AUTOMATION OF PROFILE PACKING

-MECHANICAL ENGINEERING PROJECT-

(Spring semester, 2010)

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For and in cooperation with:

INDEX

INDEX OF PICTURES

INDEX OF TABLES

1. INTRODUCTION

1.1 THE COMPANY

Alumeco´s goal is to be the solution supplier and service partner for their customers. They are the aluminium specialists who can provide consultancy, logistics and know-how for their customers. They are the guarantee for correct products and accurate solutions right from the start and on time.

It is crucial that their customers experience more value through an Alumeco solution based on such quality determinations as flexibility, insight, commitment and especially dialogue. Therefore, they support their customers´ activities through IT-integration, closer co-operation, day-to-day deliveries and stock management based on a qualified forecast.

In practice, this means that Alumeco must understand changes and shifting conditions. They must understand the market and be able to think creatively. At the same time, they must be focused on continually improving their employee's qualifications as a key to flexibility.

-PICTURE 1: ***logo of the company-***

1.1.1 THE PROBLEM AND THE OBJECTIVES OF THE PROJECT

Alumeco's strategy is to be the most effective logistic partner through effective handling and warehousing of aluminium products.

In order to achieve this goal, Alumeco has to be working with the newest technology and constantly improve processes and methods.

In the central warehouse in Odense the activity is mainly based on two high rack systems. One high rack is for handling aluminium sheets and the other one is for profiles and bars. The weekly activity on the two high racks is more than 1500 orderliness per week. (500 sheets and 1000 profiles and bars).

Therefore, Alumeco wants to investigate the opportunity to automate the process of packing profiles and bars from the existing high rack. Today the handling and packing of profiles is carried out manually by the stock workers. It means that it is a heavy physical process. Summing up, the goal to this project must be:

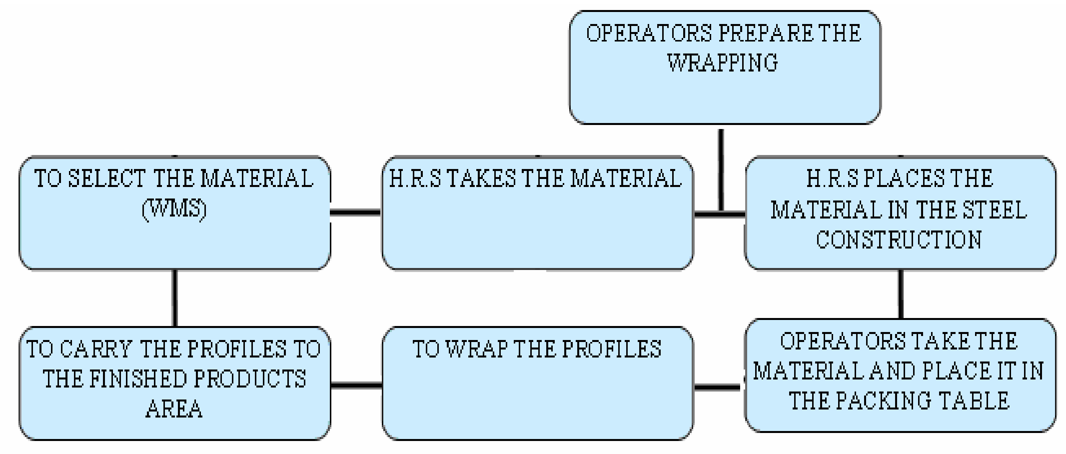
- **A packing line that can handle 70% of all orderliness**
- **No handling of material by hand or manual crane**

Getting these goals Alumeco will save money, they will increase their incomes and they will become the leader in the handling of aluminium profiles and bars because nowadays there are no factories with an automatic method. In this way one of the Alumeco's strategies we will achieve: to be the most effective logistic partner through effective handling and warehousing of aluminium products.

1.1.2 THE CURRENT CENTRAL WAREHOUSE

1.1.2.1 THE CURRENT PROCESS

Today, since the supplier brings them the profiles until the final shipment, they have to follow some steps in a chronological order. They are correlative so they need to finish the previous one to be able to go on with the next one. Therefore, it is very important to carry out all of the steps in a right way. The steps which must be carried out are going to be shown in a graphical way to see the connections between the activities clearly (from left to the right):



- PICTURE 2: *steps of the process*-

Now all of the steps are going to be explained with more details:

STEP 1: The process begins when they receive an order. Therefore the operator enters the order number in the WMS (which is an automatic system which transfers the information to a high rack system in order to take automatically the profiles that they need to the order) and selects the material for the order.

- PICTURE 3: ***step 1 of the process-***

STEP 2: Now the high rack system (which is an automatic device which takes the profiles from the high racks) delivers the material at the packing station

- PICTURE 4: ***step 2 of the process-***

STEP 3: Now the operators prepare the wrapping paper. They put it over the packing table. They make this action while the high rack system takes the profiles and places that in the packing the steel construction.

- PICTURE 5: ***step 3 of the process-***

STEP 4: In this step another automatic mechanism moves the profiles from the packing station (which is on both sides of the steel construction) to the steel construction. Now they can take the profiles that they need for the order.

- PICTURE 6: ***step 4 of the process-***

STEP 5: The two operators carry out the material from the steel construction to the packing table. The material can be carried out by hand (heavy physical process) or by crane (heavy profiles and bars).

- PICTURE 7: ***step 5 of the process-***

STEP 6: The operators finalize the packing and make the confirmation in the WMS system.

- PICTURE 8: ***step 6 of the process-***

STEP 7: When the packing is finished, it is placed in a zone close to the packing table and is ready to shipment. It is carried away by crane

- PICTURE 9: ***step 7 of the process-***

1.2 EXPLANATION OF THE IDEA'S GENERATION PROCESS

There has been a hard work to find the best solution for the problem mentioned before. It means that it has not been very easy to get it. In this chapter everything related to the final idea that has been developed is going to be explained.

1.2.1 PROBLEMS TO FIND THE PERFECT SOLUTION

As it was mentioned in the last paragraph, there have been some problems to reach the final solution because there have been a lot of variables to take into account. In this chapter the most important problems are going to be described:

- **To take into account the existing equipments:** one of the biggest problems, because every new designed equipment must be compatible with the equipment that they already have. This is a crucial aspect because, otherwise, they should change all the stuff that they already have and it would not be profitable. Beside the company has insisted on this aspect strongly.

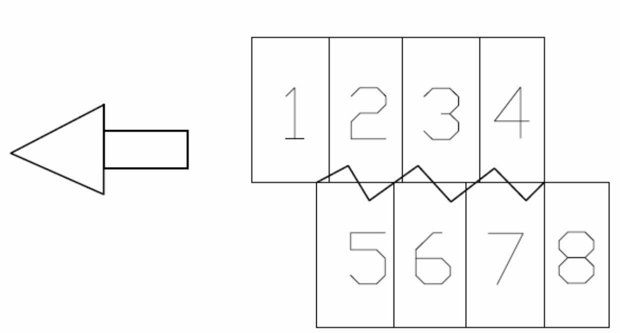
- PICTURE 10: ***examples of existing equipments-***

- **The way of making the packing:** It has also been on one of the most important problems to solve during the project. It has been very important because the wrapping paper must be over the packing table when the mechanism places the profiles on it. Every time that something has been thought about creating a mechanism to move up and down to place the profiles in the packing table, it has been found the problem of breaking the wrapping paper. But fortunately a solution has been found.

- PICTURE 11: ***problem with the wrapping paper-***

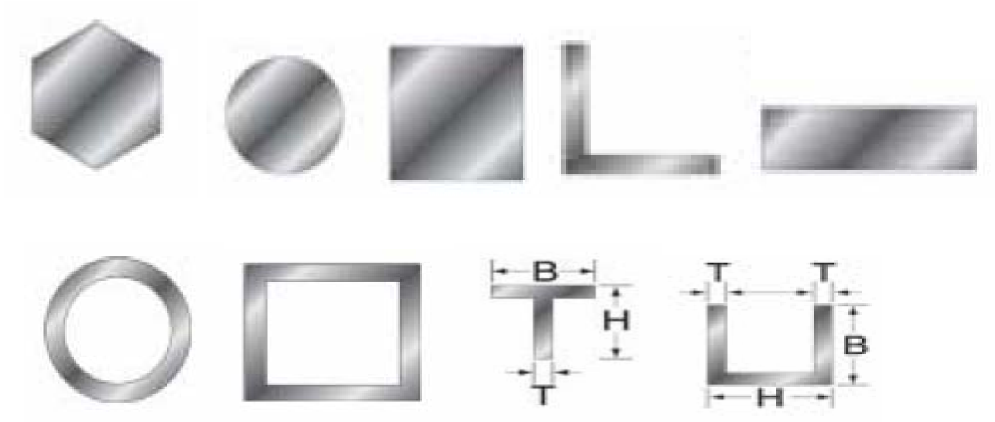
- **To count and to pick automatically the right number that they need in each order**: it has been another awkward problem. Actually, due to this problem it has been necessary to change the goals of the project (explained in **Chapter 1.1.1**) because it has been impossible to reach 70 % of the orderliness. It has been very difficult to find something to pick and count the thinnest profiles or bars. This is one of the most important conclusions which will be explained in the **Chapter 3** (**CONCLUSIONS**)

- **To move more than one row of profiles**: if one profile is moved without lifting it up ,the surface of the profile which is under it would be scratched (due to this problem, it has not been able to reach one of the goals established at the beginning of the project: to handle the 70% of the orderliness). You can see it better in the picture below



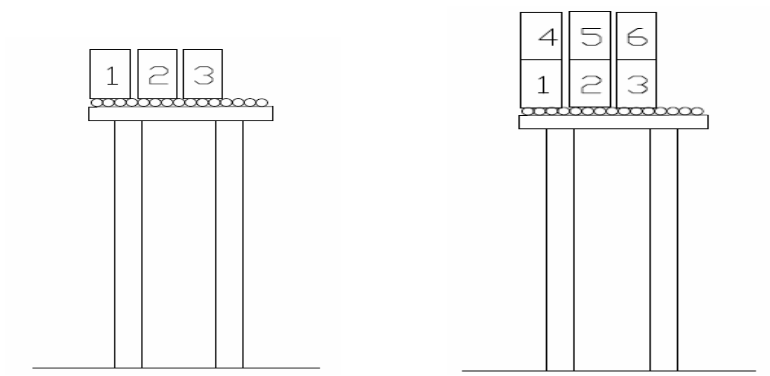
- PICTURE 12: ***problem with rows of profiles-***

- **Many different kinds of profiles**: This is another problem because the shape and the measurements of the profiles must have been taken into account. For instance, you have to take into account that round bars can turn. This is also a problem that is commented in **Chapter 3**(**CONCLUSIONS**).You can see the whole ALUMECO's range of products with all information about it in **APPENDIX Nº1**.



- PICTURE 13: ***problem with different kinds of profiles*-**

- **To place the profiles in the right position on the packing table:** this problem is related to the problem commented before about the way of making the packing .If something completely automatic is needed, the profiles must be ready to make the packing and they should be placed on the packing table in the right position to be packed. Apart from this problem, it is important to add that there is a lot of different orderliness and therefore there are no "standard" positions as in the picture below.



- PICTURE 14: ***problem of placing the profiles*-**

1.3 HOW THE PROJECT IS APPROACHED

After taking into account all of the problems and variables mentioned in the previous chapter, finally a conclusion has been chosen. It has been found that it has been impossible to reach a ‘’global solution’’ to be able to solve all the problems mentioned before. That is why it has been decided to focus this project on a ‘’ideal case’’ which has very little differences with some stuff that the company has already implemented (like the stuff to keep the profiles) but which has the same objective. Therefore, in this way, if the company finally wanted to implement a system to automate the packing line, they could use this project as a base for further studies.

Therefore with this ‘’final idea’’ many of the problems mentioned before are solved. It is important to say that we have tried to be as much flexible as possible but, understandably, the finally mechanism has some restrictions which are very important to mention:

- **The designed mechanism is only available to work with one row of profiles** (because of the problem in **Picture 12**)

- **The mechanism has been designed taking into account the information (weight and length) of the heaviest square bars that the company is currently working on. Therefore, this designed mechanism is thought to work with this kind of profiles.** You can see this kind of profiles in **APPENDIX Nº 1**

As it is clear, one the first objectives marked in this project (a packing line that can handle 70% of all orderliness) cannot be achieved because working with only the heaviest rectangular profiles it is impossible to reach this percentage of orderliness but even so it is strongly thought that with more time of studying of this developed idea, it could be possible to achieve to be more flexible and to get the desired percentage of orderliness.

In **CONCLUSIONS** the things that could be improved to get the “desired solution” will be explained with more details. In this way, it could be useful if the company wanted to go more through with this issue.

1.3.1 HOW THE COMPANY CAN IMPLEMENT THIS PROJECT

Even with all of the difficulties and with all the restrictions mentioned before, this developed idea, which is going to be explained in the following chapters, can solve many of all of the problems mentioned in **Chapter 1.2.1**.

The best way of implementing this is to implement that **to manage a smaller packing station** (which they have but they hardly ever use) in which they only could work with this heavy square bars(with later studies and optimizing this idea they would be able to work with more kinds of profiles). It could be fine because, if this mechanism is thought to work only with this kind of profiles, they could use a little station in which they could just focus the work only on this kind of profiles. In this way **they could work on parallel with the "big station" and they just could use one operator** to be the person in charge of this "little station" .They would have two lines of work and in days when many orderliness are required it could be very useful.

This idea of implementing that in the "small station" that they have has already been discussed with the company and they agree with this idea as a "possible" idea to implement that. It is a good way of implementing that because the "big station" that they have has a lot of components that are very difficult to change and therefore if they wanted to implement this idea there they should change a lot of things and it would not be profitable.

Even so the company can assess its possibilities of implementing this project and they can see better and with more detail what is better for the future of the company.

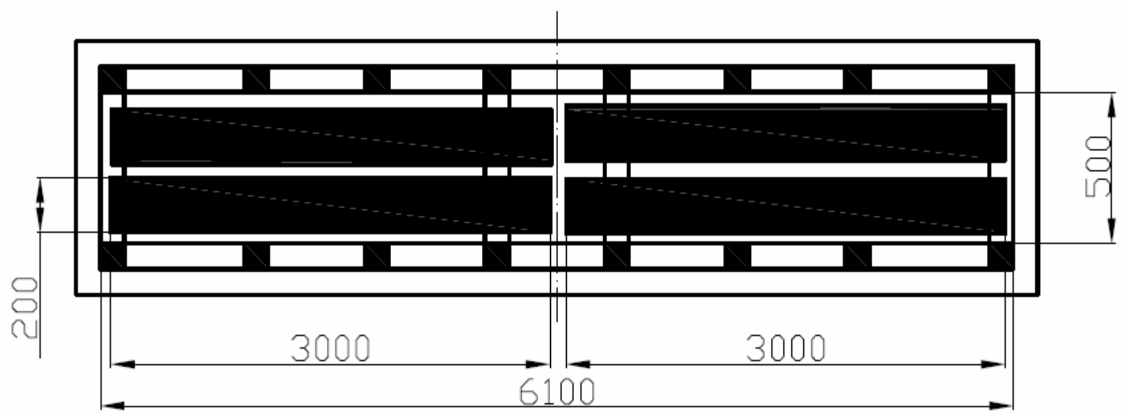
1.4 EXPLANATION OF THE FINAL IDEA

In this chapter the final idea that has come up is going to be explained with as many details as possible. In this way the idea and the designed mechanism will be understood easily.

1.4.1 GENERAL INFORMATION OF THE FINAL IDEA

The main idea of the final chosen idea consists of **designing a mechanism in the steel construction that they already have**. This mechanism consists of some bars connected all together and which are put in motion by a hydraulic cylinder. With this cylinder it is possible to lift the structure up. Besides, these bars are connected to a structure on the top in which there are two belt conveyors fixed there. In this way it is possible to move the profiles that the company needs in each order. These profiles needed for the orders, which are lifted up to a determined height, are moved to another conveyor belt which places the profiles in the packing table.

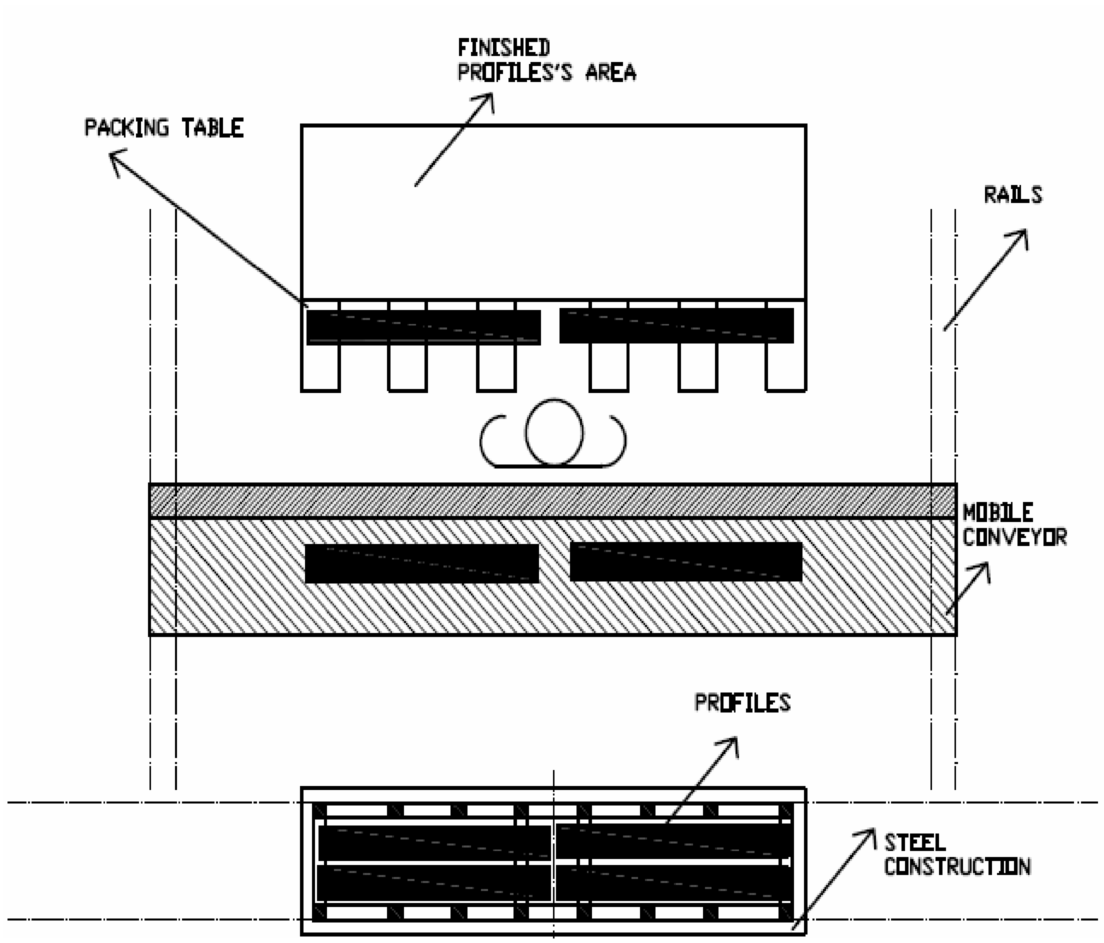
As it was said before, the project has been approached taking into account the heaviest square bars and they have a minimum length of $3m$ and a width of $0,2m$ but the structure where they are kept has a length of $6m$ and a width of $0,5m$.Therefore, each structure contains a maximum of 4 square bars (you can see that in the picture below).That is the reason why there are two mechanisms, one in each half ($3m$) of the steel construction that they already have. Besides, in this way it is possible to work on parallel with each half of the structure and if they only needed for example 1 bar it would not be necessary to lift all of the profiles of the structure.



-PICTURE 15: ***view of the structure to keep the profiles-***

Anyway this designed mechanism will be explained later in **Chapter 1.4.3** with more details. You can also take a look on **Drawing Nº1** to get a general idea about this.

This is basically the idea that is going to be carried out during this project. You can also see this idea in the floor view picture below to have a first idea about how it is going to work:



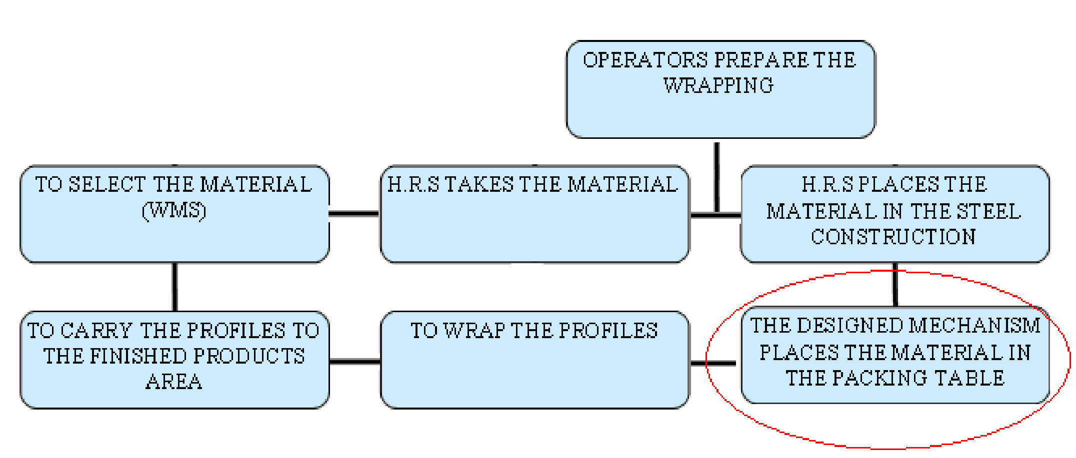
- PICTURE 16: ***floor view of the new idea-***

1.4.2 PHASES OF THE "NEW PROCESS"

Now the steps to reach the marked objectives of the project are going to be described. It is going to be shown in two different ways:

1.4.2.1 STEPS OF THE GENERAL PROCESS

The first one is a chart in which you can see the "new" entire process and the relations between the different parts that make it up.

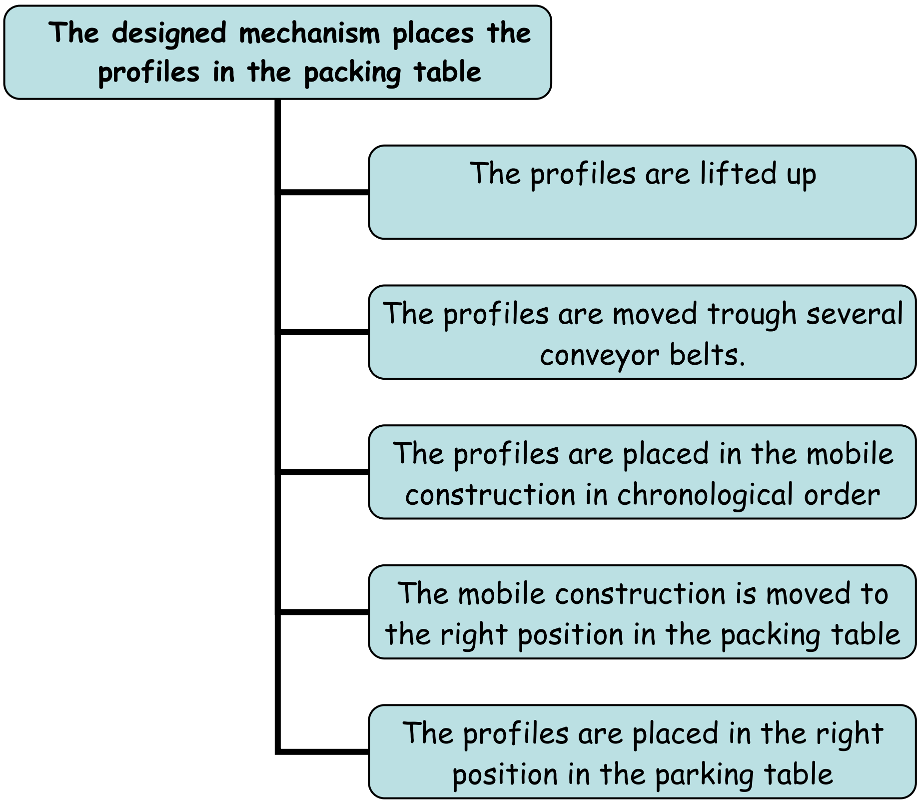


- PICTURE 17: ***new process of packing-***

It is clear to see that there is an important change with regard to the current activity that they do today (shown in **Picture 2**). This difference lies in the step in which the operators have to take the material from the steel construction to the packing table. Instead of carrying it out by operators, it will be carried out by the new designed automatic mechanism.

1.4.2.2 SUB-STEPS OF THE DESIGNED MECHANISM

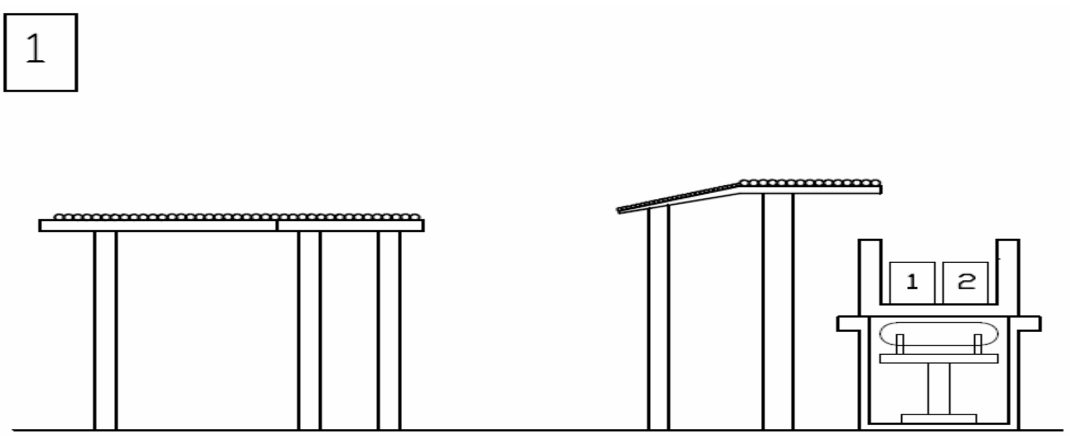
But within this "different" step there are some tasks to carry out. This step has been split up in five sub-steps. They are the steps that must be carried out to get the goal of the project. You can see that in the picture below:



- PICTURE 18: ***sub-steps of the new designed mechanism-***

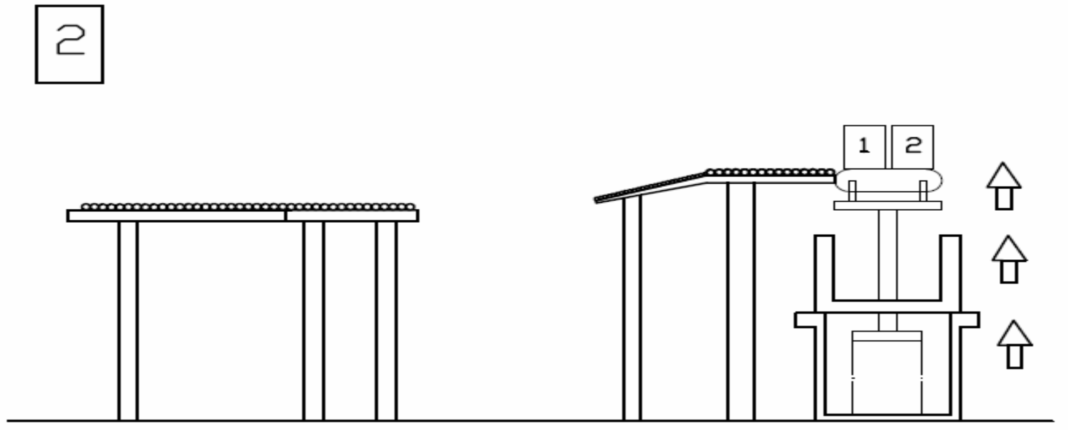
These steps shown on **Picture 18** are going to be described one by one and with pictures of each one to make this as clear as possible:

<u>STEP 1</u>: The profiles are placed in the steel construction. In this step there is nothing new with regard to the process that they currently have.



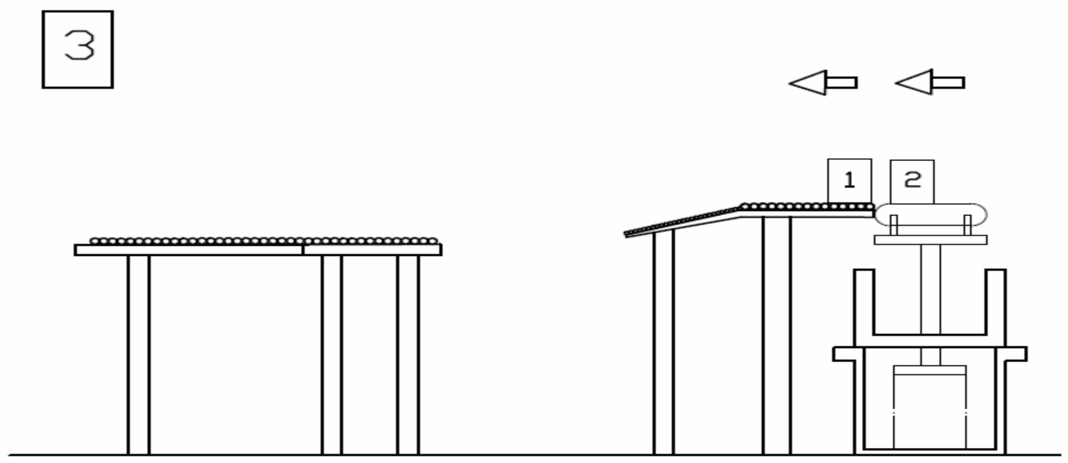
-PICTURE 19: ***picture of step 1-***

STEP 2: The profiles are lifted up by the designed mechanism. They are lifted up **a height of** $1552mm$



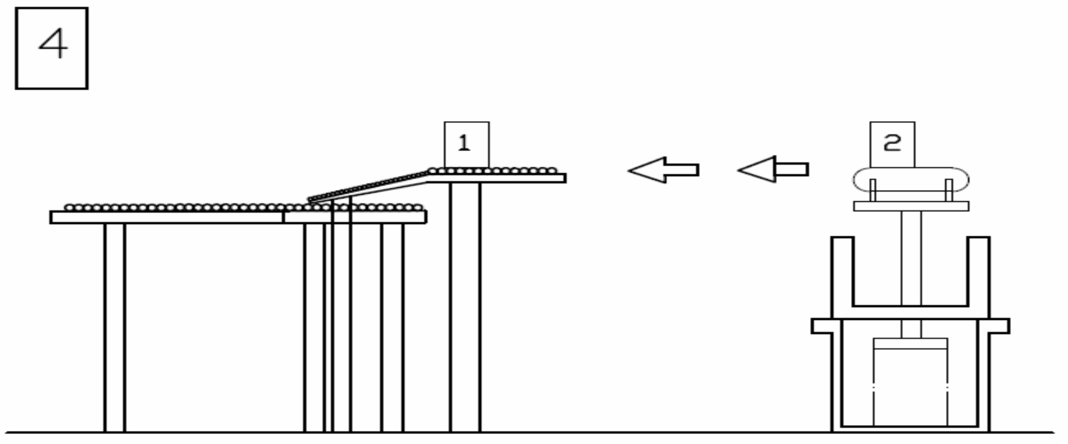
-PICTURE 20: ***picture of step 2*-**

STEP 3: The profiles are moved from the steel construction to a mobile conveyor. They are moved one by one and automatically.



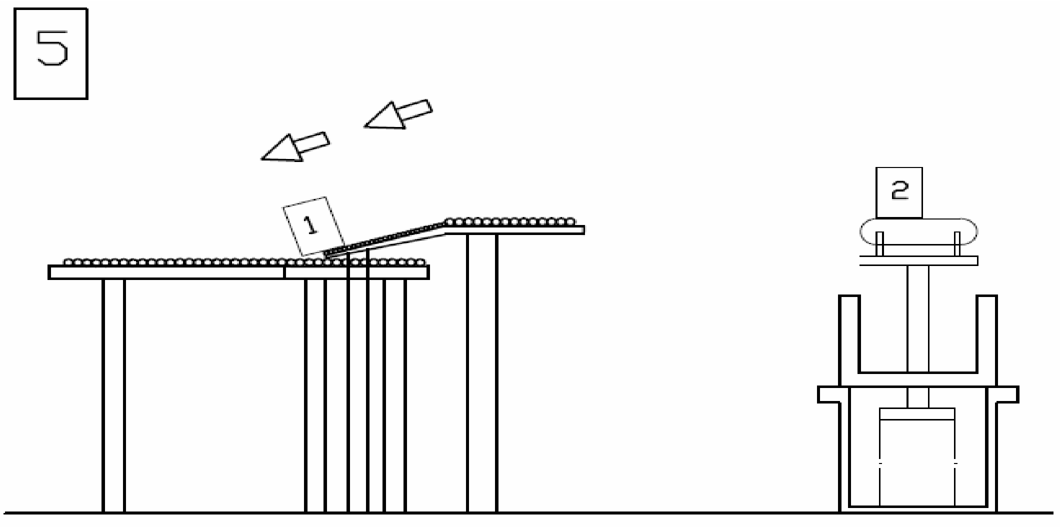
-PICTURE 21: ***picture of step 3*-**

STEP 4: Now, the profile is already on the mobile conveyor. This mobile conveyor is moved (as you could see in **Picture 15**) through two rails on both of its sides. It is also moved automatically.



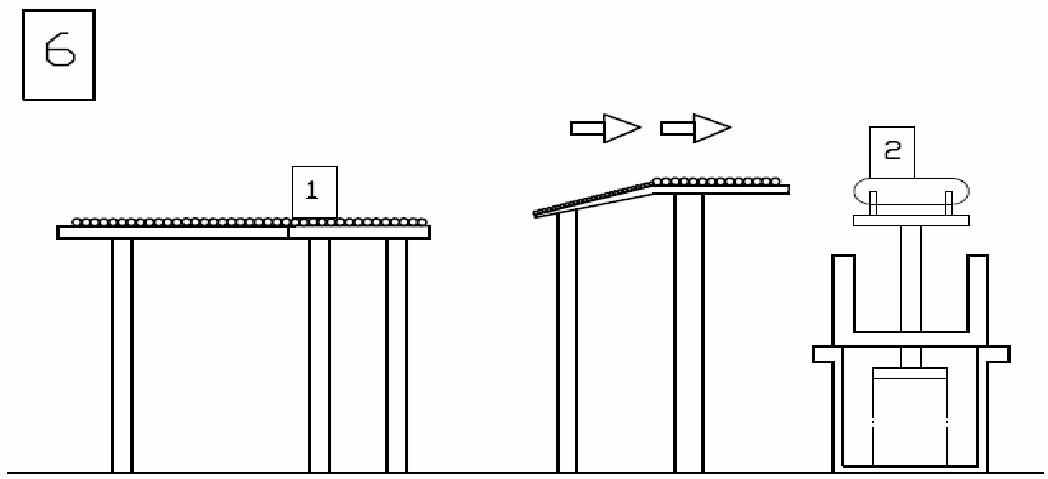
-PICTURE 22: ***picture of step 4*-**

<u>STEP 5:</u> In this step the profile is placed in the right place on the packing table.



-PICTURE 23: ***picture of step 5*-**

<u>STEP 6:</u> When the profile is placed on the packing table, the mobile conveyor goes back to take the next profile and it will repeat the steps explained before. It is also done automatically.



-PICTURE 24: ***picture of step 6***

As you have seen, on the packing table there are some rollers and the finished profile's area (also with some rollers) is next to the packing table and that is why because it was thought that it could be a good idea to push the profiles from the packing through some rollers and to place them next to the packing table. In this way they would not need to carry it to the finished profile's area ever time that they finish a packing. But this idea has not been developed so much and therefore it could be a concept to think about in subsequent studies. It will be mentioned in the chapter of **CONCLUSIONS**.

1.4.3 DESCRIPTION OF ALL OF THE PARTS OF THE DESIGNED MECHANISM

As it has been explained, a designed mechanism is going to be the stuff in charge of lifting the profiles up. We have tried to imitate the structure on the picture below. The chosen material to design the mechanical parts of the mechanism has been: **steel E350** due to the fact that this kind of steel is good for mechanical constructions. It has a yield stress of: $\sigma y = 350 Mpa$

-PICTURE 25: ***real mechanism*** **-**

1.4.3.1 PARTS OF THE MECHANISM

It contains:

- **A hydraulic cylinder** which provides the power to move the whole mechanism and which is fixed to the floor.

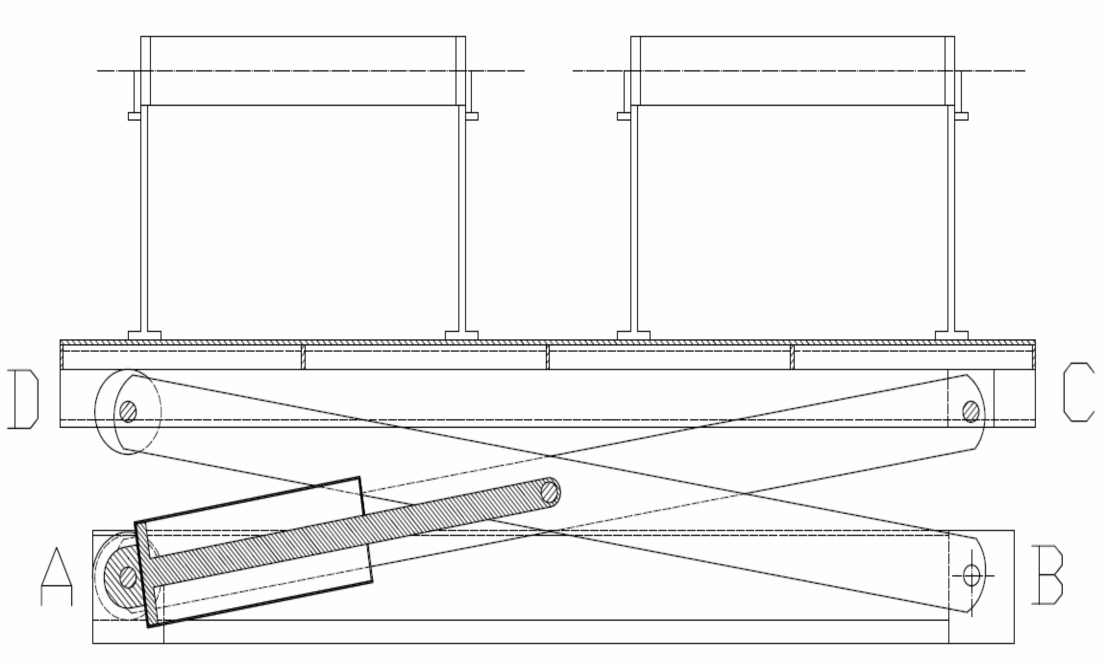
- **4 bars** that are connected between them and which are moved by a hydraulic cylinder

- **A structure on the top** in which the bars can be moved and joined and in which two belt conveyors are placed. This structure contains: **a sheet** on the top to place the belt conveyors, **two UPN profiles** to fix the bars in point C (you can see that in **Picture 26**) and to support the sheet on the top,**5 reinforcing flat bars** to avoid the bending of the sheet in the middle and a **very thin sheet** behind the reinforcing flat bars to let the wheels (see selected wheels in **APPENDIX Nº 2**) in point D go through the structure (if not, the wheels would not have any place to turn around)

- **Two conveyor belts** to move the profiles to the mobile conveyor. The selected conveyor belt is the model **GUF-P 2041 CA** of the company **MK**. This kind of conveyor has been selected due to its characteristics, like for example, the maximum load capacity (one of the most important reasons), the possible measurements of the conveyor (length and width) and because this kind of conveyor has a relatively simple integration into equipment. You can see the details about this conveyor and its support (to fix to the sheet on the top) in **APPENDIX Nº 3**.The selected length is $500mm$ and the selected width is $500mm$

- **A structure fixed to the floor** to fix the structure and the bars in points A and B

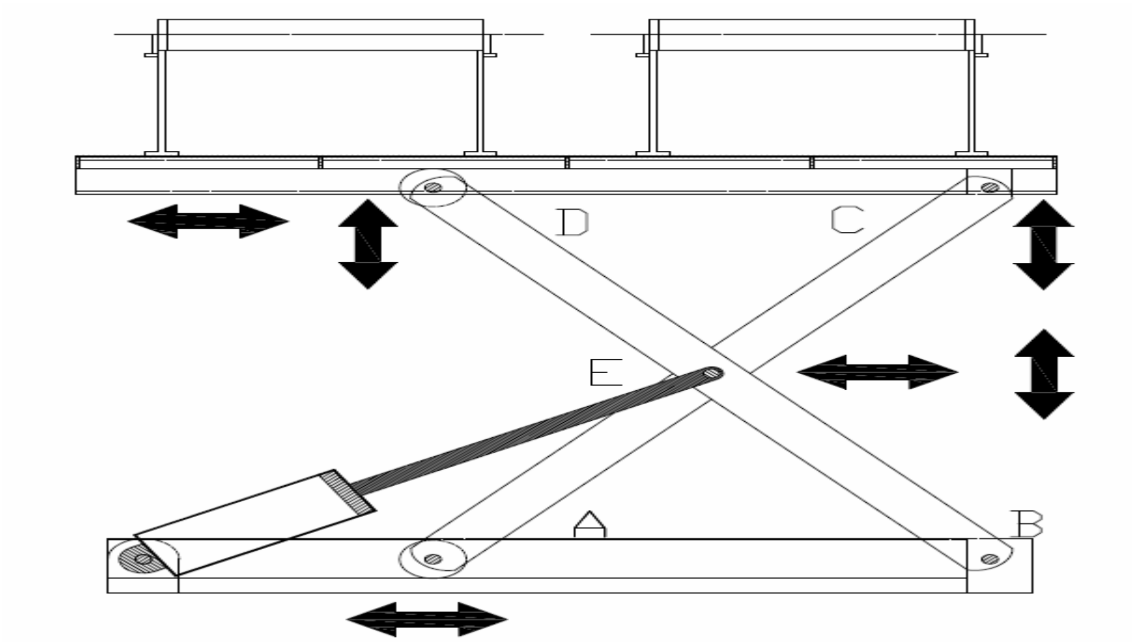
In the picture below you can see the initial position of the mechanism:



-PICTURE 26: ***drawing initial position of the mechanism-***

Therefore it works in the following way: the pump provides the fluid to the cylinder and therefore the piston goes ahead. The piston rod which is connected with the 4 bars (by a bar in the middle) moves the bars. The points B and C of the bars are fixed with bars to a structure (which is fixed on the floor) but they can turn. The other points A and D have wheels connected and therefore these wheels go through the structure on the top when the cylinder starts the movement. It is possible because there is a very thin sheet behind the reinforcing flat bars.

Therefore it goes up until a determined height ($1552mm$) as you can see in the picture below:



-PICTURE 27: ***drawing final position of the mechanism-***

1.4.3.2 STUFF TAKEN INTO ACCOUNT TO DESIGN THE MECHANISM

This mechanism has been designed to lift up a total weight of $1000kg$ .This because it has been needed to add all the weight of all stuff that has to be lifted up and this stuff is:

- **WIEIGHT 1 PROFILE:**
  - ✓ $112kg/m \cdot 3m = 336kg$.
  - ✓ But in each half it was shown (**Picture 15**) that there are two.

  Therefore:

.

Total weight of PROFILES: $336kg \cdot 2 = 672kg$

- **BELT CONVEYORS:**
  - ✓ $80kg$ Each one.
  - ✓ But there are two:

Total weight of BELT CONVEYORS: $80kg \cdot 2 = 160kg$

- **STUFF OF THE CONSTRUCTION :**
  - ✓ The dimensions of the sheet on the top are: $1,5 \times 0,5 \times 0,005$.
  - ✓ It is made of steel with a density of $\rho = 7850kg/m^3$.
  - ✓ It is also known: $\rho = \frac{M}{V}$

Total weight of the construction: $M = (1,5 \cdot 0,5 \cdot 0,005) \cdot 7850 \simeq 30kg$

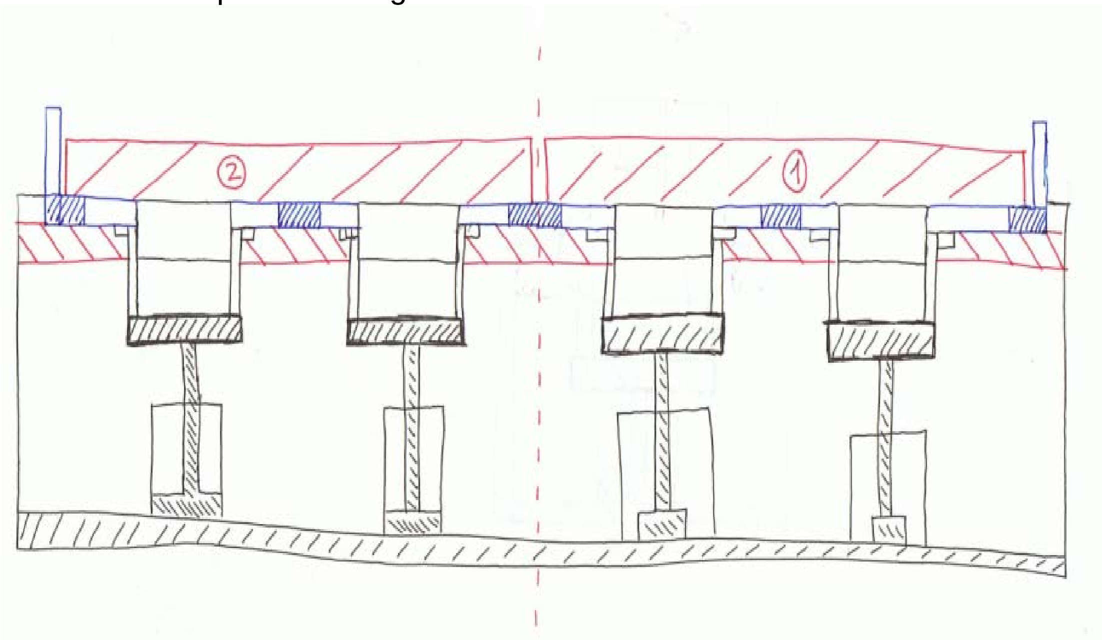
TOTAL WEIGHT = $670kg + 160kg + 30kg = 860kg$

But logically there are more parts to take into account like bars but this weight is very little in comparison to the other weights. Even so the mechanism has been designed for a total weight of:

TOTAL WEIGHT OF: 1000kg

1.4.4 ANOTHER MECHANISM

Another mechanism like the one you can see in the picture below has been another option to design.



-PICTURE 28: ***sketch of another mechanism*-**

This idea has been rejected because it should be necessary to use 4 pistons and the cost of that would be very high. It has been thought to design this mechanism but only with one cylinder in each half ($3m$) but there would be a lot of bending in the sheet to support the belt conveyors and the profiles. Besides, there are not too many mechanical parts to work on.

The other idea shown before is more complete and more reliable.

2. CALCULATIONS

2.1 INTRODUCTION

In this part of the project all mechanical stuff that is used in the mechanism described in the previous part of the project is going to be calculated. To follow and to understand better the formulas and all the process which are going to be used to design all the stuff some information is shown in the last part of the project (**APPENDIX**). In this way it is easier to understand where the calculations come from.

Now it is important to remember the general data which we are going to be working with:

- **Material = Steel E350** $\sigma y = 350 N / mm^2$ $E = 210 Gpa$
- **Coefficient of security of yield stress=2**
- **Coefficient of security of yield stress :(APPENDIX Nº5)** $Csy = \frac{\sigma y}{\sigma}$
- **Theory maximum shear (APPENDIX Nº 6)**

2.2 CYLINDER

In this chapter all of the information related to the cylinder which provides enough power to activate the designed mechanism is going to be calculated. To have the complete information about a cylinder the calculations are going to be split up into five parts: stroke, maximum force, piston's diameter, piston's thickness, piston rod's diameter (buckling of the piston rod) and pump.

2.2.1 INFORMATION

But before calculating all the elements described before, some information about the kind of the cylinder that is possible to choose is going to be shown. There are two kinds of cylinder, pneumatic or hydraulic but they have some differences between them. On the other hand, they have the common characteristic of the need of a pressure supply. Therefore, to find the right guidance system the two possibilities of pressure generation are going to be compared:

Advantages of pneumatic system:

- The storage of air is easy because of the high compressibility, so that a central pressure system is possible.
- High transfer distance of pneumatic systems, because air has a low viscosity and therefore a low decrease in pressure results
- No backflow pipe or leak pipe
- No additional fluid like oil

Disadvantages of pneumatic system

- The max. pressure is limited from 0.6 to 1.0 MPa, therefore a pneumatic system transfers lower forces as a hydraulic system.
- A steady movement is not possible
- When the air escapes (exhaust), the system is creating an exhaust noise

Advantages of a hydraulic system

- Generation of high forces and moments with compact measures
- Stepless change of actuation velocity and drive. Reversal of the moving direction is possible.

Disadvantages of hydraulic system

- High acquisition costs
- High requirements for the filtering and for the hydraulic fluid
- Low transfer distance of pneumatic systems, because of the high viscosity of the fluids
- Important properties of the hydraulic fluid (viscosity, density and compressibility) are dependent on pressure and temperature
- Increased requirements for the environmental protection
- There is a need for a backflow pipe

	pneumatic	hydraulic
Energy carrier	Air	oil
Energy source	compressor	pump
Characteristics	Pressure p ≅ 6 bar (0.6 MPa)	p ≅ 30 … 400 bar
Transfer distance	≅ 1000 m	≅ 100
Storage of energy	Pressure vessel	accumulator
Energy converter	Cylinder Compressed air motor	Cylinder hydromotor
Power density	70 … 1200 W/Ltr 70 … 300 W/kg	Approx. 2000 W/Ltr 600 … 800 W/kg

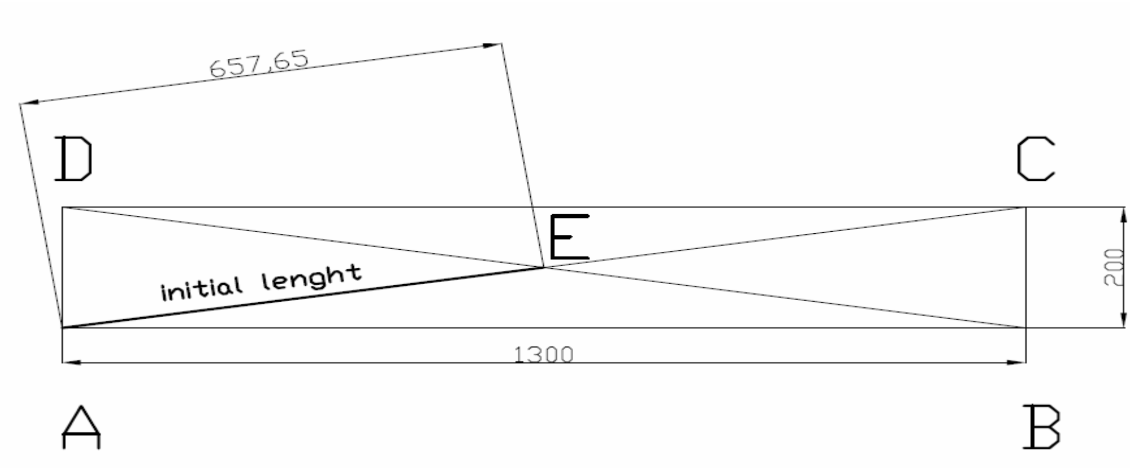
-TABLE 1: *information about cylinders*-

Taking a look at the previous table of information about the two kinds of cylinders and focusing on the pressure that each one can reach, if you compare it with the pressure that is going to be selected on **Chapter 2.2.4**, it is clear to see that the right cylinder to be used is a **hydraulic cylinder**.

2.2.2 CALCULATION OF THE STROKE

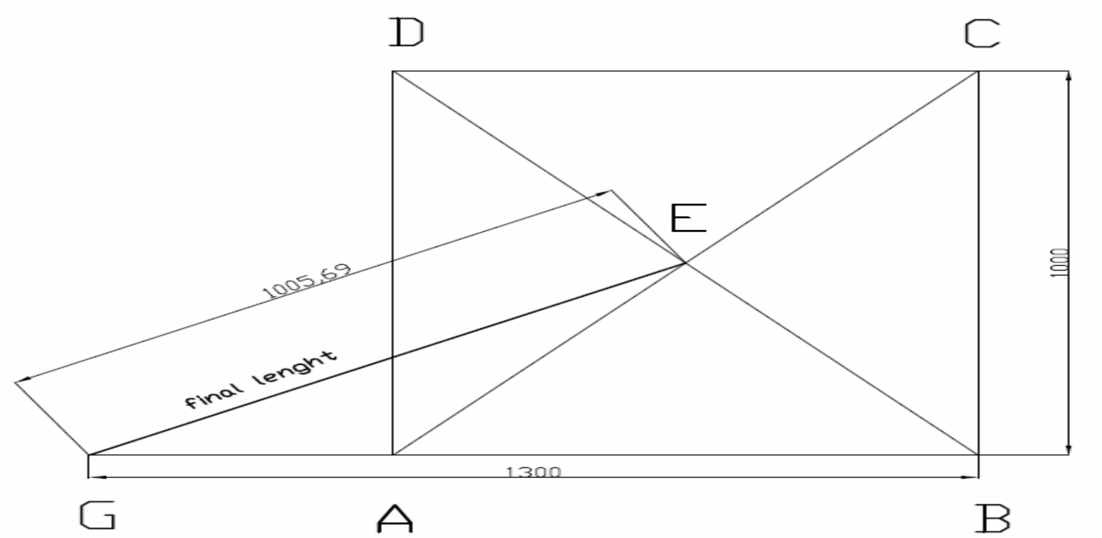
The mechanism can be represented with the following sketches below (**Picture 29 and Picture 30**). With these sketches it is possible to find out the stroke of the cylinder. It is calculated in a graphical way.

INITIAL POSITION



-PICTURE 29: initial position of the mechanism-

FINAL POSITION



-PICTURE 30: final position of the mechanism -

Therefore the stroke of the cylinder can be calculated like this:

$$stroke = Lf - Li = 1006 - 658 = 348mm$$

STROKE OF THE CYLINDER=348mm

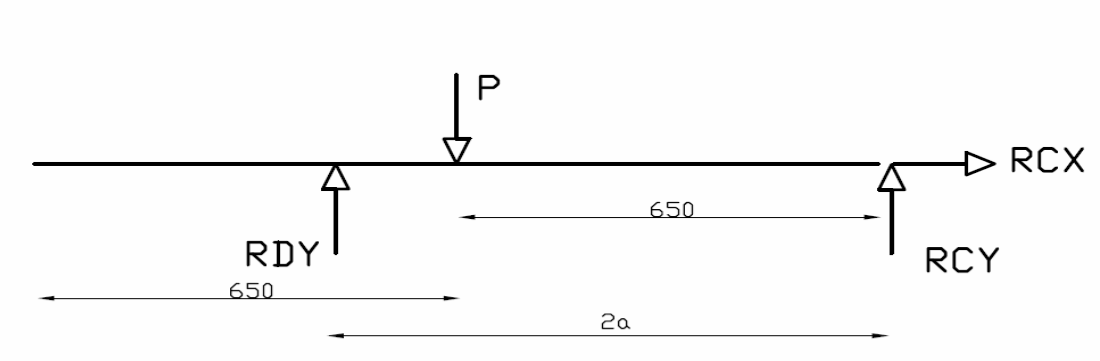
(Note: the initial measurements have been taken from a previous study of this kind of mechanisms)

2.2.3 CALCULATION OF THE FORCE

In this section the maximum force carried out by the cylinder is going to be calculated. To find it out, the diagrams of the forces of the bars which the mechanism consists of are going to be studied. In this way all reactions in the bars and the maximum force of the cylinder will be calculated. It is going to be calculated for a general position and in this way it will possible to know **the value of the force of the cylinder and each angle in each moment (APPENDIX Nº4)** .

It is important to mention that **a punctual load is assumed** to calculate all the reactions but it is known that the "real load" is not like this. It is done to make the calculations easier. In following chapters this load will be approximated to a distributed load which is more similar to the "real load" than a punctual load.

TOP TABLE

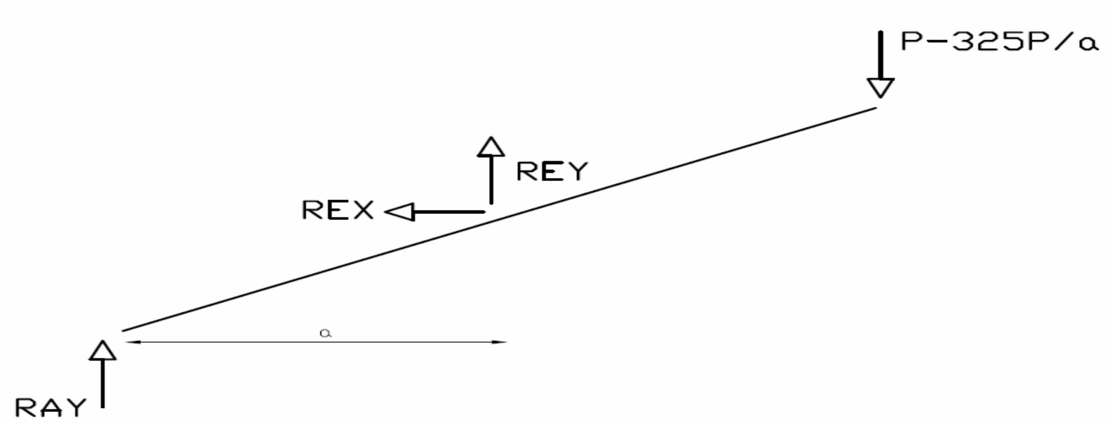


-PICTURE 31: reactions on top table-

$$\left.\begin{array}{l}\sum Fx = 0 \Rightarrow Rcx = 0 \\ \sum Fy = 0 \Rightarrow P - Rcy - Rdy = 0 \\ \sum Mzc = 0 \Rightarrow P \cdot 650 - Rdy \cdot 2a = 0\end{array}\right\}$$

$$\left.\begin{array}{l}Rdy = \dfrac{325 \cdot P}{a} \\ Rcy = \dfrac{P - 325 \cdot P}{a}\end{array}\right\}$$

A-E-C

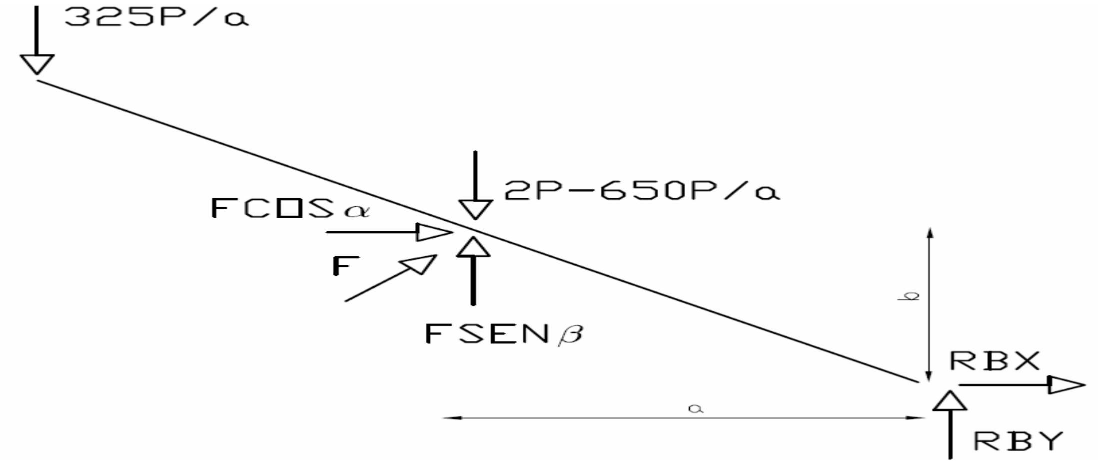


-PICTURE 32: reactions on –A-E-C bar-

$$\left.\begin{array}{l}\sum Fx = 0 \Rightarrow \mathrm{Re}\,x = 0 \\ \sum Fy = 0 \Rightarrow -P + \dfrac{325 \cdot P}{a} + \mathrm{Re}\,y + Ray = 0 \\ \sum Mza = 0 \Rightarrow -\left(P - \dfrac{325 \cdot P}{a}\right) \cdot 2 \cdot a + \mathrm{Re}\,y \cdot a = 0\end{array}\right\}$$

$$\left.\begin{array}{l}\mathrm{Re}\,y = 2 \cdot P - \dfrac{650 \cdot P}{a} \\ Rcy = -P + \dfrac{325 \cdot P}{a}\end{array}\right\}$$

D-E-B



-PICTURE 33: ***reactions on D-E-B bar--***

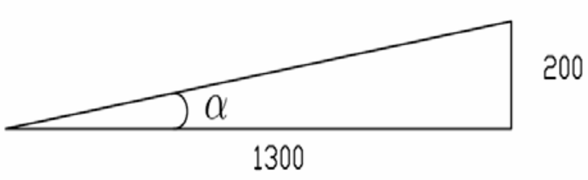
$$\left.\begin{array}{l}\sum Fx = 0 \Rightarrow \mathrm{R}\,bx + F\cos\alpha = 0 \\ \sum Fy = 0 \Rightarrow -\dfrac{325\cdot P}{a} - \mathrm{Re}\,y + Rby + Fsen\alpha = 0 \\ \sum Mzb = 0 \Rightarrow 325\cdot P\cdot 2 + 2\cdot P\cdot a - 650\cdot P - Fcil\cdot sen\alpha\cdot a = 0\end{array}\right\}$$

Solving all the equations it is possible to find the formula to calculate the force of the cylinder. It is on function of the value of the angle.

$$Fcil = \frac{2\cdot P\cdot a}{\cos\alpha\cdot b + sen\alpha\cdot a}$$

POSITION OF THE MAXIMUM FORCE OF THE CYLINDER

The **maximum force in the cylinder** is produced when the **angle is the smallest one**, therefore it is this situation:



-PICTURE 34: ***triangle of the angle with maximum force of the cylinder -***

With this drawing, the angle in the position with maximum force of the cylinder can be calculated:

$$\arctg\alpha = \frac{200}{1300} \Rightarrow \alpha = 8,75^{\circ}$$

And with this angle and with the formula calculated before, the maximum force of the cylinder is calculated:

$$Fcil(kg) = \frac{2 \cdot P \cdot a}{\cos\alpha \cdot b + sen\alpha \cdot a} = \frac{2 \cdot 1000 \cdot 650}{\cos 8,75 \cdot 100 + sen 8,75 \cdot 650} \simeq 6570kg$$

$$F\max = 6570kg \times 9,81\frac{N}{kg} \simeq 64500N$$

MAXIMUM FORCE OF THE CYLINDER=64500N

2.2.4 CALCULATION OF THE PISTON'S DIAMETER AND PRESSURE

Now that the maximum force of the cylinder has been calculated, the piston's diameter can be calculated. The pressure must be known to do that. For this reason having a look on the **Table 2** of standard piston's diameters it is clear that with the force that is needed for the piston(64500N) the pressure must be minimum 40 bar. Finally a pressure of **60 bar** and a piston's diameter of **125 mm** are selected.

Diámetro del pistón	Area Pistón	Fuerza de empuje (kN)							
		Presión (bar)							
(D = mm)	(mm^2)	6	10	40	60	100	150	200	250
25	491	0.3	0.5	2.0	3.0	5.0	7.5	10.0	12.5
32	804	0.5	0.8	3.3	4.9	8.2	12.3	16.4	20.5
40	1257	0.8	1.3	5.1	7.7	12.8	19.2	25.6	32.0
50	1963	1.2	2.0	8.0	12.0	20.0	30.0	40.0	50.0
63	3117	1.9	3.2	12.7	19.1	31.8	47.7	63.6	79.4
80	5027	3.1	5.1	20.5	30.7	51.2	76.9	102.5	128.1
100	7854	4.8	8.0	32.0	48.0	80.1	120.1	160.1	200.2
125	12272	7.5	12.5	50.0	75.1	125.1	187.6	250.2	312.7
160	20106	12.3	20.5	82.0	123.0	205.0	307.4	409.9	512.4
200	31416	19.2	32.0	128.1	192.1	320.2	480.4	640.5	800.6

-TABLE 2: ***standard diameter of hydraulic cylinders-***

Now if you have a look at the table it is clear that with a pressure of 60 bar and a piston's diameter of 125mm a force around 75000kN is reached. But the piston is going to work with a force around 64500N and for this reason a recalculation of the real pressure which the cylinder is going to work must be done.

$$P=\frac{F}{A}=\frac{64500}{\frac{\pi\cdot125^2}{4}}=5,25MPa\simeq52,5bar$$

PISTON'S DIAMETER=125mm

PRESSURE=52, 5 bar

2.2.5 CALCULATION OF THE PISTON'S THICKNESS

Firstly it assumed that the thickness can be calculated with the theory of the **"thick-walled cylinder"** (**APPENDIX Nº 7**)

This theory has the following formulas:

$$\left.\begin{array}{l}\sigma r=\sigma3\simeq0\\ \sigma\theta=\sigma1=\dfrac{P\cdot d}{2\cdot t}\\ \sigma z=\sigma2=\dfrac{P\cdot d}{4\cdot e}\end{array}\right\}$$

As it was mentioned in chapter 2.1(information) the theory of "maximum shear"" is used to calculate stresses.

It has these formulas (**APPENDIX Nº 6**):

$$\left.\begin{array}{l}\tau\max=\dfrac{\sigma1-\sigma3}{2}\\ \tau\max=\dfrac{1}{2}\cdot\dfrac{\sigma y}{Cs}\\ Cs=\dfrac{\sigma y}{2\cdot\tau\max}\end{array}\right\}$$

It is also known:

$$\left.\begin{array}{l} P = 52{,}5bar = 5{,}25MPa(N/mm^2) \\ d = 125mm \\ \sigma y = 350Mpa \end{array}\right\}$$

With these formulas and the information that is already known, it is possible to calculate the thickness:

$$\left.\begin{array}{l} \tau \max = \frac{\sigma 1 - \sigma 3}{2} = \frac{\sigma 1 - 0}{2} = \frac{P \cdot d}{4 \cdot e} \\ \tau \max = \frac{1}{2} \cdot \frac{\sigma y}{Cs} = \frac{0{,}5 \cdot 350}{2} = 87{,}5 N/mm^2 \end{array}\right\}$$

Therefore if both parts are made equal: $87{,}5 = \frac{5{,}22 \cdot 125}{4 \cdot e}$

$$e = 1{,}864mm \simeq 2mm$$

Now to check if the theory used is correct the following verification must be done:

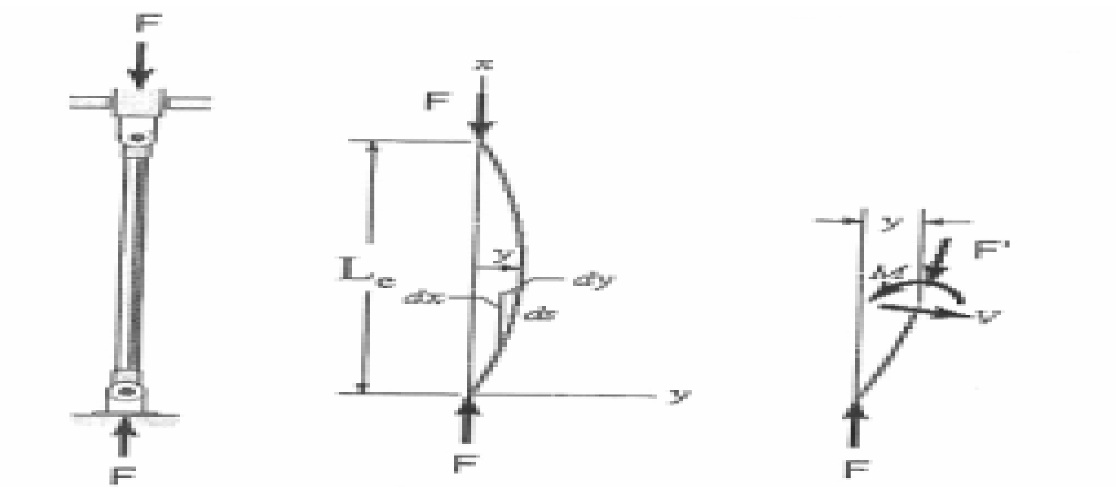
$$\frac{d}{t} > 40 \Rightarrow \frac{125}{2} = 62{,}5 > 40$$

Therefore this thickness calculated before fulfil the requirements.

PISTON'S THICKNESS=2mm

2.2.6 CALCULATION OF THE PISTON ROD'S DIAMETER (buckling of the piston rod)

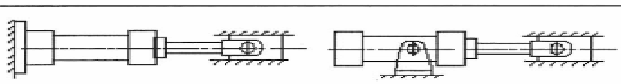
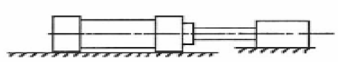
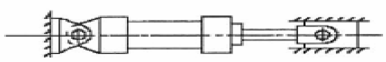
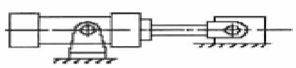
In this chapter the piston rod's diameter is going to be calculated. The **possible bucking** of the piston rod is going to be taken into account to avoid the failure of this part of the mechanism due to the compression force. This phenomenon is seen in the picture below.



-PICTURE 35: ***buckling of a column*-**

As it is known there are two theories to study the buckling of the columns (Johnson and Euler) but firstly it is assumed that the piston rod is a **"large bar"**, therefore the theory of **EULER** is going to be used to make the calculations (**APPENDIX Nº 8**) .It also assumed a **coefficient of security of 3** and the material to use is steel with a young module of 210 GPa.

First of all it is important to find out the factor of buckling (β).It is selected in the table below:

Tipo de fijación cilindro	Esquema de montaje	Factor de pandeo (β)
Articulado y rígidamente guiado		1.5
Apoyado, pero no rígidamente quiado		2.0
Articulado y rígidamente guiado		2.0
Articulado y apoyado, pero no rígidamente quiado		3.0

-TABLE 3: ***factor of buckling*-**

For this theory the maximum force that the piston rod can resist is calculated with the following formula:

$$\left.\begin{aligned} &Fcr1 = Fc \cdot Cs = 64500 \cdot 3 \simeq 194000N \\ &Fcr1 = \frac{I \cdot \pi^2 \cdot E}{Le^2} = 194000 = \frac{\pi^2 \cdot 210000 \cdot I}{(348 \cdot 2)^2} \Rightarrow I \simeq 45300mm^4 \end{aligned}\right\}$$

Now that the inertia is known, the "possible" diameter is calculated:

$$I = \frac{\pi \cdot d^4}{64} \Rightarrow d = \sqrt[4]{\frac{I \cdot 64}{\pi}} = \sqrt[4]{\frac{45300 \cdot 64}{\pi}} \simeq 30mm$$

The turning radio is calculated like this:

$$i = \sqrt{\frac{I}{A}} = \sqrt{\frac{45300}{\frac{\pi \cdot (30)^2}{4}}} \simeq 8$$

Now the slenderness of the column is going to be calculated:

$$\left.\begin{aligned} &\lambda = \frac{Le}{i} = \frac{348 \cdot 2}{8} \simeq 87 \\ &\lambda \lim = \sqrt{\frac{2 \cdot \pi^2 \cdot E}{\sigma f}} = \sqrt{\frac{2 \cdot \pi^2 \cdot 210000}{320}} \simeq 109 \end{aligned}\right\}$$

Now all information is known and it is possible to check if really it is large column or not. It is going to be checked with this:

$$\lambda > \lambda \lim$$

$$87 < 109$$

It doesn't fulfil the requirements, therefore the **"JHONSON'S method"** to short columns is going to be assessed (**APPENDIX Nº 9)**.

Now the method consist of trying with other diameters until we find a diameter whose maximum force is bigger than the previous force calculated with EULER.

A diameter of 35mm is chosen:

$$I = \frac{\pi \cdot d^4}{64} = \frac{\pi \cdot 35^4}{65} \simeq 73700mm^4$$

$$i = \sqrt{\frac{I}{A}} = \sqrt{\frac{73700}{\frac{\pi \cdot (35)^2}{4}}} \simeq 9$$

$$\lambda = \frac{Le}{i} = \frac{348 \cdot 2}{9} \simeq 77$$

$$Fcr2 = A \cdot \sigma_f \left[1 - \frac{\sigma_f \cdot \lambda^2}{4 \cdot \pi^2 \cdot E}\right] = \frac{\pi \cdot 35^2}{4} \cdot 350 \left[1 - \frac{350 \cdot 77^2}{4 \cdot \pi^2 \cdot 210.000}\right] \simeq 252000N$$

It is checked if Fcr2 is bigger than Frc1:

$$252000N > 194000N$$

Therefore, this diameter fulfils the requirements.

PISTON'S ROD DIAMETER=35mm

2.2.7 INFORMATION OF THE PUMP

As it was commented on **Chapter 2.2.1**, the cylinder chosen needs a pressure supplier and in hydraulic cylinder's case a pump is the machine in charge of supplying the compressed liquid. Therefore, in this chapter the characteristics of the pump are going to be calculated and a pump for a catalogue of a company (**APPENDIX Nº 10**) will be chosen.

2.2.7.1 FLOW

To chose a pump the speed of the **speed of the fluid is assumed as 0,04m/s.**

In this way the flow of the pump is calculated in this way:

$$Flow = A \cdot S = \frac{\pi \cdot 0{,}125^2}{4} \cdot 0{,}04 = 4{,}9 \cdot 10^{-4} m^3 / s$$

$$4{,}9 \cdot 10^{-4} \frac{m^3}{s} \times \frac{1000L}{1m^3} \times \frac{60s}{1m} \simeq 29{,}5L/\min$$

FLOW=29, 5 l/min

Now having a look to the following information about pumps the pump **BOSCH REXROTH AG-FS4-SIZE 20 is** selected. The reason why this one is selected is because if the pump with the next flow were selected there would be an unnecessary consumption of electricity. With a consumption of 28, 9 L/min, which is very close to the information calculated (29, 5 L/min) is enough.

Frame size			FS4							
Size	Size		20	25	32	40	50	63	80	100
Weight	m	kg	13.5	14	14.5	15	16	17	18.5	20
Speed range	n_{min}	min⁻¹	500	500	500	500	500	400	400	400
	n_{max}	min⁻¹	3000	3000	3000	2600	2600	2600	2200	2200
Displacement	V	cm³	20.1	25.3	32.7	40.1	50.7	65.5	80.3	101.4
Flow 1)	q_V	L/min	28.9	36.3	46.9	57.6	72.8	94.0	115.3	145.6
Operating pressure, absolute – Inlet	p	bar	0.8 to 2 (briefly at start 0.6 bar)							
– Outlet, continuous	p_{max}	bar								
	HLP fluid		250					210	160	125
	Special fluid		175					140	140	100
intermittent 2)	p_{max}	bar								
	HLP fluid		315					250	210	160
	Special fluid 3)		210					175	175	140

-TABLE 4: ***information about standard pumps*** **-**

2.2.7.2 POWER TO ACTIVATE THE PUMP

It **assumed an output of 0, 9**

The power can be calculated with the following formula:

$$POW = \frac{P \cdot Flow}{612 \cdot \eta} = \frac{52,5 \cdot 28,9}{612 \cdot 0,9} = 2,75KW$$

POWER TO ACTIVATE THE PUMP= 2, 75 KW

2.3 STRUCTURE

In this chapter all components of the structure are going to be studied. Bars, holes, welding and plates are going to be calculated. In this way all components of the mechanism will be known.

2.3.1 BARS

Here all components of the bars are going to be calculated. They are the stuff in charge of moving the mechanism. Within the components of the bars there are: holes to fix the bars and to fix the cylinder, and the cross section of the bars. All of them are going to be calculated in the following chapters

2.3.1.1 CALCULATIONS OF THE HOLES TO FIX THE BARS

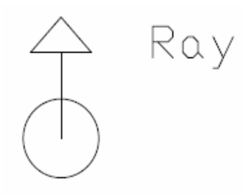
ASSUMPTIONS:

- **It is assumed that all of the diameters of the holes will have the same diameter**
- **They will work on simple shear**

As all of the holes must have the same diameter, the first step that must be done is to **find the support which will support the most efforts** because this hole will support the maximum effort. It means that the other holes will be able to support fewer efforts.

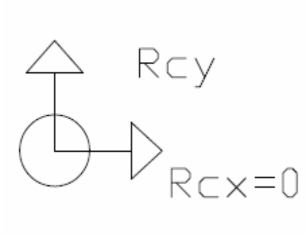
Therefore all of the supports are going to be assessed with the formulas that were calculated in **Chapter 2.2.3**:

A



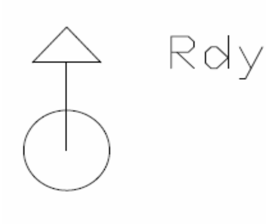
$$Ray = -P + \frac{325 \cdot P}{a} = -500 + \frac{325 \cdot 500}{650} = -250kg \simeq -2450N$$

C



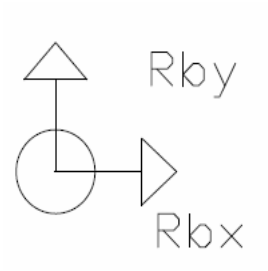
$$Rcx = P\left(1 - \frac{325}{a}\right) = 500\left(1 - \frac{325}{650}\right) = 250kg \simeq 2450N$$

D



$$Rdy = \frac{325 \cdot P}{a} = \frac{325 \cdot 500}{650} = 250kg \simeq 2450N$$

B



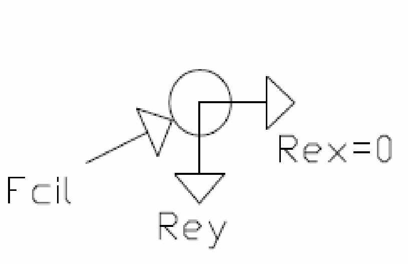
$$Rbx = -F \cdot \cos\alpha = 3285(P = 500kg) \cdot \cos 8,75^{\circ} \simeq 3250kg \simeq 31900N$$

$$Rby = \left(\frac{P \cdot 325}{a} + 2 \cdot P - \frac{650 \cdot P}{a} - F \cdot sen\alpha\right) = \left(\frac{500 \cdot 325}{650} + 2 \cdot 500 - \frac{650 \cdot 500}{650} - 3285 \cdot sen 8,75^{\circ}\right)$$

$$\simeq 250kg \simeq 2450N$$

$$Rbt = \sqrt{Rbx^2 + Rby^2} \simeq 32000N$$

E



$$\sum Fx = 0 \Rightarrow Rx = F \cdot \cos\alpha = 3285 \cdot \cos 8.75^{\circ} \simeq 3250kg \simeq 31900N$$

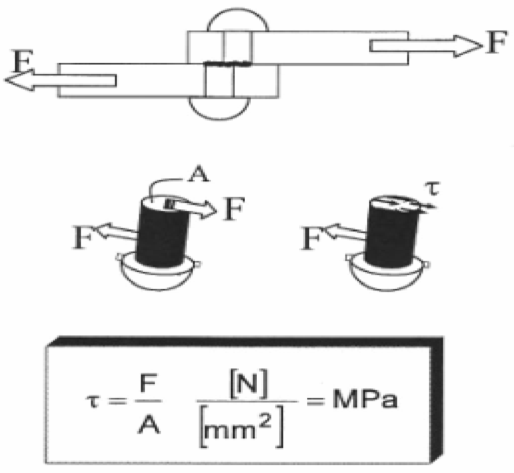
$$\sum Fy = 0 \Rightarrow Ry = \mathrm{Re}\,y - F \cdot sen\alpha = 500 - 3285 \cdot sen 8,75^{\circ} = 0$$

$$\mathrm{Re}\,t = \sqrt{\mathrm{Re}\,x^2 + \mathrm{Re}\,y^2} \simeq 31900N$$

It is clear to see that the hole which will stand more effort will be the letter B ($32000N$). Therefore all the calculations will be made taking into account this hole.

2.3.1.2 DIAMETER

Now knowing that the holes work in **simple share** (**Picture 36**) and using the theory of maximum shear:



$$\left.\begin{aligned} \tau h &= \frac{F}{A} \\ \tau \max &= \frac{\sigma f}{2 \cdot Csy} = \frac{350}{2 \cdot 2} = 87{,}5N/mm^2 \end{aligned}\right\}$$

-PICTURE 36: *simple shear*-

If τh and $\tau \max$ are the same it is possible to do this:

$$\tau \max = \tau h = \frac{F}{\frac{\pi \cdot d^2}{4}} \Rightarrow d = \sqrt{\frac{F \cdot 4}{\tau h \cdot \pi}} = \sqrt{\frac{32000 \cdot 4}{\pi \cdot 87{,}5}} = 21{,}5mm$$

DIAMETER OF THE HOLES=25mm

2.3.1.3 THICKNESS

The next information to be calculated is the thickness of the rectangular cross section. It is going to be calculated **taking into account the crush of the holes.**

To do that two formulas are going to be used:

$$\left.\begin{aligned} \sigma c &= \frac{F}{t \cdot d} \\ \sigma &= \frac{\sigma y}{Csy} = \frac{350}{2} = 175N/mm^2 \end{aligned}\right\}$$

If $\sigma c \, \tau h$ and σ are the same it is possible to do this:

$$175 = \frac{F}{t \cdot d} \Rightarrow t = \frac{32000}{175 \cdot 25} \simeq 7{,}3mm$$

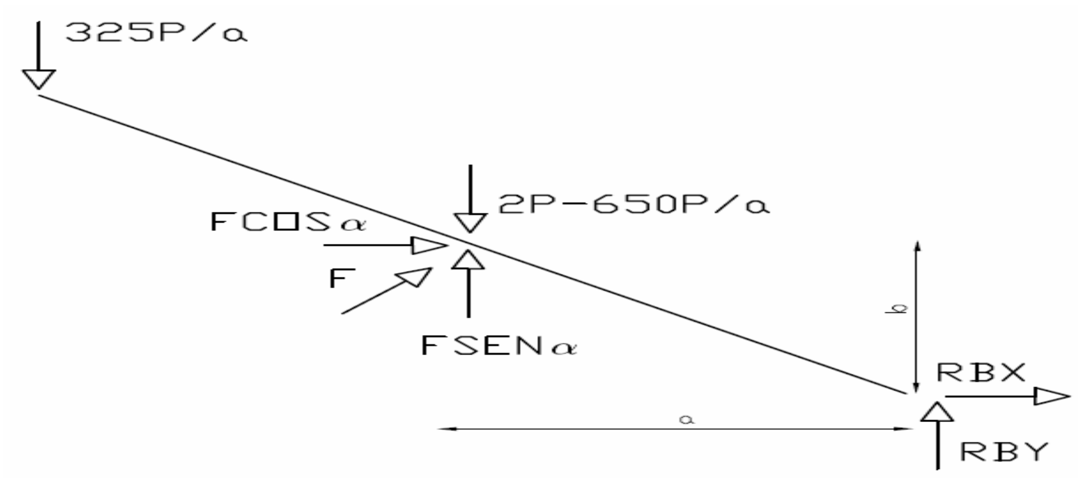
THICKNESS = 10mm

2.3.1.4 HEIGHT

Now it is possible to calculate the height of the rectangular cross section of the bars.

To calculate that, **the diagrams of moments, shears and compressions are needed.**

First of all, the bar D-E-B is going to be shown with all its forces.



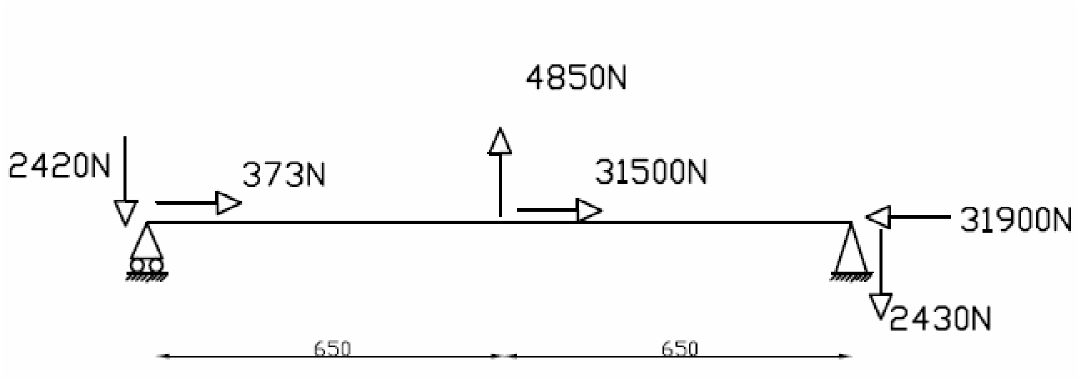
-PICTURE 37: *reactions in D-E-B bar*-

Summary of the forces:

$$\left.\begin{array}{l} Rdy = 250kg = 2450N \\ \operatorname{Re} y = 500kg = 4910N \end{array}\right\} \qquad \left.\begin{array}{l} F \cdot \cos\alpha = 3250kg = 31900N \\ F \cdot sen\alpha = 500kg = 4910N \end{array}\right\}$$

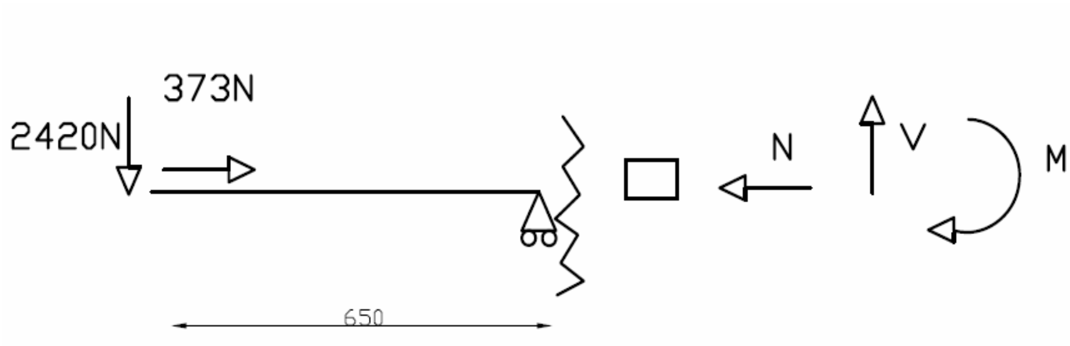
$$\left.\begin{array}{l} Fcil \simeq 6570kg \simeq 64500N \\ Rby \simeq 250kg \simeq 2450N \\ Rbx = -3250kg = -31900N \end{array}\right\}$$

Now it is known that this diagram is equal to the following one (the axes are changed to use the axis x and y of the bar):



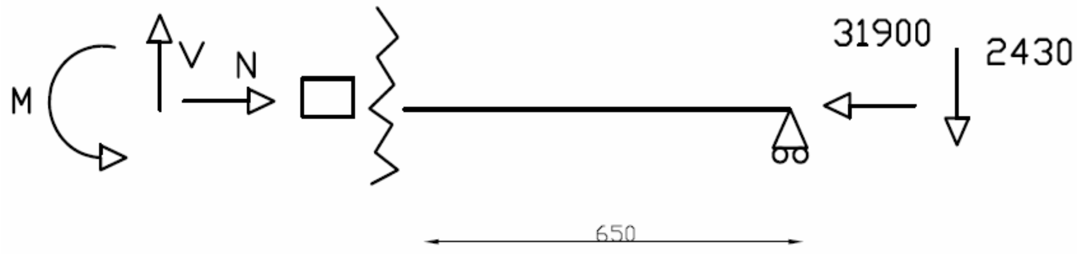
-PICTURE 38: ***reactions in D-E-B with new axes-***

Knowing the equivalent model it is possible to calculate the diagrams:



-PICTURE 39: ***calculations of diagrams of D-E-B bar. Part 1-***

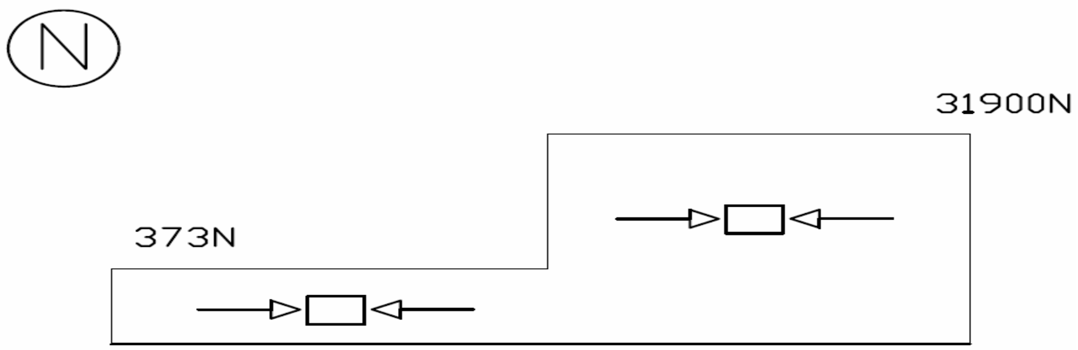
$$\left.\begin{array}{l} N = 373N \\ V = 2420N \\ M = 2420 \cdot x \Rightarrow (x = 0 \Rightarrow M = 0N) \Rightarrow (x = 655 \Rightarrow M \simeq 1590000 N \cdot mm) \end{array}\right\}$$



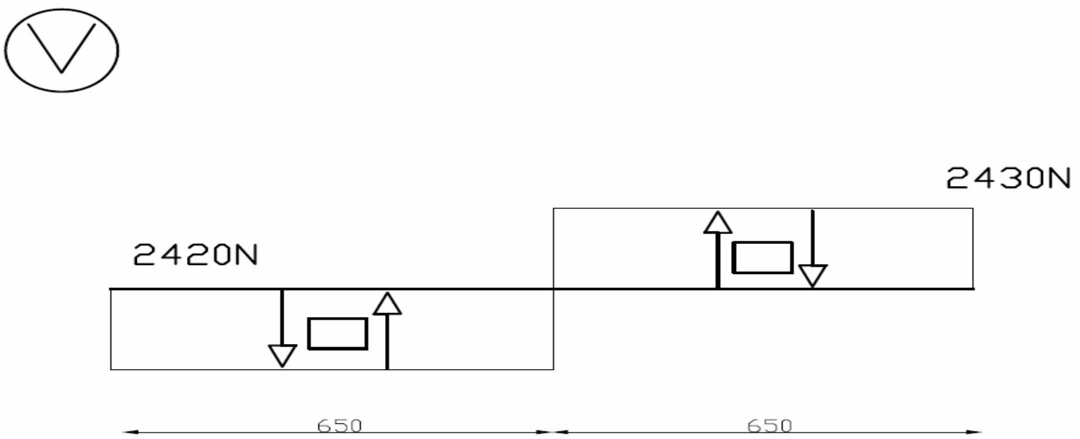
-PICTURE 40 ***calculations of diagrams of D-E-B bar. Part 2-***

$$\left.\begin{array}{l} N = 31900N \\ V = 2430N \\ M = 2430 \cdot x \Rightarrow (x = 0 \Rightarrow M = 0N) \Rightarrow (x = 655 \Rightarrow M \simeq 1590000N \cdot mm) \end{array}\right\}$$

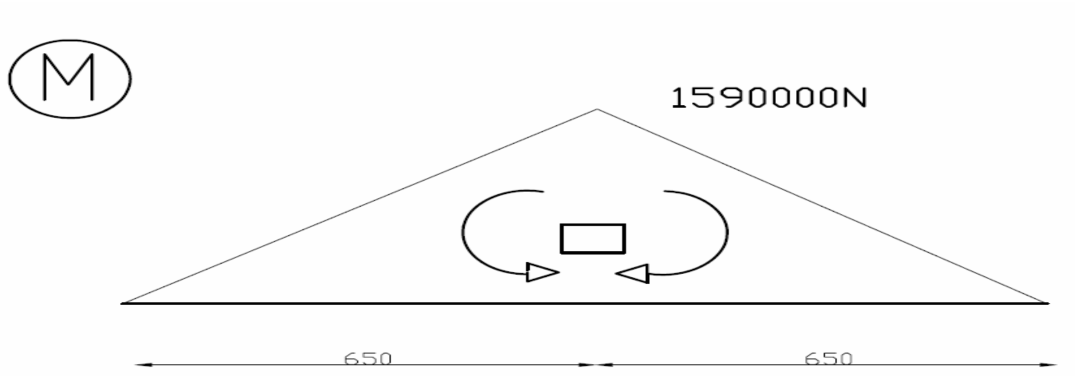
DIAGRAMS



-PICTURE 41: ***diagram of compression forces of D-E-B bar-***



-PICTURE 42 ***:diagram of shears of D-E-B bar-***



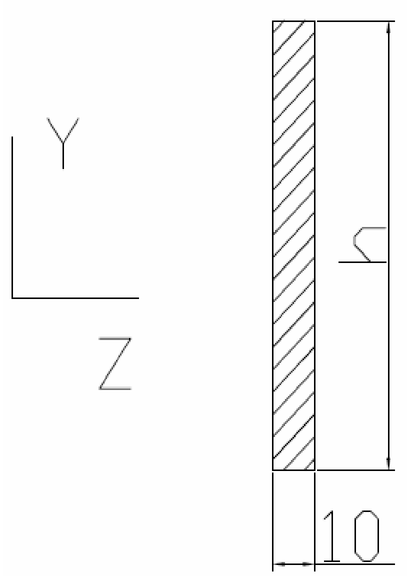
-PICTURE 43 *diagram of moments of D-E-B bar-*

Once that the diagrams have been solved, it is possible to calculate the height of the rectangular cross section.

To calculate that, this formula is going to be used (**APPENDIX Nº11**):

$$\sigma x = \frac{Mz}{Wz} + \frac{N}{A} \leq \frac{\sigma y}{Csy} = \sigma$$

The rectangular cross section is like the picture below and with this cross section it is possible to calculate:

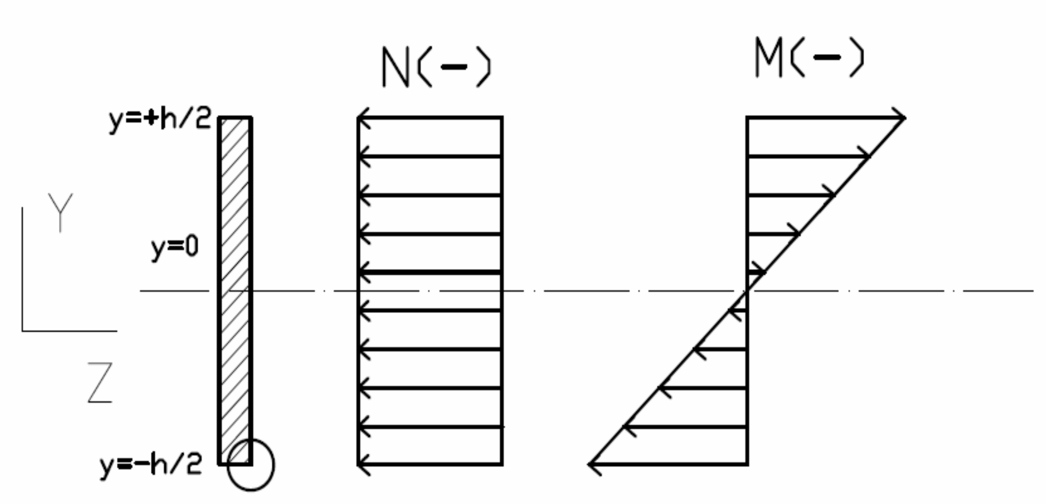


$$\left.\begin{array}{l} \sigma \leq \dfrac{\sigma y}{Csy} = \dfrac{350}{2} = 175 N/mm^2 \\ Inertia = \dfrac{1}{12} \cdot b \cdot h^3 = \dfrac{1}{12} \cdot 10 \cdot h^3 = 0,83h^3 \\ Y\max = -0,5h \\ Wz = \dfrac{inertia}{Y\max} = \dfrac{0,83h^3}{-0,5h} = -1,66h^2 \\ Area = b \cdot h = 10 \cdot h \end{array}\right\}$$

-PICTURE 44: *cross section of D-E-B bar-*

It is important to say where the negative value of $Y\max$ comes from. Due to the criteria of the signs of the forces and moments (**APPENDIX Nº12**), **there is a negative moment and a negative force** (compression) (you can check that in the previous diagrams). Besides, another important information to taken into account is that the value of the stress produced by the shore is not taken into account in this kind of cross section because it is very small in comparison with the value of the normal stress produced by the moment and by the compression force.

Therefore there are these forces and moments in the cross section:



-PICTURE 45: ***compression force and moment in D-E-B cross section--***

As you can see the **most unfavourable part** of this cross section is in $Y = -h/2$ because there is, on the one hand, a negative compression force and, on the other hand, a negative value of moment. If you add these values, it is clear to see that this part will support more stress than the other ones. Therefore, it is clear that it is necessary to work with this part because if this part supports the effort, the other ones will also do.

With all information explained before the height of the rectangular cross section is calculated in this way:

$$175 = \frac{-1590000}{-1,66 \cdot h^2} + \frac{32000}{10 \cdot h}$$

$$175 \cdot h^2 = 957831 + 3200 \cdot h$$

$$175 \cdot h^2 - 3200 \cdot h - 957831 = 0$$

$$h = \frac{3190 \pm \sqrt{3200^2 - 4 \cdot 175 \cdot (-957831)}}{2 \cdot 175}$$

$$\left.\begin{array}{l} h = 83,7mm \\ h = -65,4mm \end{array}\right\}$$

There are two possible values for the height of the bars but logically a negative value does not make sense for a height. In this way the height of the bars is:

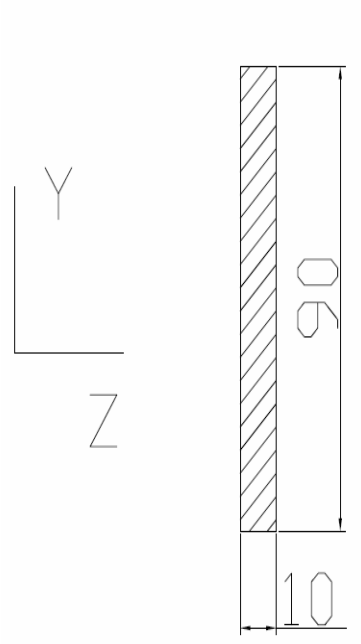
HEIGHT=90mm

2.3.1.5 BUCKLING

Now that all information is known, it is very important to check if with these measurements the bars will resist to buckling.

To check it, the **security coefficient to buckling will be calculated**. If this coefficient is less than 1, the measurements will have to be recalculated but if the coefficient is 1 or more than 1, it will resist to buckling.

The rectangular cross section of the bar is like this:



$$\left.\begin{array}{l} Area = b \cdot h = 90 \cdot 10 = 900mm^2 \\ Inertia(y) = \frac{1}{12} \cdot h \cdot b^3 = \frac{1}{12} \cdot 90 \cdot 10^3 = 7500mm^4 \end{array}\right\}$$

-PICTURE 46: complete *cross section of D-E-B bar* -

(Note: to calculate the inertia the y axis has been taken. It is because is the critical axis, it means that it is the axis with less inertia)

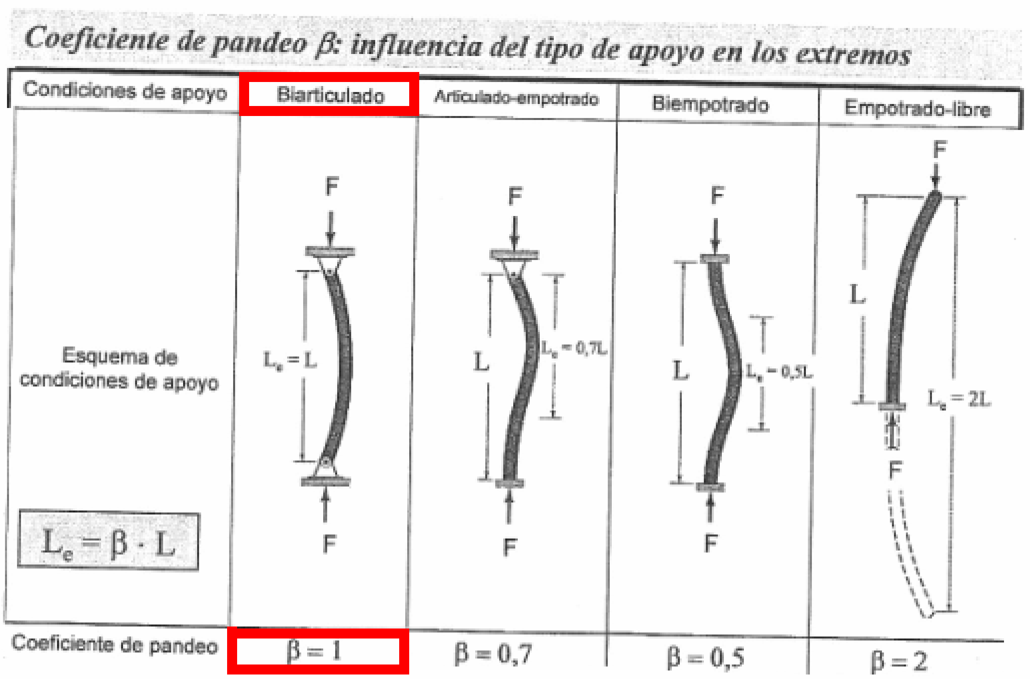
Now it is very important to check if the bar is either a large column (EULER) or a short one (JHONSON).

To check it is going to be proceeded in the same way than in **Chapter 2.2.6:**

$$i = \sqrt{\frac{I}{A}} = \sqrt{\frac{7500}{900}} = 2{,}88$$

$$\lambda \lim = \sqrt{\frac{2 \cdot \pi^2 \cdot E}{\sigma f}} = \sqrt{\frac{2 \cdot \pi^2 \cdot 210000}{320}} \simeq 109$$

To know the value of β the following table will be assessed:



Coeficiente de pandeo β: influencia del tipo de apoyo en los extremos

Condiciones de apoyo	Biarticulado	Articulado-empotrado	Biempotrado	Empotrado-libre
Esquema de condiciones de apoyo $L_e = \beta \cdot L$	F, $L_e = L$, F	F, L, $L_e = 0{,}7L$, F	F, L, $L_e = 0{,}5L$, F	F, L, $L_e = 2L$, F
Coeficiente de pandeo	$\beta = 1$	$\beta = 0{,}7$	$\beta = 0{,}5$	$\beta = 2$

-TABLE 5: ***coefficients of buckling-***

$$\lambda = \frac{Le}{i} = \frac{L \cdot \beta}{i} = \frac{655 \cdot 1}{2{,}88} \simeq 227$$

Finally it is possible to check that:

$$227 > 109$$

In this way this bar can be studied like a **''large column'' (EULER).**

Euler's theory says that (**APPENDIX Nº8**):

$$\left.\begin{aligned} &Fcr1 = Fc \cdot Cs \\ &Fcr1 = \frac{I \cdot \pi^2 \cdot E}{Le^2} = \frac{\pi^2 \cdot 210000 \cdot 7500}{(655 \cdot 1)^2} = 36200N \end{aligned}\right\}$$

On the other hand the maximum compression force which was calculated in **Chapter 2.3.1.2** and which was placed on the hole ''B'' is known.

$$Fc = 32000N$$

Finally, if the two formulas are put together, it is possible to find out the value of security coefficient

$$Csb = \frac{Fcr}{Fcomp} = \frac{36200}{32000} = 1{,}13$$

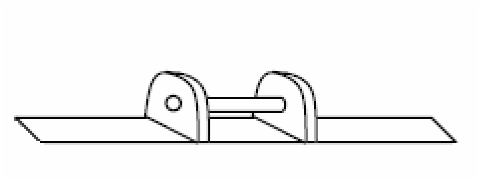
COEFFICIENT OF SECURITY AGAINST BUCKLING= 1, 13

The security coefficient is bigger than 1, therefore **the bars will stand the buckling and they will not be broken**.

Therefore it is not needed to recalculate the measurements of the bars.

2.3.2 SUPPORTER OF THE CYLINDER

The cylinder will be fixed with the construction below:

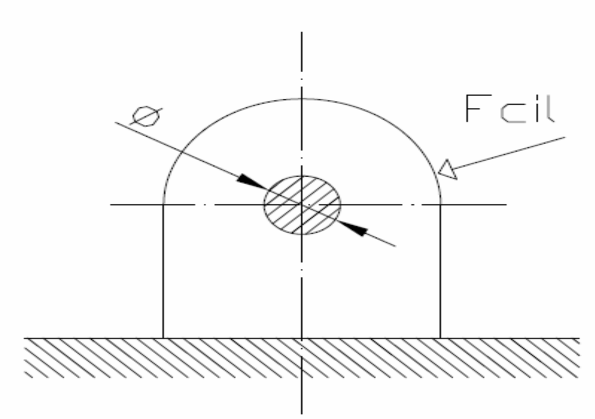


-PICTURE 47: ***supporter of the cylinder-***

Therefore, it is necessary to calculate all the information about the two structures that will support the bar in which the cylinder will be joined. In this chapter all this information is going to be calculated

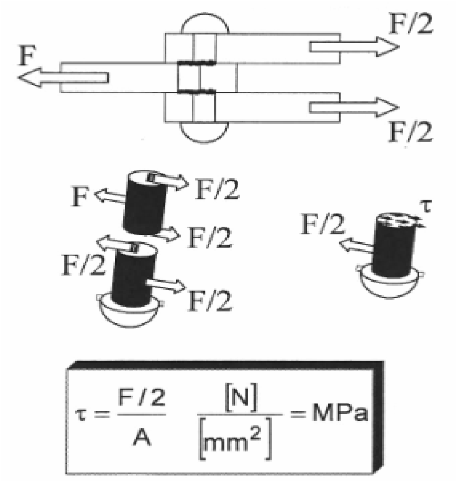
2.3.2.1 DIAMETER OF THE HOLE

As you can see in the picture below it is necessary to calculate the diameter of the hole where the bars to support the cylinder will be inserted. In this hole there is only one force and this is the entire maximum force of the cylinder (calculated in **Chapter 2.2.3**).



-PICTURE 48: ***forces on the support of the cylinder-***

The diameter is going to be calculated as the previous ones but with a little difference. The difference is that now there are two supports (as you could see in **Picture 47** and therefore now **there is a double shore**. You can see that in **Picture 49**:



$$\tau h = \frac{F}{2 \cdot A}$$
$$\tau \max = \frac{1}{2}\frac{\sigma y}{Csy} = \frac{350}{2 \cdot 2} = 87{,}5 N/mm^2$$

-PICTURE 49: ***double shear-***

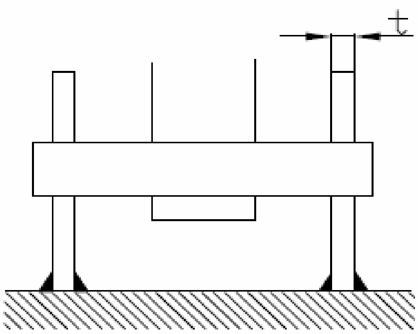
If τh and $\tau \max$ are the same it is possible to do this:

$$\tau \max = \tau h = \frac{F}{\frac{\pi \cdot d^2}{4}} \Rightarrow d = \sqrt{\frac{F \cdot 4}{\tau h \cdot \pi}} = \sqrt{\frac{64500 \cdot 4}{\pi \cdot 87{,}5 \cdot 2}} = 21{,}7mm$$

DIAMETER OF THE HOLES OF THE SUPPORT OF THE CYLINDER =25mm

2.3.2.2 THICKNESS

In this chapter the thickness of the supports of the cylinder is going to be calculated. To do that, **the crush of the support is going to be taken into account**. As it was seen in a previous **Chapter 2.3.1.3,** to calculate thickness two formulas are needed. Therefore, these same formulas are going to be used to calculate the thickness of the support.



$$\sigma c = \frac{F}{t \cdot d}$$
$$\sigma = \frac{\sigma y}{Csy} = \frac{350}{2} = 175 N/mm^2$$

$$175 = \frac{F}{t \cdot d} \Rightarrow t = \frac{32300}{175 \cdot 25} = 7{,}3mm$$

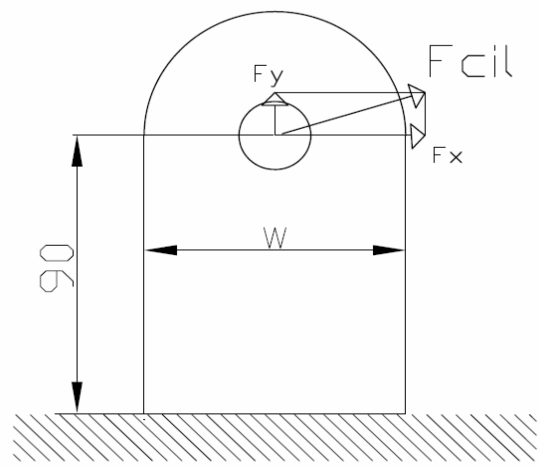
-PICTURE 50: ***thickness of the support of the cylinder-***

THICKNESS OF THE SUPPORT OF THE CYLINDER: 10 mm

2.3.2.3 WIDTH

To calculate the width there are **two forces that must be taken into account** (Fy and Mz).They will act in the base of the support.

You can see that in the picture below:



-PICTURE 51: ***width of the support of the cylinder-***

In this way the following formula is going to be used (**APPENDIX Nº11**):

$$\sigma w = \frac{Fy}{t \cdot w} + \frac{Mz}{\frac{t \cdot w^2}{6}}$$

And the forces are these ones:

$$\left.\begin{aligned} Fy &= Fcil \cdot sen\alpha = 32300 \cdot sen8,75º \simeq 4910N \\ Mz &= Fcil \cdot \cos\alpha \cdot d = 32300 \cdot \cos 8,75º \cdot 90 \simeq 2870000N \cdot mm \end{aligned}\right\}$$

Firstly, it is going to be **tried with just Mz** because, otherwise, the calculations would be more difficult (there would be the unknown "w" up to 3).In this way there will be a **"possible" value of "w"** that will be to have assessed.

Therefore:

$$w = \sqrt{\frac{Mz \cdot 6}{t \cdot \sigma w}} = \sqrt{\frac{2870000 \cdot 6}{10 \cdot 175}} = 99 \simeq 100mm$$

On the other hand, it is known that:

$$\sigma w \leq \sigma = 175 N / mm^2$$

Therefore, we need to check this equality:

$$\sigma w = \frac{Fy}{t \cdot w} + \frac{Mz}{\frac{t \cdot w^2}{6}} = \frac{4910}{10 \cdot 100} + \frac{2870000 \cdot 6}{10 \cdot 100^2} \simeq 177 N / mm^2$$

With $100 mm$ of width **the equality is not right**, so we need to try with another higher measurement.

We are going to try with $110 mm$ **:**

$$\sigma w = \frac{Fy}{t \cdot w} + \frac{Mz}{\frac{t \cdot w^2}{6}} = \frac{4910}{10 \cdot 110} + \frac{2870000 \cdot 6}{10 \cdot 110^2} \simeq 147 N / mm^2$$

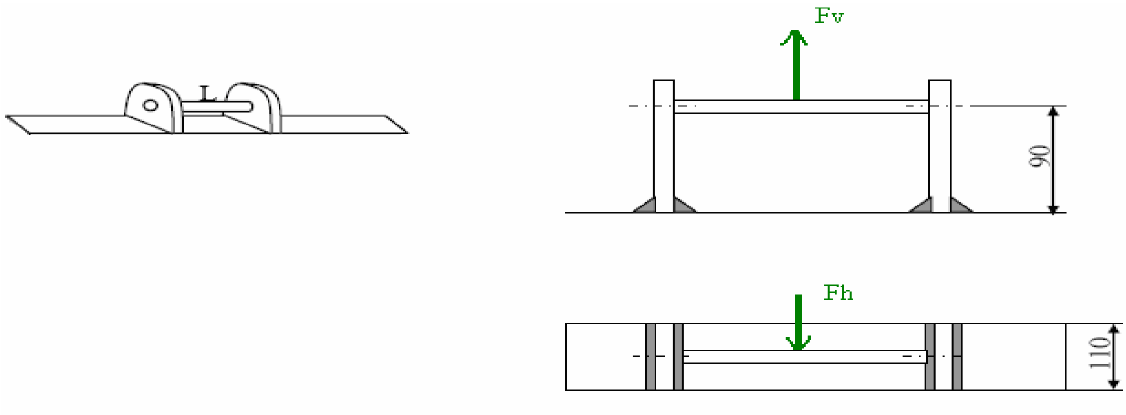
With this measurement, **the equality is right** because σ is bigger than σw.In this way it is guaranteed that the material will not break because it will work with a stress smaller than the limit stress to be broken.

Therefore:

WIDTH OF THE SUPPORT OF THE CYLINDER = 110mm

2.3.2.4 WELDING

As it was explained in the previous chapter the support of the cylinder will consist of two supporters joined by a bar. You can see that in the picture below.



-PICTURE 52: ***welding of the support of the cylinder--***

As you can see the two supports must be fixed to the ground and to do that a welding through all length is going to be used. As it is also known, the force of the cylinder has two components, one vertical and another horizontal. **The horizontal one will produce flexion** in the welding and the **vertical one will produce traction**. Besides, another thing that is important to comment is that in the formula of the normal stress there are two forces acting (moment of Fh and traction of Fv) and therefore it is necessary to add the stress produced by these two forces.

Therefore, knowing the value of the forces is possible to calculate the right welding to work on.

You can see where the formulas come from in **APPENDIX Nº14** (traction case) and in **APPENDIX Nº15** (flexion case)

Therefore the forces actuating on the supporter are :

$$FcilMax = 64500N \quad \left\{ \begin{array}{l} Fh = 64500 \cdot \cos 8,75^{\circ} = 63700N \\ Fv = 64500 \cdot sen 8,75^{\circ} = 9810N \end{array} \right.$$

But there are two supporters and therefore each supporter will stand half of the load. Therefore:

$$\left. \begin{array}{l} Fh = 63700/2 = 31850N \\ Fv = 9810/2 = 4905N \end{array} \right\}$$

SECTION 1

$$t1 = 0$$

$$t2 = \frac{Fh/2}{L \cdot a} = \frac{31850/2}{110 \cdot a} = \frac{145}{a}$$

$$n\max = \frac{M}{W} + \frac{N}{a} = \frac{Fh \cdot d/2}{a \cdot L^2/6} + \frac{Fv/2}{a} = \frac{31850/2 \cdot 90}{a \cdot 110^2/6} + \frac{4905/2}{a \cdot 2 \cdot 110} = \frac{711}{a} + \frac{22}{a} = \frac{733}{a}$$

SECTION 2

$$\left.\begin{aligned}
\tau 1 &= \frac{t1 - n\max}{\sqrt{2}} = -\frac{733}{\sqrt{2}\cdot a} \\
\tau 2 &= t2 = \frac{145}{a} \\
\sigma &= \frac{t1+n}{\sqrt{2}} = \frac{0+\frac{733}{a}}{\sqrt{2}} = \frac{733}{\sqrt{2}\cdot a}
\end{aligned}\right\}$$

In this case a **coefficient of security of 2 is assumed** and the formula of the coefficient of security is also know .That is why it is possible to calculate the section of the welding:

$$\left.\begin{aligned}
\sigma y &= 350 N/mm^2 \\
Cs &= 2
\end{aligned}\right\} \quad Cs = \frac{\sigma y}{\sigma} \Rightarrow \sigma = \frac{350}{2} = 175 N/mm^2$$

Now the equivalent stress (because there are tangential and normal stresses) must be calculated like this:

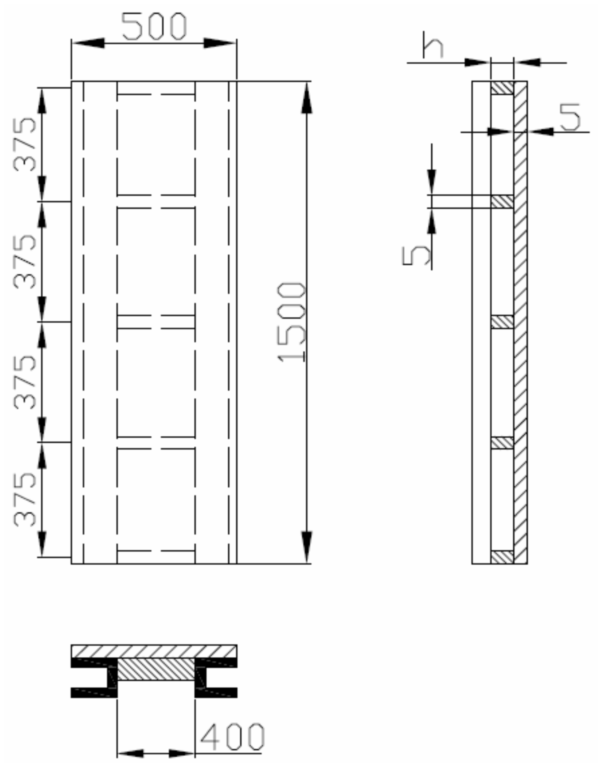
$$\sigma eq = \sqrt{\sigma^2 + 3\left(\tau 1^2 + \tau^2\right)} \leq \sigma$$

$$\sqrt{\left(\frac{733}{\sqrt{2}\cdot a}\right)^2 + 3\left[\left(\frac{-733}{\sqrt{2}\cdot a}\right)^2 + \left(\frac{145}{a}\right)^2\right]} \leq 175$$

WELDING OF = 6mm

2.3.3 STRUCTURE ON THE TOP

To fix the belt conveyors, a structure on the top of the mechanism is needed. It will consist of: a sheet on the top, two “UPN” profiles, five reinforcing flat bars and a thin sheet glued to these flat bars. The function of each one is going be explained in the following chapter but, before that, it is possible to have an idea about how the top of the construction will be with the picture below:



-PICTURE 53: ***structure on the top*****-**

It is important to emphasize that, as you could see in **Chapter 2.2.3**, in which the maximum force of the cylinder was calculated, the total load was assumed as a punctual load. **But in this chapter a distributed load is assumed**. It is done to be more precise with the calculations because the “real load” is more similar to a distributed load than a punctual load. Even so, it is known and assumed that the “real load” in reality is not acting in all the surface with the same value but to make the calculations a distributed load is a good approximation.

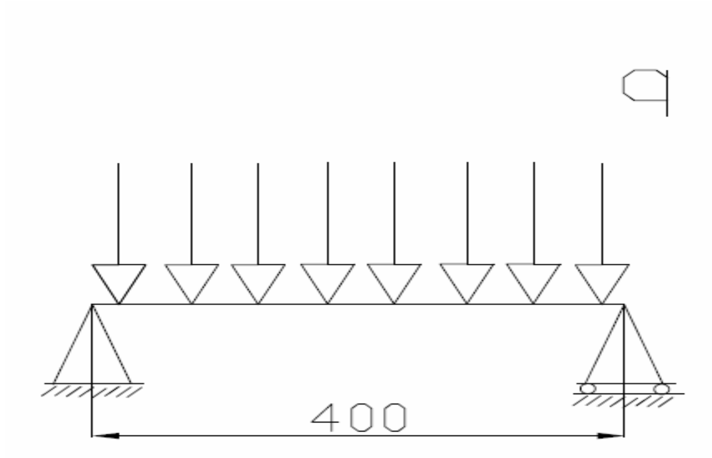
In this chapter all elements in the previous picture are going to be designed.

(*Note: as you can see the total length of the plate should be 1505mm due to the thickness of the reinforcing flat bars but it is taken 1500 to make the calculations)*

2.3.3.1 SHEET ON THE TOP

As you can see in **Picture 53** the structure on the top has a sheet. Therefore in this chapter the thickness of the sheet is going to be calculated.

The first step is to know **the model of the structure** that is going to be calculated. With this model it will possible to calculate the maximum moment of the structure and with this value it will be possible to calculate the thickness of the sheet. The model is similar to the one below:



-PICTURE 54: ***model of the sheet on the top-***

As you can check**, both sides have been removed** because as you will see in **Chapter 2.3.3.3** the selected UPN profiles have a length of $50mm$ and they go until the end of each side of the sheet. Therefore, it means that both sides can be removed to make the calculations.

Now it is time to calculate the unknown "q". As it was said before, now there is not a punctual load and that is why we need to calculate the distributed load acting in the sheet.

First of all, we need to know the **total load in the total surface** and it is done with this formula:

$$Q = \frac{m \cdot g}{A} = \frac{1000 \cdot 9,81}{1500 \cdot 500} = 13,1 \cdot 10^{-3} N / mm^2$$

But to calculate the sheet, the **load in the surface of the sheet** is needed.

That is why:

$$q = 13,1 \cdot 10^{-3} \cdot 1500 \simeq 19,7 N / mm$$

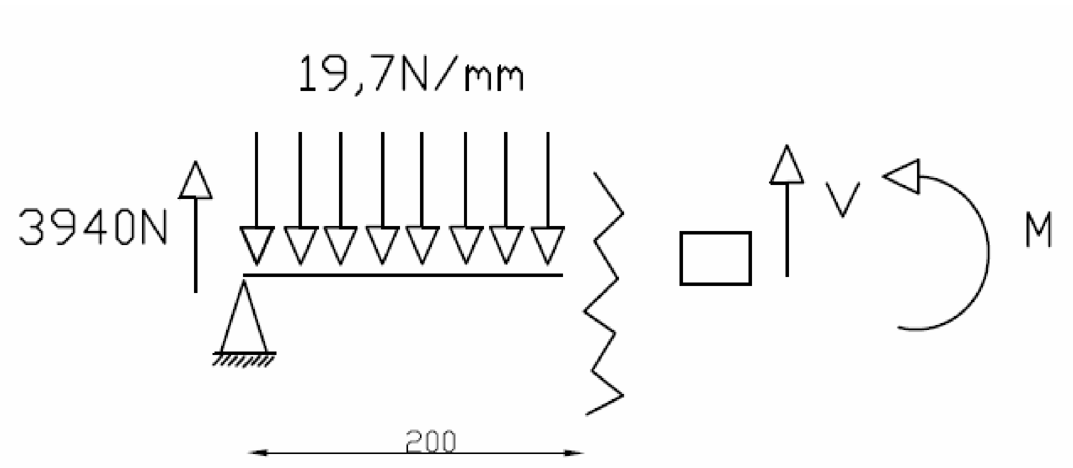
This is the real distributed load acting along the profile.

Now it is possible to calculate the reactions in the model and after that the maximum moment

$$\left.\begin{aligned} &\sum Fy = 0 \Rightarrow Ray + Rby = 19,7 \cdot 400 \\ &\sum Fx = 0 \Rightarrow Rax = 0 \\ &\sum Mzd = 0 \Rightarrow 19,7 \cdot 400 \cdot 205 - Ray \cdot 400 = 0 \end{aligned}\right\}$$

$$\left. Ray = Rby = 3940N \right\}$$

And the maximum moment is calculated in this way because it is known that it will be on the middle of the surface, therefore:



-PICTURE 55: ***calculation of the maximum moment on the sheet on the top-***

$$M = -19,7 \cdot 200 \cdot 100 + 3940 \cdot 200 = 394000Nmm$$

Therefore this value is going to be used for the following calculations.

It is also known that:

$$\sigma x = \frac{Mz}{Wz} + \frac{N}{A} \leq \frac{\sigma y}{Csy} = \sigma \qquad \left\{\begin{aligned} &Inertia = \frac{1}{12} \cdot b \cdot t^3 = \frac{1}{12} \cdot 1500 \cdot t^3 = 125t^3 \\ &Y\max = 0,5t \\ &Wz = \frac{inertia}{Y\max} = \frac{125t^3}{0,5t} = 250t^2 \end{aligned}\right.$$

Therefore:

$$\frac{394000}{250t^2}+0\leq\frac{350}{2}\Rightarrow t\geq 3mm$$

The final thickness chosen is:

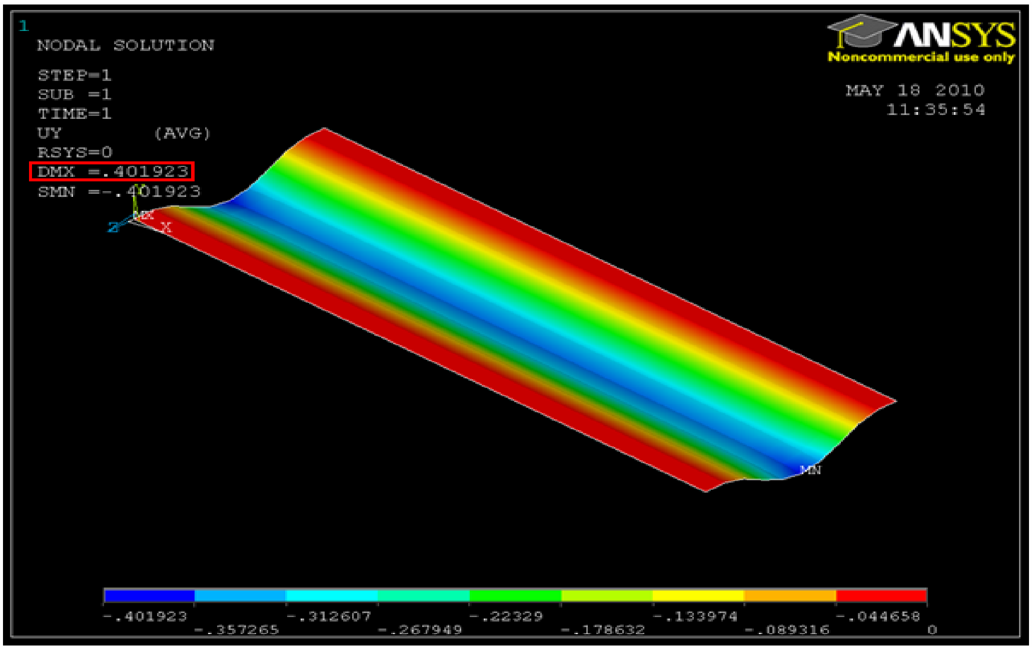
THICKNESS OF THE SHEET ON THE TOP = 5mm

Also in this chapter the **deformations of the sheet are going to be shown with the program called "ANSYS"**. In this programme the deformations of the sheet have been studied with a load of pressure in all of the surface and with a constrain of all of the movements in each $50mm$ to each side (because as you can see in **Picture 53** the profiles are in contact with the sheet in $50mm$ to each side and it will not have any movement).

The pressure was calculated in this way:

$$Q=\frac{m\cdot g}{A}=\frac{1000\cdot 9,81}{1500\cdot 500}=13,1\cdot 10^{-3}\,N/mm^2$$

And the result of the study with "ANSYS":



-PICTURE 56: ***deformations of the sheet on the top-***

As you can see in **PICTURE 56,** the **maximum deformation takes place in the middle of the surface** and it has a value of $0,4mm$.Therefore, this value can be assumed like an acceptable value of deformation.

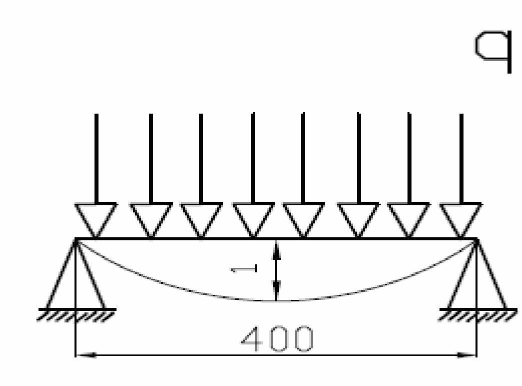
2.3.3.2 REINFORCING FLAT BARS

The function of these bars (the little parts in the previous pictures) is to avoid the flexion and the bending of the table in the middle of his surface. They are distributed logically through the table each $375mm$.

Therefore, as you could see in **Picture 53** the only unknown value is the value of the height of the reinforcing flat bars **because it is given a thickness of 5 mm.**

It is going to be calculated based on a restriction. This restriction is that the **maximum vertical displacement of these reinforcing flat bars is 1mm**.In this way a big vertical displacement is avoided.

The first step is to know the **model of the structure** that is going to be calculated. This model is similar to the one below:



-PICTURE 57: ***model of the reinforcing flat bars-***

The second step is to find out the load.

As it was mentioned in the previous chapter, the distributed load in the entire surface of the mechanism is:

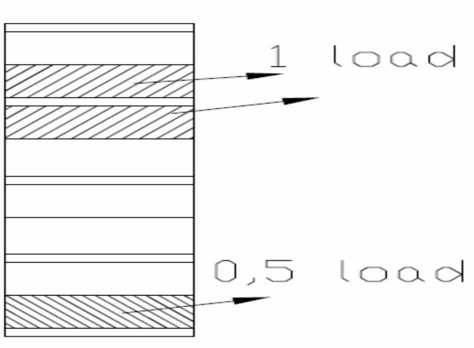
$$Q = \frac{m \cdot g}{A} = \frac{1000 \cdot 9,81}{1500 \cdot 500} = 13,1 \cdot 10^{-3} N / mm^2$$

But the load needed to make the calculations must be calculated by dividing the total load in the entire surface by the length between each reinforcing flat bar because it is the "real" load acting in each bar.

Therefore:

$$q = 13,1 \cdot 10^{-3} \cdot 375 = 4,91 N / mm$$

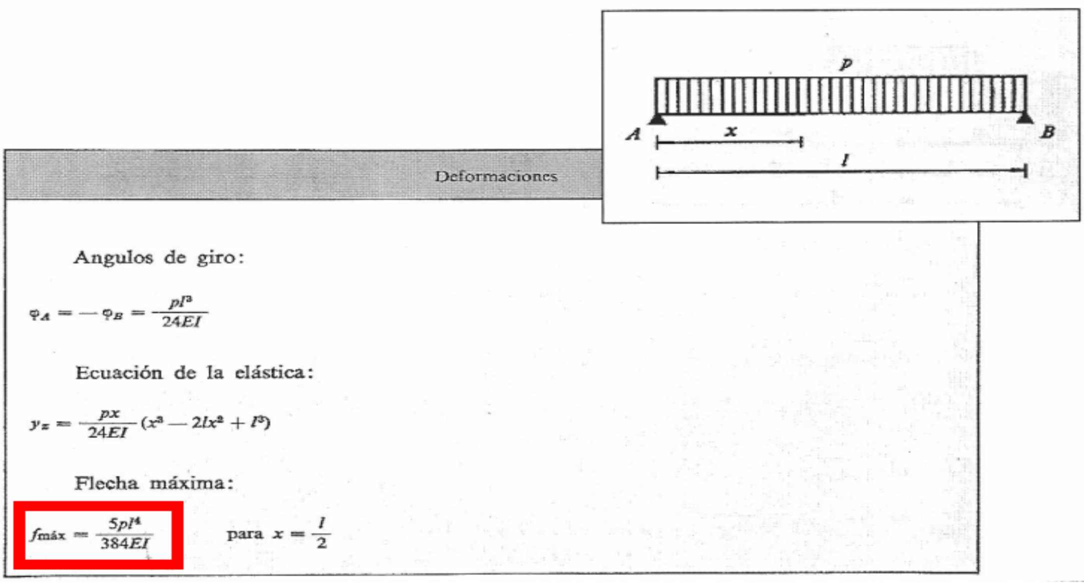
Important information is to explain why the total load, Q, is multiplied by 375mm.That is because now only one reinforcing flat bar is being calculated, therefore it is necessary to know the load in only one reinforcing flat bar. The bars in the sides support only the half of the load and the bars in the middle support half load in each side. But if you add the distances of each half load the result is 375mm. But it is more clear to see that in the picture below:



-PICTURE 58: ***explanation of loads in reinforcing flat bars-***

Now it is possible to calculate the height.

As it was said, the maximum vertical displacement must be $1mm$, therefore ,the following formula is going to be used to calculate the height of the bars because it is the same model as in the picture below:



-PICTURE 59: ***formulas to calculate maximum displacements-***

$$f\max = \frac{5 \cdot q \cdot l^4}{384 \cdot E \cdot I} \qquad \begin{cases} q = 4{,}91 N/mm^2 \\ L = 375mm \\ E = 210.000 Mpa(steel) \\ I = \frac{1}{12} \cdot b \cdot h^3 = \frac{1}{12} \cdot 5 \cdot h^3 \end{cases}$$

$$384 \cdot 210.000 \cdot h^3 \cdot 5 = 12 \cdot 5 \cdot 4{,}91 \cdot 400^4 \Rightarrow h = 26{,}5$$

HEIGHT OF THE REINFORCING FLAT BARS= 30mm

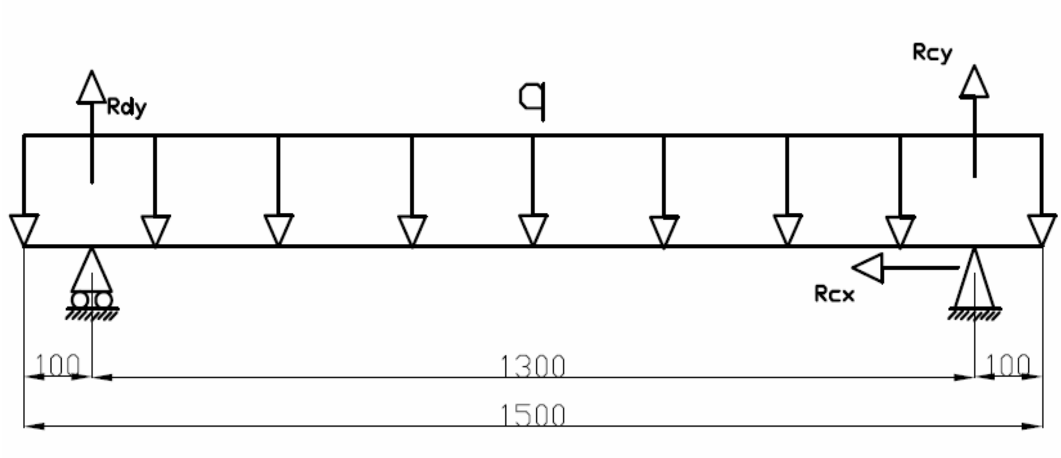
2.3.3.3 UPN PROFILES

Now it is time to calculate the profiles which will be glued to the sheet on the top as you could see in **Picture 53**. They are UPN profiles because they are the best kind of profile for this kind of structure. They have another mission and this is to fix the bars that are used to lift the structure up (they were calculated in **Chapter 2.3.1**)

To find the right profiles, we need to calculate the module "Wx" of the section and to do that we need to calculate the maximum moment acting in the section. Once that it has been calculated, the standard profile will be chosen from a list of these kinds of profiles.

But firstly, as it has been done almost in all of the chapters, we need to find the equivalent model to calculate the measurements.

In this case **the model** is like this:



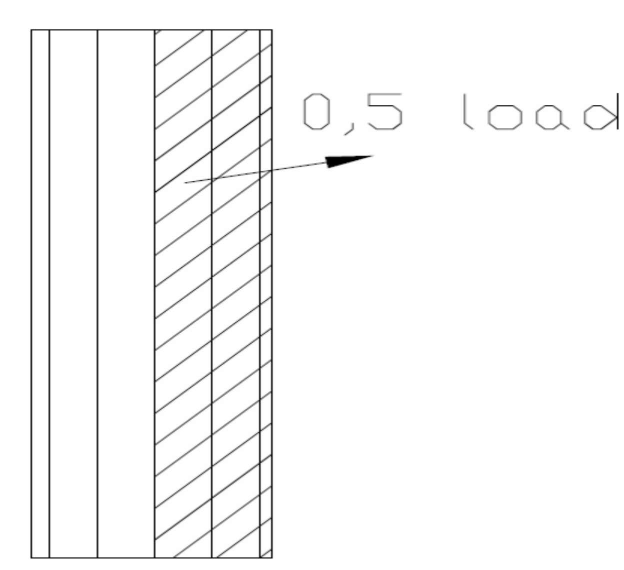
-PICTURE 60 : *model of UPN profiles*-

In this case we also need **to find out the unknown "q"** .It is going to be calculated in a similar way to the one in **Chapter 2.3.3.2.**

$$Q = \frac{m \cdot g}{A} = \frac{1000 \cdot 9,81}{1500 \cdot 500} = 13,1 \cdot 10^{-3} N / mm^2$$

$$q = 13,1 \cdot 10^{-3} \cdot 250 = 3,28 N / mm$$

Now the total load is multiplied by 250mm because of the same reason than in the previous chapter:



-PICTURE 61: ***load of the UPN profiles*-**

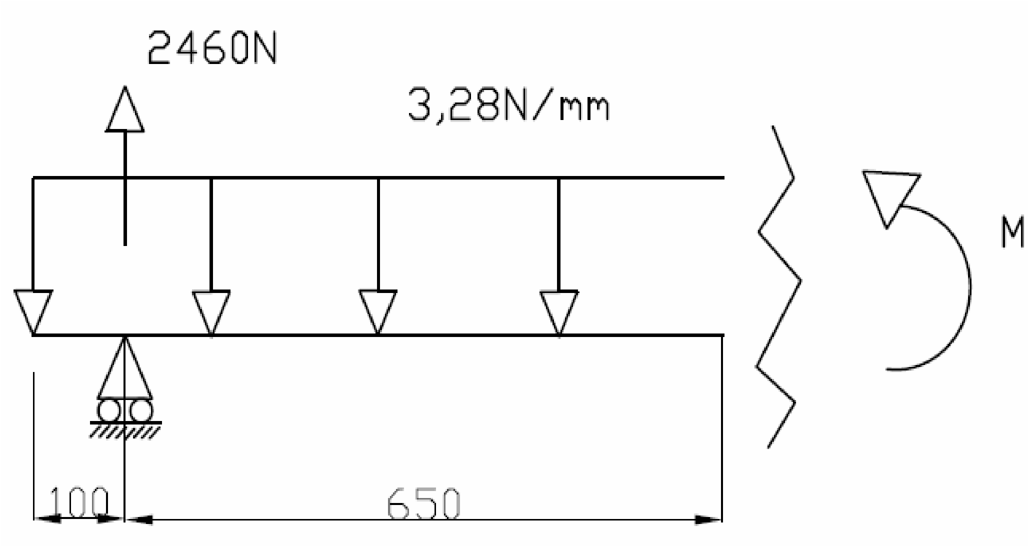
Another unknown value is the value of the **reactions in the supports**. They must be calculated again because they are not like in the first chapter.

Therefore:

$$\left.\begin{aligned} &\sum Fx = 0 \Rightarrow Rcx = 0 \\ &\sum Fy = 0 \Rightarrow Rdy + Rcy = 3,28 \cdot 1500 \\ &\sum Mzd = 0 \Rightarrow 3,28 \cdot 1400 \cdot 700 - 3,28 \cdot 100 \cdot 50 = Rdy \cdot 1300 \end{aligned}\right\}$$

$$\left.\begin{array}{l} Rcy = 2460N \\ Rdy = 2460N \end{array}\right\}$$

Now it is possible to calculate the **maximum moment**. It is known that it will be in the middle of the profile:



-PICTURE 62:*calculations of maximum moment in the UPN profiles-*

$$M = 2460 \cdot 650 - 3,28 \cdot 750 \cdot 375 = 677000Nmm$$

Therefore this value is going to be used for the following calculations.

It is also known that:

$$\sigma x = \frac{Mz}{Wz} + \frac{N}{A} \leq \frac{\sigma y}{Csy} = \sigma w$$

Therefore:

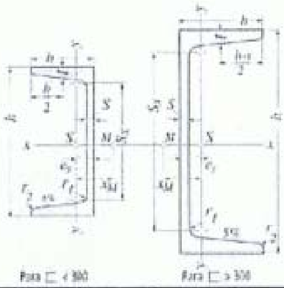
$$\sigma x = \frac{677000}{Wz} + 0 \leq \frac{350}{2}$$

$$Wx \geq 3870mm^3 = 3,87cm^3$$

With this value it is possible to select a profile from the **Table 6** below:

Perfil Normal "U" - UPN

F= Sección
G= Peso
J= Momento de inercia
U= Superficie exterior por metro de perfil
W= Momento resistente
i= Radio de giro
S_x= Momento estático de media sección del perfil
s_x= J_x/S_x - Separación entre los centros de tracción y compresión
X_m= Distancia del centro del esfuerzo cortante al eje y-y



Denominación	Dimeniones en mm								Eje flexión x-x			Eje flexión y-y					Distancia del eje y-y	
						F	G	U	J_x	W_x	i_x	J_y	W_y	i_y	S_x	s_x	e_y	X_m
	h	b	s	t	r	cm^2	Kg/m	m^2/m	cm^4	cm^3	cm	cm^4	cm^3	cm	cm^3		cm	cm
30x15	30	15	4.0	4.5	2.0	2.21	1.74	0.103	2.53	1.69	1.07	0.38	0.39	0.42	-	-	0.52	0.74
30	30	33	5.0	7.0	3.5	5.44	4.27	0.174	6.39	4.26	1.08	5.33	2.68	0.99	-	-	1.31	2.22
40x20	40	20	5.0	5,5 - 5	2.5	3.66	2.78	0.142	7.58	3.79	1.44	1.14	0.86	0.56	-	-	0.67	1.01
4	40	35	5.0	7.0	3.5	6.21	4.87	0.199	14.1	7.1	1.50	6.68	3.08	1.04	-	-	1.33	2.32
50x25	50	25	5.0	6.0	3.0	4.92	3.86	0.181	16.8	6.7	1.85	2.49	1.48	0.71	-	-	0.81	1.34
50	50	38	5.0	7.0	3.5	7.12	5.59	0.232	26.4	10.6	1.92	9.12	3.75	1.13	-	-	1.37	2.47
60	60	30	6.0	6.0	3.0	4.46	5.07	0.215	31.6	10.5	2.21	4.51	2.16	0.84	-	-	0.91	1.50
65	65	42	5.5	7.5	4.0	9.03	7.09	0.273	57.5	17.7	2.52	14.1	5.07	1.25	-	-	1.42	2.60
80	80	45	6.0	8.0	4.0	11.00	8.64	0.312	106	26.5	3.10	19.4	6.36	1.33	15.9	6.65	1.45	2.67
100	100	50	6.0	8.5	4.5	13.50	10.60	0.372	206	41.2	3.91	29.3	8.49	1.47	24.5	8.42	1.55	2.93
120	120	55	7.0	9.0	4.5	17.00	13.40	0.434	364	60.7	4.62	43.2	11.1	1.59	36.3	10.0	1.60	3.03
140	140	60	7.0	10.0	5.0	20.40	16.00	0.489	605	86.4	5.45	62.7	14.8	1.75	51.4	11.8	1.75	3.37
160	160	65	7.5	10.5	5.5	24.00	18.80	0.546	925	116	6.21	85.3	18.3	1.89	68.8	13.3	1.84	3.56
180	180	70	8.0	11.0	5.5	28.00	22.00	0.611	1,350	150	6.95	114	22.4	2.02	89.6	15.1	1.92	3.75
200	200	75	8.5	11.5	6.0	32.20	25.30	0.661	1,910	191	7.70	148	27.0	2.14	114	16.8	2.01	3.94
220	220	80	9.0	12.5	6.5	37.40	29.40	0.718	2,690	245	8.48	197	33.6	2.30	146	18.5	2.14	4.20
240	240	85	9.5	13.0	6.5	42.30	33.20	0.775	3,600	300	9.22	248	39.6	2.42	179	20.1	2.23	4.39
260	260	90	10.0	14.0	7.0	48.30	37.90	0.834	4,820	371	9.99	317	47.7	2.56	221	21.8	2.36	4.66
280	280	95	10.0	15.0	7.5	53.30	41.80	0.890	6,280	448	10.90	399	57.2	2.74	266	23.6	2.53	5.02
300	300	100	10.0	16.0	8.0	58.80	46.20	0.950	8,030	535	11.70	495	67.8	2.90	316	25.4	2.70	5.41
320	320	100	14.0	17.5	8.75	75.80	59.50	0.982	10,870	679	12.10	597	80.6	2.81	413	26.3	2.60	4.82
350	350	100	14.0	16.0	8.0	77.30	60.60	1.047	12,840	734	12.90	570	75.0	2.72	459	28.6	2.40	4.45
380	380	102	13.5	16.0	8.0	80.40	63.10	1.110	15,760	829	14.00	615	78.7	2.77	507	31.1	2.38	4.58
400	400	110	14.0	18.0	9.0	91.50	71.8	1.182	20,350	1,020	14.9	846	102	3.04	618	32.9	2.65	5.11

-TABLE 6: ***UPN profiles-***

But it is important to take into account that, for designing reasons, the final profile is bigger than the following with a bigger Wx than $3,87cm^3$. Otherwise, it would be impossible to place the wheels of the bars which lift the mechanism up and the bars would touch with the reinforcing flat bars and the movement would be impossible. You can see it better in **DRAWING Nº1**

Taking into account all that was said the profile chosen is:

PROFILE "UPN" 100x50

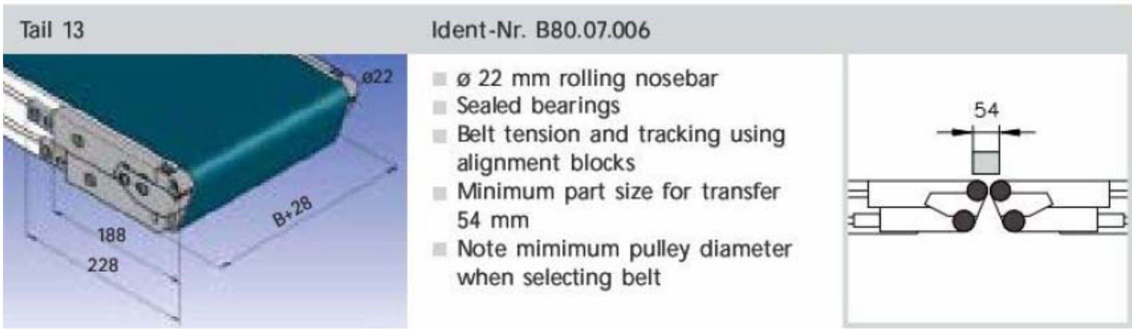
3. CONCLUSIONS

In this project a mechanism to automate the profile packing has been designed and as it was said in **Chapter 1.3.1** this mechanism can be perfectly implemented in the little station that they have, but to implement this idea there, it should be necessary to look into some aspects that for the problem of time it has been impossible to optimize.

Unfortunately, as it was said in **Chapter 1.3** this mechanism has not fulfilled all of the desired objectives of the company. However it is strongly thought that with more time of studying it could be possible to reach a better solution to solve all of the problems that this project has not been able to solve.

Even so, if the company really wanted to implement this idea or to get a global solution to solve all of the problem mentioned in **Chapter 1.2.1** , they should look into and they should optimize the following aspects:

- **To lift the profiles with the belt conveyor:** It should be necessary to look into this aspect due to it could be possible to lift up and to move more kind of profiles than the ones that we have thought about (heaviest square bars).It depends on the kinds of tails.



-PICTURE 63:*optimize the available profiles to work on*-

For our idea with this tail is enough because the profiles to work with have a minimum width of $100mm$ and therefore as you can see on **Picture 63** you only need a distance between conveyors of $54mm$.Therefore it could be interesting to look into this and to figure out which kind of profiles (apart from the heaviest square bar) are available to use with the idea explained during this project. For example a good kind of profiles to deal with could be the round profiles because they have the inconvenient that they can turn and therefore they could fall from the conveyor.

- **To optimize the mobile conveyor:** as it was explained in **Chapter 1.4** there is a mobile conveyor to move the profiles from the belt conveyors to the packing table. This step has not been looked into and therefore it should be necessary to think about this mobile conveyor in aspects like for example: the kind of movement (by rails or by another mechanism) the kind of conveyor, the speed of the movement etc.

- Related to the previous comment it also should be necessary to look into **the step in which the profiles are finally placed in the packing table**, like for example: they way of placing them, the rights positions in the packing table etc.

- It is also very important to look into the **electronic stuff** of the whole mechanism because as it was explained, everything should work automatically and therefore some sensors and electronic parts are needed.

- As it was explained in **Chapter 1.4.2.2** it would also be interesting to take a look on the last part of the process of profile packing. It takes place when the operator finishes the packing and he has to move it to the place where all finished product are. It was commented that it could be a good idea to put some rollers in the packing table and to place this area of finished products close to that. Therefore, in this way they could push he profiles they would not need to take the profiles by hand to place in the commented area. It could be good to look into this step.

Therefore taking a look on that the project should success and the company could become the leader in the handling of aluminium profiles and bars.

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5. APPENDIX

APPENDIX Nº1: CATALOGUE OF ALUMECO'S PRODUCTS

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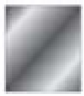
Aluminium Bars - Square

EN 573-3, 754-1, 754-2, 754-4, 755-1, 755-4



mm	Kg/m	EN AW-6060/6063 Length: 6000 mm	EN AW-6082 Length: 3000-6000 mm	EN AW-6262R (cut and drilling quality) Length: 3000 mm	EN AW-2011 (cut and drilling quality) Length: 3000 mm
8	0.18	•			
10	0.27	•	•		•
12	0.39	•	•		
15	0.61	•	•		•
20	1.08	•	•	•	•
25	1.69	•	•		•
30	2.52		•	•	•
35	3.33		•	*•	•
40	4.48		•	•	•
45	5.47		•	•	
50	6.80		•	•	•
55	8.20		•		
60	9.72		•	•	•
65	11.80		•		•
70	13.23		•	•	•
80	17.30		•		•
85	20.30		•		
90	22.96		•	•	•
95	24.50		•		
100	27.00		•	•	•
110	33.00		•		
120	39.00		•		
130	47.30		•		
140	54.90		•		
150	63.00		•		
160	69.90		•		
180	90.70		•		
200	112.00		•		

*Price is dimension dependent.
For bars over 100 mm the length is 3000 mm for alloy EN AW-6082.

(Note: this is the kind of profile that has been taken into account to approach the project)

alumeco

Aluminium Bars - Round

EN 573-3, 754-1, 754-2, 754-3, 755-1, 755-2, 755-3

Diameter mm	Kg/m	EN AW 6060/6063 Length: 6000 mm	EN AW 6082 Length: 3000-6000 mm	EN AW-6262R (cut and drilling quality) Length: 3000 mm	EN AW-2011 (cut and drilling quality) Length: 3000 mm	EN AW-2014 (cut and drilling quality) Length: 3000 mm	EN AW-7075 (cut and drilling quality) Length: 3000 mm
3	0.02						*•
4	0.04						*•
5	0.06				•		*•
6	0.08				•		*•
7	0.11				*•		
8	0.15	•		•	•		*•
9	0.19			*•	*•		
10	0.22	•	•	•	•		*•
12	0.33	•	•	•	•		
13	0.38				*•		
14	0.44	•			•		
15	0.50	•	•	•	•		
16	0.58	•	•	*•	•		
17	0.65			*•	•		
18	0.73			•	•		
19	0.81				*•		
20	0.89	•	•	•	•	•	•
21	1.00				•		
22	1.08		•	•	•		
23	1.19						
24	1.29			•	•		
25	1.38	•	•	•	•	•	•
26	1.51			*•	•		
28	1.76		•	•	•		
30	1.98		•	•	•	•	•
32	2.29		•	•	•		
33	2.44						
35	2.79		•	•	•		
36	2.90				*•		
38	3.23		•	•	•		
40	3.60		•	•	•	•	•
42	3.95		•	•	•		
45	4.60		•	•	•		
50	5.50		•	•	•	•	•
55	6.80		•	•	•		
60	8.05		•	•	•	•	•
65	9.47		•	•	•		
70	10.70		•	•	•	•	•

Diameter mm	Kg/m	EN AW 6082 Length: 3000-6000 mm	EN AW-2007 (cut and drilling quality) Length: 3000 mm	EN AW-6262R (cut and drilling quality) Length: 3000 mm	EN AW-2011 (cut and drilling quality) Length: 3000 mm	EN AW-2014 (cut and drilling quality) Length: 3000 mm	EN AW-7075 (cut and drilling quality) Length: 3000 mm
75	12.60	•		•	•	•	*•
80	14.20	•		•	•	•	•
85	16.20	•		•	•		
90	18.10	•		•	•		•
95	20.20	•		•	*•		
100	22.40	•		•	•		•
105	24.70	•		*•	•		
110	27.10	•		•	•		•
115	29.60	•		•	•		
120	32.10	•		•	•		•
125	35.00	•			*•		
130	37.50	•		•	•		•
140	43.80	•		•	•		
145	47.20						
150	50.10	•		•	•		
160	57.10	•		•	•		•
165	60.90	•					
170	64.70	•			•		
175	67.30	*•					
180	72.50	•	•		•		
190	81.30	•					
200	89.50	•	•		•		•
210	98.70	•	*•				
220	108.40	•	•				
240	128.90	•	•				
250	136.00	•	•				
260	151.40	•	*•				
280	175.60	•					
300	202.00	•	•				
310	215.00		*•				
320	229.00		•				
350	274.00	•	*•				
360	290.00		*•				
380	323.00	*•	*•				
400	358.00	•	•				
430	414.00		*•				
450	453.00	•	*•				
480	515.00		*•				
500	560.00	*•	*•				

*Price is dimension dependent.
Bars with a diameter of more than 200 mm are casted and machined.
For bars over 100 mm in diameter the length is 3000 mm for alloy EN AW-6082
All stated weights are theoretical weights, which may vary.

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Aluminium Bars - Hexagonal

Manufacturing lengths 3000 - 4000 mm
EN 573-3, 754-1, 754-2, 754-6, 755-1, 755-2, 755-6

mm	Kg/m	EN AW-2011 (cut and drilling quality) Length: 3000 mm
8	0.16	
10	0.25	•
14	0.48	•
17	0.72	•
19	0.89	•
22	1.20	•
27	1.80	•

All stated weights are theoretical weights, which may vary.

alumeco

Aluminium Profiles - Angle - EN AW-6060/6063 T6 - EN AW-6082 T6

Manufacturing length 6000 mm. EN 573-3, 755-1, 755-2, 755-9

Even-sided mm W x H x T	kg/m	Uneven-sided mm W x H x T	kg/m	Uneven-sided mm W x H x T	kg/m
10 x 10 x 2	0.10	15 x 10 x 2	0.13	60 x 40 x 4	1.04
15 x 15 x 2	0.16	20 x 20 x 2	0.16	60 x 40 x 5	1.30
15 x 15 x 3	0.22	* 20 x 10 x 3	0.25	* 60 x 40 x 6	1.53
20 x 20 x 2	0.21	20 x 15 x 2	0.18	* 60 x 50 x 2	0.59
20 x 20 x 3	0.30	* 25 x 10 x 2	0.18	65 x 50 x 6	1.78
* 20 x 20 x 4	0.42	25 x 15 x 2	0.21	* 70 x 20 x 2	0.49
25 x 25 x 2	0.26	* 25 x 15 x 3	0.30	* 70 x 20 x 3	0.71
25 x 25 x 3	0.38	25 x 20 x 2	0.24	* 70 x 25 x 2.5	0.63
25 x 25 x 4	0.50	25 x 20 x 3	0.35	* 70 x 30 x 2	0.53
25 x 25 x 5	0.64	30 x 10 x 2	0.21	70 x 50 x 5	1.68
30 x 30 x 2	0.32	* 30 x 15 x 2	0.24	75 x 50 x 5	1.68
30 x 30 x 3	0.47	* 30 x 15 x 3	0.35	75 x 50 x 6	2.02
30 x 30 x 4	0.61	* 30 x 15 x 4	0.45	* 75 x 50 x 7	2.25
30 x 30 x 5	0.74	30 x 20 x 2	0.26	75 x 50 x 8	2.60
35 x 35 x 3	0.55	30 x 20 x 3	0.39	* 80 x 20 x 2	0.55
35 x 35 x 4	0.72	* 30 x 25 x 2	0.29	* 80 x 15 x 2	0.51
* 35 x 35 x 5	0.89	30 x 25 x 3	0.43	80 x 30 x 3	0.90
40 x 40 x 2	0.43	* 35 x 20 x 3	0.43	* 80 x 40 x 3	0.99
40 x 40 x 3	0.65	* 35 x 25 x 2	0.31	* 80 x 40 x 4	1.26
40 x 40 x 4	0.83	* 35 x 30 x 3	0.51	* 80 x 40 x 5	1.63
40 x 40 x 5	1.02	* 40 x 10 x 2	0.26	* 80 x 40 x 6	1.85
* 40 x 40 x 6	1.19	* 40 x 15 x 2	0.29	* 80 x 50 x 5	1.76
45 x 45 x 3	0.71	40 x 20 x 2	0.32	80 x 50 x 6	2.01
45 x 45 x 5	1.22	40 x 20 x 3	0.47	* 90 x 50 x 6	2.20
50 x 50 x 2	0.53	* 40 x 20 x 4	0.61	* 100 x 20 x 2	0.63
50 x 50 x 3	0.79	* 40 x 25 x 2	0.35	* 100 x 30 x 3	1.02
50 x 50 x 4	1.04	40 x 25 x 3	0.51	* 100 x 20 x 2	0.63
50 x 50 x 5	1.29	* 40 x 25 x 4	0.68	100 x 50 x 3	1.24
50 x 50 x 6	1.52	40 x 25 x 5	0.83	100 x 50 x 5	1.96
50 x 50 x 8	1.99	* 40 x 30 x 2	0.37	100 x 50 x 6	2.34
50 x 50 x 10	2.43	* 40 x 30 x 3	0.55	100 x 50 x 7	2.80
* 60 x 60 x 2	0.65	* 40 x 30 x 4	0.73	100 x 50 x 8	3.07
60 x 60 x 3	0.98	* 40 x 30 x 5	0.88	* 100 x 50 x 10	3.79
60 x 60 x 4	1.26	* 45 x 30 x 1.5	0.31	* 100 x 60 x 4	1.73
* 60 x 60 x 5	1.58	* 50 x 15 x 2	0.36	* 100 x 60 x 6	2.50
60 x 60 x 6	1.85	50 x 20 x 2	0.37	* 100 x 65 x 8	3.44
* 60 x 60 x 8	2.52	* 50 x 20 x 3	0.55	* 100 x 65 x 9	3.81
* 60 x 60 x 10	2.97	50 x 25 x 2	0.40	* 100 x 75 x 6	2.84
* 70 x 70 x 5	1.83	50 x 25 x 3	0.60	* 100 x 75 x 8	3.61
* 70 x 70 x 6	2.18	50 x 25 x 4	0.77	* 120 x 40 x 4	1.75
70 x 70 x 7	2.52	50 x 25 x 5	0.96	* 120 x 60 x 6	2.50
* 75 x 75 x 5	1.96	* 50 x 30 x 2	0.43	* 120 x 80 x 10	5.30
75 x 75 x 8	3.11	50 x 30 x 3	0.63	* 130 x 65 x 8	4.22
75 x 75 x 9	3.50	50 x 30 x 4	0.84	130 x 65 x 10	5.27
75 x 75 x 10	4.00	50 x 30 x 5	1.02	* 130 x 75 x 9	4.77
* 80 x 40 x 6	1.90	* 50 x 40 x 4	0.93	* 130 x 80 x 6	3.33
* 80 x 80 x 3	1.27	50 x 40 x 5	1.15	* 150 x 50 x 5	2.63
* 80 x 80 x 4	1.68	* 60 x 15 x 2	0.40	* 150 x 75 x 8	4.70
80 x 80 x 5	2.14	* 60 x 20 x 2	0.44	* 150 x 75 x 9	5.26
* 80 x 80 x 10	4.05	* 60 x 25 x 3	0.66	* 150 x 100 x 10	6.60
* 100 x 100 x 4	2.11	* 60 x 30 x 2	0.48	* 200 x 100 x 10	8.22
* 100 x 100 x 5	2.70	60 x 30 x 3	0.71		
* 80 x 80 x 6	2.50	* 60 x 30 x 4	0.93		
80 x 80 x 8	3.29	* 60 x 30 x 5	1.20		
* 100 x 100 x 6	3.24	60 x 40 x 2	0.54		
100 x 100 x 10	5.13	60 x 40 x 3	0.79		

* Price is dimension dependent.
All stated weights are theoretical weights, which may vary.

Aluminium Profiles

EN AW-6060/6063 T6 - EN AW-6082 T6
Manufacturing length 6000 mm EN 573-3, 755-1, 755-2, 755-5

W x H mm	kg/m	W x H mm	kg/m	W x H mm	kg/m
10 x 2	0.06	15 x 8	0.33	25 x 4	0.27
10 x 3	0.09	15 x 10	0.41	25 x 5	0.36
10 x 4	0.11	20 x 2	0.11	25 x 6	0.41
10 x 5	0.14	20 x 3	0.17	25 x 8	0.54
*10 x 8	0.22	20 x 4	0.22	25 x 10	0.68
*12 x 3	0.10	20 x 5	0.27	25 x 12	0.81
*12 x 4	0.13	20 x 6	0.33	25 x 15	1.02
*12 x 8	0.26	20 x 8	0.44	*25 x 20	1.35
15 x 2	0.09	20 x 10	0.54	30 x 2	0.17
15 x 3	0.13	20 x 12	0.65	30 x 3	0.25
15 x 4	0.17	*20 x 15	0.81	30 x 4	0.33
15 x 5	0.21	25 x 2	0.14	30 x 5	0.41
15 x 6	0.24	25 x 3	0.21	30 x 6	0.49

Aluminium Tubes - Rectangular - EN AW-6060/6063 T6

Manufacturing length 6000 mm
EN 573-3, 755-1, 755-2, 755-8

mm	kg/m	mm	kg/m	mm	kg/m
20 x 10 x 1.5	0.24	50 x 40 x 4.0	1.78	100 x 50 x 3.0	2.36
20 x 10 x 2.0	0.29	* 60 x 20 x 2.0	0.83	100 x 50 x 4.0	3.07
* 20 x 15 x 2.0	0.35	60 x 25 x 3.0	1.29	* 100 x 50 x 5.0	3.78
25 x 15 x 2.0	0.40	60 x 30 x 2.0	0.93	* 100 x 60 x 3.0	2.50
25 x 20 x 2.0	0.45	60 x 30 x 3.0	1.36	100 x 60 x 4.0	3.40
* 30 x 15 x 2.0	0.46	60 x 40 x 2.0	1.04	* 100 x 80 x 3.0	2.89
30 x 20 x 2.0	0.50	60 x 40 x 2.5	1.30	* 120 x 18 x 2.0	1.46
* 30 x 25 x 2.0	0.56	60 x 40 x 3.0	1.60	* 120 x 20 x 2.0	1.54
35 x 20 x 2.0	0.56	60 x 40 x 4.0	1.99	* 120 x 30 x 3.0	2.43
* 35 x 25 x 2.0	0.61	* 60 x 50 x 3.0	1.70	* 120 x 40 x 2.0	1.69
* 40 x 15 x 2.0	0.56	* 70 x 20 x 2.0	0.92	120 x 40 x 3.0	2.49
40 x 20 x 1.5	0.46	* 80 x 20 x 2.0	1.08	* 120 x 40 x 4.0	3.29
40 x 20 x 2.0	0.61	* 80 x 30 x 2.0	1.15	* 120 x 50 x 4.0	3.64
* 40 x 20 x 2.5	0.81	* 80 x 30 x 3.0	1.71	* 120 x 60 x 2.5	2.37
40 x 20 x 3.0	0.88	* 80 x 40 x 2.0	1.28	* 120 x 60 x 3.0	2.81
40 x 25 x 2.0	0.66	80 x 40 x 3.0	1.85	* 120 x 60 x 4.0	3.70
40 x 30 x 2.0	0.72	80 x 40 x 4.0	2.40	* 140 x 50 x 4.0	3.73
* 40 x 30 x 3.0	1.12	80 x 50 x 4.0	2.64	150 x 40 x 4.0	3.92
* 50 x 15 x 2.0	0.66	* 80 x 60 x 4.0	3.03	150 x 50 x 3.0	3.14
50 x 20 x 2.0	0.72	* 90 x 30 x 2.5	1.55	* 150 x 50 x 4.0	4.15
50 x 25 x 2.0	0.80	* 100 x 18 x 2.0	1.24	* 150 x 50 x 5.0	5.15
50 x 25 x 3.0	1.19	* 100 x 20 x 2.0	1.26	* 150 x 100 x 3.0	3.95
50 x 30 x 2.0	0.83	* 100 x 25 x 1.5	1.00	* 150 x 120 x 5.0	7.10
50 x 30 x 2.5	1.10	* 100 x 30 x 3.0	2.18	* 160 x 40 x 4.0	4.20
50 x 30 x 3.0	1.20	* 100 x 40 x 2.0	1.50	* 180 x 40 x 4.0	4.58
* 50 x 34 x 2.5	1.15	100 x 40 x 2.5	1.90	* 200 x 50 x 4.0	5.25
* 50 x 40 x 2.0	0.96	100 x 40 x 3.0	2.28	* 200 x 100 x 4.0	6.48
50 x 40 x 2.5	1.20	100 x 40 x 4.0	2.94	* 200 x 100 x 5.0	7.83
50 x 40 x 3.0	1.54	* 100 x 50 x 2.0	1.60		

* Price is dimension dependent.
All stated weights are theoretical weights, which may vary.

Aluminium Tubes - Square - EN AW-6060/6063 T6

Manufacturing length 6000 mm
EN 573-3, 755-1, 755-2, 755-8

mm	kg/m	mm	kg/m	mm	kg/m
10 x 10 x 1,0	0,10	35 x 35 x 2,0	0,75	60 x 60 x 3,0	1,94
12 x 12 x 1,0	0,12	40 x 40 x 2,0	0,83	* R 60 x 60 x 3,5	2,10
* 15 x 15 x 1,5	0,23	* R 40 x 40 x 2,5	1,05	60 x 60 x 4,0	2,42
* 15 x 15 x 2,0	0,32	* R 40 x 40 x 3,0	1,19	70 x 70 x 2,0	1,50
* 16 x 16 x 1,5	0,24	40 x 40 x 4,0	1,56	70 x 70 x 4,0	2,86
18 x 18 x 1,0	0,20	45 x 45 x 2,0	0,93	80 x 80 x 3,0	2,50
20 x 20 x 1,0	0,21	50 x 50 x 2,0	1,05	80 x 80 x 4,0	3,30
20 x 20 x 1,5	0,30	* R 50 x 50 x 2,5	1,30	* R 80 x 80 x 5,0	4,25
20 x 20 x 2,0	0,39	50 x 50 x 3,0	1,54	* 100 x 100 x 2,0	2,16
25 x 25 x 1,5	0,38	50 x 50 x 4,0	1,99	100 x 100 x 4,0	4,15
25 x 25 x 2,0	0,52	* 50 x 50 x 5,0	2,43	100 x 100 x 5,0	5,19
25 x 25 x 3,0	0,72	55 x 55 x 2,0	1,15	* 100 x 100 x 10,0	9,85
30 x 30 x 2,0	0,61	* R 60 x 60 x 1,8	1,10	120 x 120 x 5,0	6,40
30 x 30 x 3,0	0,88	* 60 x 60 x 2,0	1,30	* 150 x 150 x 5,0	7,90

R = Corner radius.
* Price is dimension dependent.

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Aluminium Tubes - Round

EN AW-6060/6063 T6 - EN AW-6005 T6 / EN AW-6082 T6
Manufacturing length 6000 mm
EN 573-3, 755-1, 755-2, 755-8

mm OD x t	kg/m	mm OD x t	kg/m	mm OD x t	kg/m
6.0 x 1.0	0.05	* 22.0 x 2.0	0.40	* 40.0 x 2.5	0.79
8.0 x 1.0	0.06	* 22.0 x 3.0	0.48	40.0 x 3.0	0.95
10.0 x 1.0	0.08	25.0 x 1.0	0.21	40.0 x 3.5	1.09
* 10.0 x 1.5	0.11	25.0 x 1.5	0.30	* 40.0 x 4.0	1.23
* 10.0 x 2.0	0.14	25.0 x 2.0	0.39	40.0 x 5.0	1.49
12.0 x 1.0	0.10	* 25.0 x 2.5	0.47	40.0 x 7.5	2.07
12.0 x 1.5	0.14	25.0 x 3.0	0.57	* 42.0 x 2.5	0.85
* 12.0 x 2.0	0.17	25.0 x 3.5	0.64	* 42.0 x 3.0	1.00
13.0 x 1.5	0.16	25.0 x 5.0	0.85	* 42.0 x 3.5	1.15
14.0 x 3.0	0.28	28.0 x 1.5	0.34	* 42.0 x 5.0	1.60
* 15.0 x 1.0	0.12	30.0 x 2.0	0.48	45.0 x 2.0	0.74
15.0 X 1.5	0.18	* 30.0 x 2.5	0.59	45.0 x 3.0	1.17
* 15.0 x 2.0	0.23	30.0 x 3.0	0.69	45.0 x 5.0	1.70
16.0 X 1.5	0.19	* 30.0 x 4.0	0.89	* 48.0 x 2.5	0.99
* 16.0 x 2.0	0.25	* 30.0 x 5.0	1.07	* 48.0 x 3.0	1.15
16.0 x 3.0	0.34	* 32.0 x 1.5	0.41	48.3 x 4.0	1.53
18.0 x 1.0	0.15	32.0 x 2.0	0.51	50.0 x 1.5	0.62
* 18.0 x 1.2	0.18	* 32.0 x 3.0	0.73	50.0 x 2.0	0.82
18.0 x 1.5	0.21	32.0 x 3.5	0.85	* 50.0 x 2.5	1.00
* 18.0 x 2.0	0.28	35.0 x 1.5	0.43	50.0 x 3.0	1.20
* 19.0 x 1.0	0.16	35.0 x 2.0	0.56	50.0 x 3.5	1.39
19.0 x 1.5	0.23	* 35.0 x 2.5	0.74	50.0 x 4.0	1.57
* 19.0 x 2.0	0.31	* 35.0 x 3.0	0.82	50.0 x 5.0	1.91
20.0 x 1.0	0.16	* 35.0 x 5.0	1.28	* 50.0 x 10.0	3.81
20.0 x 1.5	0.24	* 36.0 x 4.0	1.08	* 50.0 x 12.0	3.90
20.0 x 2.0	0.31	38.0 x 1.5	0.47	* 50.0 x 15.0	4.45
20.0 x 3.0	0.44	* 38.0 x 3.0	0.89	54.0 x 2.0	0.89
* 20.0 x 4.0	0.54	* 38.0 x 4.0	1.16	55.0 x 2.0	0.90
* 20.0 x 5.0	0.64	40.0 x 1.5	0.49		
22.0 x 1.5	0.27	40.0 x 2.0	0.65		

mm OD x t	kg/m	mm OD x t	kg/m	mm OD x t	kg/m
* 55.0 x 2.5	1.17	90.0 x 5.0	3.61	150.0 x 10.0	12.40
* 55.0 x 5.0	2.27	* 90.0 x 10.0	7.25	* 150.0 x 15.0	17.20
* 60.0 x 1.5	0.78	* 90.0 x 20.0	11.80	* 150.0 x 20.0	22.50
* 60.0 x 2.0	0.99	* 96.0 x 3.0	2.37	* 160.0 x 5.0	6.60
* 60.0 x 2.5	1.30	100.0 x 2.0	1.70	* 160.0 x 15.0	18.50
60.0 x 3.0	1.46	* 100.0 x 3.0	2.47	* 160.0 x 20.0	24.17
60.0 x 4.0	1.90	* 100.0 x 4.0	3.30	* 164.0 x 7.0	9.40
60.0 x 5.0	2.40	100.0 x 5.0	4.04	170.0 x 10.0	13.81
* 60.0 x 6.0	2.94	* 100.0 x 6.0	5.01	* 170.0 x 15.0	20.00
60.0 x 10.0	4.67	100.0 x 10.0	7.65	* 175.0 x 7.0	9.99
* 60.0 x 15.0	6.12	* 100.0 x 16.0	11.43	* 180.0 x 10.0	15.11
* 63.0 x 1.5	0.79	* 100.0 x 20.0	13.90	* 180.0 x 20.0	27.50
* 65.0 x 5.0	2.55	* 100.0 x 30.0	18.13	* 180.0 x 40.0	48.00
* 65.0 x 10.0	5.52	* 102.0 x 1.7	1.48	* 190.0 x 10.0	16.07
70.0 x 2.0	1.16	* 106.0 x 3.0	2.73	* 190.0 x 15.0	23.50
* 70.0 x 3.0	1.71	* 110.0 x 2.0	1.83	* 200.0 x 5.0	8.30
* 70.0 x 4.0	2.39	110.0 x 5.0	4.50	200.0 x 8.0	14.40
70.0 x 5.0	2.76	* 110.0 x 10.0	8.93	* 200.0 x 10.0	16.20
* 70.0 x 10.0	5.19	120.0 x 5.0	4.90	* 200.0 x 15.0	23.96
75.0 x 3.0	1.85	* 120.0 x 10.0	9.82	* 200.0 x 20.0	31.50
75.0 x 5.0	3.02	* 120.0 x 15.0	13.60	* 206.0 x 3.0	5.50
* 75.0 x 10.0	5.51	* 120.0 x 20.0	16.96	* 210.0 x 5.0	8.69
* 76.0 x 3.0	1.90	125.0 x 4.0	4.12	* 210.0 x 10.0	16.99
80.0 x 2.0	1.33	125.0 x 7.5	7.50	216.0 x 8.0	14.37
* 80.0 x 3.0	1.96	* 130.0 x 3.0	3.35	* 230.0 x 10.0	18.70
* 80.0 x 4.0	2.58	* 130.0 x 5.0	5.31	* 240.0 x 10.0	19.90
80.0 x 5.0	3.18	* 130.0 x 10.0	10.84	* 250.0 x 5.0	10.80
* 80.0 x 10.0	5.95	140.0 x 5.0	5.72	* 250.0 x 10.0	20.40
* 80.0 x 15.0	8.27	* 140.0 x 10.0	11.05	* 260.0 x 10.0	21.25
* 86.0 x 3.0	2.11	* 150.0 x 3.0	3.74	* 266.0 x 8.0	17.70
* 90.0 x 3.0	2.22	150.0 x 5.0	6.18	* 318.0 x 9.0	23.60
* 90.0 x 4.0	2.91	* 150.0 x 8.0	9.66		

* Price is dimension dependant.
All stated weights are theoretical weights, which may vary.

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Aluminium T-Profiles - EN AW-6060/6063 T6

Manufacturing length 6000 mm
EN 573-3, 755-1, 755-2, 755-9

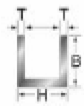
Even-sided mm H x W x T	kg/m	Even-sided mm H x W x T	kg/m
20 x 20 x 2	0.21	* 50 x 50 x 3	0.79
* 25 x 25 x 2	0.26	* 50 x 50 x 4	1.04
25 x 25 x 3	0.39	50 x 50 x 5	1.27
30 x 30 x 3	0.47	* 60 x 60 x 4	1.30
* 40 x 40 x 3	0.63	60 x 60 x 6	1.90
40 x 40 x 4	0.82	80 x 80 x 8	3.35

* Price is dimension dependent.

alumeco

Aluminium Profiles - U - EN AW-6060/6063 T6

Manufacturing length 6000 mm
EN 573-3, 755-1, 755-2, 755-9



Even-sided mm W X H x W x T	kg/m	Uneven-sided mm W X H x W x T	kg/m	Uneven-sided mm W X H x W x T	kg/m
10 x 10 x 10 x 1,5	0.11	20 x 10 x 20 x 2	0.25	* 30 x 50 x 30 x 4	1.15
10 x 10 x 10 x 2	0.15	* 20 x 15 x 20 x 2	0.28	* 30 x 50 x 30 x 5	1.35
12 x 12 x 12 x 2	0.20	10 x 20 x 10 x 2	0.20	40 x 50 x 40 x 4	1.41
14 x 14 x 14 x 2	0.22	* 15 x 20 x 15 x 2	0.25	* 30 x 60 x 30 x 3	0.96
15 x 15 x 15 x 2	0.23	* 30 x 20 x 30 x 2	0.43	* 30 x 60 x 30 x 4	1.27
20 x 20 x 20 x 2	0.32	* 40 x 20 x 40 x 2	0.52	* 30 x 80 x 30 x 3	1.10
* 20 x 20 x 20 x 3	0.43	15 x 25 x 15 x 2	0.29	* 40 x 60 x 40 x 3	1.14
25 x 25 x 25 x 2	0.40	* 15 x 30 x 15 x 2	0.30	40 x 60 x 40 x 4	1.52
25 x 25 x 25 x 3	0.59	15 x 30 x 15 x 3	0.45	40 x 60 x 40 x 5	1.78
* 30 x 30 x 30 x 2	0.49	* 20 x 30 x 20 x 2	0.36	40 x 70 x 40 x 4	1.54
30 x 30 x 30 x 3	0.72	20 x 30 x 20 x 3	0.54	* 40 x 80 x 40 x 3	1.25
* 30 x 30 x 30 x 4	0.88	* 20 x 50 x 20 x 3	0.69	40 x 80 x 40 x 4	1.64
* 35 x 35 x 35 x 3	0.80	* 40 x 30 x 40 x 3	0.87	40 x 80 x 40 x 5	2.03
* 40 x 40 x 40 x 2	0.62	* 20 x 35 x 20 x 2	0.39	* 50 x 80 x 50 x 5	2.30
* 40 x 40 x 40 x 3	0.93	* 20 x 40 x 20 x 2	0.51	* 40 x 100 x 40 x 3	1.40
40 x 40 x 40 x 4	1.21	* 20 x 40 x 20 x 3	0.63	40 x 100 x 40 x 4	1.98
* 50 x 50 x 50 x 3	1.22	30 x 40 x 30 x 3	0.79	* 50 x 100 x 50 x 3	1.58
50 x 50 x 50 x 4	1.54	25 x 40 x 25 x 3	0.72	50 x 100 x 50 x 5	2.57
50 x 50 x 50 x 5	1.90	* 25 x 45 x 25 x 3	0.73	* 50 x 100 x 50 x 8 x6x8	3.65
* 60 x 60 x 60 x 4	1.86	* 20 x 50 x 20 x 3	0.73	55 x 120 x 55 x 10	6.22
* 60 x 60 x 60 x 5	2.29	* 25 x 50 x 25 x 4	1.00	60 x 120 x 60 x 5	3.20
		* 30 x 40 x 30 x 4	0.99	* 100 x 200 x 100 x 10	10.26
		* 30 x 50 x 30 x 3	0.90		

* Price is dimension dependant.

APPENDIX Nº2: SELECTED WHEELS

	CODIGO
65 x 30	**66369**
80 x 30	**66370**
100 x 35	**66371**
125 x 40	**66373**
150 x 40	**66374**
150 x 40	**66375**
175 x 50	**66376**
200 x 50	**66377**

Aro de poliamida 6 (nylon).
Eje liso, sobre el propio material de rueda (nylon).

Características Técnicas

Temperatura de empleo –15ºC a +80ºCVelocidad máxima de empleo 4 Km./h.
Medio de tracción, manual.

CUADRO GENERAL DE COTAS Y CARGAS

65	30	100	40	12	Eje liso
80	30	150	40	12	Eje liso
100	35	200	40	12	Eje liso
125	40	300	46	15	Eje liso
150	40	400	46	15	Eje liso
150	40	400	60	20	Eje liso
175	50	500	60	20	Eje liso
200	48	500	60	20	Eje liso

APPENDIX Nº3: BELT CONVEYOR

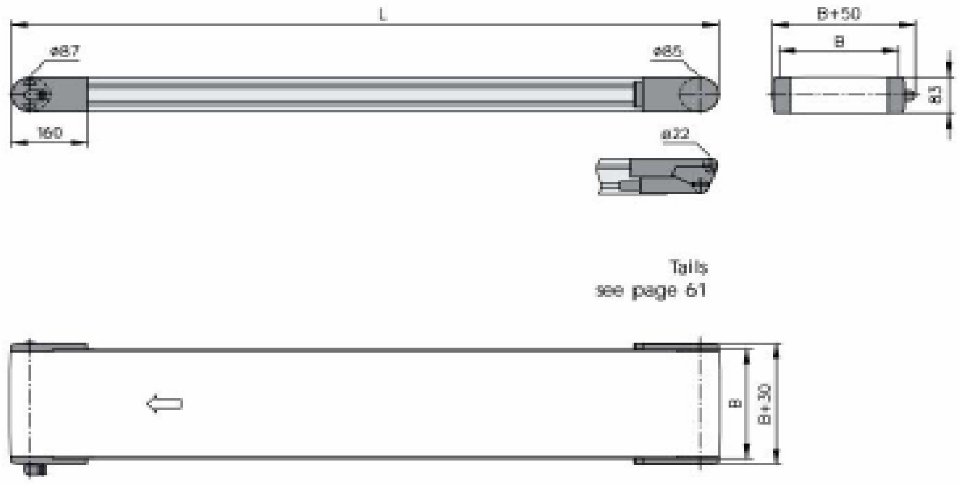
- **GENERAL INFORMATION**

GUF-P 2041 CA

Belt Conveyors with Driven Roller

TECHNOLOGY GROUP mk®

B20.40.005



Features:
Drive Version CA with Driven Roller is the most compact drive version available for System GUF-P 2041. By integrating the motor within the drive roll itself, there is no mechanical interference. The integration of this conveyor into equipment is therefore relatively simple.

	Dimensions – Technical Information	Notes
Conveyor length L	between 500 - 3000 mm	any increment possible
Conveyor width B	200, 250, 300, 350, 400, 450 and 500 mm	others on request
Belt Width	B-10 mm	see page 86
Drive and Speed	2.9; 4.1; 5.1; 6.1; 7.4; 8.7; 10.6; 10.7; 13; 13.1; 15.6; 18.7; 22.3; 23; 27.4; 33.6; 48.2 and 59.2	see page 60
Stands and Side Rails		see page 262
Load Capacity max.	on request	

- **STANDS**

Stand

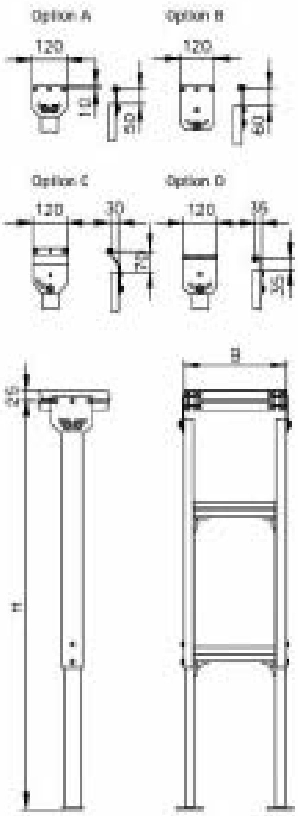
Stand 53.1

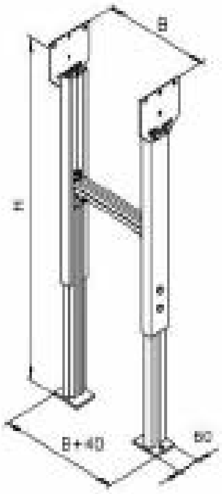
Light-duty telescoping stand with
Profile mk 2001 (25x50 mm).
Allows height and incline adjustment.
Ident Nr. B67.06.001

Standard Height:
H 325 mm ± 25 mm
H 400 mm ± 50 mm
H 550 mm ± 100 mm
H 700 mm ± 150 mm
H 850 mm ± 200 mm
H 1000 mm ± 200 mm
H 1200 mm ± 200 mm

Standard Width:
B = 100 - 1200 mm

As of H 700 mm
with 2 braces





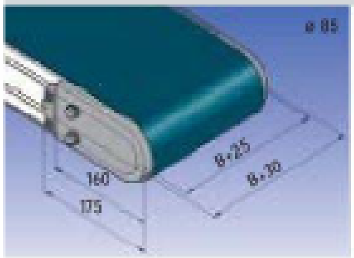
- **TAILS**

GUF-P 2041

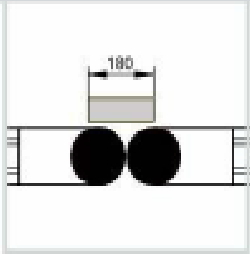
Tails

TECHNOLOGY GROUP mk

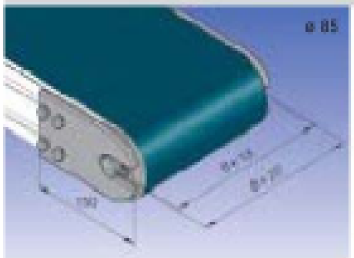
Tail 01 — Ident-Nr. B80.07.001



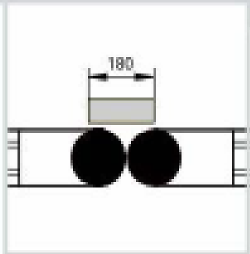
- ø 85 mm crowned roll
- Sealed bearings
- Belt tension and tracking using alignment blocks
- Minimum part size for transfer 180 mm
- Cast aluminum roll holders



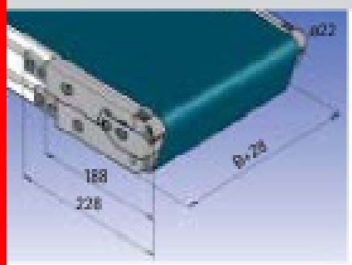
Tail 02 — Ident-Nr. B80.07.009



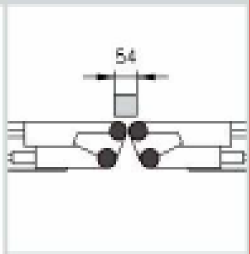
- Cylindrical drum ø 85 mm
- Sealed bearings
- Belt tension and tracking using tension shafts
- Minimum part size for transfer 180 mm
- Not suitable for sideloading



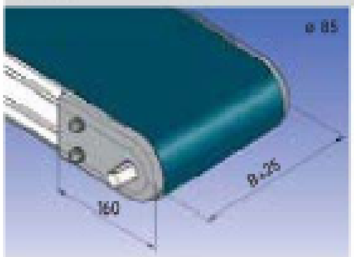
Tail 13 — Ident-Nr. B80.07.006



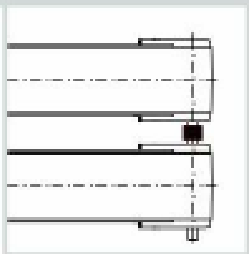
- ø 22 mm rolling nosebar
- Sealed bearings
- Belt tension and tracking using alignment blocks
- Minimum part size for transfer 54 mm
- Note mimimum pulley diameter when selecting belt



Tail 19 — Ident-Nr. B80.07.002

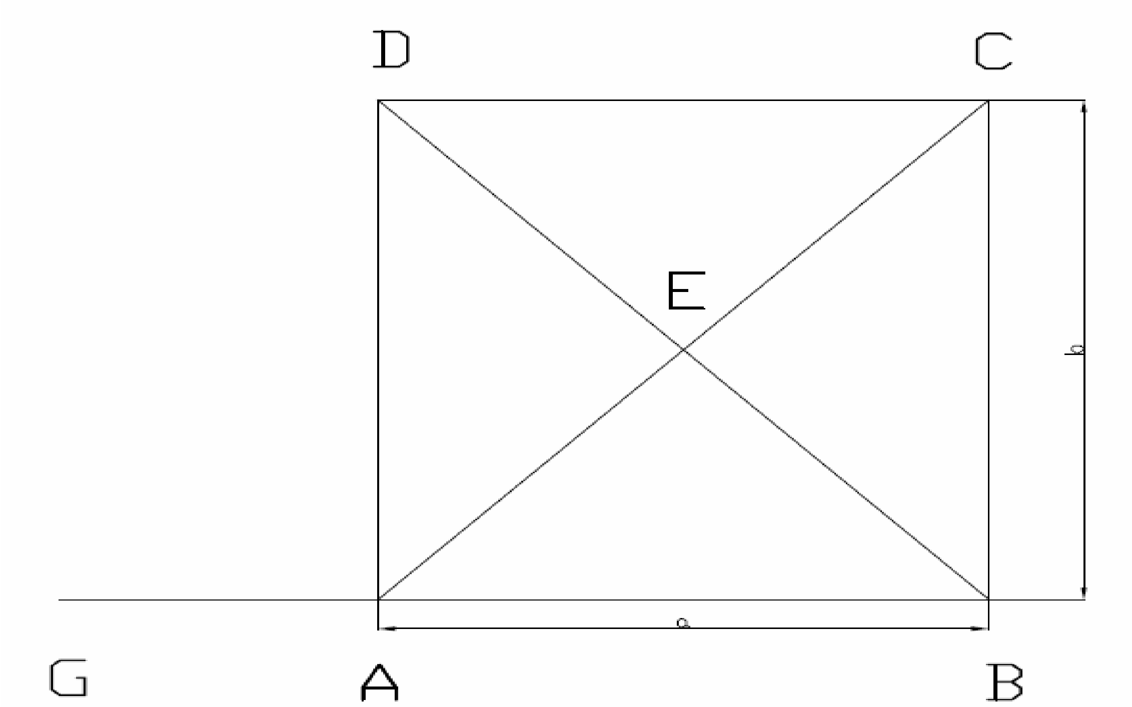


- ø 85 mm crowned roll
- Sealed bearings
- ø 20 x 27.5 mm long shaft, 6x6x22 mm shaft key (DIN 6885)
- Coupling of two lanes using one drive
- Additional output shaft (specify right, left or both sides)



APPENDIX Nº4: TABLE WITH FORCES OF THE CYLINDER

b(mm)	a(mm)	α (º)	Fcil(N)
200	1294,64	8,72	64508,00
300	1275,19	12,77	43570,41
400	1247,44	16,48	33193,14
500	1210,83	19,81	26980,26
600	1164,52	22,70	22786,77
700	1107,29	25,14	19680,18
800	1037,35	27,12	17177,86
900	951,89	28,65	14987,47
1000	846,23	29,71	12891,83



APPENDIX Nº5: SECURITY COEFFICIENT

Coeficiente de seguridad: $C_s = \dfrac{\text{Resistencia material}}{\text{Tensión generada por el esfuerzo}}$

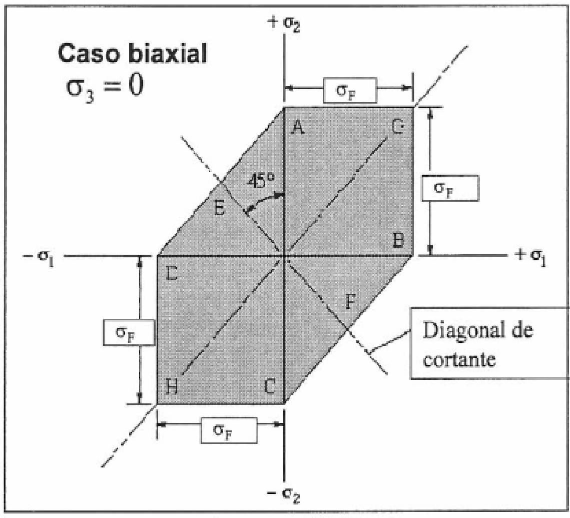
permanent load

$$C_{s,R} = \frac{\sigma_R}{\sigma} \qquad C_{s,F} = \frac{\sigma_F}{\sigma} \qquad C_{s,R} = \frac{\tau_R}{\tau} \qquad C_{s,F} = \frac{\tau_F}{\tau}$$

yield

Valores orientativos del coeficiente de seguridad para cálculo estático			
	Materiales DUCTILES		Materiales FRÁGILES
Tipo de carga	Criterio de resistencia a la rotura	Criterio de resistencia a la fluencia	Criterio de resistencia a la rotura
Carga permanente	3 a 4	1,5 a 2	5 a 6
Carga repetida, en una dirección gradual	6	3	7 a 8
Carga repetida, invertida gradual	8	4	10 a 12
Carga con choque violento	10 a 15	5 a 7	15 a 20

APPENDIX Nº6: THEORY OF MAXIMUM SHEAR



La falla de un material ocurre siempre que en cualquier elemento la tensión de cortadura máxima sea igual a la tensión cortante máxima en una probeta a tracción.

$$\sigma_1 \geq \sigma_2 \geq \sigma_3$$

$$\tau_{máx} = \frac{\sigma_1 - \sigma_3}{2}$$

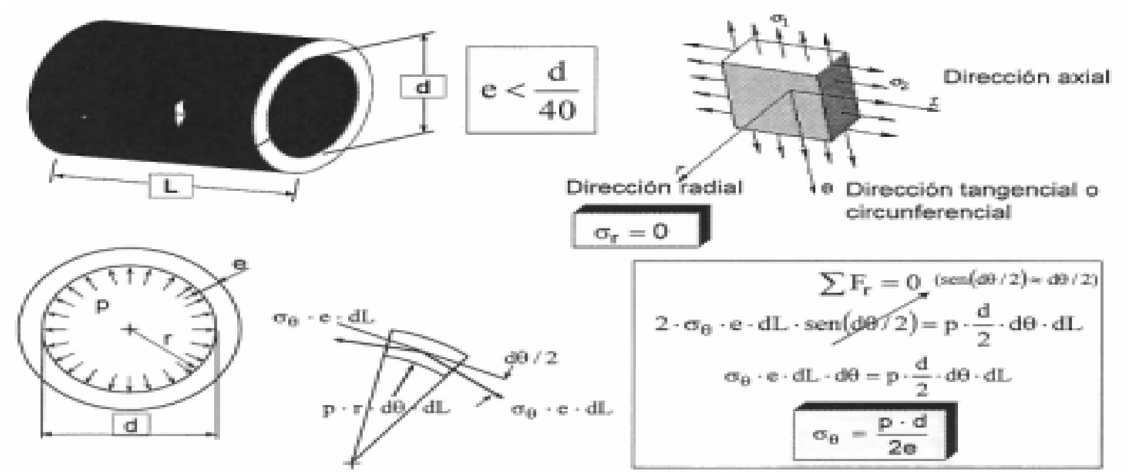
$$C_S = \frac{\sigma_F}{2\tau_{max}} \rightarrow \sigma_1 - \sigma_3 = \frac{\sigma_F}{C_s}$$

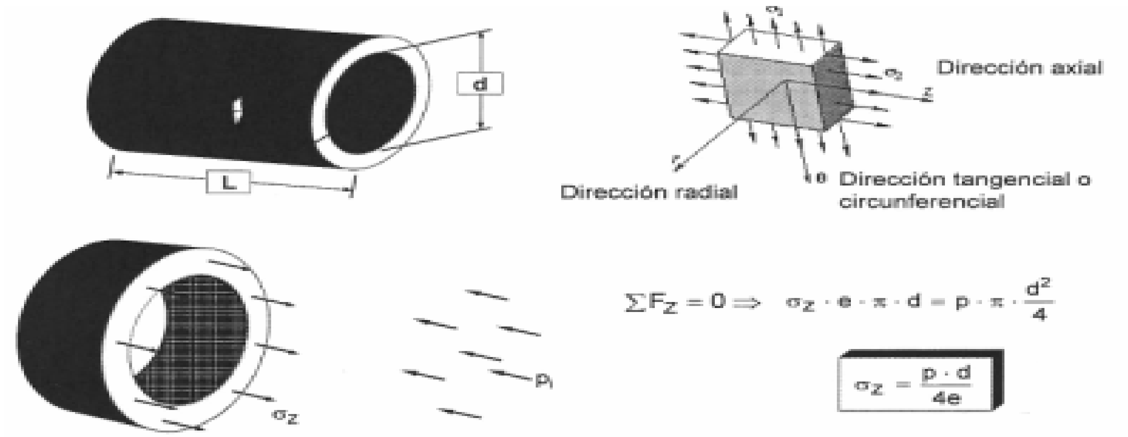
$$\tau_{max} = \frac{1}{2}\frac{\sigma_F}{C_s}$$

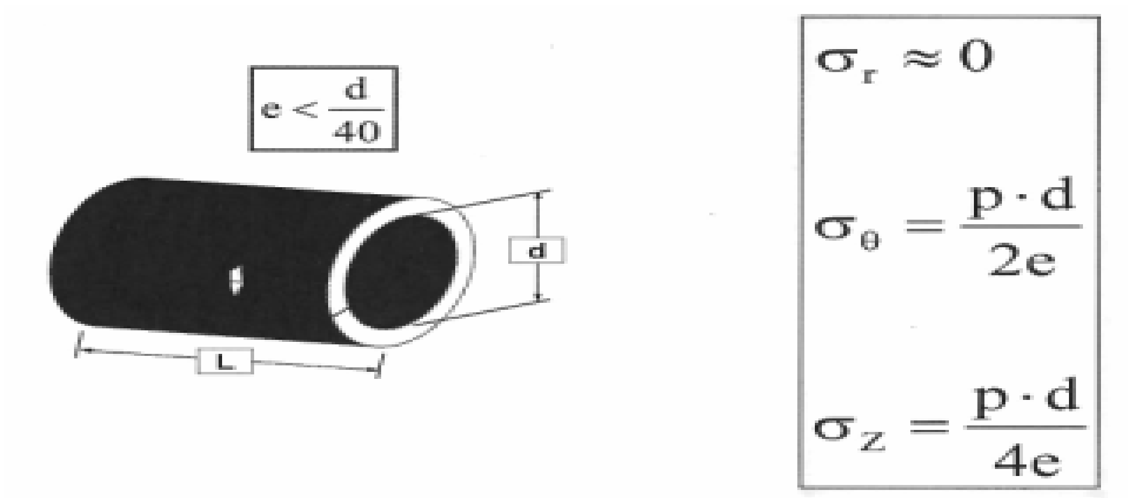
Ensayo a tracción

$$\sigma_2 = \sigma_3 = 0 \qquad \tau_{max\_ens.trac} = \frac{\sigma_F}{2}$$

APPENDIX Nº7: THEORY OF THICK-WALLED CYLINDERS



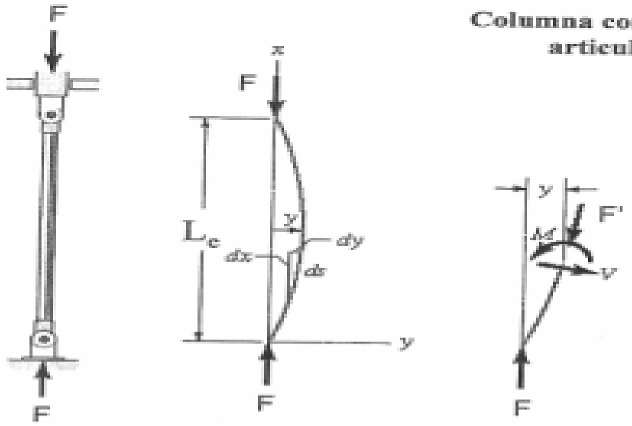




APPENDIX Nº8: THEORY OF BUCKLING (EULER)

Determinación de la carga crítica de pandeo:

Columna con extremos articulados



Momento flector de la viga deformada:

$$M = F \cdot y$$

Ecuación de la elástica (ecuación diferencial de segundo orden):

$$\frac{d^2y}{dx^2} = -\frac{M}{EI} \Rightarrow \frac{d^2y}{dx^2} = -\frac{F}{EI}y \qquad \frac{d^2y}{dx^2} + \frac{F}{EI}y = 0$$

Solución general:

$$y = A \cdot sen\sqrt{\frac{F}{EI}}x + B \cdot cos\sqrt{\frac{F}{EI}}x$$

1ª Condición de contorno:

$$x = 0 \Rightarrow y = 0 \Rightarrow B = 0$$

$$y = A \cdot sen\sqrt{\frac{F}{EI}}x$$

2ª condición de contorno:

$$x = L_e \Rightarrow y = 0 \qquad \Rightarrow \qquad A \cdot sen\sqrt{\frac{F}{EI}} \cdot L_e = 0$$

Solución trivial A = 0 que indica que la barra permanece recta, es decir, existe la posibilidad de que la barra conserve su forma recta aun cuando esta posición no sea de equilibrio estable.

Solución:

$$\operatorname{sen}\sqrt{\frac{F}{EI}}L_e = 0 \longrightarrow \sqrt{\frac{F}{EI}}L_e = n\pi \quad \text{n número entero}$$

La elástica toma la forma de infinitas sinusoides de amplitudes "A" infinitésimas, las cuales representan infinitas posiciones de equilibrio próximas a la recta.

Para n=1 se obtiene el menor valor de F que verifica la ecuación, y es la que se denomina **carga crítica de pandeo**

$$F_{cr} = \frac{\pi^2 EI}{L_e^2}$$ *Fórmula de Euler*

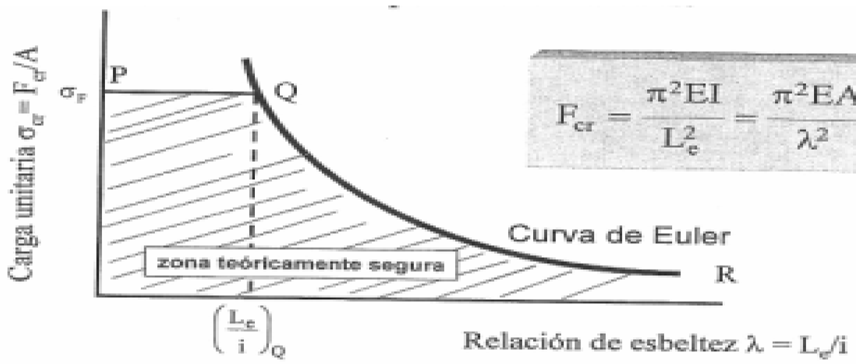
Máxima fuerza a compresión que puede soportar una columna sin sufrir fallo por pandeo

$$F_{cr} = \frac{\pi^2 EI}{L_e^2}$$

¿Qué **factores influyen** en la carga crítica de EULER que puede soportar una columna antes de fallar por pandeo?

- El módulo elástico del material, E.
- Geometría (Inercia de la sección, área y longitud)
- Condiciones de apoyo en los extremos

La carga crítica es **independiente** de la resistencia del material.



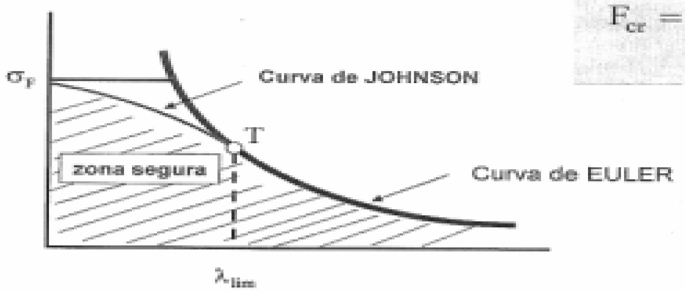
$$F_{cr} = \frac{\pi^2 EI}{L_e^2} = \frac{\pi^2 EA}{\lambda^2}$$

Según lo visto hasta ahora:

- Columnas que tengan su esbeltez entre P y Q, fallarán por fluencia.
- Columnas con esbeltez superior a Q, fallarán si F supera F_{cr}.

APPENDIX Nº9: THEORY OF BUCKLING (JOHNSON)

Cuando la esbeltez de la columna es inferior al valor de la esbeltez límite, el cálculo de la carga crítica a pandeo, viene dada por la expresión definida por J.B. Johnson:



$$F_{cr} = A \cdot \sigma_F \left[1 - \frac{\sigma_F \cdot \lambda^2}{4\pi^2 E} \right]$$

$$F_{cr} = A \cdot \sigma_F \left[1 - \frac{\sigma_F \cdot \lambda^2}{4\pi^2 E} \right]$$

¿Qué **factores influyen** en la carga crítica de JOHNSON que puede soportar una columna antes de fallar por pandeo?

- El módulo elástico del material, E.
- Geometría (Inercia de la sección, área y longitud)
- Condiciones de apoyo en los extremos
- El límite elástico del material, σ_F

APPENDIX Nº10: INFORMATION ABOUT PUMPS

- **SELECTED PUMP**

4/26 Bosch Rexroth AG | Hydraulics PGH | RE 10223/10.05

Technical data (for applications outside these parameters, please consult us!)

General	
Design	Internal gear pump, gap-compensated
Type	PGH
Type of mounting	SAE 2-hole flange to ISO 3019/1 or 4-hole flange to VDMA 24560 part 1 and ISO 3019/2
Type of connection, pipe connection	Flanged connection
Installation position	Optional
Shaft loading	Radial and axial forces (e.g. pulley) only after consultation
Direction of rotation (viewed to shaft end)	Clockwise or counter-clockwise – not bidirectional!

Frame size			FS2			FS3		
Size	Size		5.0	6.3	8.0	11	13	16
Weight	m	kg	4.3	4.4	4.6	4.8	5	5.3
Speed range	n_{min}	min^{-1}	600					
	n_{max}	min^{-1}	3000					
Displacement	V	cm^3	5.24	6.5	8.2	11.0	13.3	16.0
Flow [1]	q_V	L/min	7.5	9.3	11.8	15.8	19.1	23.0
Operating pressure, absolute – Inlet	p	bar	0.8 to 2 (briefly at start 0.6 bar)					
– Outlet, continuous	p_{max}	bar						
	HLP fluid		315					
	Special fluid		210					
intermittent [2]	p_{max}	bar						
	HLP fluid		350					
	Special fluid [3]		230					

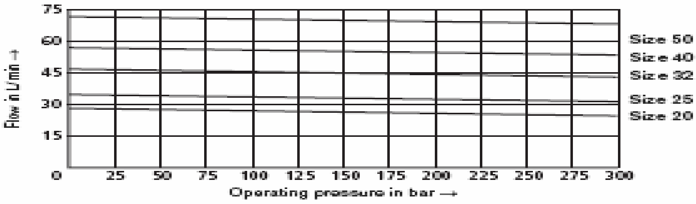
Frame size			FS4							
Size	Size		20	25	32	40	50	63	80	100
Weight	m	kg	13.5	14	14.5	15	16	17	18.5	20
Speed range	n_{min}	min^{-1}	500	500	500	500	500	400	400	400
	n_{max}	min^{-1}	3000	3000	3000	2600	2600	2600	2200	2200
Displacement	V	cm^3	20.1	25.3	32.7	40.1	50.7	65.5	80.3	101.4
Flow [1]	q_V	L/min	28.9	36.3	46.9	57.6	72.8	94.0	115.3	145.6
Operating pressure, absolute – Inlet	p	bar	0.8 to 2 (briefly at start 0.6 bar)							
– Outlet, continuous	p_{max}	bar								
	HLP fluid		250					210	160	125
	Special fluid		175					140	140	100
intermittent [2]	p_{max}	bar								
	HLP fluid		315					250	210	160
	Special fluid [3]		210					175	175	140

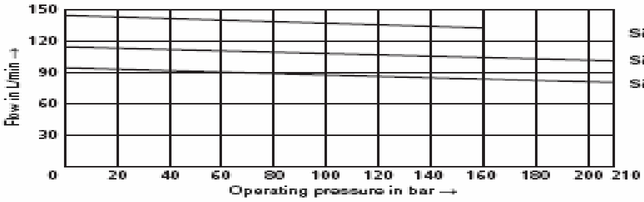
- **CHARACTERISTICS**

8/26 Bosch Rexroth AG | Hydraulics PGH | RE 10223/10.05

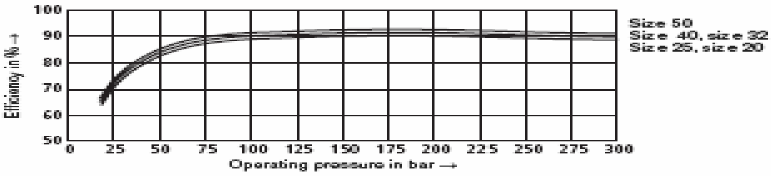
Characteristic curve average values of FS 4 (measured at n = 1450 min⁻¹; ν = 46 mm²/s and ϑ = 40 °C)

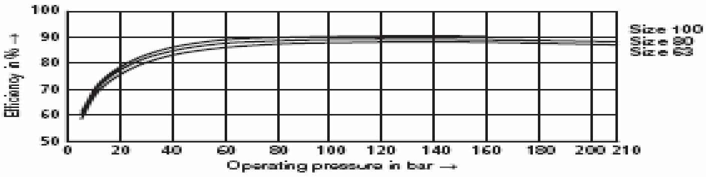
Flow



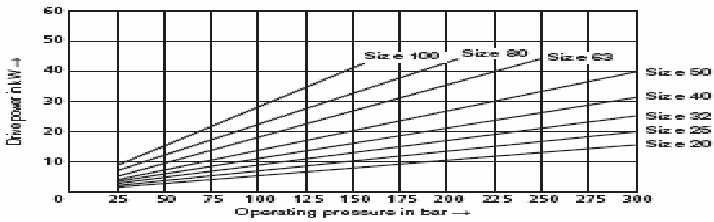


Efficiency



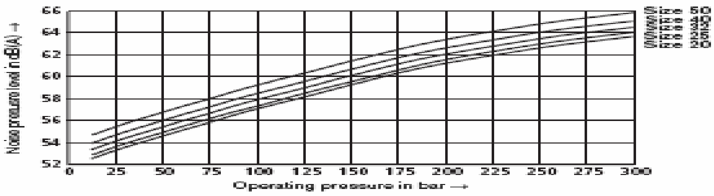


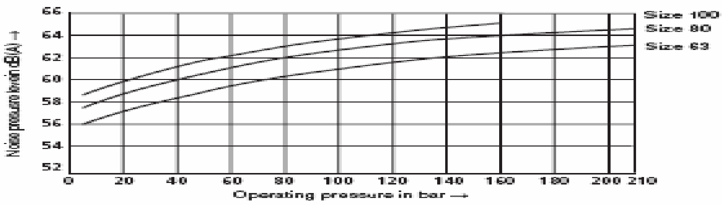
Drive power



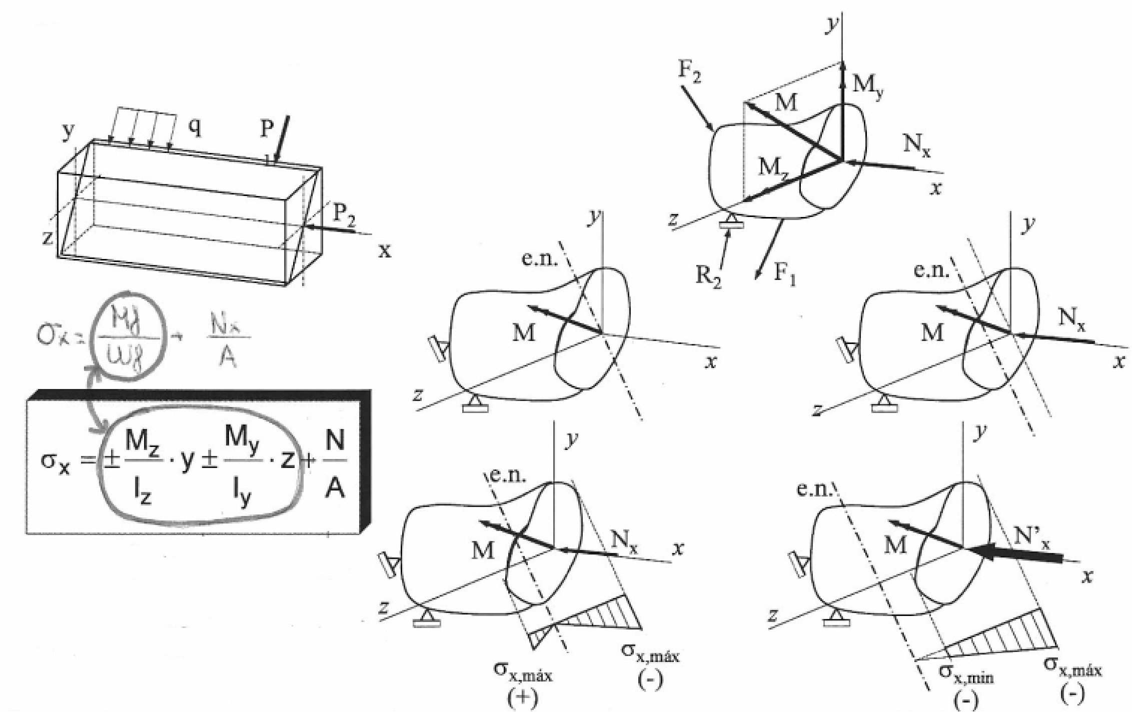
Noise pressure level

Measured in the anechoic chamber in line with DIN 45635, page 26
Distance from microphone to pump = 1 m

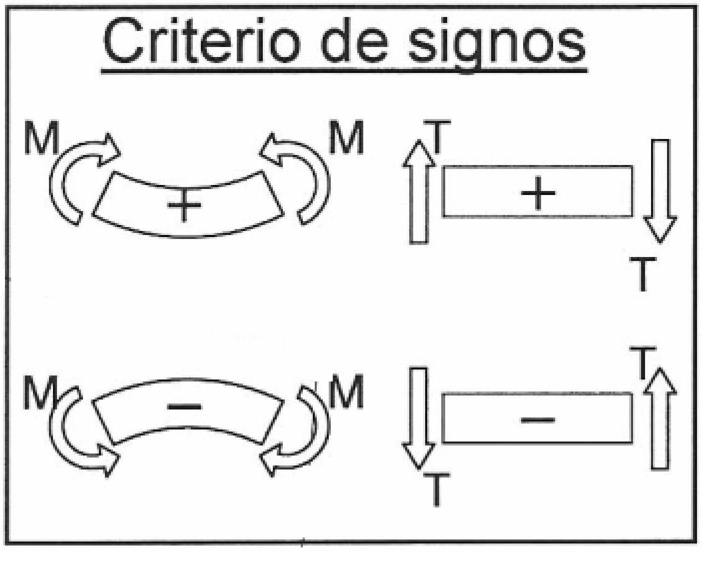




APPENDIX Nº11: COMPOUND FLEXION

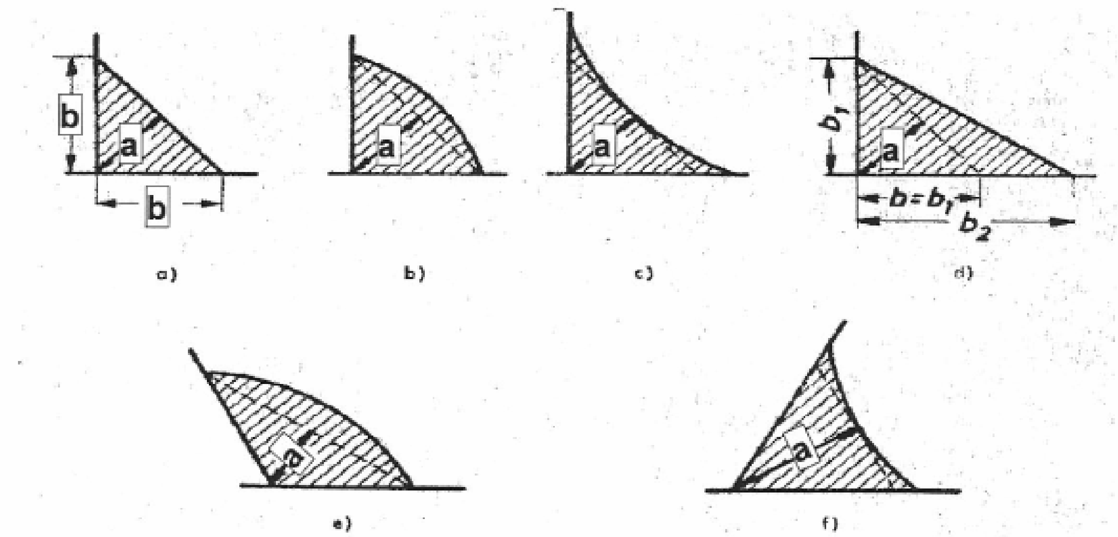


APPENDIX Nº12: CRITERIA OF SIGNS OF THE MOMENTS AND SHEARS



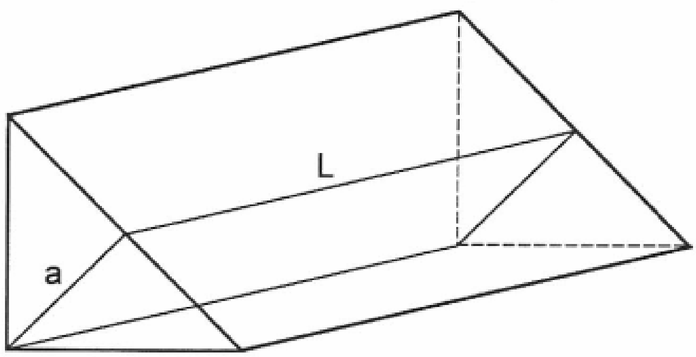
APPENDIX Nº13: THEORY OF WELDINGS

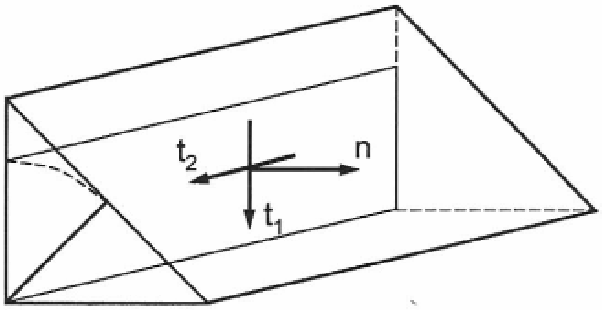
Garganta (a): altura del máximo triángulo isósceles inscrito en la sección transversal del cordón de soldadura



Longitud eficaz (L): longitud total del cordón, descontados los cráteres de los extremos. La longitud de cada uno de estos cráteres, se toma igual al valor de la garganta (a).

Área de la sección de la garganta: es la obtenida multiplicando la garganta del cordón por su longitud eficaz.



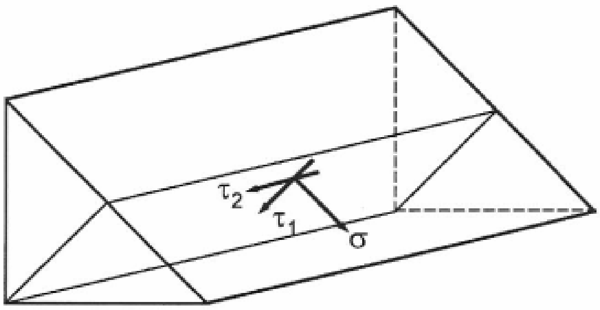


Tensiones sección abatida

n: tensión normal

t_1: componente transversal de la tensión tangencial

t_2: componente longitudinal de la tensión tangencial

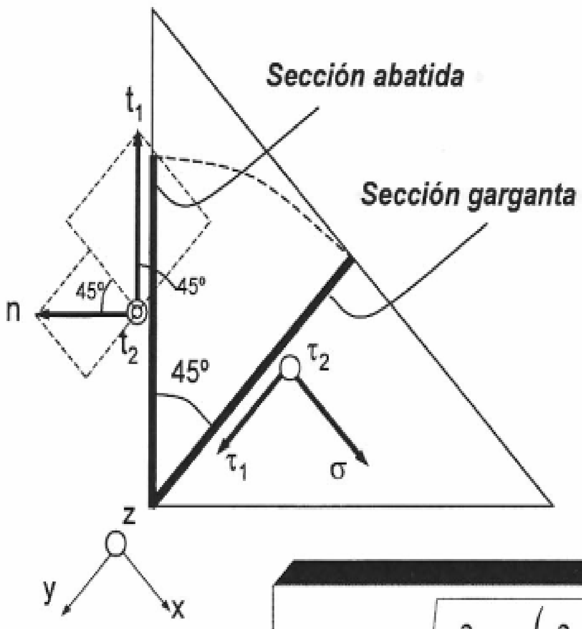


Tensiones sección garganta

σ: tensión normal

τ_1: componente transversal de la tensión tangencial

τ_2: componente longitudinal de la tensión tangencial



$$\sum F_x = 0 \Rightarrow \sigma - t_1 \cdot \text{sen}\,45º - n \cdot \cos 45º = 0$$

$$\boxed{\sigma = \frac{t_1 + n}{\sqrt{2}}}$$

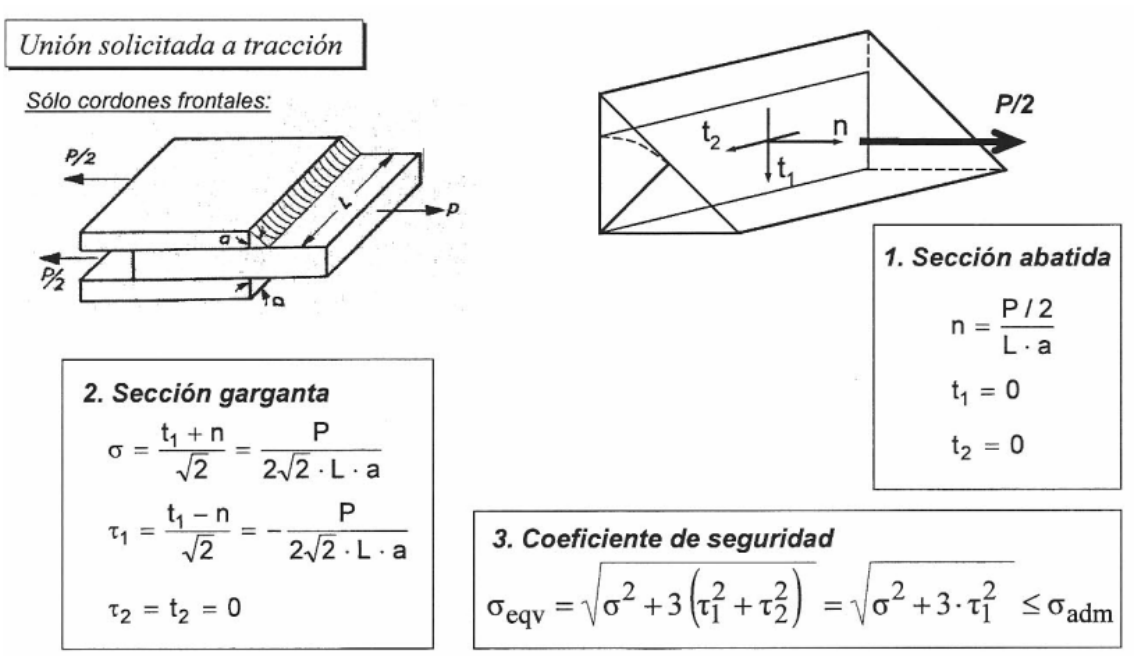
$$\sum F_y = 0 \Rightarrow \tau_1 - t_1 \cdot \cos 45º + n \cdot \text{sen}\,45º = 0$$

$$\boxed{\tau_1 = \frac{t_1 - n}{\sqrt{2}}}$$

$$\sum F_z = 0 \Rightarrow \boxed{\tau_2 = t_2}$$

$$\boxed{\sigma_{eqv} = \sqrt{\sigma^2 + 3\left(\tau_1^2 + \tau_2^2\right)} \leq \sigma_{adm}}$$

APPENDIX Nº14: THEORY OF WELDINGS (TRACTION)



APPENDIX Nº15: THEORY OF WELDINGS (SIMPLE FLEXION)