Design of a Cupola to Download Concrete

R,. Miralbes [(a)], D., Ranz [(a)], R., Comas [(a)],J.L., Santolaya[(a)]

[(a)] Design and Manufacturing Department, University of Zaragoza (Spain)

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Abstract

Purpose:
The aim of this article is to demonstrate by means of a concrete example the iteration of the diverse areas of knowledge involved in the development of a mechanical project and their particular contribution

Method:
It has been used a multi-criterion design method that involves some *areas of knowledge that interact between them to obtain the best final product design.*

Result:
The result is the development of a new mechanical design using multi-criterion methods and diverse areas of knowledge related to the design to obtain a new and optimized with some competitive advantage

Discussion & Conclusion:
The principal conclusion that stems from the raised work is that, uniting efforts by means of the application of knowledge of diverse knowledge areas and with a correct interaction, planning and communication between them it can be obtained a design with a high added value and a clear competitive advantage.

1 Introduction

The main aim of the project is the design of a new cupola to download concrete used in the environment of the construction, attending to criteria of multidisciplinary design that they include: manufacture, assembly, costs, selection of materials, structural analysis, analysis of market, etc. This implies that there exist a series of variables of design to take in consideration and that must be weighted to obtain the best results (ej: thickness of sheet. A Higher thickness implies higher mechanical resistance but also a higher weight and price).So it is tried to demonstrate using a practical example as, by means of the joint application of several areas of knowledge and with a correct interaction, planning and communication between them it can be obtained a design with a high added value and clear competitive advantages.

The cupola chose for the development, is an automatic download cupola that use it own potential energy to download. It must be efficiency and versatile

The design of this element implies several areas of knowledge that must be applied together: market research, analysis of use and environment, ergonomics, structural analysis, functional-formal analysis, safety studies and risk prevention, mechanical analysis, analysis of assembly, Due to the wide quantity of studies developed only will be commented some of them of detailed form.

2 Market analysis

The first step before initiating any design is to analyze the art state, the technological solutions used by the diverse manufacturers, the patents and other possible technological solutions of similar that could be applied to the our design, so it has been analyzed the market of this product and has been observed that the principal manufacturers have many different typologies of cupola with specific uses, in a sector in which the tasks are diverse, and therefore, a few cupolas are very effective for some works, and very unfavourable for others.

To make the study and to establish the product to develop a sample of 84 products have been analyzed using nine variables: form of unload, position of filling, mechanism cone, channel, form of the chute, system of elevation, system of opening, arms of elevation, material (appearance) and capacity. The image 1 shows some of the products analyzed.

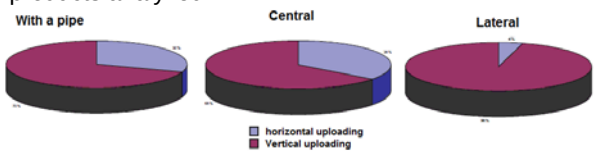


Fig. 1 Upload method analysis

3 Design Requirements

The study of the market and the analysis of other products it can be obtained some requirements that they must be included in the design:

- It must be robust due to the fact that the construction is a very aggressive environment
- The cupola must be able to be piled up for an easy the transport.
- It can be cleaned easily, avoiding zones of difficult access that provoke the accumulation of dry concrete

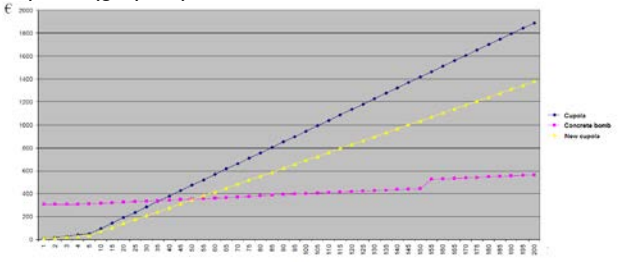
- The cupola must be as versatile as possible in the use so it must incorporate auxiliary elements and a system of elevation that allows it to use with a lift truck
- The maximum height of the cupola must not exceed 1.60 m due to the fact that it is the maximum height channel allows which to unload by means of one a truck cement mixer.
- To part of coming out of assisted form, the cupola has to be able to disburden manually, already it is to open the hatch during the task of cleanliness of the same one, or for if the assisted system gets damaged at any one time.

Besides these factors there have appeared some specified previous requirements for the design determined by the manufacturer to position the product: with unload using of its own potential energy, compact, with systems of accumulation of energy, system of opening that could be regulated and system of control of opening and closing, with a useful life of 5 years, made of iron standard products and with a 400 litters capability

Also It has been observed that the cupolas that allow unloads distantly have very expensive systems that increase too much the price, and that the transport of the cupola from the manufacturer to the client constitutes a considerable increase of the price.

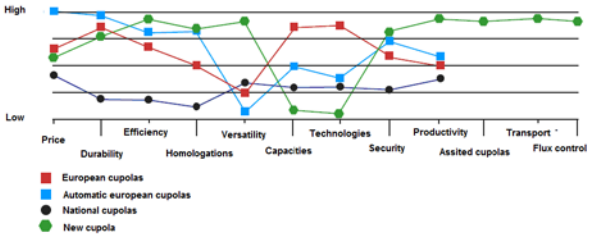
The new design must allow unloading of concrete distantly using a mechanical system and taking advantage of its own potential energy, activated by means of radio frequency. This cupola will be able to be sold to the client with a price higher than a normal cupola that not have this system, but without coming to a price so rose as those who have nowadays the cupolas that are driven distantly.

To determine the repercussion on the market of this cupola, there has been realized a study of profitability, in which it is compared the times of use of this cupola with regard to the concrete bomb and the conventional cupolas (graph 1).



Graph 1: study of profitability of the cupola opposite to Other technologies

Also there has been made an analysis of value of the cupola with the characteristics that will differentiate its (graph 2) respect of others and that will be a competitive advantage.



Graph 2: comparive analysis of the value

As you can see, my starting point is very down-to-earth, and it may seem to some that I have treated the most spiritual matter in too terrestrial a fashion; but I may be permitted to observe that the goods of the Greeks were not enthroned in the seventh or in the tenth heaven but on the Olympus, taking a giant-sized stride not from sun to sun but, at most, from mountain to mountain.

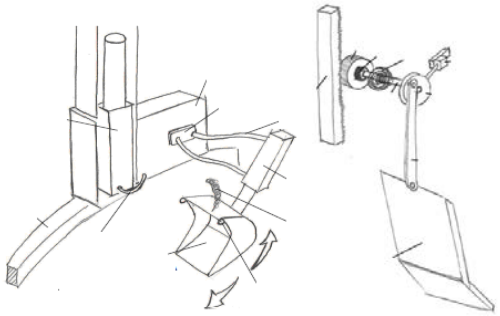
4 Regulations

The regulations to take in mind for the development of the cupola are:

- UNE-ENV 1991-4:1998. Euro code 1. Bases of project and actions in structures. – [1]
- Technical Regulation in equipments of elevation of loads. [2]

5 Analysis of the opening system

This is one of the key points in the design of the product since it is the main value characteristic of this type of cupolas opposite to the rest and that it can suppose a competitive advantage. To develop the opening system there are some technologies that are summarized in hydraulic and pneumatic systems:



Figures 2: Opening Systems: pneumatic (left) and mechanics (right)

Finally it was chosen the mechanical system due to the low comparative cost of the mechanical system opposite to the pneumatic since they present similar characteristics of functioning. This system developed completely for an effective functioning and for his operation by means of radio frequency but with an accumulation of mechanical energy without need of auxiliary elements as compressors or batteries with the exception of that of the recipient of radio frequency. Due to the confidentiality and request of patents it is not possible to show the final design of this part of the product.

6 Ergonomic analysis

In this paragraph of the development of the concrete download cupola it must be take in consideration the user iteration and the anthropometry. Some parts of the cupola that have been an object of study in this aspect and it has been set some handle as for the zone of grasp of this one and the height of the cupola.

The handles are the principal element of the user – cupola interaction. There are five equal elements in the global set. Four are in the set chute and other one in the set of the incidental channel. Initially, there appeared the purchase of commercial handles to include them in the cupola, nevertheless, they were rejected due to the high cost, therefore they have been designed for own manufacture.

Hooper handles

The handles that are arranged in the hooper have the function to allow that the user could guide the cupola when it is suspended in the air. The handles, in addition, fulfil a safety function since the set sliding panel, on having descended, can produce a smashed fingers" of the user, if this one has the hands on the top part of the chute. Existing these handles, the user can seize the cupola safely, and in addition can take it with both hands, preventing that another hand could place it between the chute and the sliding panel inadvertently. A high percentage of effects in any large system are caused by a low percentage of variables.

There are two handles in the right and two in the left part of the cupola separated by a distance. This distance of separation, it has been studied bearing in mind the necessary measure of study of the parts of the body, and which is the most unfavourable percentile. It has been considered to establish the distance between the handles of the set chute the distance of the body of the user of shoulder to shoulder (maximum width of the body, figure 3), since the cupola will need both hands, one in every handle and being with a view to them.

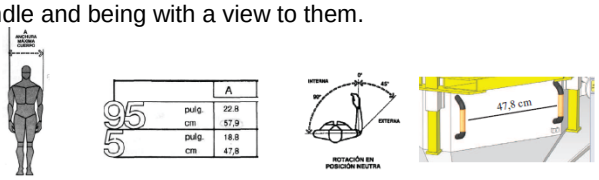


Figure 3: design of the handles in the hooper in relation to the users shoulders

Distance that has been left between hands in 47.8 cm, which it coincides with the man's P5 that figure 3. For the design of the handle, they have been considered the following measures:

- Height of grasp: there has been studied the width of the set of four fingers different from the thumb (figure 4). It has thought that it is a problem of space, therefore, it turns out to be inconvenient to the percentile 95, which if the height of grasp of the handle is minor, and it will not be able to seize it well. The distance that has been applied is of 9.6, as one shows in the table of the figure 4.
- Distance between the handle and the hooper (number 1 in image 4): For this measure, it has thought that also it is a problem of space since if there is few distance between the zone of grasp and the hooper, the major percentile will not be able to enter the fingers and therefore to seize the handle. To calculate this distance, there has taken "L" that shows himself in the figure 4 of the percentile 95, that it is 23,1, the distance has reduced "K" of the major percentile before studied two times and has divided between two, to know the width of the fingers in profile. This obtained distance has been of 1.95. The final distance left between the grasp and the wall of the chute has been 4 cm to allow enough roominess, since there has been born in mind that the operatives generally work with gloves.

Diameter of section (D in the figure 4): It has been considered of 31 mm since the task needs energy grasp[3].

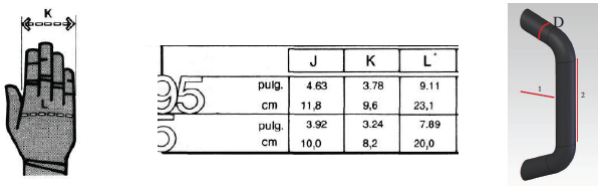


Figure 4: design of the handles in the hooper in relation to the hands

Handle of the channel

This handle, is like the hooper owns, so it has the same measures that already have been analyzed. The function that has this handle is it of flip-top canal allows the grasp of in order that the user could open and, therefore, lengthen the distance of emptying of the concrete it.

6.2 Accessory roasts manual

This accessory, it has not been previously studied ergonomically due to the fact that it is considered to be an auxiliary element which function is it of allowing that the cupola should continue in functioning, if the automatic system gets damaged, until it is repaired. The distance that has been studied is that of zone of grasp that specifies with the letter “A” in the image 5 and with a diameter of section of 38 mm, bearing in mind that treats itself about a grasp with which force will be realized. The studied distance has been that there is between the shoulders of the major percentile man. This distance shows itself in the figure 6. In this case the major percentile has taken in order that it could seize well the accessory and it is allowed use.

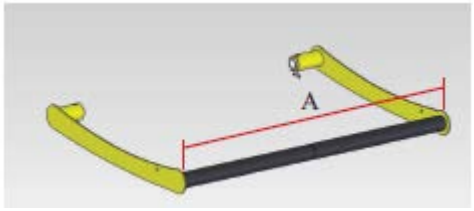


Figure 5: manual accessory to unload

7 Analysis of interaction user – product

The iteration user - product is determined by his iteration with several elements: the handles (studied previously), radio frequency control, the pilot and the carrack.

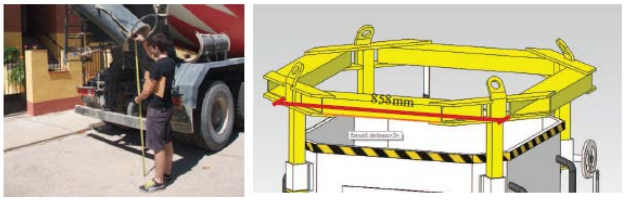
Figure 6: control, pilot and carrack

The control acts with the user who drives the opening of the hatches and it is a commercial element that has been chosen and has only one operation button and a led that informs visually the user if it has been driven. The button of operation is of small size, as the control, due to the fact that there has been born in mind that the same user who raises the cupola by means of push-cart or derrick is the one that drives it, therefore it must not occupy very much space. In addition, this user does not take gloves in the managing, with which it can drive the button without problem.

The pilot placed is set on the framework of the mechanisms and allows to report, by means of the ignition of the light, to the user of that the recipient has caught the sign issued by the user by means of the issuer. The carrack is lodged on the constrainer of couple of the mechanisms and his function is it of informing about auditory form the user with whom the mechanisms have been loaded totally.

8 Analysis of iteration environment - product

The interaction that more has been born in mind of the product is with the environment. Also it is necessary to emphasize that the compactness of the product allows him to move for the environment of the work without provoking shocks.



Figures 7: measurements and measures to adapt the cupola to it environment

The interaction between cupola and concrete mixer truck cement takes place during the load of the cupola. The maximum height that can unload the truck is the determined by the height of the cupola that coincides with the top part of the hooper, since if this one is major that the maximum height to which can unload the truck, might not happen the unload towards the hooper of the cupola. To know the maximum height to which a truck can unload, it was investigated by Internet, finding information only it brings over of that this height was normalized, therefore the direct measurement was proceeded to realize on a truck being this measure of 1750mm. The total height of the cupola from the soil to the top part is of 1225 mm, therefore, it fits perfectly down.

Due to the fact that the cupola can be hoisted by means of push-cart by means of the arms of elevation, the distance was studied between these in order that they could enter without problem the nails of the lift truck. As requirement, the interior was marked as minimal distance between arms and the nails of the available bull in the company in order that the cupolas could be distributed inside this one. This minimal distance between the nails of the bull is of 840mm, and in the cupolas it has been established of 858mm between the arms of elevation (it figures 7) to give more roominess. With the interaction with the lift trucks used in the works there is no problem of distances since the minimal distance between the nails is of 1000mm.

9 Analysis of use

In this paragraph there will be studied the sequence of use of the cupola since it comes to the client up to like there is mounted each of the complements and his utilization. This paragraph is fundamental in order to be able to measure the cupola that interacts adequately with the user and with the environment and the costs of transport are minimized. With it some of the dimensions are established of the cupola and it appreciates the sequence of use of the same one; in addition there is analyzed the process of assembly that the final user must realize and to be studied in order that it is the possible simplest and simple thing.

9.1 Receipt to the client

This concrete cupola has the characteristic of being stackable (figure 8) in order that the logistic costs are minor in case the client acquires more of one since the hooper is the part that more occupies. Depending on the height of the box of the truck of transport they can be piled up to a maximum of 3 cupolas. The cupola has a height of 1225 mm from the soil to the top part, and when other one piles up inside this one they gained height is of 475, increasing the total height to 1700mm, that when the set raising sliding panel of the cupola of below to position them, increases 210 more mm. The cupola is placed in the part that touches with the soil, so it is not necessary any disassembly except that of the complement channel in order that it occupies less, but those who are piled up on this one, need disassembly of the joint foot, the hatches, the accessories and the set of flying lever. The flying lever and some of the accessories will be introduced inside the chute to occupy less space, and the others will go to part.

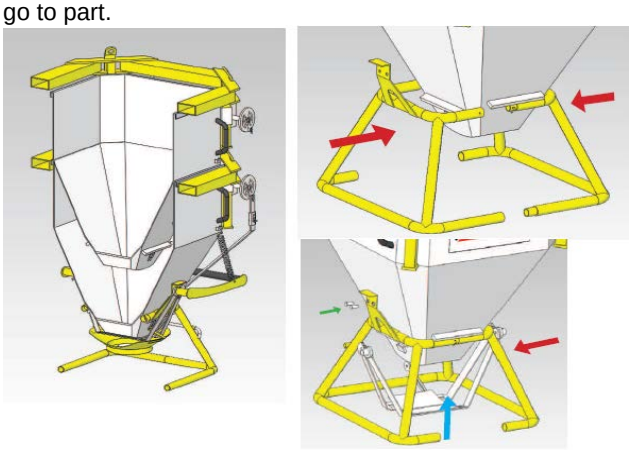


Figure 8: stackable and assembly of the foot

9.2 Assembly of the joint foot, the levers and the hatches

If the client needs a cupola, this one comes prepared for be used, but if he asks for more of one, those who are piled up are necessary an assembly before the use. It is necessary that the cupola raised by means of the set is kept sliding panel. The structure interferes foot left and right between the set hooper, spending the top pipes between the guides. A structure is inserted to other one to form the joint foot and is fixed by means of two pins in "R". The hatches interfere on the lateral part of the joint foot and rise up to the position of union and join the joint foot by means of four bolts with pin in "R".

9.3 Assembly of accessories

Assembly cone: the cone comes joined already with the pipe of rubber with metallic claspers. The first step for the assembly is to introduce the cone for the front opening of the joint foot (figure 9), then the leg places fixation in the platen that exists in the chute (figure 9) and finally, the leg of the insurance joins the insurance that exists in the chute, pressing in order that it closes (figure 9).

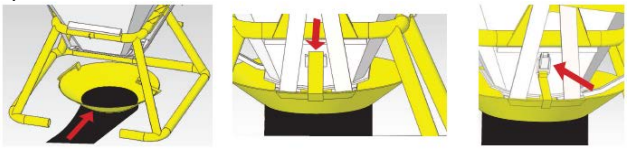


Figure 9: assembly of the cone

Assembly of the channel: to mount the channel is necessary that the cone is dismantled, since they are not compatible. First the joint channel interferes on the part opened of the joint foot (figure 10) and later, it joins this set by means of a pin that they put in the top on a pin in "R" in order that it does not leave (figure 10). If one wants to open flip-top canal, the user has to remove first the insurance formed by a chain-stitch and then it must pull the handle to open it like one show in the figure 10.

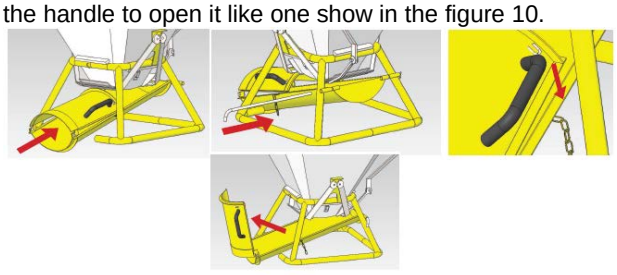


Figure 10: assembly of the channel

Assembly of the manual roasts: this accessory is more an auxiliary element that allows that the cupola should continue in use if the automatic system gets damaged. To be able to assembly this accessory, first it is necessary to dismantle the set flying lever, disconnect the hatch. In the image 11 one sees since the accessory is initially, without joining and without the wharves. The union of both parts does to itself on the set simultaneously that joins the tips that they find in the hatches (fig. 11). After joining both parts, the wharves join the lateral platens and the chute. This accessory comes with a built-in rope on that it puts in the part of grasp and it is allowed that the manual handle should be driven distantly.

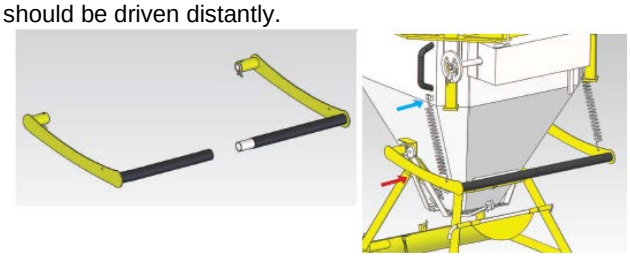


Figure 11: Assembly of the manual handle

9.4 Unload process

Once mounted and assembled the accessory of unload wished, one proceeds the cupola to realize the unload. First, the cupola rises with a derrick or a lift truck and position below the canal of the cement mixer truck, where proceeds to load the cupola (figure 12). Once I fill, other one is hoisted to see the cupola and removes up to the zone of unload. In this place, the user activates the mechanism of opening. If the automatic way is broken, simply throwing down of the accessory manual handle the unload is done.

If the automatic mode works, the user interacts with the control, ordering a sign the cupola, allowing the unload of the mechanisms and the hatches being opened, as one shows in the figure 12. To close the hatches, the user must return to drive the button of the control and these are closed, as one sees in the figure 12. The closing during the use with manual handle is made giving up this accessory, which returns to the site thanks to the wharves which it has.

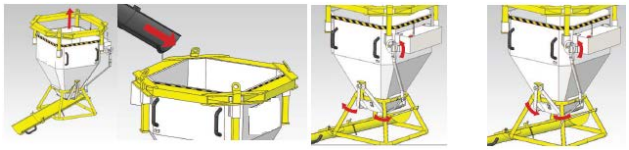


Figure 12: unload process

10 Product development

After realizing the market research and search information, developing also a statistical study, the analysis of value of the product and the economical study, there were established a series of final conclusions and there developed a conceptual phase with which presents three different alternatives of the product.

Figure 13: alternatives of the product: left side: round chute mechanical system, centre: elliptical chute hydraulic system, right: square chute mechanical system

There wears chosen as concept to develop the, "Mechanic - Square Chute " after valuing three concepts, seeing the advantages and disadvantages that there

present each of them. The third concept was chosen because it integrates very well all the elements, he has square chute that will be easier and cheap of making and in addition, for being able to seize the cupola with the lift truck for four directions and with the derrick without it obstructs no element with the useful one of elevation.

Once selected the concept, it was started developing completely, first beginning on the part of the set of the chute, the foot and the sliding panel, since they are the parts that condition more the global form and finishing with the accessories and the mechanisms that allow the opening distantly. Finally after a series of modifications of design it came near to the following final model that stands out for:

- Wide separation of the set or foot and the hatches of the chute
- Stackable
- The arms of elevation of the joint foot in the top part of the set of hooper in order that in the zone not Stackable of this one the mechanisms were lodged that the sliding panel
- The chute passed of section squared to octagonal in order that the set of the sliding panel could slide for the bevels, integrating the form, critical requirement of design. And in addition, of this form the vertical walls of the chute were remaining free to lodge the mechanisms.
- The hatch is a double to allow the tour necessary to open them out minor and more butchers were entering the closing.
- The lever that joins this steering wheel with the hatches, was established in such a way that it was joining during the whole tour that it realizes.
- In the accessories, there was designed a canal that was allowing unload laterally and became flip-top, being a factor that none cupola of the market has.

The cone developed as for the tie in the set and the manual handle created to allow, that if the automatic system gets damaged, the cupola could continue working up to the repair.

In the following image it is possible to estimate the final design

Figure 14: final design

11 Mechanical analysis

To design a mechanical set of these characteristics the mechanical analysis of the set turns out to be indispensable to be able to measure completely each of the pieces that they it form with the minor possible thickness and, therefore, with the minor possible cost, but trying to use merchant irons and simple technologies of manufacture that will influence positively the cost. Due to the advantages that present the current technologies of numerical simulation it has been chosen for the numerical design using the commercial package Solid-Works. An important aspect is the definition of the material to using. For it there have been in use irons of low cost and high weld ability.

An important aspect is the definition of the material to using. For it there have been in use low cost and high weld ability iron. The first step is the definition of the cases of load and contour conditions. For it there has been realized an analysis of use of product so much opposite to normal conditions of load since you carry to extremes and the obtained conclusion has been that the cases of load that must be analyzed are the following ones:

- Empty chute
- Empty cupola is raised by the set fills with concrete supported on the joint foot - sliding panel
- Empty chute raised by the set sliding panel
- Combine sliding panel holding the cupola in the air for the arms of elevation
- Force of reaction applied on the substructure foot
- Effort on I combine hinge
- Joint Cone full of concrete –
  Joint channel full of concrete
- Hatch with the weight of the column of concrete raises
- I Strike on the chute
- Bulge of the lever of the steering wheel

In each of them there have been estimated the loads that the structure has to support, has been added the own weight of the structure and of the concrete and the contour conditions have been imposed. After it the simulation has been realized and the results have been obtained in the shape of Von Mises's tensions, displacements, deformations and safety coefficients in the structure. There have been established a few minimal criteria of mechanical design for every value and every case of load and one has come from iterative form up to obtaining the ideal design of the structure so that he supports the tensions of effective form, so that there is no interference between pieces and the mechanisms are not blocked due to the deformation and that obtains the minimal thickness in every piece that will guarantee the minor possible cost. Later several images appear for the case of load of " Cupola empty raised by the set sliding panel ":

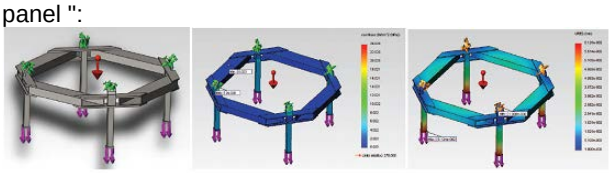


Figure 15: left side: loads and contour conditions; I centre: Von Mises's Tensions; right: displacements and deformations

The following step is the analysis of I overturn of the structure with the empty cupola and with the full cupola to assure the stability of the structure. This one has developed of analytical form opposite to both cases of load.

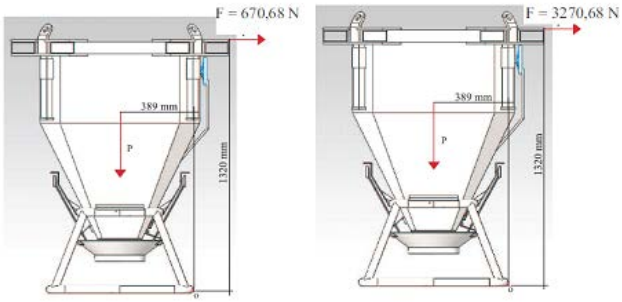


Figure 16: analysis of the overturn of the empty structure (left) and (right) flood

12 Final results and conclusions

The product that is an object of the article consists of a cupola for unload of concrete which principal characteristic is it of allowing to control the outflow of concrete distantly on the part of the user by means of the operation of a control. The necessary energy to allow the opening and closing of the hatches accumulates by means of mechanics and comes from the own potential energy of the cupola. This cupola, in addition, allows to regulate the outflow of concrete by means of the control of opening of the doors

With regard to the way of raising the cupola, it allows to be hoisted by means of derrick by four directions. The capacity is 400 litters sheltered in a chute of section octagonal that has resistance great. He has accessories since they are a cone anti spots with pipe of rubber that allows him the central unload by means of pipe of rubber, one drop-down canal that allows the lateral unload and a handle of manual operation with rope which function is it of allowing the manual unload of the cupola.

The principal characteristics that this cupola has are the polyvalence in the use, the form of control of the unload, the power to regulate the outflow of concrete, which is not possible in the cupola of operation distantly that exists on the market, and stackable, which is obtained separating the joint foot, the set of the hatches and the accessories, and it allows to cheapen the logistics from the company to the client. The polyvalence allows him to have a more wide and ideal use since they are very changeable and depend on determining many that not always can be controlled. It is necessary to emphasize that for the production of the project there has been necessary the integration of multiple areas of knowledge which have had to interact between them.

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