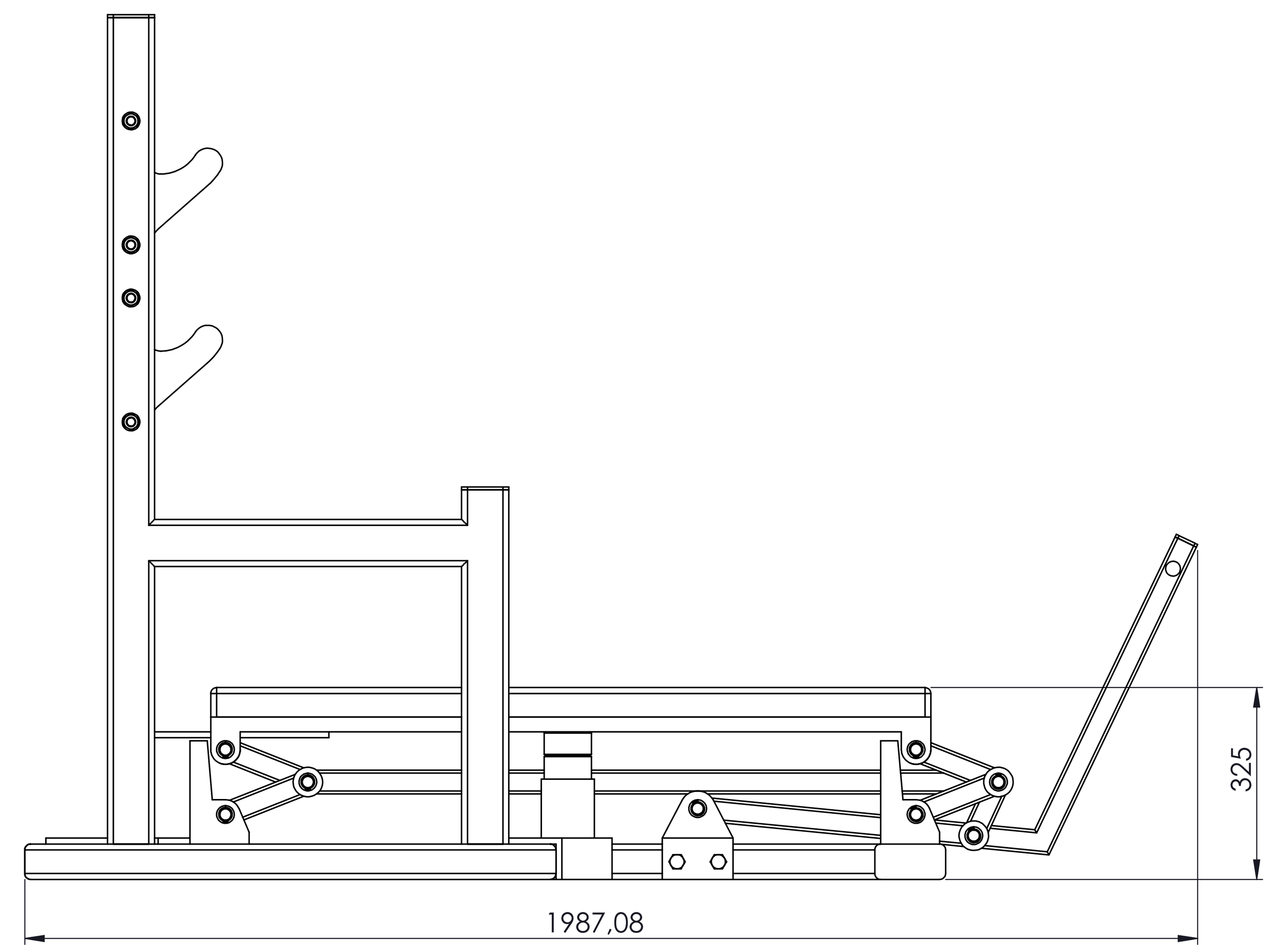


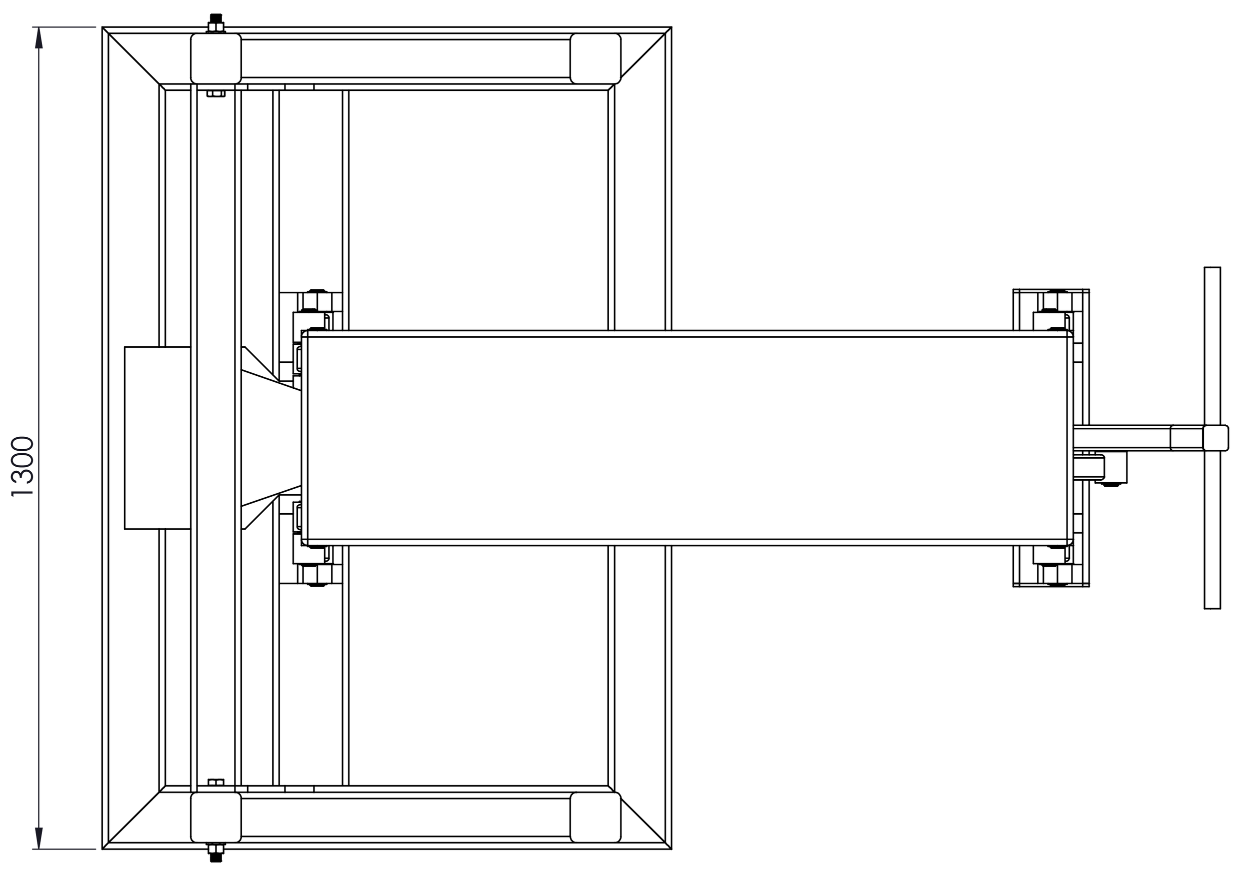
Manufacturing and construction costs

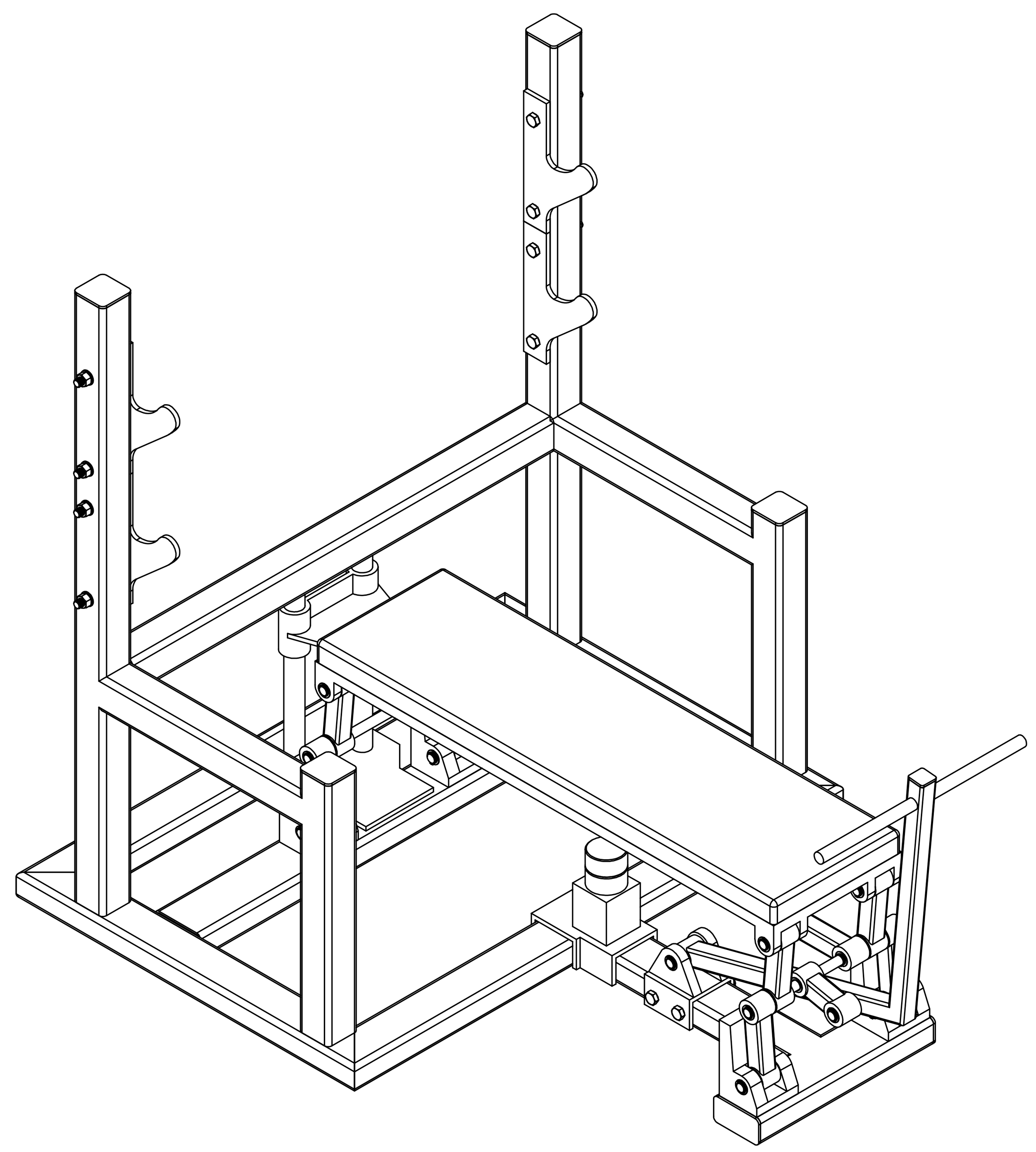
Break-even point

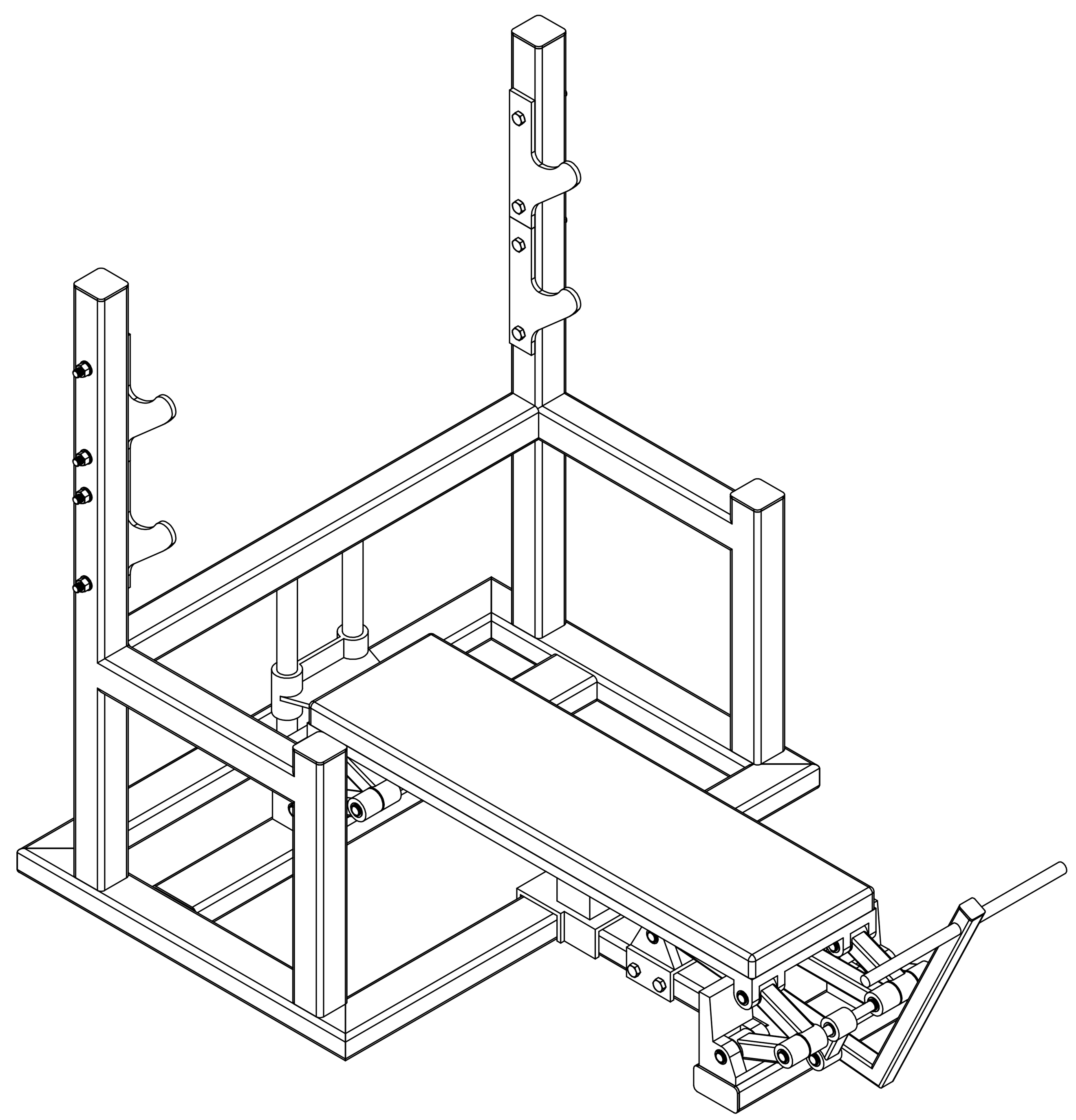
Reference Nº.	Other information:	Material:			Scale:	
Responsibility:	Consulted by:	Document type: Economic drawing			Document status: Educational	
Owner: VGTU MPfuc-16	Drawn by: Rodrigo Castedo	Title: Economic characteristics of a weightlifting bench	Drawing Nº. MPfuc-16.04.002			
	Checked by: Paulius Ragauskas		Rev.	Date: 22/05/2020	Lang. en	Sheet: 12/12











	Case No.	Additional Information	Material	Scale 1:10
Resp. Dep. Dprt. of Mech	Consultant	Document type Drawing general view		Document Status Educational
Owner VGTU	Compiled by Rodrigo Castedo	Title	Bookmark MPfuc-16.01.001	
MPfuc-16	Checked Paulius Ragauskas	Weightlifting Bench	Relase A, Date 21/05/2020, Lang en	Page 1/12