TÉCNICO LISBOA

DESIGN AND DEVELOPMENT OF A SHUTTER FOR FRESNEL LENS

Luis Javier Martínez Fernández

Degree in Mechanical Engineering

Area Mechanical Design and Manufacturing

Tutor: Luis Guerra Rosa

CO-Tutor: Bertinho Andrade Costa

Completion date - 24/05/2016

Contents

1-Objective

From a working group at the "Instituto Superior Técnico" of Lisbon we want to develop an equipment which is able to transmit sunlight through optical fiber. This field is still unexplored and our main goal is, by using a Fresnel lens, get to transmit solar radiation from the reception point to another point of use.

We can ask ourselves, how we can use this radiation transmission. Well, we can use this resource as a source of energy for smelting, to perform a chemical catalyst in a reactor or, simply, lighting (as we can see in the Figure 1.1).

This is a big project and my role in it is to develop a kind of shutter that, through the timely control system, will regulate the light intensity that will receive our Fresnel lens. We carry out this regulation because Fresnel lenses do not work like solar panels that store the excess radiation in batteries. In our case, we have to dissipate the electromagnetic radiation that we are not interested to get at the point of use. The objective of this is that our optical fiber always transmit the amount of sunlight that we need.

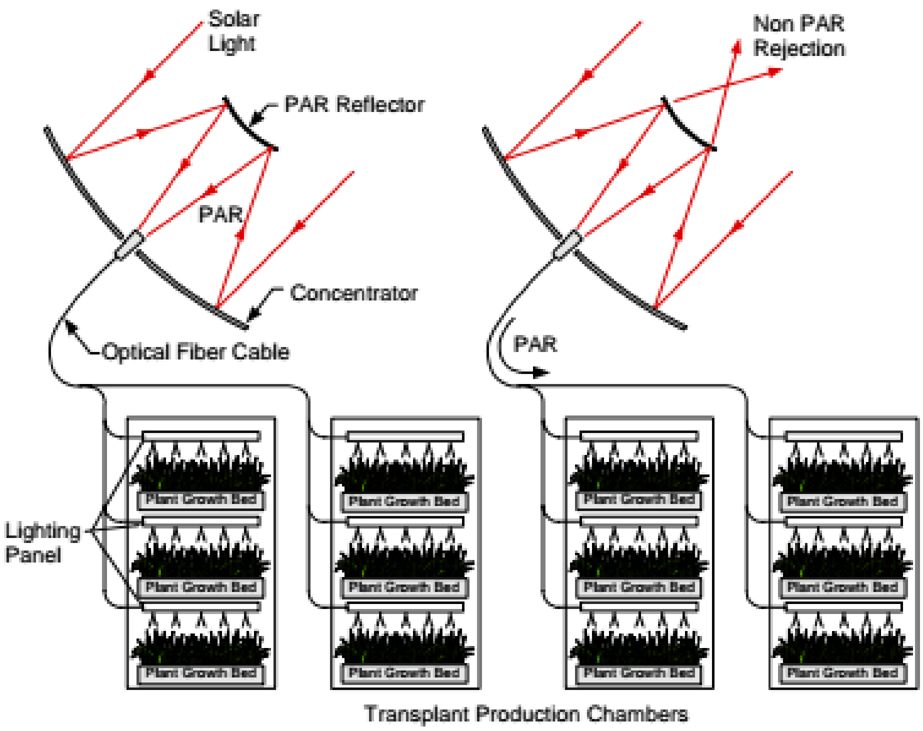


Figure 1.1-Example of use from Optical Fiber for "Green Houses" [1]

2-Scope

We are going to design the shutter we want to use in the development of our device. Once the design is done, we decided to go with the detailed engineering. In this part, we should generate all the components that form the shutter.

We will try to choose commercial elements to get that the final price of the entire device will be really economical and with the objective to market it. In all the components, we are going to detail the processes which we will get the different materials.

3-Antecedents

Initially, in this project was designed a prototype of shutter that we think might work correctly. To continue with the project, we decided to improve the existing prototype (take a look in the Figure 3.1) developed by the team before starting the project.

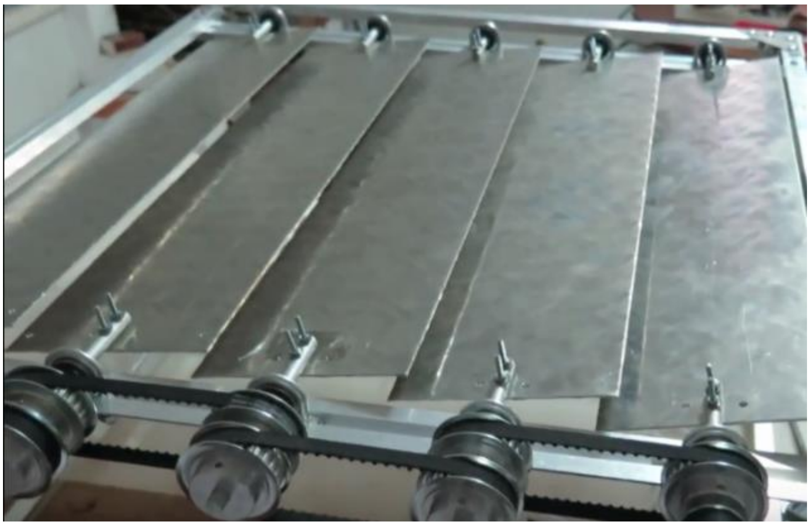


Figure 3.1- Prototype of a light regulator for receptors, such as solar panels

In Figure 3.1 can be seen, clearly, the existing design of the shutter which we started to work for get the final design we want to develop. To achieve this, we will justify all the calculations that we will make element by element trying to generate an improvement in the initial prototype.

4-Elements of the mechanism

Shutter Sheet

Operation

With this element of the mechanism we will get regulate the light which are going to arrive at the Fresnel lens. As shown in Figure 4.1, with the turning of the sheets, we will get a higher or a lower amount of radiation at the surface.

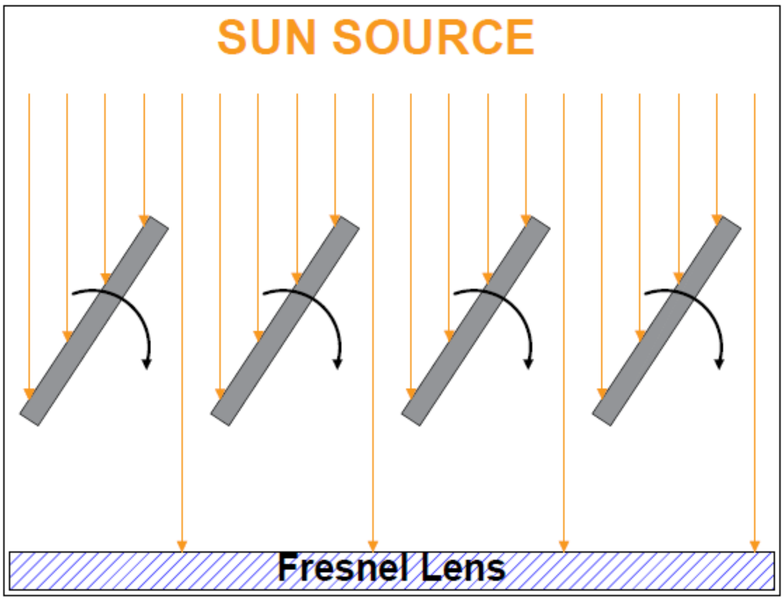


Figure 4.1-Graphical description for the working of the shutter sheets

This regulation allows to control the temperature in the lens. This kind of mechanisms are used in solar farms with this last objective, although this mechanism is not particularly developed and the turning of the sheets is slow and heavy.

Material Selection

To make the selection of the material we are going to study the problematic that comports this element. In the first place, it has to have a big rigidity to allow that the system are stable and there are not fluctuations in the control of the radiation that arrives to the lens. East could be a big problem for the control and for the focus receptor of the radiation.

Second, we have the problem of the thickness of the sheet. What elder was the thickness of our leaves of shutter, greater will be the quantity of solar radiation that we are wasting in the opening moment total.

These two problems are really important and contradictory then, what elder was the slenderness worse will be the stability and vice versa. That is to say, that will achieve a greater rigidity sacrificing in the size of the thickness of the sheet. In our case, we will study the rigidity flexional, which we can value applying the equation 4.1:

$$K_{flex} = \frac{E \cdot I}{L}, \text{ being } I = \frac{1}{12} \cdot e^3 \cdot L \qquad (4.1)$$

Our aim is to achieve minimise the two problems choosing the suitable material. The first thing in what we think, is in a material that have an elastic module the sufficiently big to achieve a high rigidity and a slenderness sufficient.

We are going to analyse the possibility to choose between distinct types of materials and see which of them fulfils in better measured the specifications. We decide to work in all with a thickness of 2mm for like this can compare the results. We will continue analysing the distinct prices of each material, because although a material can give some better results, if his price is too elevated in comparison with the improvement, we are going to refuse it.

We are going to obtain the properties of the materials in the database "CES 2015" and remembering that the module of inertia for all the materials goes to be:

$$I = \frac{1}{12} * 2^3 * L \rightarrow I = \frac{2}{3} L \ mm$$

Research of possible materials

We are going to work with fine sheet, by what look for material that can be plastically deformed by means of a process of lamination. According to our database, we can use ferrous alloys, alloys no ferrous or a compound material.

Inside the materials composed, the database recommends us to use a metallic compound of aluminium with carbide of silicon. This material has a price between the 4 and the 6 € by kilogram of material purchased. His module of Young finds between the 81 and the 100 GPa.

Of the same way that the previous material, we look for in the database all the materials that are useful for our process of manufacture. In the Table-4.1, we have all the materials that collects our database.

MATERIAL	MODULE OF YOUNG [GPa]	APROXIMATE COST [€/kg]	RIGIDITY [N/m]	INERTIA MODULE [g·mm²]
Al-SiC	81-100	4.66-6.21	66’67	4907812’00
High carbon Steel	200-215	0.389-0.434	143’33	13770120’00
Low alloy Steel	205-217	0.419-0.464	144’67	13770120’00
Low carbon steel	200-215	0.389-0.434	143’33	13858390’00
Medium carbon steel	200-216	0.389-0.434	144’00	14123200’00
Stainless steel	189-210	4.4-4.85	140’00	13593580’00
Age-hardening wrought Al-alloys	68-80	1.58-1.74	53’33	4607812’00
Cast Al-alloys	72-89	1.63-1.8	59’39	4775407’00
Non age-hardening wrought Al-Alloys	68-72	1.59-1.75	48’00	4819542’00
Brass	90-110	4.15-4.57	73’33	15535520’00
Bronze	70-105	5.96-6.57	70’00	15535520’00
Copper	112-148	5.29-5.83	98’67	15712060’00
Gold	77-81	3.03e4-3.34e4	54’00	33542600’00
Commercially pure lead	13-15	1.61-1.77	10’00	-
Lead alloys	13-17	5.17-5.69	11’33	-
Cast magnesium alloys	42-47	2.34-2.58	31’33	3001180’00
Wrought magnesium alloys	42-47	2.34-2.57	31’33	3031520’00
Nickel	190-220	13-14.3	146’67	15005900’00
Nickel-based super alloys	150-245	15.6-17.2	163’33	14465280’00
Nickel-chromium alloys	200-220	16.9-18.6	146’67	14016280’00

Silver	69-73	484-533	48’67	19419400’00
Tin	41-45	16.9-18.6	30’00	-
Commercially pure titanium	100-105	7.5-8.25	70’00	8120840’00
Titanium alloys	110-120	16.6-18.3	80’00	7714797’86
Commercially pure zinc	90-107	1.62-1.78	71’33	11828180’00
Zinc die-casting alloys	68-100	1.8-1.98	66’67	11651640’00

Table 4.1- Relation between possible materials and his different characteristic

To calculate the rigidity, we have applied the formula 4.1, defined previously and we have decided to choose the module of Young higher inside the rank of possibilities that gives us the database. Choose this module also does us choose the highest value possible for the cost of the material.

As second step in the program of modelling 3D “SolidWorks”, we calculate the module of inertia that would correspond to each material for a same piece. We include these data in the table, which maybe go to influence in our decision.

Criteria of decision

To decide what material go to choose value an average between the module of inertia, that will say us as of easy will be to move our leaves and the rigidity that will guarantee a greater stability.

In the Figure 4.2 we value which are the materials that will provide us greater rigidity for a common element. As second criterion, we go to value the moment of inertia of these materials for a same piece, our leaf of shutter (Figure 4.3).

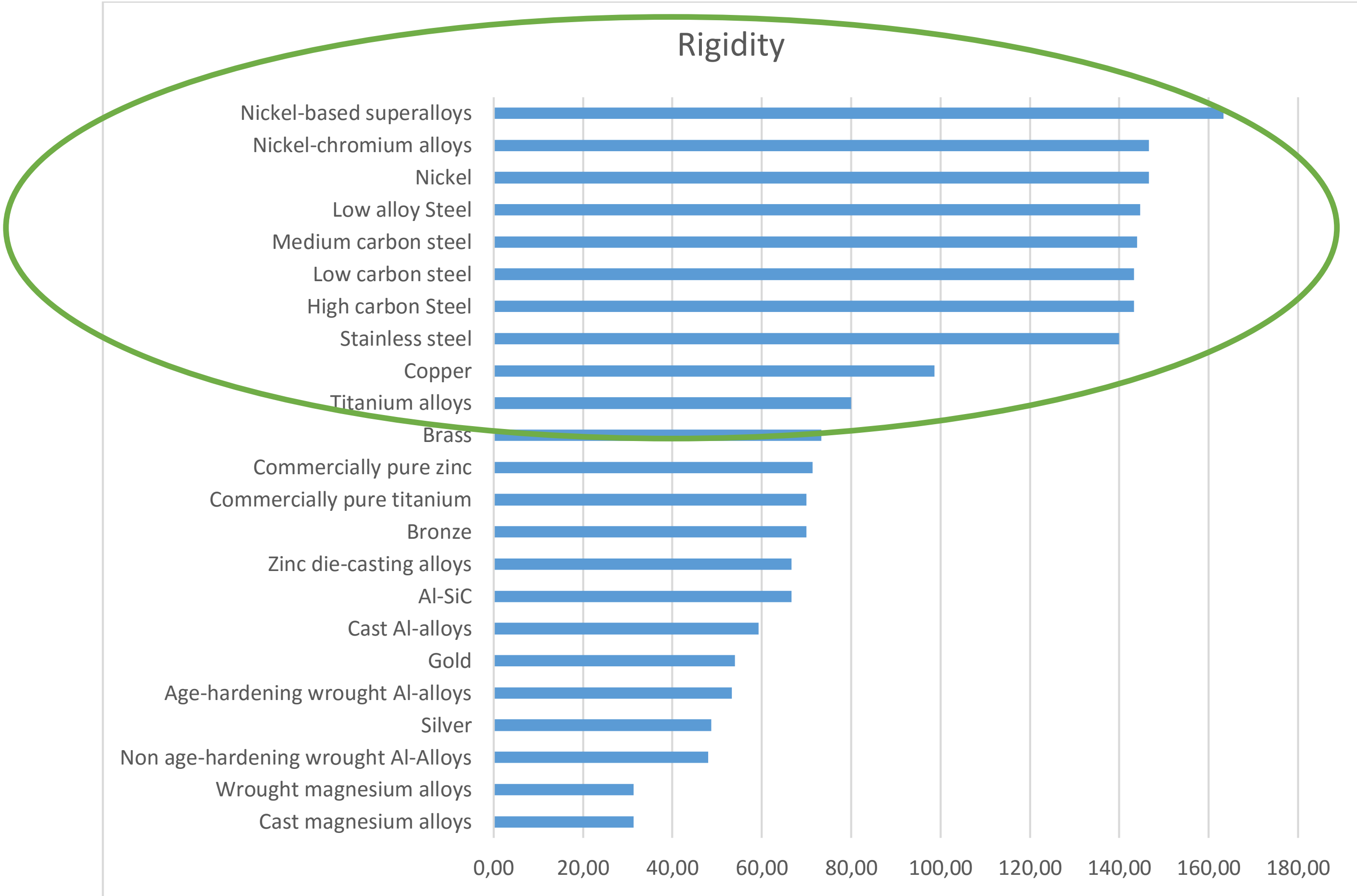


Figure 4.2- Relation between the material to choose and his rigidity

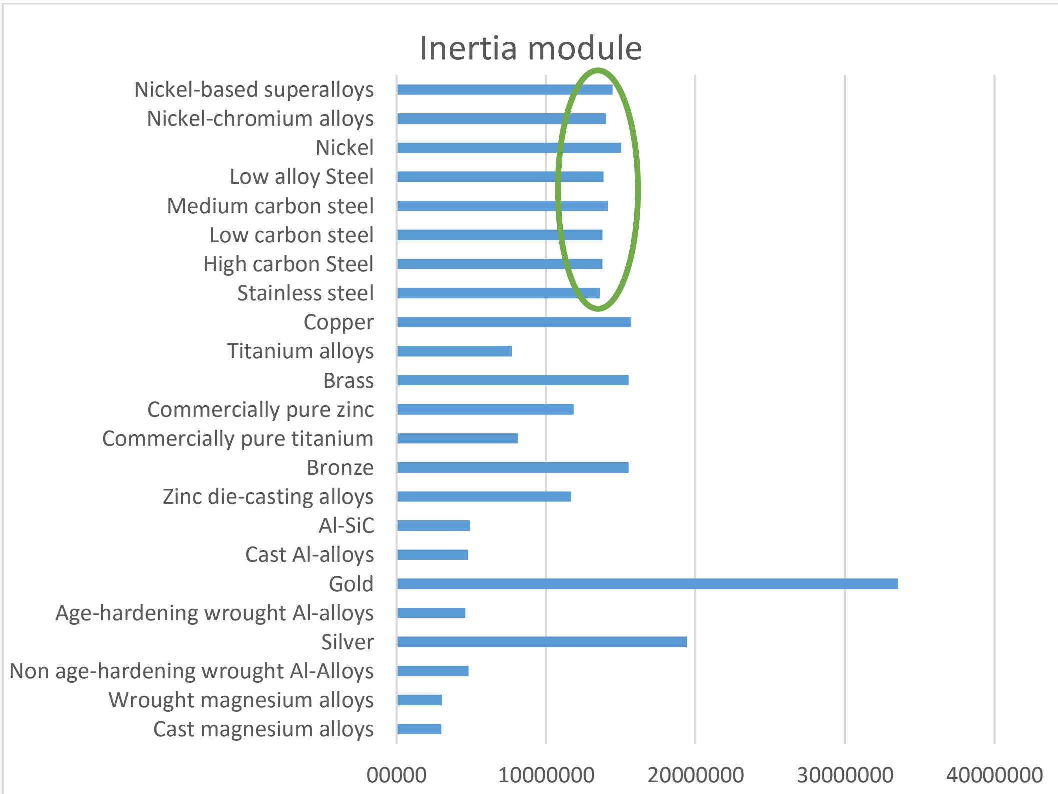


Figure 4.3- Moments of inertia in function of the material for our piece

We see that really the inertia will not be a factor determinant in the selection of the material, since the materials with greater rigidity have a moment of similar inertia. They are all the values inside the same order of magnitude.

To decide what material we are going to choose, we have to think that our device goes to be situated in the outside, by what goes to be suffering constantly efforts owed to the wind and the components can oxide because of the presence of rain in the surroundings.

After this first phase, we decide to decant then by the alternative of the stainless steel or of the nickel super ally. The nickel super alloy has a price four greater times that the stainless steel, so we decide to decant by the steel that is much cheaper and is the material that better results can give us in surroundings of variable operation

Design of the element

If we remember the design of that had split, this element does not have a big complication. It is simply a flat sheet with the suitable measures to the lens and to the structure that goes it to sustain.

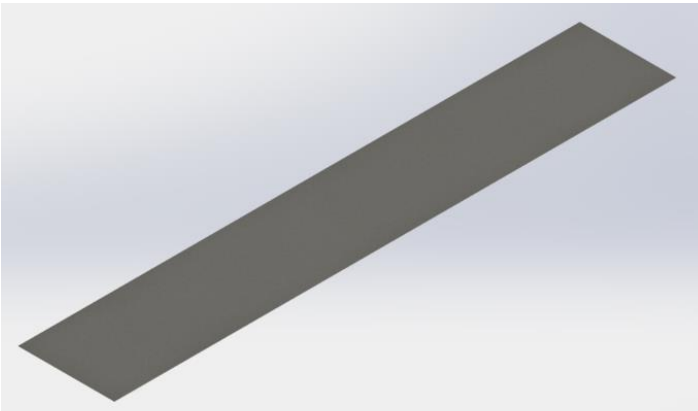


Figure 4.4- Desing of the leaf for shutter in "SolidWorks"

The main problem goes to be in the loads that goes to have to bear owed to the wind, mainly. Basing us in the structural calculation and following the technical code of edification, we are going to see which load has to be borne by the axes of the shutter.

We are working with "Basic Document SE Actions in the edification" that regulates the Spanish government to make constructions. As we are making a machine that goes to be in the outside assume that the loads of wind that go him to affect are the same that for an edification.

We do not owe to lose of sight in any moment that this is an approximation to be able to estimate that load go to bear our axes and our rolling.

Following the steps that marks us the document know that the action of the wind goes to be represented like:

$$q_e = q_b \cdot c_e \cdot c_p$$

Dynamic pressure of the wind (q_b), calculated according to the Anejo D like 0.52kN/m² for a zone of exhibition of wind C. We are calculating this machine to situate it in Lisbon, where the wind is really a load to take into account because of his speed in this point.

Coefficient of exhibition (c_e), go to suppose that we go to install our device in an urban or industrial zone. The team goes to be situated in the ceiling of the installation, so we go to suppose a height of some 20m. With this consider a value of 2.3.

Coefficient of pressure (c_p), assume that it goes to have a value of 0.8 according to the tables that collects the document with which are working.

With all this can say that the wind goes to suppose a load of:

$$q_e = 0.52 \cdot 2.3 \cdot 0.8 \rightarrow q_e = 0.96kN/m^2$$

The planes made for the construction of the leaf of the shutter are in the ANNEX I.

Providers and acquisition

For the leaves of the regulator go to purchase a sheet in the company "ACERINOX". It is a very recognised steelworks that sells so much wholesale as to the by minor. We will purchase a sheet of steel AISI 304 (austenitic) in shape of iron, laminated in cold, annealing and pickling.

Figure 4.5- Sheet from "ACERINOX" [2]

The sheet has some dimensions normalised of 1000X2000mm. Of it, we go to obtain by means of cut of sheet (in a centre of mechanised, for example) the different leaves of the shutter that go to use.

Considerations for the design of the axes

Premises

The function of our axes is the one to bear the transmission of the movement from the engine to the distinct leaves of our shutter. Our aim is that the speed of obturation, that is to say, the speed which the shutter open and close achieve a complete movement in a second. Or what is the same, we want that the shutter give half complete turn in a second:

$$n = \frac{180º}{s} \cdot \frac{1revolution}{360º} \cdot \frac{60s}{1min} \rightarrow n = 30rpm$$

We can also determine the maximum pair in the extreme of the leaf of the shutter that, in the case more unfavourable, will have to win our engine because of the load of the wind. We go to see in the following figure as it is applied the load on our shutter.

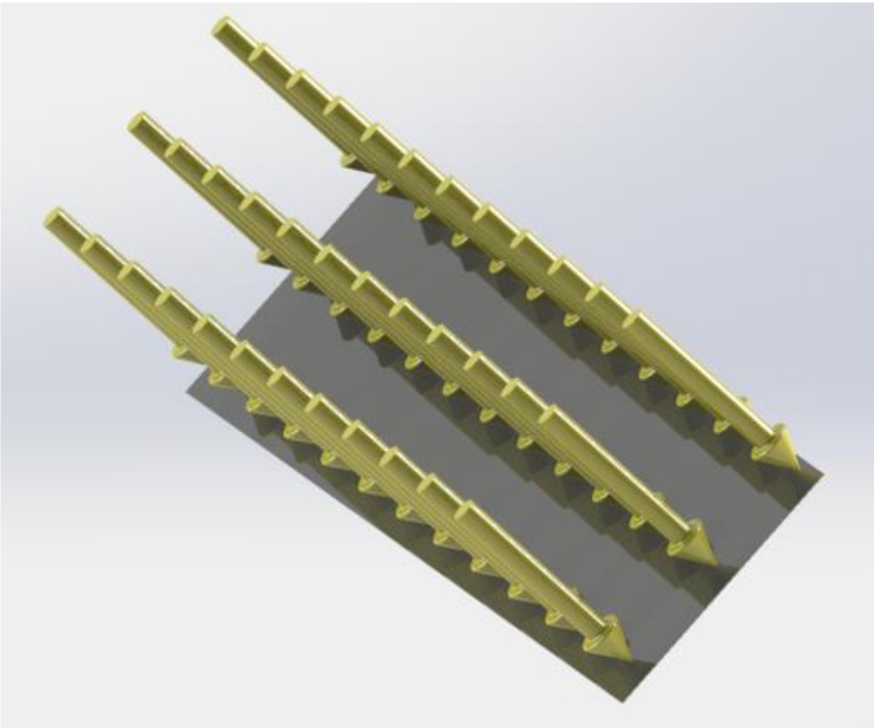


Figure 4.6-Load of the wind in the leaf of the shutter

We can say that we assume the load of wind like a load distributed, with the value that have calculated in the previous section. With this load can determine the efforts to which go to be subjected our axes.

In the Figure 4.6, we can see that this load does not go to generate torsor moment in our axes, since we assume maximum load in perpendicular situation to the surface. In this moment, concerning the centre of gravity (place in which it goes to be situated the axis), compensate some strengths with the others. As in the perpendicular sense have a really small section despise the efforts in this sense.

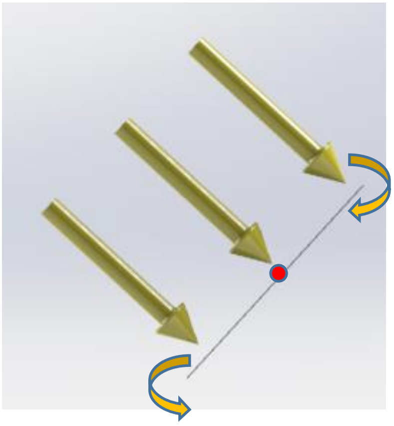


Figure 4.7-Torsor moment generated by the wind

However, these efforts will not be despicable in the longitudinal sense. We go to design an isostatic system, by what one of the bearings will be axially fixed, whereas another no. Although one of them have of this characteristic, our axes go to load mainly and like consequence of the existence of wind in radial position.

With all this can resume that the engine that go to put to our machine goes to be the only that transmit the torsor moment to the device, being minor in function of the vicinity of the corresponding leaf to the transmission. That is to say, the driving main will have a torsor moment greater that his driven and like this successively. As we want a homogeneous machine go to calculate the first of the leaves, that is to say, to which goes him to transmit the movement in the first place and, like consequence, the most loaded. We will assume for the rest of the mechanism these same premises.

Have our case of isostatic that really is very simple. We assume that the wind acts like a punctual load in the centre of the leaf of the shutter as we can see in the Figure 4.8. The bearings represent in the points A and B, one of them axially fixed.

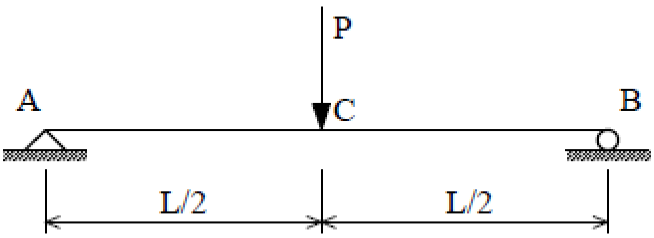


Figure 4.8- Representation from the isostatic case to solve

To calculate the load P, only have to take into account the surface on which acts the wind and the load distributed.

$$P = q_e \cdot L \cdot b \rightarrow P = 0.96kN/m^2 \cdot 0.7m \cdot 0.12m \rightarrow P = 80N$$

Each one of the axes will bear the transmission of a load of 40N since, by symmetry, the load distributes of uniform way.

The axes that find in the same side that the engine not only have this load. Those that situate in the contrary side have besides the loads of the pulleys and of the transmission of the movement because of the pair torsor necessary.

Consideration of the initial iteration

As we are checking that the loads are really small go from some axes in which we suppose a diameter of 12 millimetres. It is a really small diameter and that go to check of iterative form once that we decide as it goes to be the transmission, the necessary power to transmit etc.

Union between the axis and the leaf of the shutter

Operation

The aim of this element is to join the axes go to design and the leaves of the shutter. We want to make this of the most economic form possible, so we decide to see that objects there is in the market and how much can cost us.

We look for a piece that achieve to attach the axis of safe form, by what will need obviously that our piece have a hole that allow the insertion of the axis and later his tighten.

Besides, it has to have a flat surface which can attach it to the leaf of the shutter by means of mechanical unions. As we know, the sheet of stainless steel has a very small thickness and, to avoid damage it, refuse the idea of weldings or another type of unions.

With these ideas go us in search of a commercial product, no too expensive and that adapt to our needs.

Providers and acquisition

After looking for in several catalogues decide to remain us with an industrial clamp that offers the provider “PHOENIX MECANICA ESPAÑA”. In his catalogue find a big variety of products, but decide to decant us by the clamp that see in the Figure 4.9. Said element has a hole that allows to attach an axis of 12mm of diameter.

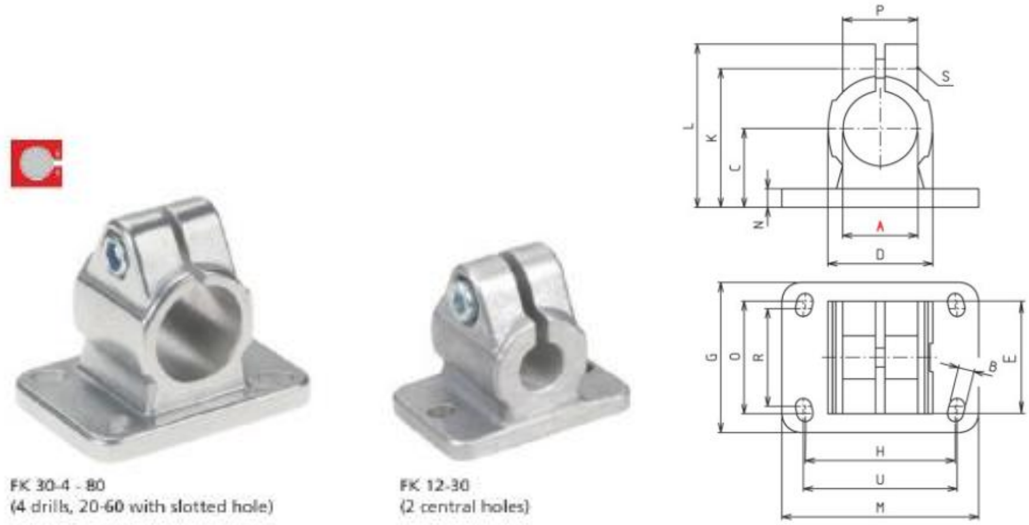


Figure 4.9- Conexión between the axis and the leaves from the shutter

FK - Industrial design

[mm]

Code No.	Type	A	B	C	D	E	G	H**	K	L	M	N	O*	P	R	S	U	m [g]
12120000020	FK 12	12,1																67
12140000020	FK 14	14,1																64
12150000020	FK 15	15,1	5,5	18	26	32	35	38	32,5	41	50	5	–	23	–	M6x20	40	62
12160000020	FK 16	16,1																60
12180000020	FK 18	18,1																56
12200000020	FK 20	20,1											–		–			202
12200100020	FK 20-4	20,1											40		35			205
12250000020	FK 25	25,1	6,5	30	40	40	55	53	53	63	78	7	–	33	–	M8x25	60	184
12250100020	FK 25-4	25,1											40		35			188
12300000020	FK 30	30,1											–		–			162
12300100020	FK 30-4	30,1											40		35			166

Table 4.2- Dimensions of the element in agreement with the Figure 4.9

We remember that the previous section have decided to make the iteration with an axis of 12mm of diameter and to be able to make back calculations need to know all the elements of the mechanism that go to turn.

We have requested budget to determine if we can choose this component or no, because as we have said previously, look for a cheap and competitive element. In the following image see the price according to the material that choose for the component:

Empresa :	**INSTITUTO SUPERIOR TÉCNICO PORTUGAL**
Persona de contacto :	Luis Javier Martínez Fernández
Fecha :	04 de abril de 2016
Nº de Oferta :	**16OFR0163**

Código	**Descripción**	**Cantidad**	**Unidad medida**	**Precio venta**	**Importe**
121200000	ABRAZADERA DE BRIDA FK 12	1	Unidad	8,01	8,01
1212000038	ABRAZADERA INOX FK-VA12	1	Unidad	21,44	21,44
			Total EUR		**29,45**
			Importe IVA		6,18
			Total EUR IVA incluido		**35,63**

Figure 4.10- Budget from the company

As we go to plant 5 leaves of shutter for our device and, in each one of them, have two industrial clamps, will need a total of 10 clamps for each shutter that want to develop.

Material Selection

We can choose between two materials: steel to standard carbon or stainless steel. To the equal that decide in the leaves of the shutter, our device is designed to work in an external space and can suffer by the existent climate. So we decide to purchase the clamp of stainless steel.

Design of the element

This element is commercial. Have all the necessary measures to make a simulation in the catalogue of the manufacturer that finds in the Figure 4.11 that have taught previously.

Figure 4.11- Connexion between axis and leaves in "SolidWorks"

In the program of design go him to give a more striking colour, as to other pieces, so that in the final assembling can see more easily all the components that go to have in our device.

Considerations in the calculation of the power to transmit

To make the selection of the engine we have to know which speed we want to turn our leaves, the inertia that have to win in the movement and the loads that are against to it. It seems very simple to say it does not go to exist any external load that are against the twist of our engine (except the load of wind that go to include) by what the only we have to know is the inertia that have to win.

Thanks to the program SolidWorks, we can determine the moment of inertia of all the components that are turning in our device and that our engine has to move.

As we are in a first approximation go to consider the power obtained with a factor of security of 3. We make this consideration because we do not know even the inertia that go to have the chains and the toothed wheels that go to form part of the transmission.

In fact, this first consideration make it to be able to calculate the size of necessary transmission that, iterating, go to correct if it was precise.

Inertia of the components

LEAF OF THE SHUTTER → $I_p = 14123200.00\ g \cdot mm^2$

CONNEXION → $I_c = 79128.80\ g \cdot mm^2$

NUTS AND BOLTS → $Assume\ negligible$

LONG AXLE → $I = ?$

SHORT AXLE → $I = ?$

BEARINGS → $I = ?$

WHEELS AND CHAIN → $I = ?$

Still we have a lot of doubts in our project but, for a first iteration, we consider appropriate the security factor that have imposed to the not taking into account a lot of components, like the axes or the transmission. All this will take into account for the definite calculation.

Calculations of necessary power

We know that the necessary power to move all the device depends on the loads of wind and the inertia of the components.

Also of the angular acceleration of the device that has to begin to work, reaching his speed of regimen in half second and brake totally in another half second:

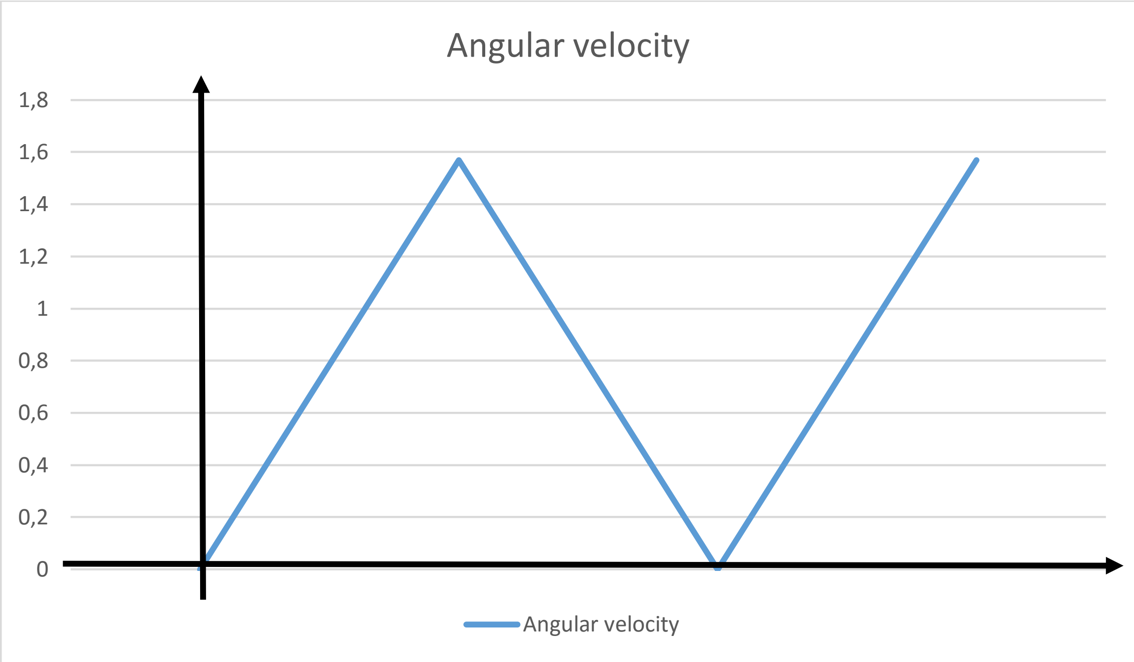


Figure 4.12- Evolution for the angular speed with the time

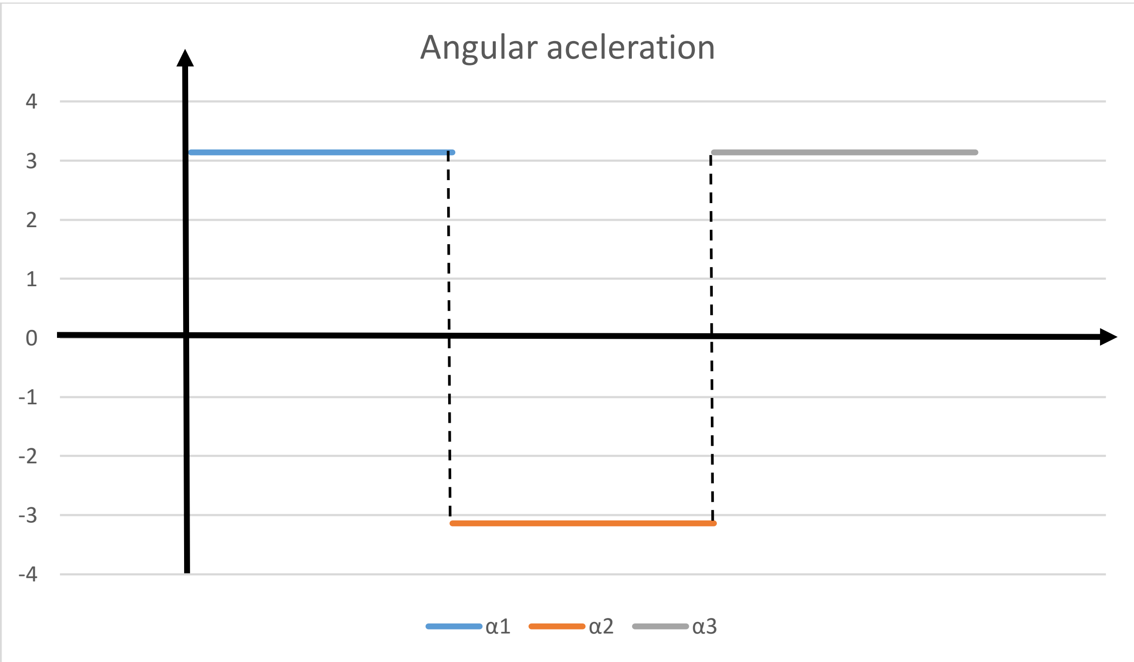


Figure 4.13- Evolution for the angular acceleration with the time

$$\alpha = \frac{\Delta w}{\Delta t} = \frac{\frac{90}{360} \cdot 2\pi \, rad/s}{0.5s} \rightarrow \alpha = 3.14 \, rad/s^2$$

1) Inertia of the system

$$I_{system} = I_p \cdot n_p + I_c \cdot n_c + \cdots$$

As we have said we go to despise all what was not the shutter and the connections. The number of leaves of shutter is 5 for the device that have in mind and, therefore, the number of connections is necessarily the double. This is like this because each shutter has to his sides an axis that bears it.

$$I_{system} = 14123200 * 5 + 79128.8 * 10 \rightarrow I_{system} = 71407288\ g \cdot mm^2$$

$$I_{system} = 0.0714\ kg \cdot m^2$$

2) Inertia due to wind load

$$I_{wind} = \frac{F_{wind} \cdot R}{\alpha}, being\ \alpha\ angular\ aceleration$$

We know which the strength of the wind is that exerts on the shutters, because we have calculated it previously. The distance that generates the pair ("R") we go to consider that it is the half of the width of the shutter. We have to take into account that we are considering that the wind delivers of form homogeneous on the 5 leaves.

Once that we have it all can calculate the total pair that has to win the engine:

$$M_{total} = \alpha \cdot \left(I_{system} + I_{wind}\right) = I_{systme} \cdot \alpha + F_{wind} \cdot R, with\ numbers:$$

$$M_{total} = I_{system} \cdot \alpha + F_{wind} \cdot R = 0.0714 kg \cdot m^2 \cdot \frac{3.14 rad}{s^2} + (80N \cdot 0.06m) * 5$$

$$M_{total} = 24.22\ N \cdot m$$

Finally we determine the necessary power of initial calculation for our engine:

$$N_{motor} = M_{total} \cdot n \cdot FS = \frac{24.22 \cdot 30}{9550} \cdot 3$$

$$N_{motor} = 220\ W$$

Transmission of power

Supposed the power of our engine, proceed to calculate our transmission by chain. The approximate distance between axes is defined by the width that have given him previously to the leaf of the shutter, being able to guarantee a total closing of the mechanism when including an small overlap between leaves.

We have decided that like the width of the leaves is of 120 millimetres go to consider an overlap by each side of the leaf of some 20 millimetres. Of this form guarantee that the shutter can cover the lens of Fresnel completely.

With this condition determine that the distance between axes will be of 100 millimetres. Previously we define the speed of the pinions like 30 rpm that will be exactly the same to the one of the wheels driven($i_{chain} = 1$). This deduction translates in that the pinion and the wheel of our transmission will have the same specification.

Supporting calculations

In accordance with the equation detailed to continuation, obtain a first value for our power of crash:

$$P_D = \frac{P_{nominal}}{m \cdot k}$$

As we go to have an only pinion and four wheels driven consider all the power of our device. For simple chains the value of m=1 and k is a factor of power related with the factor of crash “c” and the number of teeth of the wheel.

This factor of crash in accordance with the tables consulted (See bibliography, see DIN 8195) corresponds with a value of 1.5 (rotary machine) and supposing Z= 15 teeth (because we want a small wheel) consider a factor k=0.53.

$$P_D = \frac{220}{1 \cdot 0.53} \rightarrow P_D = 415\ W$$

With this data together with the angular speed of our pinion attend to the tables consulted in the same document and obtain a type of chain. In our case a chain 12B and knowing already the type of chain can obtain his technical data like the step that is of 19.05mm.

As we want a small wheel, have said that chose wheels of 15 teeth, following the valid rule and the bibliography consulted know that:

$$n_z = 4.8097 \rightarrow d_{piñon} = p \cdot n_z = 19.05 \cdot 4.8097 \rightarrow d_{piñon} = 90mm$$

Providers and acquisition

Some distributors have of these components in on-line catalogues because they are normalised according to the norm DIN. We look for companies that manufacture the components that we need. With them and with help of the program of modelling 3D that carry using in all the work can determine the inertia of the components that, beside the axes, will give us a more real approximation for the calculation of the power for the engine that go to use in our device.

With the previous data, when having 5 leaves of shutter, take for granted that we will need 5 toothed wheels of 15 teeth. One of the wheels will work like wheel driving (pinion) and the others 4 like wheels driven. Also we know the number of links that need to purchase when applying the following equation:

$$X = 2 \cdot \frac{a'}{p} + \frac{Z_1 + Z_2}{2} + \left(\frac{Z_2 - Z_1}{2\pi}\right)^2 \cdot \frac{p}{a'} = 2 \cdot \frac{500}{19.05} + \frac{15 + 15}{2} + \left(\frac{15 - 15}{2\pi}\right)^2 \cdot \frac{19.05}{100}$$

Resolving this equation determine that we need 68 links to complete the chain.

We attend to the catalogue of the company “IWIS”. In her we find a wheel for our chain with the specifications that show in the Annex II of components.

Attending also to a catalogue purchase in the same company the chain 12B that need for the flexible transmission that have designed.

With help of the program “SolidWorks” already can determine the moment of inertia of the system of chain and wheels that goes to have to move our engine. In this case:

RUEDAS Y CADENA → $I = 38670723.17\ g \cdot mm^2$

We can see that this data is not at all despicable and that goes to influence to a large extent in the power to transmit by the engine. In this moment seems that the factor that initially adopt seems to be chord to the results expected.

To define the position of the wheels of the chain go to use rings of retention that will purchase to the company “EMILE MAURIN”. To the equal that with the two previous components, his specifications find in the Annex II of this document.

Selection of the axes

In this section will calculate the dimensions of the axis of the conductive wheels and driven of the chain, in addition that will serve of support in another extreme of the structure. The axis that serves of support, really, is the one who less efforts goes to bearing. By this reason assign him an equal dimension to which go him to give to the greater axis, with the aim to homogenise our machine.

We calculate the axis on which go to go the wheels that transmit the movement and the pertinent supports. We go to make these calculations with the program of mechanical design “ADIMEC” developed like a tool of calculation that follows the principles to be followed by the mechanical engineering.

On the axes of transmission go to have a similar design to the following:

Figure 4.14- Isostatic system with cantilever

The first dimension to take into account will be the length of our axes, which has to be the sufficiently big so that they fit the two wheels of the chain and the pertaining rollings to each one of the sides of the axis.

We do not have elements very big, but have to take into account the width of the distinct elements that will situate in the axis. With all this and for leaving a margin to the structure, that still have not designed, go to suppose a size of some 180mm to be in a comfortable situation.

We situate the distinct supports and the different loads in function of what have said and obtain a distribution as it sees in the Figure 4.15

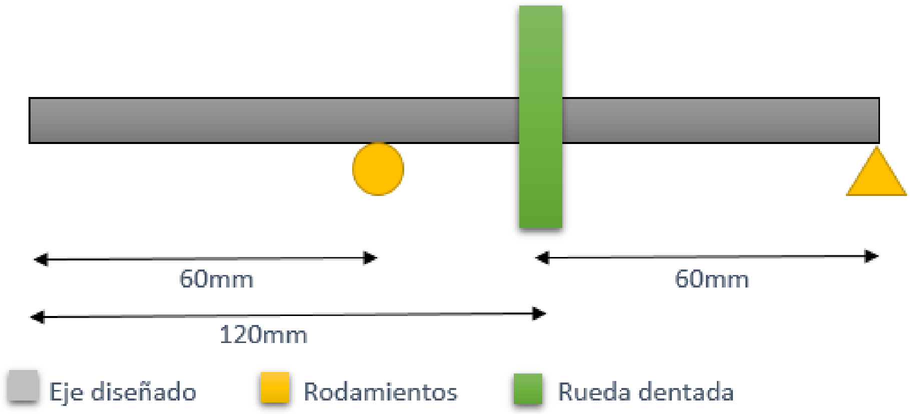


Figure 4.15- Representation the different elements in the long axle

As we have said previously, we check in the program “ADIMEC” if the diameter of the axis that supposed initially is sufficient for the loads with which are working.

In group, the loads that have to take into account are really small. In the first place, the load of wind that will situate like punctual in the extreme of the cantilever. We owe to take into account that this load will have distributed between the long axis and the short axis, with what only will take into account the half of his value (40N).

The engine generates a moment torsor that it has to transmit by the different wheels, but with a really small value (25Nm). This generates an effort torsor maximum from the attachment of the engine until the first driving wheel in the first axis.

Obviously, we do not go to design the 5 axes of different form. We go to design the first, which is the one who is more loaded, because of the load that transmits the engine that finish to comment.

Also we will determine also the reactions in the supports for the calculation of the rollings that will have to make in a back section.

Entering all these data in the program of mechanical design “ADIMEC” we determine that this diameter of 12 mm is sufficient and happen to design the tree to situate the different elements that want to enter.

Providers and Acquisition

Have to purchase bar of 14 millimetres because it is the section of greater size that go to use. The changes of section can mechanise them by means of turning and like this achieve the dimension of 12 millimetres.

Like the sheets for the shutter buy like long product in “ACERINOX” the bar with a diameter of 14 millimetres.

Selection of the material

The company where go to purchase the bars gives us a big fan of possibilities between which can choose. We choose bars with a length of 2000mm (need 10 axes by each regulator) of steel AISI 316 (bar of stainless steel annealing). We choose this steel because has some good properties and is easy to mechanise in the lathe.

Design of the axes

In “SolidWorks” we design the axes with the agreed size and with changes of section to facilitate the setting of our device obtaining the following results:

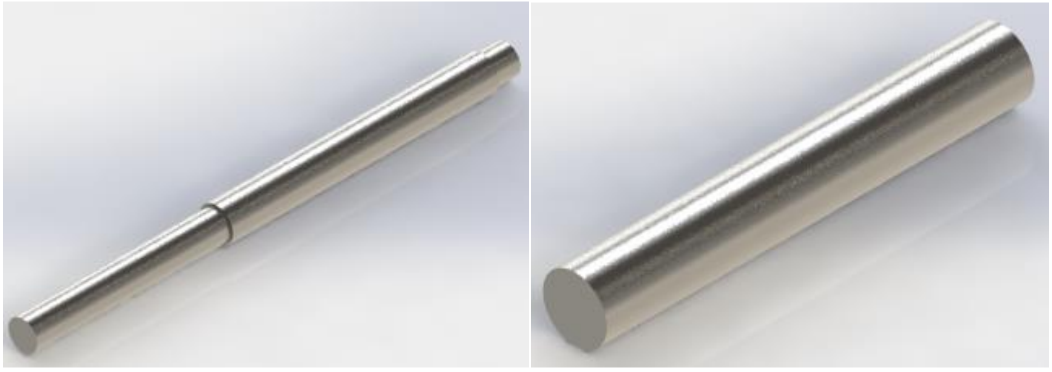


Figure 4.16- Design of the axis in "SolidWorks"

In the previous images see the two already designed axes and with his clear-cut material. In axis of greater size (left) has changes of section to ensure of form more efficient the different rollings that go to plant and, of this form, not using of constant form rings of retention.

In the short axis (right) do not need to make this type of changes of section because it already will remain sufficiently fix with help of the connection to the leaf of the shutter. We do not have two rollings as in the long axis, only will use one.

Selection of the engine

Now that we already have of all the elements of which have to consider the inertia can make a totally real calculation of the power of the necessary engine:

LEAF OF THE SHUTTER	→	$I_p = 14123200.00\ g \cdot mm^2$
CONNEXION	→	$I_c = 79128.80\ g \cdot mm^2$
NUTS AND BOLTS	→	$Assume\ negligible$
LONG AXLE	→	$I = 84818.56\ g \cdot mm^2$
SHORT AXLE	→	$I = 37565.78\ g \cdot mm^2$
BEARINGS	→	$I = 338.47\ g \cdot mm^2$
WHEELS AND CHAIN	→	$I = 38670723.17\ g \cdot mm^2$

Supporting calculations

It is analogous to what did in previous sections but already with all the data.

1) Inertia of the system

$$I_{system} = I_p \cdot n_p + I_c \cdot n_c + \cdots$$

As we had said we go to despise all the nuts and bolts because it is minimum. The number of leaves of shutter is 5 for the device that have in mind and, therefore, the number of connections is necessarily the double. This is like this because each shutter has to his sides an axis that bears it.
In consequence will have 5 long axes and 5 short axes in addition to all the system of transmission. By the distribution considered have also 15 exactly equal bearings.

$$I_{system} = 14123200 * 5 + 79128.8 * 10 + 84818.56 * 5 + 37565.78 * 5$$

$$+338.47 * 15 + 38670723.17$$

$$I_{system} = 0.1107\ kg \cdot m^2$$

2) Inertia due to wind load

$$I_{wind} = \frac{F_{wind} \cdot R}{\alpha}, being\ \alpha\ angular\ aceleration$$

Once that we have it all can calculate the total pair that has to win the engine:

$$M_{total} = \alpha \cdot \left(I_{system} + I_{wind}\right) = I_{systme} \cdot \alpha + F_{wind} \cdot R, with\ numbers:$$

$$M_{total} = I_{system} \cdot \alpha + F_{wind} \cdot R = 0.1107kg \cdot m^2 \cdot \frac{3.14rad}{s^2} + (80N \cdot 0.06m) * 5$$

$$M_{total} = 24.35\ N \cdot m$$

Finally we determine the necessary power of initial calculation for our engine:

$$N_{motor} = M_{total} \cdot n \cdot FS = \frac{24.35 \cdot 30}{9550} \cdot FS, being\ \ FS\ a\ security\ factor$$

$$N_{motor} = 80\ W, con\ FS = 1$$

Providers and acquisition

Look for in a catalogue of servomotors one that fulfil us the characteristics that are looking for. In this case we purchase an engine of alternating current in the company Siemens that generates us a power of 0.18Kw. With this achieve a factor of security slightly upper to 2, giving sufficient margin of operation to our machine.

Figure 4.17- Engine AC from Siemens [3]

The problem now is the speed of exit that needs the engine. We will need to incorporate him a variator of frequency that change the own frequency of the network to a determinate frequency that generate the speed of exit that we look for in each moment.

The own manufacturer gives us several options and choose one of them, the one who seems us better for our aim.

Coupler

We need to purchase an attachment (flexible) to join the driving axis to the engine. In our case with help of the on-line configurator of “PERIFLEX” we enter all our data, with a factor of security of 2, and obtain the attachment that need.

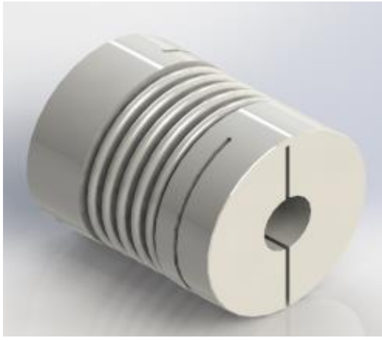


Figure 4.18- Coupler drawn in “SolidWorks”

Bearing and support selection

We will need radial bearings that bear the loads which are working. In the on-line interactive catalogue of INA-FAG can enter the data of which have and obtain possible rollings that can satisfy our needs.

Search of the bearings

In the first place, we define the radial loads that will have to bear the most loaded bearing. We go to select 15 exactly equal bearing for the distinct parts of the machine because we want to homogenise the device.

We decide that the lubrication that have the bearing was for life, that is to say, that do not need maintenance. We define also the size of the axis that has to sustain. As we have designed it previously this dimension will be of 12 millimetres.

Finally, we decide that mainly they bear radial load being able to bear also, although in lower measure, axial loads. With all these conditions obtain a rigid rolling of balls with the technical characteristics that specify in the Annex II.

Search of the supports

Once that we already have the rolling, in the same page of INA-FAG, can obtain the different supports that can be appropriate for the rolling that have selected. We choose a support with legs, to fix to the structure directly of simple form.

Have all the dimensions and data of the support chosen in the Annex II together with the others commercial elements of our device.

Design of the structure

Really of form simplified, choose pipes normalised according to the norm ISO. With the program of modelling 3D “SolidWorks” we go giving him form to the structure to be able to situate all the components that have in our regulatory device of light.

Figure 4.19- Structure in “SolidWorks”

In the design of the structure have taken into account a place to plant the lens of Fresnel and facilitate the back setting of all the optical fibre, the system of solar follow-up, etc.

Also we have thought in losing some centimetres planting the elements underneath of the bars (rollings, engine…) to be able to like this cover with one covers of sheet folded all the elements that can deteriorate.

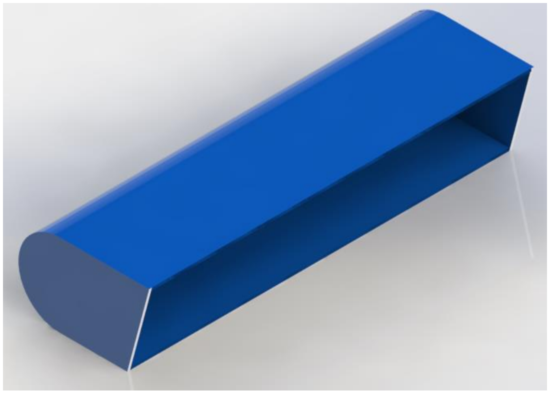


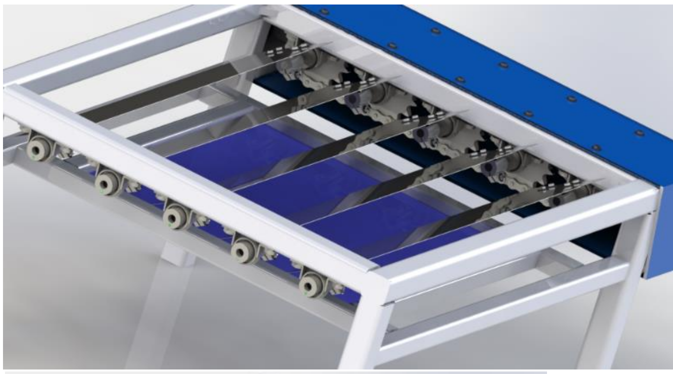
Figure 4.20- Folded sheet to protect the transmission elements

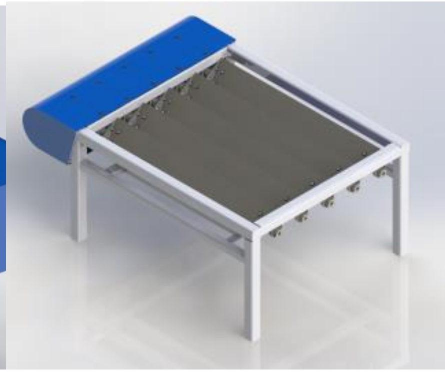
Selection of materials

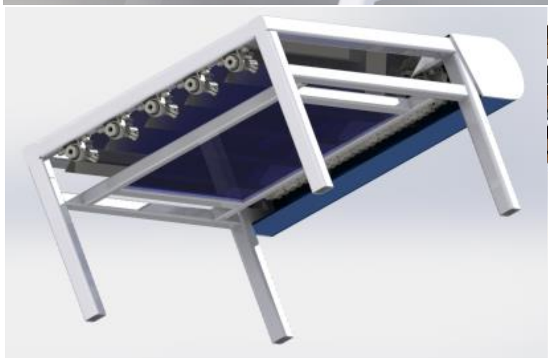
For the structure go to purchase tube of aluminium because, in addition to being really cheap, easy to manipulate and to mechanise, also is very easy to purchase in any skilled shop.

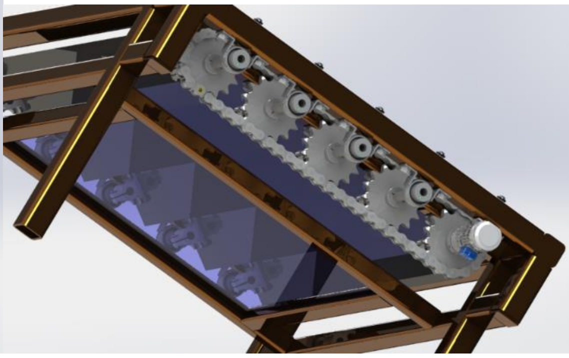
5-Final Design

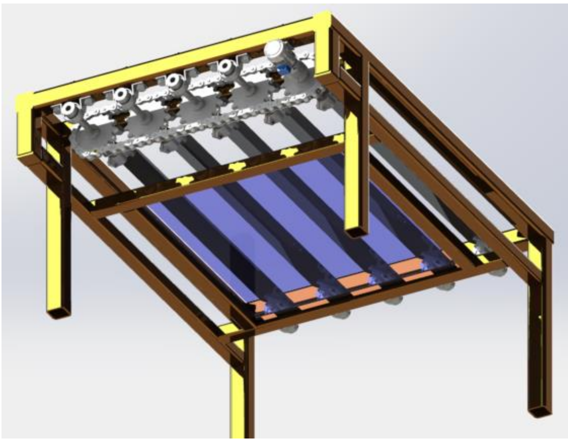
In this section want to show the final appearance that pretend that have our device. In the final design are included all the elements that have gone calculating during all the project, in addition to the lens of Fresnel, that is the main element to achieve our aim.







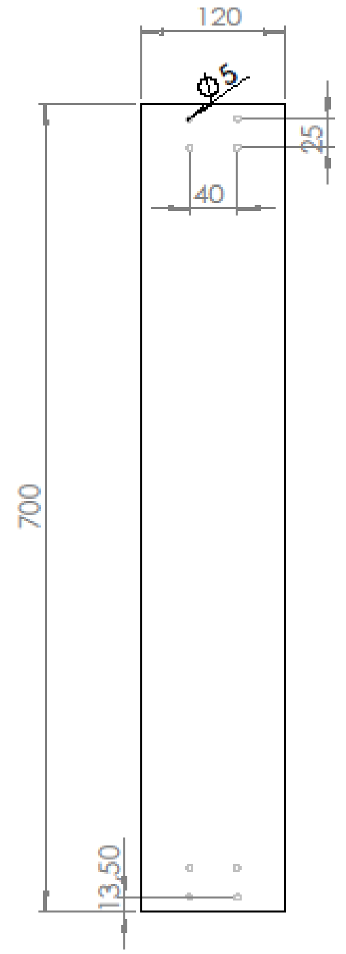




We owe to take into account that the change of colours has like aim identify of form simpler the different elements in each one of the images

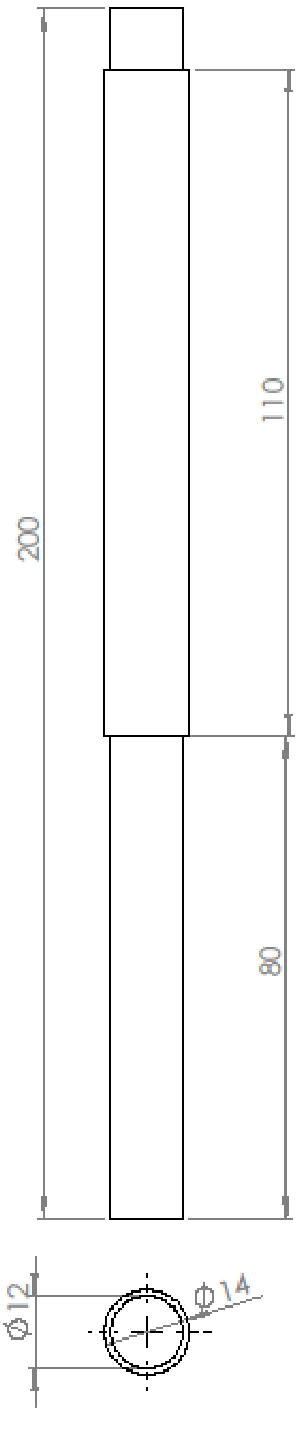
Annex 1- Planes

Sheet for the shutter



	Fecha	Nombre	Firmas	TÉCNICO LISBOA
Dibujado	22/05/16	Luis Martínez		
Comprobado				
Escala 1:5	Hoja del regulador			Observaciones: Espesor 0.5 mm
				Material: AISI 304
				Número de plano: 001

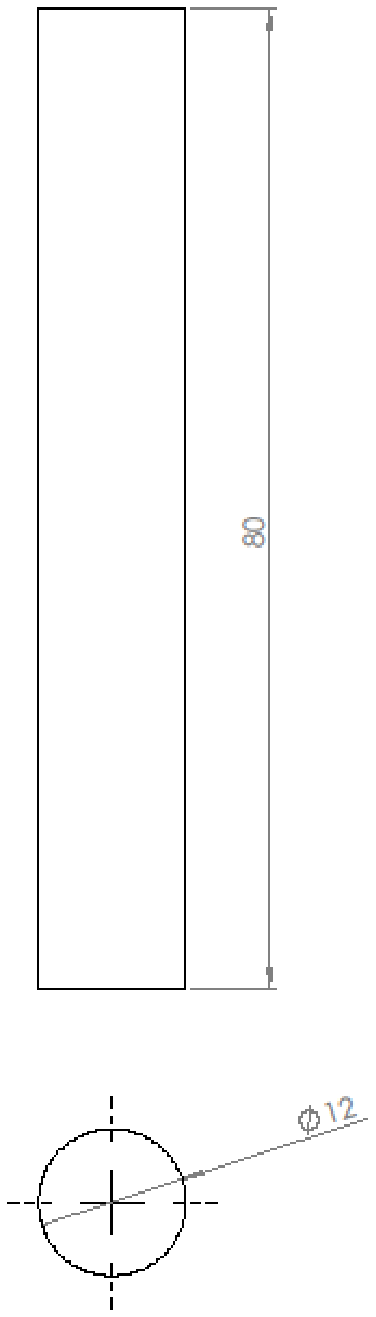
Long Axle



	Fecha	Nombre	Firmas	TÉCNICO LISBOA
Dibujado	22/05/16	Luis Martínez		
Comprobado				

Escala	Eje Largo	Observaciones
1:1		Material: AISI 316
		Número de plano: 002

Short Axle



	Fecha	Nombre	Firmas
Dibujado	22/05/16	Luis Martínez	
Comprobado			

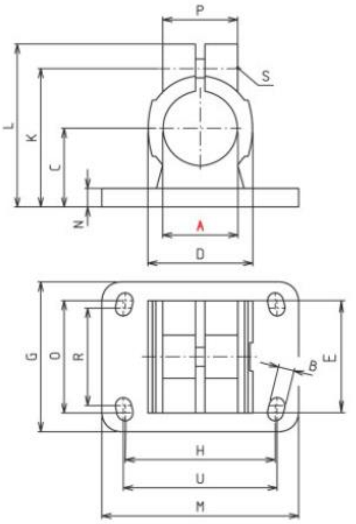
Escala 2:1	Eje Corto	Observaciones Material: AISI 316 Número de plano: 003

Annex 2- Comercial components

Connexion between sheet and axle

FK 30-4 - 80
(4 drills, 20-60 with slotted hole)

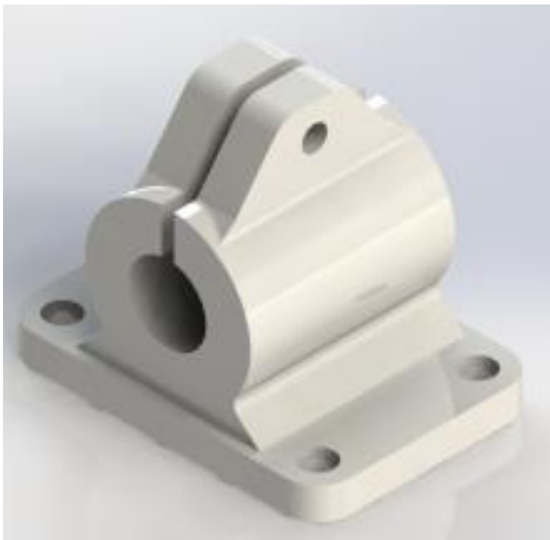
FK 12-30
(2 central holes)



FK - Industrial design

[mm]

Code No.	Type	A	B	C	D	E	G	H**	K	L	M	N	O*	P	R	S	U	m [g]
12120000020	FK 12	12,1																67
12140000020	FK 14	14,1																64
12150000020	FK 15	15,1	5,5	18	26	32	35	38	32,5	41	50	5	–	23	–	M6x20	40	62
12160000020	FK 16	16,1																60
12180000020	FK 18	18,1																56
12200000020	FK 20	20,1											–		–			202
12200100020	FK 20-4	20,1											40		35			205
12250000020	FK 25	25,1	6,5	30	40	40	55	53	53	63	78	7	–	33	–	M8x25	60	184
12250100020	FK 25-4	25,1											40		35			188
12300000020	FK 30	30,1											–		–			162
12300100020	FK 30-4	30,1											40		35			166



Chain for the flexible transmission

12B

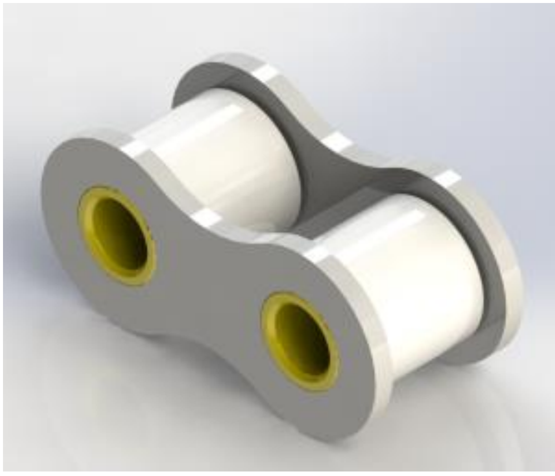
iwis

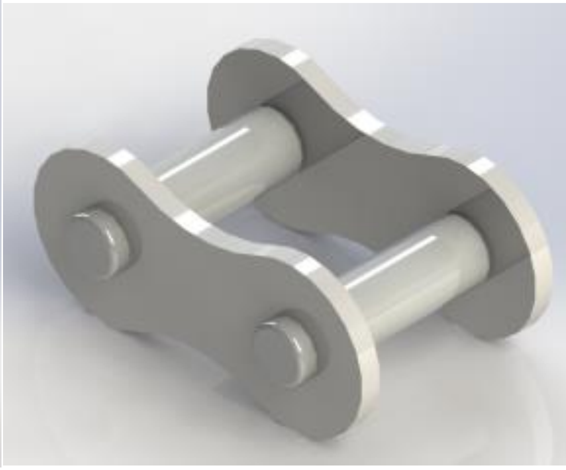
www.iwis.com
sales@iwis.com

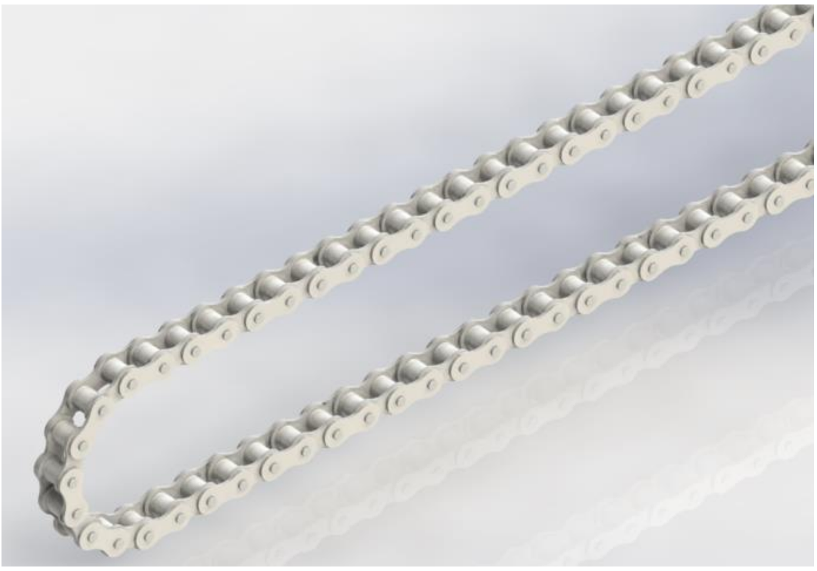
Request a quotation

0

Part Number	Description	pitch [mm]	max. roller diameter [mm]	inner width [mm]	max. width over pins a1 [mm]
12B-1	roller chains type 12B-1	19,050	12,07	11,75	22,70
12B-2	roller chains type 12B-2	19,050	12,07	11,75	42,10
12B-3	roller chains type 12B-3	19,050	12,07	11,75	61,50







Wheel for the flexible transmision

Plate wheels ISO 12B

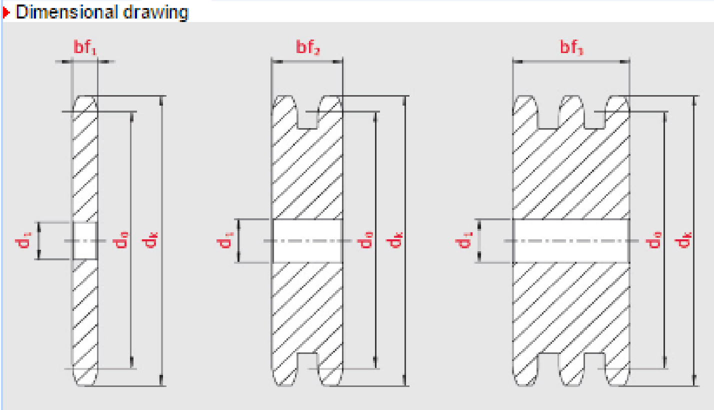
iwis

iwis
wir bewegen die welt

www.iwis.com
sales@iwis.com

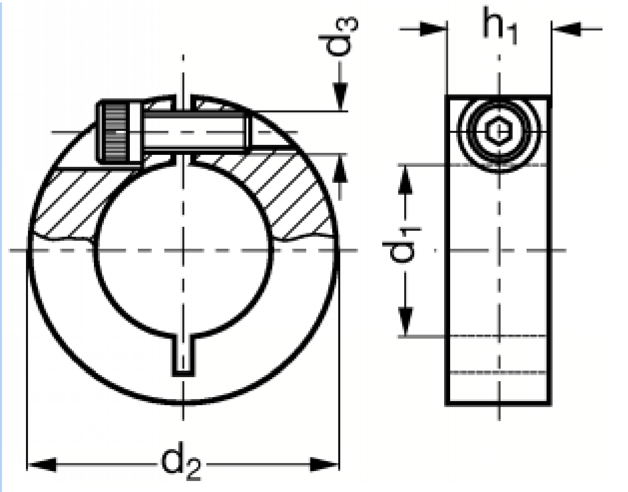
Request a quotation

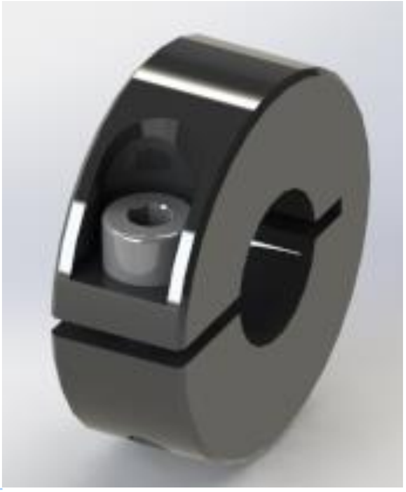
Dimensional drawing



Type	Simplex (12B-1)
Teeth z	15
Pitch circle ø d0	91.63 mm
Tip circle ø dk	99.97 mm
Tooth width bf	11.1 mm
Pilot bore ø d1	14 mm

Retainer ring



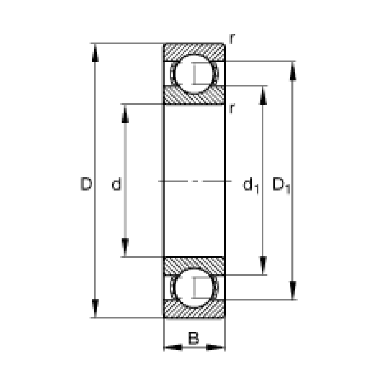


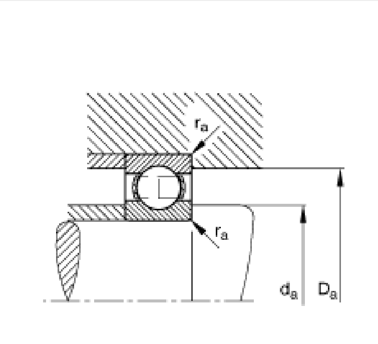
Ref	d1 (mm)	d2 (mm)	d3 (mm)	h1 (mm)
31-741-3	3	16	M3	9
31-741-5	5	16	M3	9
31-741-17	17	38	M5	13
31-741-24	24	45	M6	15
31-741-38	38	60	M6	15
31-741-45	45	75	M8	19
31-741-50	50	78	M8	19
31-741-60	60	90	M8	19
31-741-6	6	20	M3	9
31-741-8	8	22	M4	9
31-741-10	10	26	M4	11
31-741-12	12	30	M4	11
31-741-14	14	32	M4	11
31-741-15	15	36	M5	13
31-741-16	16	36	M5	13
31-741-18	18	42	M5	15
31-741-20	20	42	M5	15
31-741-22	22	48	M5	15
31-741-25	25	48	M5	15
31-741-28	28	55	M6	15
31-741-30	30	55	M6	15
31-741-32	32	60	M6	15
31-741-35	35	60	M6	15
31-741-40	40	65	M6	15

Deep groove ball bearing

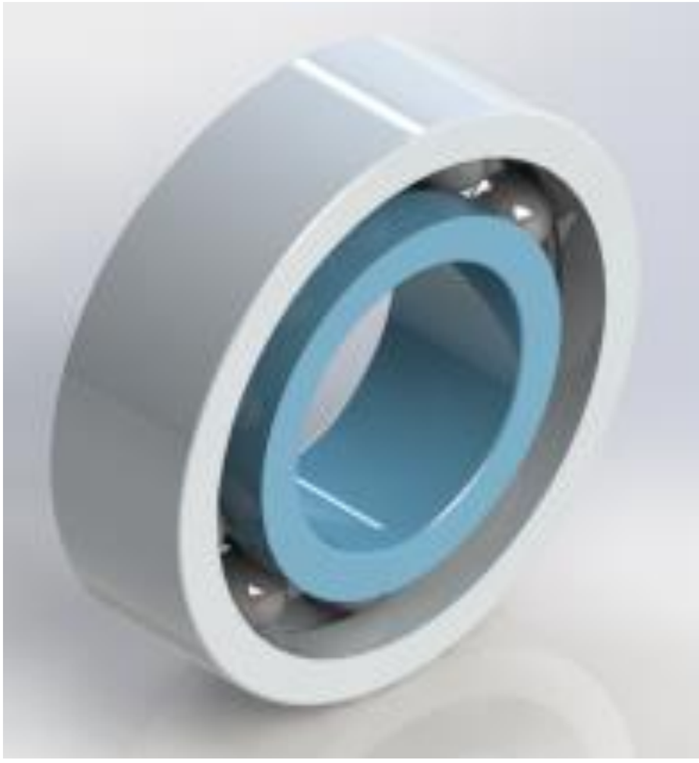
Rodamiento rígido a bolas 6001

medidas principales según DIN 625-1



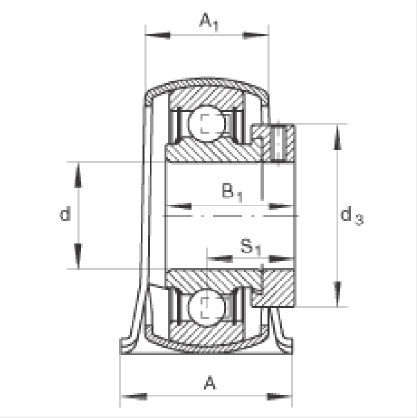


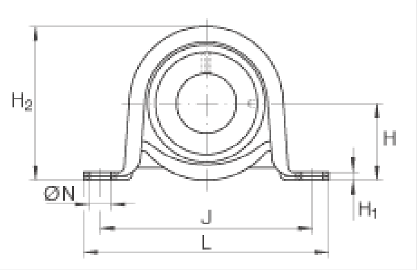
d	12 mm	
D	28 mm	
B	8 mm	
D_1	23,5 mm	
$D_{a\ max}$	26 mm	
d_1	16,7 mm	
$d_{a\ min}$	14 mm	
$r_{a\ max}$	0,3 mm	
r_{min}	0,3 mm	
m	0,02 kg	Peso
C_r	5400 N	Capacidad de carga dinámica, radial
C_{0r}	2370 N	Capacidad de carga estática, radial
n_G	38500 1/min	Velocidad límite
n_B	24200 1/min	Velocidad de referencia
C_{ur}	120 N	Carga límite de fatiga, radial



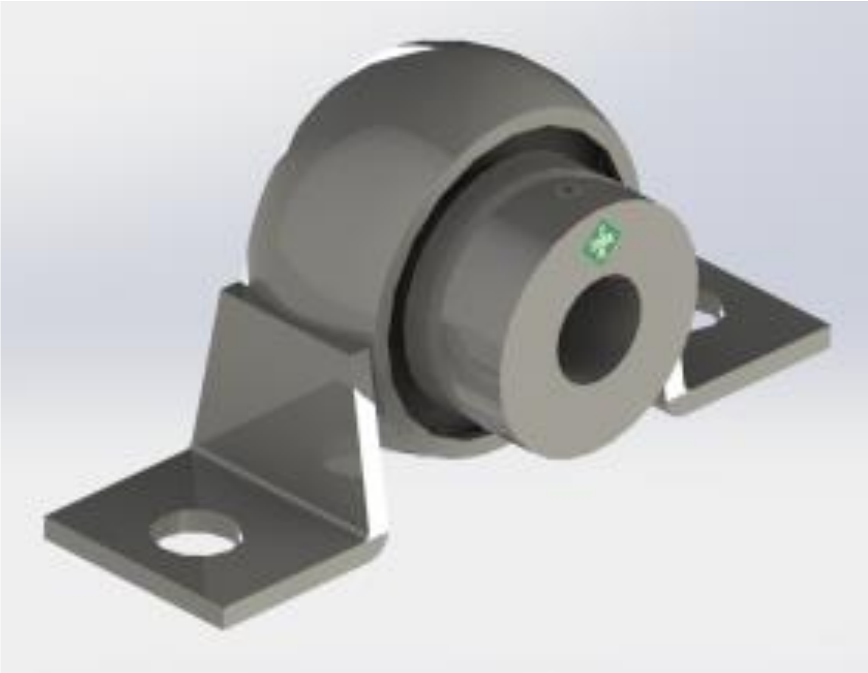
Support for the bearing

Accesorios





d	12 mm	
L	85,7 mm	
H_2	43,2 mm	
A	25,4 mm	
A_1	18,4 mm	
B_1	28,6 mm	
$d_{3\ max}$	28,4 mm	
H	22,2 mm	
H_1	2,6 mm	
J	68 mm	
N	9,5 mm	
S_1	22,1 mm	
m	0,17 kg	Peso
$C_{0r\ G}$	1350 N	Capacidad de carga del soporte, radial
C_r	10100 N	Capacidad de carga dinámica, radial
C_{0r}	4750 N	Capacidad de carga estática, radial
	GEH40-BT	Denominación del soporte Con recubrimiento Corrotect®.
	RAE12-XL-NPP-B	Denominación del rodamiento



Electrical engine

The right motor for every application		
		Asynchronous
		Low dynamic performance
		Low-voltage motors for line and inverter operation
		
Core features		With aluminum frame: Light, reliable, compact, with efficiency classes EFF1, EEF2 (IEC); EPAct, Ultra NEMA Premium (NEMA)
Rated voltage		IEC: 230 ... 690 V NEMA: 220 ... 575 V
Rated speed, velocity at rated force		IEC: Line operation at 50 Hz: 750 ... 3000 rpm NEMA: Line operation at 60 Hz: 900 ... 3600 rpm
Maximum speed		Inverter operation: Up to 6000 rpm
Rated power		IEC: 0.06 ... 45 kW (0.08 ... 61.2 HP) NEMA: 1 ... 20 HP
Rated torque, rated force		IEC: 0.3 ... 292 Nm NEMA: 1.5 ... 60 lb-ft

Bibliography

Theoretical calculations

Shigley: Diseño en Ingeniería Mecánica, Ed. McGraw-Hill, 1985;

Niemann: Elementos de Máquinas, Ed. Labor, 1985;

Catálogos, normas y manuales: sobre los distintos elementos y sistemas del programa;

Problemas de Cálculo Construcción y Ensayo de Máquinas. Publicado por el servicio de publicaciones de la Universidad de Oviedo (1996 – Autores: J. E. Fdez Rico y J. M. Sierra)

Providers and research of elements

http://www.tracepartsonline.net/

http://www.schaeffler.es/

http://www.stromag.com/

Programs of calculation and databases

ADIMEC

SolidWorks

AutoCAD

CES

References

[1] Optical Waveguide System for Solar Power Applications in Space, Takashi Nakamura

[2] http://www.acerinox.com/

[3] https://www.siemens.com/