Capítulo 8 Design and development of a prototype production line with automated control mechanisms

Chapter 8 Diseño y desarrollo de una línea de producción prototipo con mecanismos de control automatizados

ROMERO-MITRE, Román Daniel, HERNÁNDEZ-CORONA, José Luis, GALAVIZ-RODRÍGUEZ, José Víctor and MENDOZA-VÁZQUEZ, Ernesto

Universidad Tecnológica de Tlaxcala, Carr. A El Carmen Xalpatlahuaya S/N, El Carmen Xalpatlahuaya, CP. 90500, Huamantla, Tlaxcala, México

ID 1[er] Author: Román Daniel, Romero-Mitre / **ORC ID:** 0000-0002-8208-2948, **Researcher ID Thomson:** Q-9833-2018, **arXiv ID:** roman. romero

ID 1[er] CoAuthor: José Luis Hernández-Corona / **ORC ID:** 0000-0001-9209-9287, **Researcher ID Thomson:** Q-9710-2018, **arXiv ID:** JoseLuis69#

ID 2[o] CoAuthor: José Víctor Galaviz-Rodríguez / **ORC ID:** 0000-0003-4006-3463, **Researcher ID**: Q-9883-2018, **arXiv ID:** victor#65,

ID 3[er] CoAuthor: Ernesto Mendoza-Vázquez / **Researcher ID**: Q-9861-2018

R. Romero, J. Hernández, J. Galaviz and E. Mendoza.

J. Tolamatl, D. Gallardo, J. Varela y J. Méndez. (Dir.) Strategies and successful practices of innovation in the automotive industry, Science of technology and innovation. Handbooks-©ECORFAN-Mexico, Tlaxcala, 2018.

Abstract

Improving the production process is a must in many factories that want to be competitive in the automotive industry, therefore it is important to invest in new machinery and structures to do this activity even there is in Mexico a model of linking that enables to work industry and Universities, and this is the case that it presents in this work in order to design and manufacture of a prototype production line with automated control mechanisms. This work is supported by the using the Finite Element Method in order to validate the design stage.

Design, prototype, mechanism.

1. Introduction

The use of the correct amount of material in any mechanical structure or device is very important in the cost and manufacture of it that include the time and energy needed for this last issue, therefore it is necessary to design this kind of products in an effective way, this starts with the analysis of the function of the part to implement in the process in this case. In order to have a well design product, it can be used the module of the Finite Element Analysis that is included in a CAD software, at first to calculate the stresses and deformations that will be produced by the forces applied to the parts and then if necessary optimizing the cross sections that depend on the thickness of the piece.

So this job focuses in the analysis of the stresses produced by the loads applied to a prototype production line that is integrated by supports, rails, tubes, plates, reinforcements. On the other hand it presents the methodology to select the motors and devices to automate the prototype production line. This job is important because the reliability of the product function can be made through this kind of analysis and in this way the cost must be the adequate for it. The conventional stress calculations of structures subjected to loads are very complicated to do, and the selection of several items in a production line is an information that is available to the experienced people in the industry world.

Therefore, this project means to be a reference how to make the design and development of mechanical components and the establishing of a methodology of selecting items in an electromechanical product. The main problem to solve is the transportation of flocked pieces, from the beginning of the process passing through the application of flock in a furnace, and finally delivering them to the next process. Taking into account, the time to cool these products, so it has to set a speed that controls this variable, by electrical motors in order to accomplish the production rate.

The hypothesis is that the design of automated mechanisms must be assessed, by means of the Finite Element Method in order to assure that the whole transportation of the flocked pieces will not fail because of the lack of material of the components. On the other hand, the cost of the prototype line will not be excessive due to the specification of more material than the necessary.

This chapter integrates a theoretical revisión, the methodology, the case study breakdown in: modeling of prototype line structure components, simulation of stresses and deformations, optimizing of cross sections, virtual subassembly of prototype line, Making of drawings, manufacture of prototype line parts, final assembly, selection of electrical components, results and conclusions.

2. Theoretical Revision

Several authors have considered that Archimedes used a method similar to the finite element to determine the volume of some solids. Although he calculated areas, lengths and volumes of geometric objects, dividing them into simpler ones and then adding up his contributions, the concept of variational approximation is nowhere to be seen. The relationship with the definition of MEF is very poor. It can be argued that the measurement of the volume (area, length) of an object is a scalar function of its geometry. Changing "measured" by energy and "objects" by elements in the previous lines, the description is close to that established by the MEF "the energy of the system is equal to the sum of the energy of each element". However, Archimedes needed derivative definitions to perform his energy calculations and Calculus was not invented until 20 centuries later.

In 1941, Hrenikoff presented a solution for elastic problems using the "frame work method". In an article published in 1943, Courant used polynomial interpolation by parts on triangular sub-regions to model torsional problems. The basic ideas of the finite element method originated in the structural analysis of aircraft. In the 1950-1962 period, Turner working for Boeing formulates and perfects the Direct Stiffness Method. Turner and other researchers obtained stiffness matrices for trusses, beams and other elements and presented their results in 1956. Clough was the first to coin and use the term finite element in 1960. In the early 1960s, engineers used the method to obtain approximate solutions in problems of stress analysis, fluid flow, heat transfer and other areas. A book by Argyris, published in 1955, on energy theorems and matrix methods, cemented additional methods in finite element studies. The first book on finite elements by Zienkiewicz and Cheng was published in 1967. At the end of the 1960s and the beginning of the following decade, finite element analysis was applied to non-linear problems and large deformations.

Technological advances, together with capital and labor factors, have been seen for some time as essential for economic growth. Consistent with this broad and generally accepted belief, governments of developed or developing countries have allocated resources for research and technological development, with diverse results. Since the end of the war of 1939-1945, fears have frequently been expressed about the future of human society under the pressure of technological progress. It is said that it was an executive of the Ford Motor Company who coined the word "automation" (automation, automatic synthesis and mechanization) at the beginning of the 1950s, in Figure 8.1 the application of mechanics and in the Figure 8.2 the use of computational mechanics for the modeling of solids and structures, are shown.

Figure 8.1 Application of mechanics

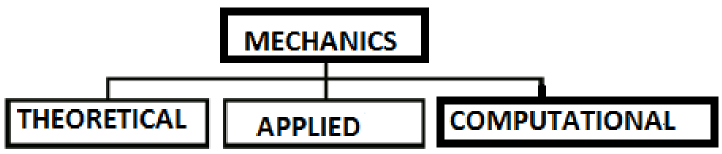
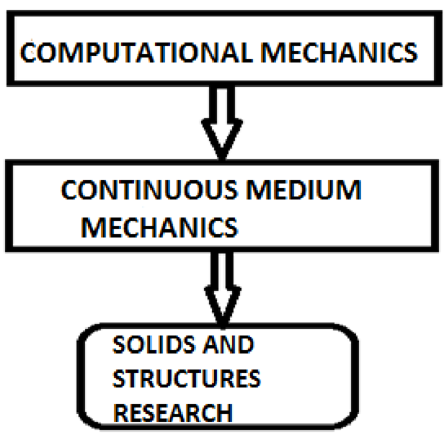


Figure 8.2 Divisions of computational mechanics



The global recession, has created unemployment in all industrial countries in different proportions, has tended to mask the unemployment generated by technological advances. But union leaders are more than aware of the erosion of the jobs of their affiliates in certain sectors of industry, as in the graphic arts of the United Kingdom, the struggle to introduce the "new technology" in Fleet street It has lasted for years, to the point that the proposed technology is far from being new. The composition and printing of English newspapers is carried out with facilities and machinery almost a century old, in terms of design. The new technology, which uses composition by computer, photography and offset printing, is a much shorter process, with less margin of error, easier to correct, silent (except web-offset presses), as it is a technology more refined, because the editing and advertising texts could be typed directly by editors and journalists, using screens in which their composition is visually controlled. [Andrew, 1981].

The problems of the design of mechanical elements have a design approach to systems engineering following a typical design process. The preliminary, intermediate and final design is made after an identification of the design problem, within that process a sequence of tasks such as synthesis, analysis, prototyping and evaluation was completed. An example is a design idea that selected five initial design concepts and became the final system after the evaluations and modifications. The results of the tests showed that the designed machine can be easily integrated. The weight and manufacturing cost for the design were reduced to a minimum, to facilitate the application of this equipment designed to replace human work by providing high performance, for highly automated and modern factories. [Yucheng, 2017].

For the development of computational models that present underlying ideas of a computer program that takes as input a scheme of a mechanical or hydraulic energy transmission system, more specifications and a utility function, and returns predefined catalog numbers for optimal selection of the components that implement the design. Unlike programs for designing individual components or systems, this program provides the designer with a high level "language" to compose new designs. Then he performs some of the detailed design processes for him. The process of "compiling" or transforming a description from high to low level is based on a formalization of quantitative inferences about sets of artifacts and operating conditions organized hierarchically. This allows the compilation of the design without the exhaustive enumeration of alternatives. [Ward, 2008].

Research has shown that during the conceptual design, designers continuously seek potential design results, which consist of problems, solutions and evaluation criteria, in different design spaces. Both quality and quantity design results are affected by various factors, such as the design method used, the capacity of the participating designers and the design problems used. Works are presented using the understanding of the search for design spaces, developing methods to evaluate the effects of various factors, such as individual capacity, the method of creativity used and the problems solved, in the quality and quantity of design results. Design experiments are used to empirically identify the effects of these factors on the design results. We observe that, compared to the capacity of the participating designers and the problem used, the design methods strongly influence the design results. In addition, it is possible to predict the influences of the designers on the design results by understanding the profiles generating solutions of the designers in other experiments. [Sakar, 2014].

Variability of Design Methods

Every year, both researchers and professionals continue to design different methods to solve increasingly complex design problems. This wealth of design methods is both a blessing and a curse: on the one hand, having a broader set of methods deepens our toolkit for problem solving, which allows us to find better solutions; On the other hand, the variety of options quickly becomes overwhelming. For example, the largest current database lists more than 300 different design methods [Roschuni, 2011]: a conservative estimate that easily exceeds any designer's ability to learn or even search manually.

The solution to many design problems involves two steps: the designer (1) creates a configuration by making choices of components and (2) selects values for the parameters associated with the components in that configuration. For example, in car design a configuration decision may be to use disc brakes and a single turbocharger. Consequently, the parametric values to choose include the radius of the disk and the entrance area of the turbo. The mathematical models used to represent such problems and to evaluate the chosen alternatives tend to be large, non-linear and involve discrete and continuous variables. Since, in general, a single design algorithm will not suffice to solve such problems, the currently available computer tools are generally limited to a small range of problems or parts of major problems. We believe that a computing environment that allows flexible access to a diverse set of tools can help designers quickly generate high-quality solutions for a wide range of problems. [Ramaswamy, 1993].

In the last three decades, various computational, cognitive and innovative approaches have been developed to advance in the fields of artificial intelligence and knowledge-based design systems. The diverse investigations develop the systems of generative design in the literature. They present a framework of a generative design system with several examples of real design. Finally, the document examines the future direction for the advancement of the generative design.

A generative design system supports the generation and exploration of a large number of alternative design solutions, using automatic transformation algorithms. It maintains a consistent style of all the solutions explored, but with design characteristics and variables. It can also include an evaluation mechanism in the generative process for the system to look for potentially optimal design solutions. [Jia, 2017]. Dealing with this abundance of methods raises several questions: what makes the methods similar and how do you classify them effectively? How are methods applied in different situations and what differences help designers decide which method to apply? How should designers address new methods not used? Previous attempts to answer these questions have meticulously reviewed collections of methods or case studies of design (summaries of a particular design problem along with methods used by the designer) to discover why some methods work in some contexts, but not in others [Broadbent, 1969, 1979] [Jones, 1992] [Margolin, 1996]. While these types of studies provide a valuable basis, they necessarily cover only a small part of the design methods: scaling that type of analysis to the large number of current methods requires a prohibitive effort.

In the area of automotive engineering, different studies are carried out focused on the solution of problems in different areas, an example that was carried out to reduce the aerodynamic drag, evaluates the performance of the aerodynamic resistance devices of the lower part of the body in function of the real shape of a sedan type vehicle. A covert air dam was applied under the side flap as aerodynamic drag reduction devices on the underside of the body. In addition, the effects of interactions based on the combination of aerodynamic drag reduction devices were investigated. A commercial sedan type vehicle was selected as a reference model and its shape was modeled in detail. The aerodynamic drag was analyzed by computational fluid dynamics at a general road speed of 120 km / h. The simple aggregation of the effects of the aerodynamic drag reduction by the individual device did not provide the precise performance of the combined aerodynamic drag reduction devices. An additional aerodynamic drag reduction of 2.1% was obtained on average in comparison with the reduction in resistance of the expected advance, which was due to the synergy effect of the combination, this performed by computational simulation systems. [Junho, 2017].

Another example was made in production processes such as high-strength leaf springs, which consists of shearing, punching, heat treatment, hot cambering, shot peening, scraging and later speed, load and durability tests were carried out. . The processing of the raw material plays a vital role in achieving life with the required fatigue. The objective of determining the effects of material processing and the design parameter on the fatigue life of leaf springs is paramount. The processing parameters of the material considered are the decarburization of the surface and the scraping effort, while the design parameter considered is the inclination of the individual sheet. Partial and complete surface decarburization is determined during lamination and its effect on the fatigue life is predicted. The effect of searing tension on the life of fatigue is also determined. An ideal range of burning effort is proposed for the improvement of the fatigue life. A suitable leaf inclination is proposed for the individual sheets. Modeling is applied for the determination of the effect of the assembly tensions due to the inclination of the individual blade in the fatigue life. [Arora, 2015].

Every year, design professionals and researchers develop new methods to solve problems. This increasingly large collection of methods causes a problem for novice designers: how do you choose which design methods to use for a given problem? Experienced designers can provide case studies that document what methods they used, but studying these cases to infer the appropriate methods for a new problem is inefficient. It is determined that knowing which methods occur frequently together allows you to recommend design methods more effectively than just using the description text of the problem itself. In addition, it is demonstrated that the automatic grouping of the methods that frequently occur in a conglomerate spectral form replicates the groupings provided by humans with 92% accuracy. Leveraging existing case studies, recommendation algorithms can help novice designers navigate efficiently in the growing range of design methods, leading to a more effective product design. [Mark, 2014].

Technological advances focus on design processes that are very useful in the preliminary development stage through the effective support of simulations. This type of design processes based on simulation are effective in the development of mechanical and process drives among others. Based on multiple test results, they show performance improvements that include low friction and vibration, improved durability and profitable parts design, compared to conventional processes. These studies propose an integrated approach to preliminary design.

The approach involves structural and dynamic analysis. The studies summarize the dynamic and structural analyzes, as well as the topological optimization to describe a process to obtain optimal results. [Jung, 2017]. When studying mechanical parts are taken into account as engineering components often exhibit unavoidable local stress concentrations due to steps, notches or other geometric discontinuities. Such stress concentration sites under service load can drastically reduce the operating life of a structure. To preserve structural integrity, it is essential to understand the stress-strain responses in the critical areas of failure (notches). When carrying out finite element analysis, elastic stresses and finite-thickness plate deformations containing notches on the opposite U-shaped side with different notch configurations are systematically investigated. The plate is subject to uniaxial tension. For the analysis of a plate, the finite element analysis (FEA) is used, this shows that even if the plate is in an elastic state, the stress and strain concentration factors are different. It is also shown that the effect of Poisson's ratio is significant in the weakest point concentration factor. The accuracy of finite element results is verified with analytical solutions available in the literature. [Khatawate, 2016].

The elements of machines on the market today have been designed and implemented for many decades. Research is carried out to carry out the optimization of the design. A reports are shown on the directions of the conceptual evolution of the traditional design components and the feasibility of their significant improvements. The role of the "axiom of ideality" and of the prevailing tendencies of the evolution of engineering systems in the creation of novel concepts is emphasized. Descriptions of new concepts of gear and power transmission couplings, key connections, vibration isolators, cantilever design components characterized by high performance parameters are presented, all modeled in a computational way and using the numerical or finite element methods They give certainty to the new designs. [Rivin, 2008].

A good option for mechanical design studies is the development of widely applicable formulations to investigate the propagation of designs in mechanisms. Here the analytical criteria are presented in terms of the variations of the articulation position vectors and the orientation matrices for the plane and spatial mechanisms. Mechanisms are represented using graph theory and closed loops are converted to a tree-like structure by cutting together and introducing new constraints. The Jacobian matrix in the Cartesian space is transformed into the space of joint coordinates. Two cases are considered: a pair of bodies that remain connected by a joint after cutting the additional joints and a pair of bodies are disconnected after cutting the joints. Using this method, a designer has the ability to study the propagated effect of changing a design variable. The presented formulation is validated through a numerical example of a McPherson strut suspension system. The system is analyzed and an assembled configuration is calculated after a design change. [Zou. 2007].

The Finite Element

The finite element method is a numerical method for the resolution of differential equations, it is based on dividing the body, on which are defined certain integral equations that characterize the physical behavior of a certain problem. The set of finite elements forms a partition of the domain, also called discretization. Within each element a series of representative points called nodes are distinguished. The set of interconnected nodes is known as mesh. The calculations are made on a mesh or discretization created from the domain with mesh generating programs.

The set of relationships between the value of a given variable between the nodes can be written as a system of linear (or linearized) equations, the matrix of said system of equations is called the system's stiffness matrix. The number of equations of said system is proportional to the number of nodes. Typically, the finite element method is computationally programmed to calculate the field of displacements and, subsequently, through kinematic and constitutive relationships, the deformations and stresses respectively, when dealing with a problem of deformable solids mechanics or more generally a problem of mechanics of the continuous medium. The numerical solution of partial differential equations is an indispensable tool in much of modern science and engineering.

However, the development and successful application of advanced solvers with partial derivative equations presents complex problems and requires the combination of diverse skills in mathematics, scientific computation and low level code optimization, which rarely is that level of expert presented in a single guy For the finite element method, a skill set is required that includes at least the knowledge of the system that is simulated, the analysis of the resulting partial derivatives, the numerical analysis to create appropriate discretizations, mesh generation, graph theory to create data structures in these meshes, the analysis and implementation of linear and non-linear solvers, parallel algorithms, vectorization and optimization of loop nests under memory restrictions. [Florian, 2016].

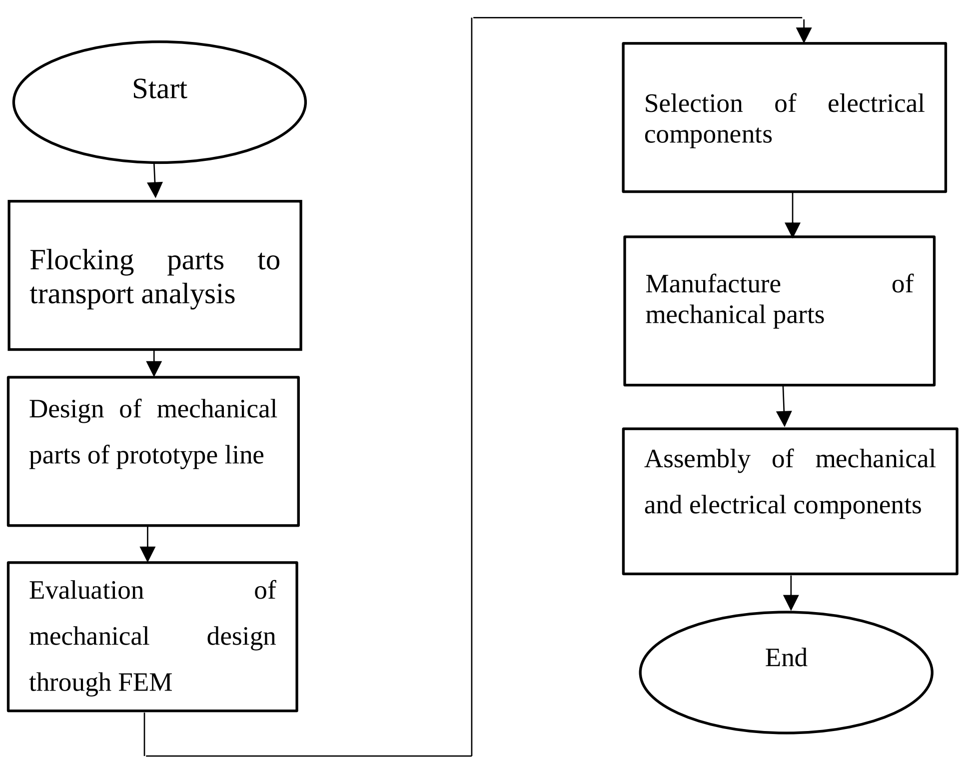
When modeling with finite element is analyzed the possibility of replacing the gray iron, traditionally used for the production of relevant parts in machines, with ductile iron or vermicular iron. Experimental computational tests are performed to determine the mechanical behavior of ductile and vermicular irons with respect to tensile, fatigue and fracture loads, and microstructures were also analyzed. The results show that ductile or vermicular cast iron in parts and components of machine tools could provide additional rigidity and strength with respect to gray iron. A balanced use of these alternative irons would make the most of each specific property (such as strength, hardness, weight, etc.). [Fragassa, 2016].

In the design and manufacture of mechanical devices, there are parameters whose values are determined by the manufacturing process in response to errors introduced in the manufacturing or operating environment of the device. These parameters are called adjustment parameters and are different from the design parameters for which the designer selects values as part of the design process. Studies show that by introducing adjustment parameters in the design methods of: optimization, Taguchi method and imprecision method (Wood and Antonsson, 1989). Including adjustment parameters in the design process can result in designs that are more tolerant of variational noise. [Otto, 2008]

3. Methodology

The variables that handles in the Project were the load that corresponds to the weight of each piece of the flocked parts. Another variable is the speed that must be specified to move the pieces from the beginning to the end of the flocking processes these are the main variables that must be taken into account to design the automated mechanisms and the selection of the electrical components.
In Figure 8.3 observes the process diagram to accomplish this methodology.

Figure 8.3 Methodology to design and develop of prototype line



Source: Own Elaboration

Another way to do this project is to design the mechanical components without taking into account an assessment of them, which represents a risk from the safety point of view or it can be expensive from the costs issue due to excess of material. The value that this project adds is the optimization of the mechanical parts, but the rest of the components are important to mention because all of them integrate the prototype line.

In Table 8.1 shows the comparison between the methodology used in this work and the regular methodology.

Table 8.1 Comparison between two methodologies for design of mechanical components

Methodology	Advantages	Disadvantages
Using of FEM to evaluate mechanical components	FEM is useful to optimize mechanical parts through several criteria that assures the structural function.	When using FEM requires a CAD/CAE license that is expensive.
Using of experience to specify mechanical components	No need for CAD/CAE license.	Uncertainty about structural specification

Source: Own Elaboration

3.4. Case Study

At first, it receives information from the production department according to the needs of a prototype line that includes:

- Length of the line
- Space of the facility
- Maximum production rate

This information analyzes and the drawings of the mechanical components are made, these components are:

- Poles
- Brackets
- Supports
- Rails
- Chains
- Plates
- Reinforcements
- Tubes
- Angles

3.4.1 Modeling of prototype line structure components

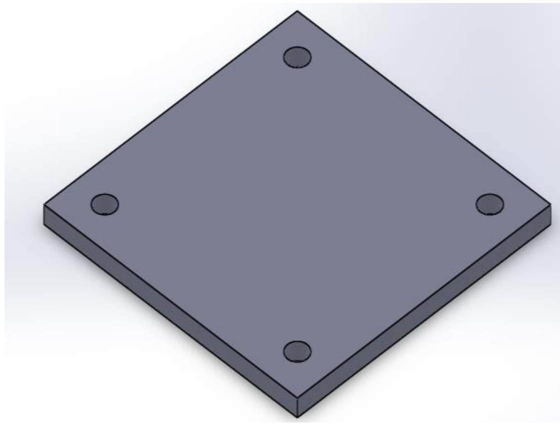
All of these parts draw in a CAD/CAE software and they show in figures 8.4 to 8.9. There are mandatory dimensions in every part, and calculated dimensions. The difference between both types are summarized in table 8.2

Table 8.2 Differences between mandatory and calculated dimensions

Mandatory dimensions	Calculated dimensions	Differences
Length of process	Thickness of parts	A mandatory dimension is the dimension that cannot be changed because of the function of the part, and the calculated dimensions can be optimized for better use of material.
Height of prototype	Length of pieces	

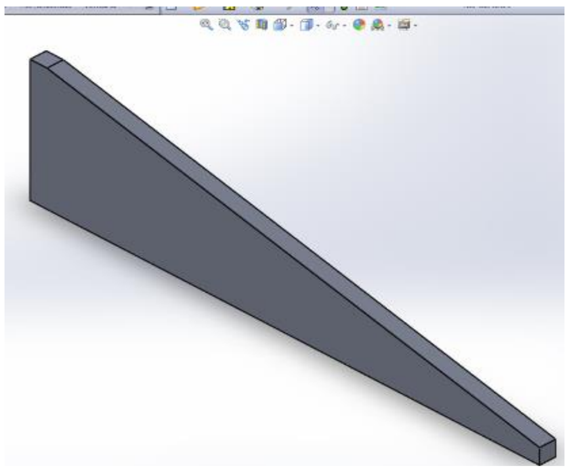
Based on these concepts of mandatory and calculated dimensions, it draws the parts of the prototype line. The mechanical parts of the prototype line integrate a structure, therefore, it specifies a structural steel when designing these components, and in this case the best option due to its economical price is A36 steel. For the structural components like tubing, it specifies a square profile, also selects the size of the chain that carries out the flocking parts to move from the beginning of the process until the next process that is the inspection of the part by quality staff.

Figure 8.4 Base plate



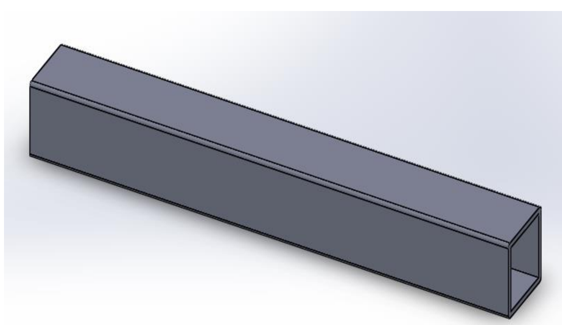
Source: Own Elaboration

Figure 8.5 Reinforcement



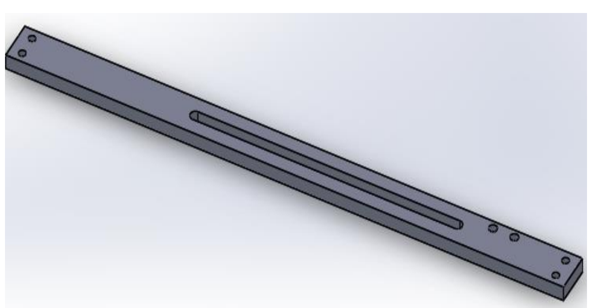
Source: Own Elaboration

Figure 8.6 Square tube



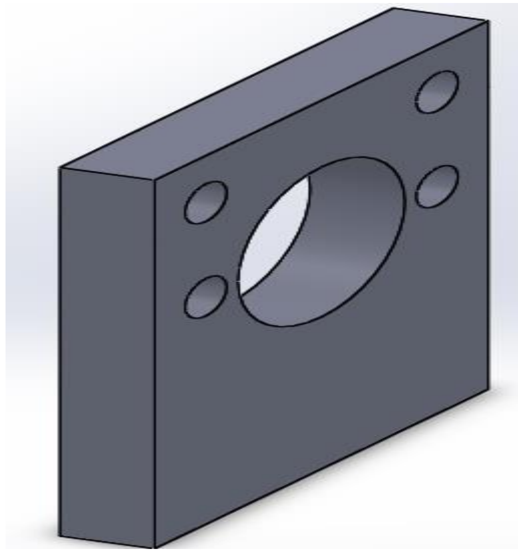
Source: Own Elaboration

Figure 8.7 Rail support



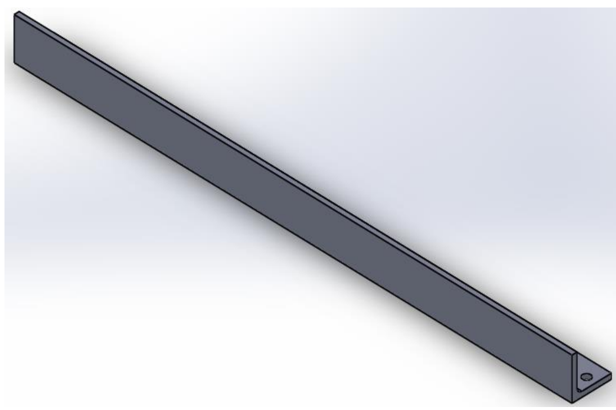
Source: Own Elaboration

Figure 8.8 Reinforcement plate



Source: Own Elaboration

Figure 8.9 Rail angle



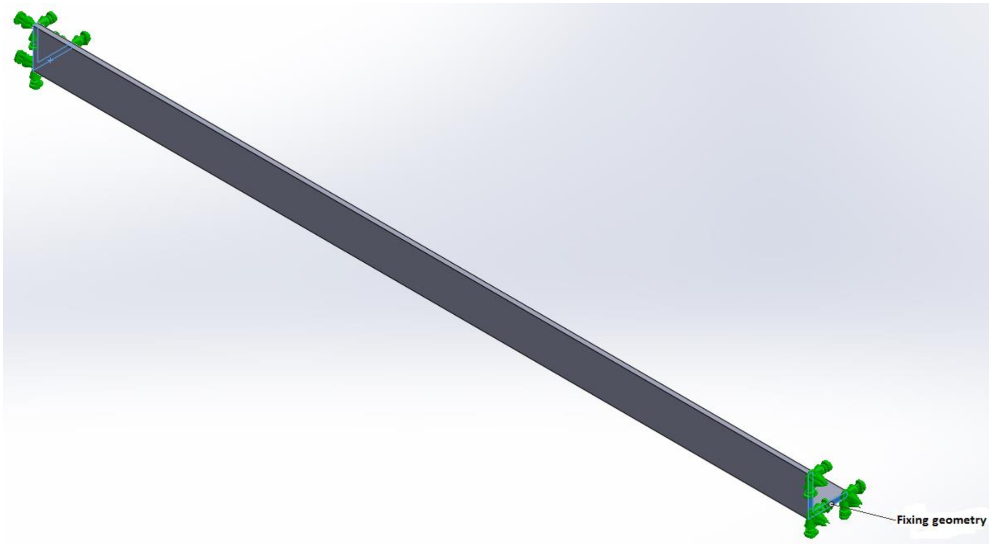
Source: Own Elaboration

After modeling the parts of the prototype line in a CAD software, they can be simulated by in the CAE software.

3.4.2 Simulation of stresses and deformations

In order to have a better idea about how the structural components of the prototype line work regarding the loads which apply to it. In this case the loads are the weight of each piece of plastic that arrives at the start of the prototype line. Another case is the supporting of components like the electrical motor that is part of the structure. When doing the simulation of stresses and deformations, it is necessary to define the references like the supports of each part and establish the direction, type and magnitude of the load. The first step is defining the geometry of the fixing that supports the part, it shows in Figure 8.10.

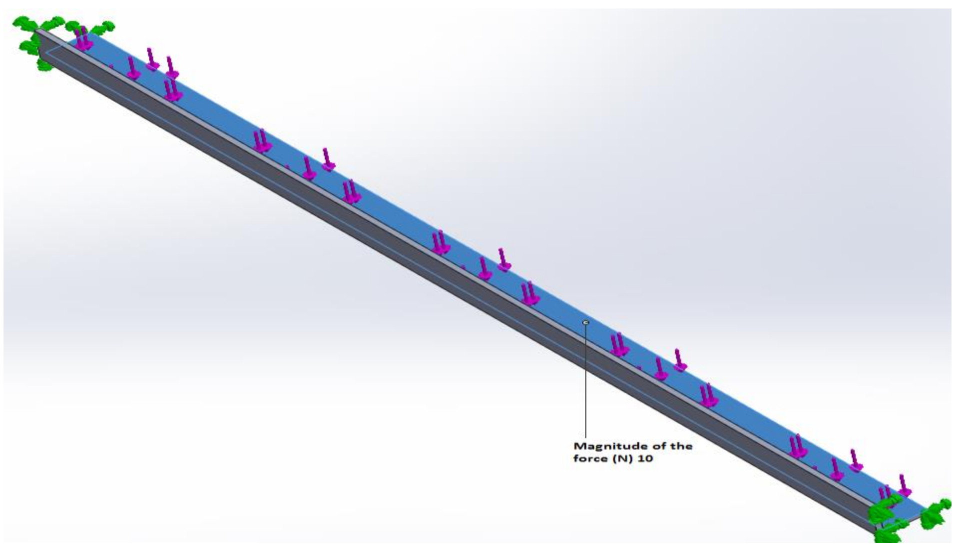
Figure 8.10 Fixing geometry of the part



Source: Own Elaboration

After this step is necessary to determine the load, in this case a force that is applied to the component, in Figure 8.11 observes this.

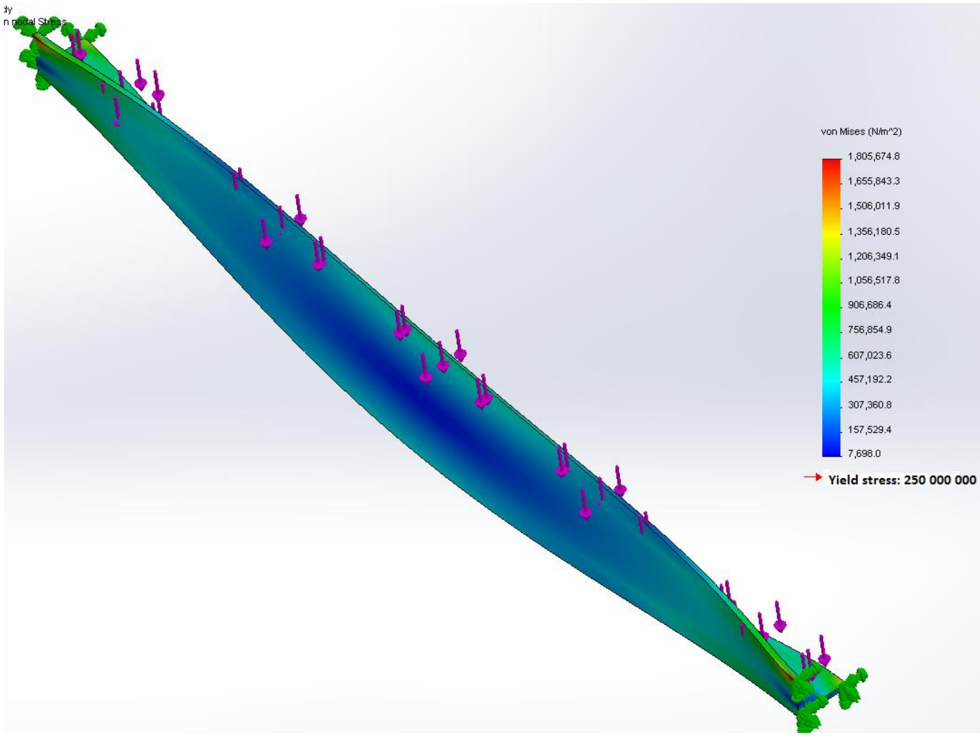
Figure 8.11 Determination of direction and magnitude of the force applied



Source: Own Elaboration

In the CAE software defines the material of the part in order to take into account the properties of it, such as elastic module, Poisson coefficient, shear module, density, yield stress, ultimate stress that the CAE software requires to calculate the stresses and deformations. Then it executes the simulation and gets the results that shows in figure 8.12

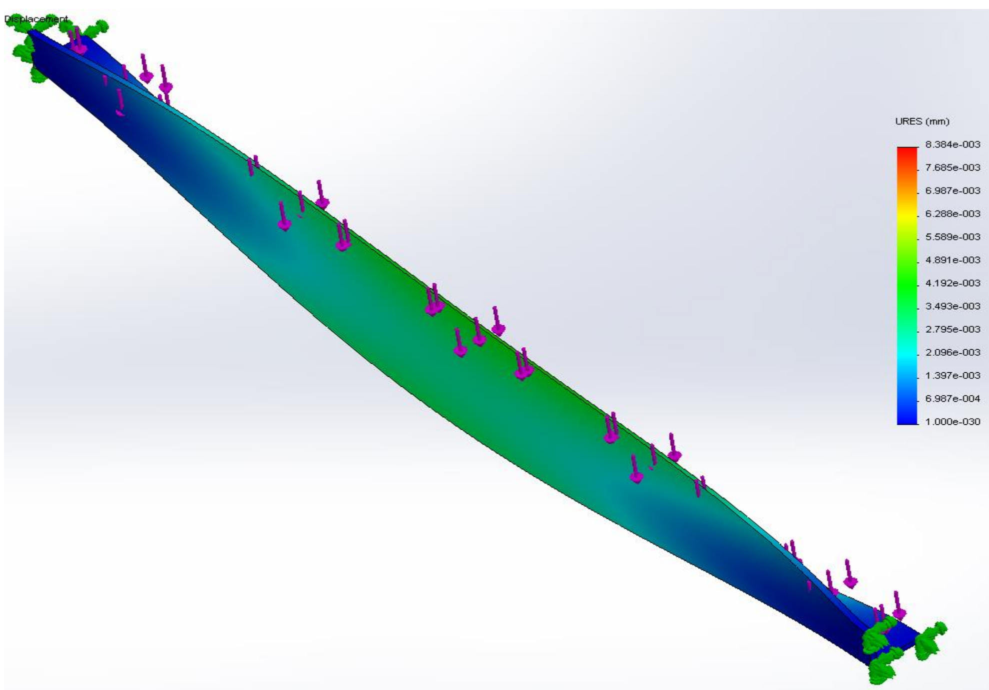
Figure 8.12 Stress results



Source: Own Elaboration

Then it also runs the deformation simulation to identify the maximum value, this shows in figure 8.13.

Figure 8.13 Simulation of deformation



Source: Own Elaboration

This steps are necessary to do because it can compare the maximum values of stress and deformation and compare them

3.4.3 Analyzing of stresses and deformations

Once the stresses and deformations are displayed in the CAE software, it proceeds to analyze them in order to determine if an optimization is required.

A criterion to take into account to determine the rightness of the design is the safety factor that in many engineering applications must be from 1.25 to 3 for ductile material like the ASTM A36 is. On the other hand, the maximum deformation is a reference about the behavior of the material under load, the criterion for this case is the stiffness that the component needs to have to accomplish its function in the structure.

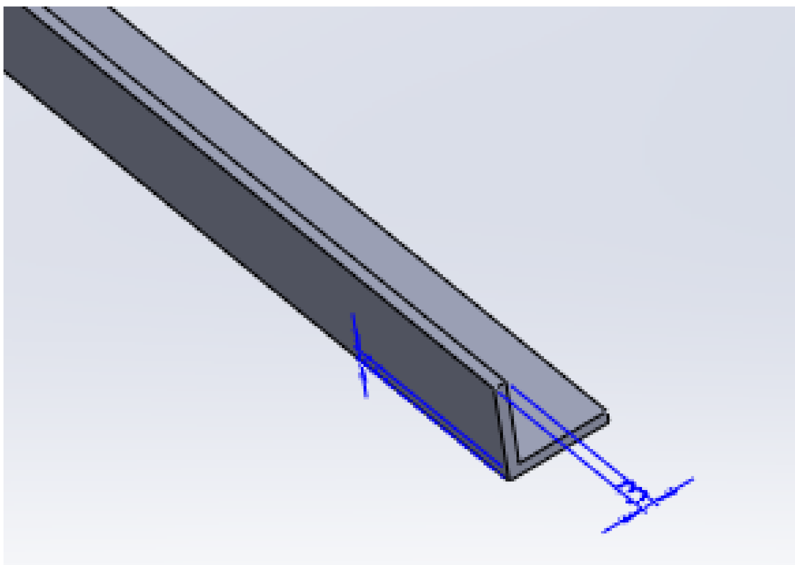
Based on these criteria, it has to determine if the cross section of the material is appropriate or not. If it is appropriate then goes on to design the next components, if it is not right the cross section, it runs an optimization to make it right.

3.4.4 Optimization of cross sections

When running the optimization process, it is necessary to define the thickness as the variable to optimize, this shows in Figure 8.14, and select one criterion that in this case the criteria available are:

- Safety factor
- Maximum displacement
- Maximum stress

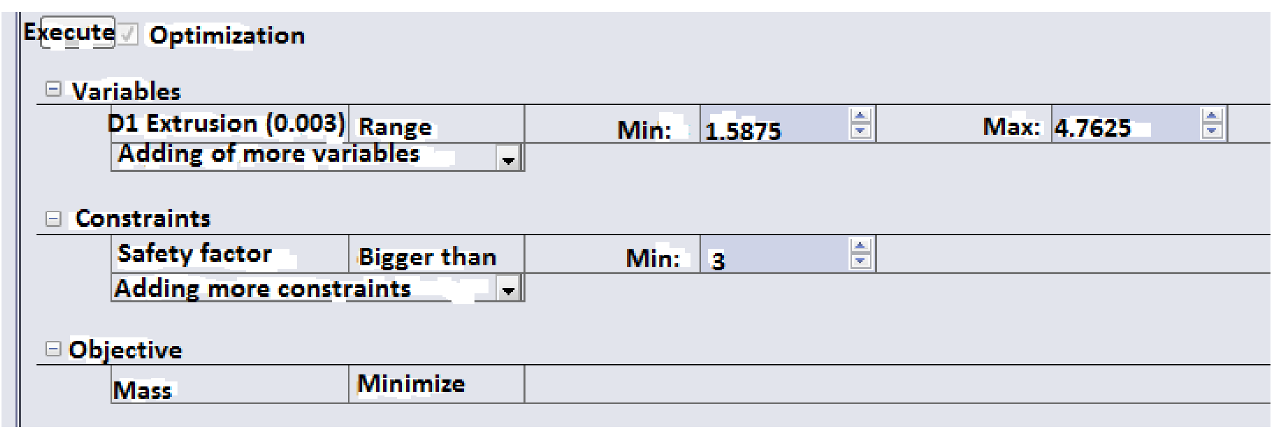
Figure 8.14 Selection of thickness to optimize.



Source: Own Elaboration

The criterion selected in this case is the safety factor and it can use a range of thicknesses that are useful, in order to range properly, it takes into account the thicknesses available in the trade issue. In Figure 8.15 shows the variable to optimize, the range of thickness, the constraint and the objective that is to minimize the mass.

Figure 8.15 Parameters needed to run optimization.



Source: Own Elaboration

Once run the optimization, it is possible to see the results, in this case the parameters of Figure 8.15 generated a reduction in thickness by a half, reduced the safety factor a 26% and the same value for the mass was reduced, this shows in Figure 8.16 As it can see this procedure helps use the material in a better way, so the costs due to this variable can lower and it obtains a design that accomplishes the same function.

Figure 8.16 Optimization results

Optimization results

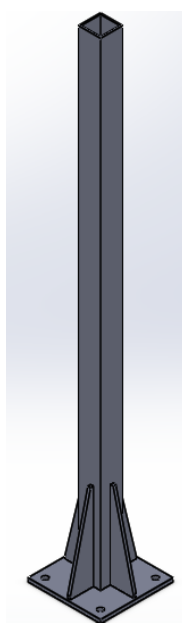
	Initial	Optimum
D1 Extrusion (0.0015)	3 mm	1.5 mm
Safety factor	138	102
Mass	0.55 kg	0.42 kg

Source: Own Elaboration

3.4.5 Virtual subassembly of prototype line

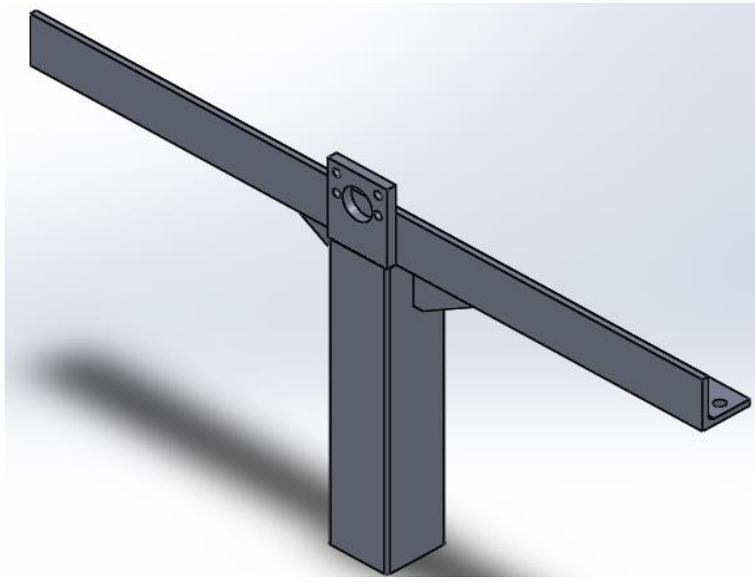
When all of the optimizations are done, it proceeds to make the virtual subassembly, Figures 8.17 to 8.21 show some of these components, these virtual assemblies are just a sample of all that integrate the prototype line.

Figure 8.17 Base-pole subassembly



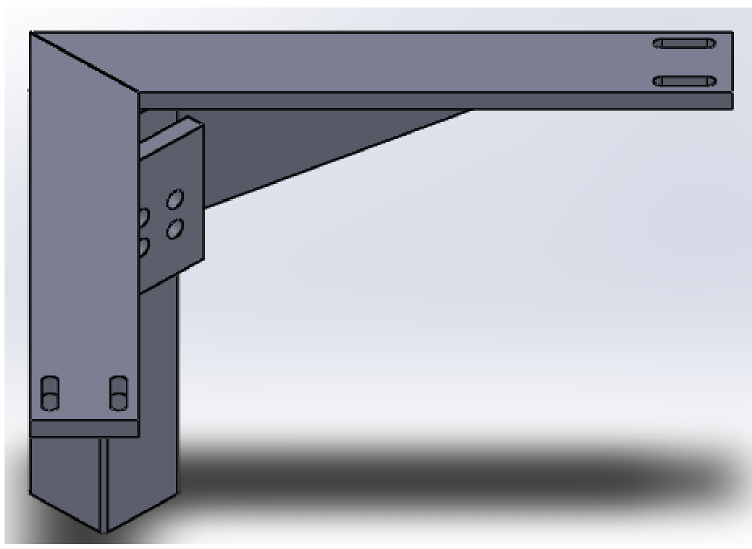
Source: Own Elaboration

Figure 8.18 Support with reinforcements subassembly



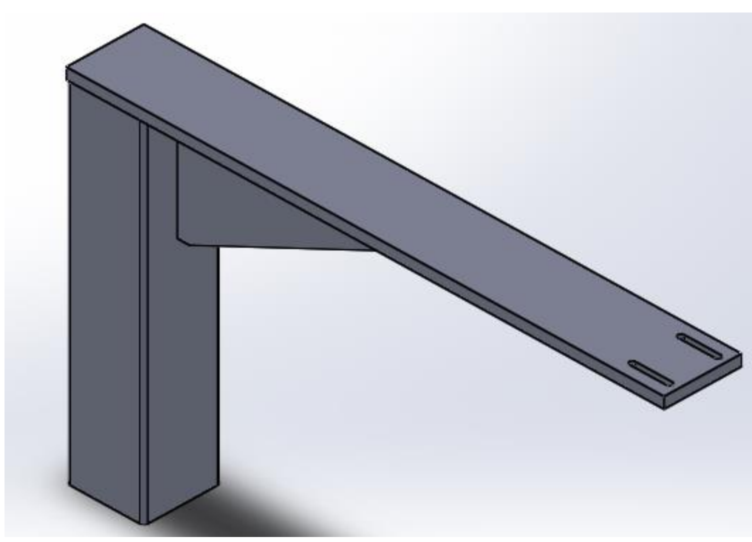
Source: Own elaboration

Figure 8.19 Change of direction support subassembly



Source: Own Elaboration

Figure 8.20 Chain support subassembly

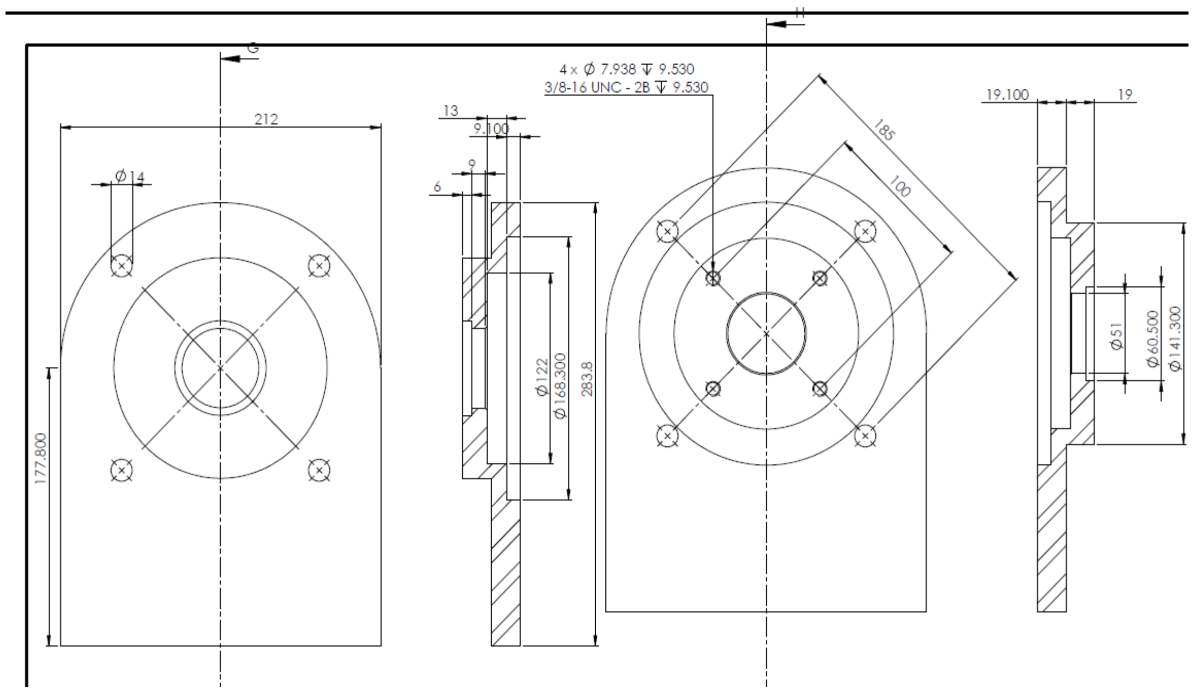


Source: Own Elaboration

3.4.6 Make of drawings

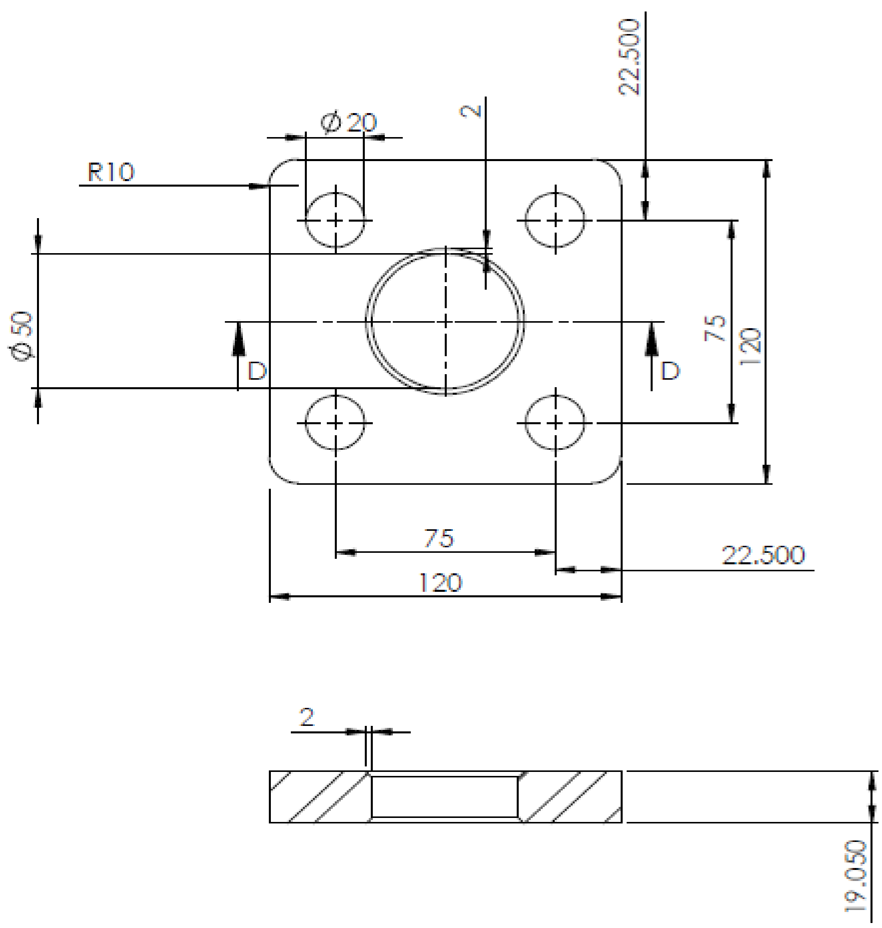
In this stage it proceed to specify the final dimensions according to the analyzing and optimization stages. Then all of the components of the prototype line are defined by technical specifications in order to manufacture each of them. Some of the drawings are presented in Figures 8.21 and 8.22

Figure 8.21 Blueprint of base plate



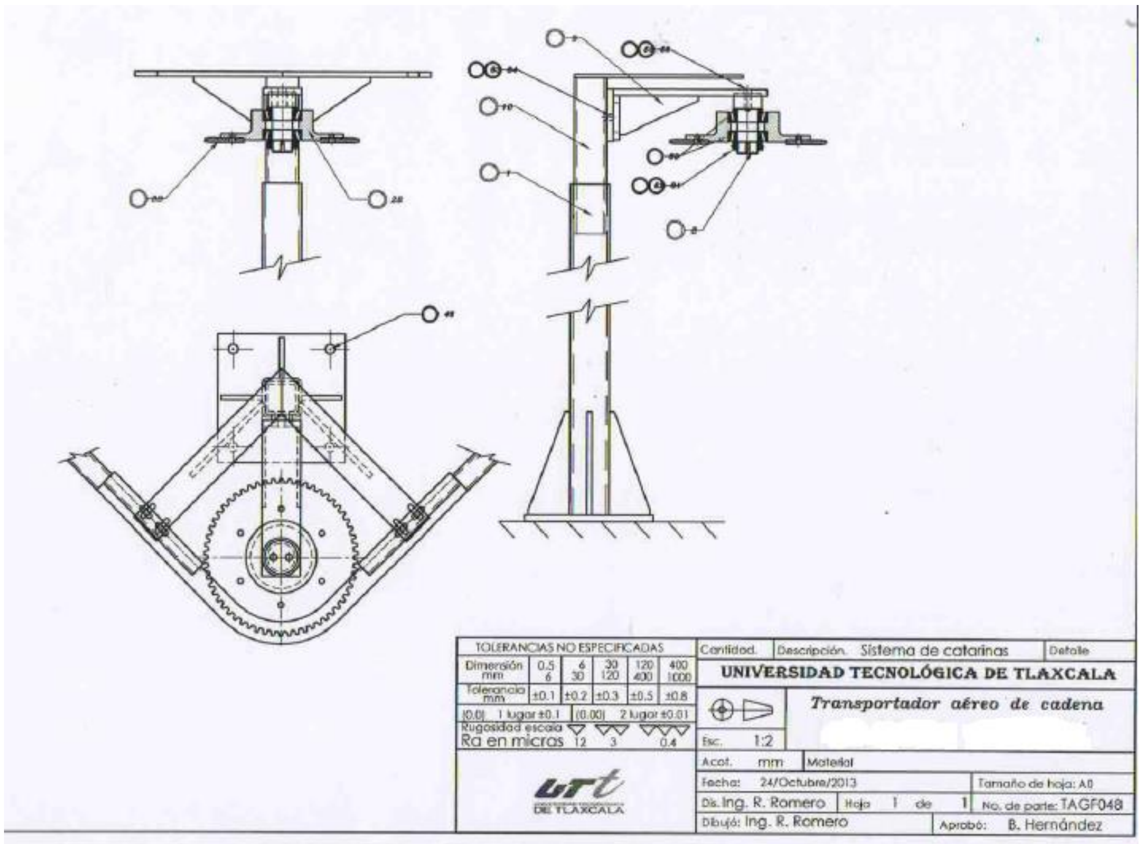
Source: Own Elaboration

Figure 8. 22 Blueprint of lower plate



Source: Own Elaboration

Figure 8.23 Assembly drawing of tension system



Source: Own Elaboration

The technical specifications include:

- Dimensions
- Geometrical and Dimensional Tolerances
- Roughness
- Material
- Refererences
- Section cuts

All of these specifications meet the requirements to assure a correct assembly of the prototype line.

3.4.7 Manufacture of prototype line parts

When all of the drawings were done, it used the information contained in them to manufacture all the prototype line components. The processes that were necessary to accomplish were:

- Cutting
- Welding
- Drilling
- Threading
- Assembly

3.4.8 Final assembly

When the prototype line components were manufactured, it assembled all of them to build it. In figures 8.23 to 8.26 show some aspects of the final prototype line.

Figure 8.23 Side view of rail

Source: Own Elaboration

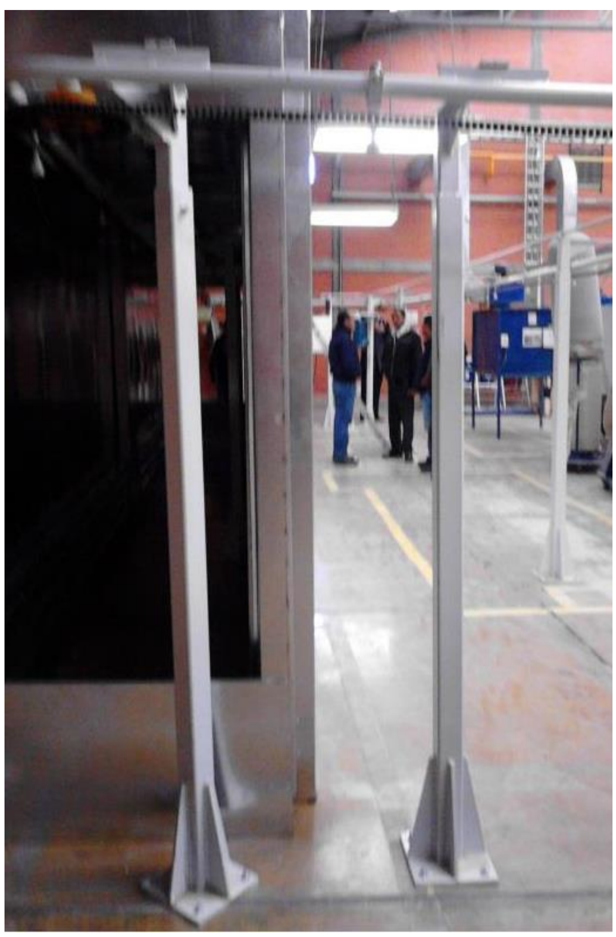
Figure 8.24 Gear motor

Source: Own Elaboration

Figure 8.25 Tension system

Source: Own elaboration

Figure 8.26 Front of prototype line



Source: Own Elaboration

4. Results

The prototype line works as it was designed and now it is possible to run batches of flocked parts in this equipment in order to test some new parts before they enter into the production of the company and in this to assure that the quality and quantity of this product will be according to the Master Production Schedule.On the other hand the participation of professors and students in this project was useful to apply theory issues in design and manufacture works, so it was a meaningful experience to everybody who made some drawing and selections of components.

5. Acknowledgment

We thank to the directive staff of Universidad Tecnológica de Tlaxcala for allowing to work in this project.

6. Conclusions

The work that develop Enterprises and Universities is a good way of achieving projects to innovate products and processes that can impact in cost reduction of structures keeping the security of the equipments that are developed.

.

7. References

Arora, V., Bhushan, G. And Aggarwal, M. (2015). Effect of Surface decarburisation, scragging stress and individual leaf camber on fatigue life of leaf springs, International Journal of Design Engineering, _6_ (1), 22-29.

Broadbent, G., and Ward, A. (1969). Design Methods in Architecture, AA Papers, Lund Humphries, _4_ (4), 204

Broadbent, G., (1979). “The Development of Design Methods,” Des. Methods Theor., _13_(1), 41–45.

Cristiano Fragassa, (2016). Material selection in machine design: The change of cast iron for improving the high-quality Iin woodworking, Journals of Mechanical Engineering Science, _23_(1), 18-30.

Fuge M., Peters B. And Agogino A. (2014), Machine Learning Algorithms for Recommending Design Methods, Journal of Mechanical Design, _136_(10), 1-8.

Hong, J., K. And Yee, K., (2017). Comparative investigation on the aerodynamic effects of combined use of underbody drag reduction devices applied to real sedan, International Journal of Automotive Technology, _18_ (6), 959–971.

Jia Cui; Ming Xi Tang, (2017). Towards generative systems for supporting product design, International Journal of Design Engineering, _7_ (1), 1– 16.

Jones, J. C. (2nd ed). (1992). Design Methods, Wiley, John Wiley and Sons, New York.

Margolin, V., and Buchanan, G. R. (first ed.), (1996). The Idea of Design, The MIT Press, Cambridge, MA.

Otto K. N., E. K. Antonsson, 2008, Tuning Parameters in Engineering Design, Journals of mechanicals Desing, _115_ (1), 1-6.

Sarkar, P. And Chakrabarti, A. (2014). What affects design outcomes of conceptual design?, International Journal of Design Engineering, 5(4), 1-8.

Ramaswamy R., Ulrich, K., Kishi N. and Tomikashi M. (1993). Solving Parametric Design Problems Requiring Configuration Choices, Journals of mechanicals design, _115_ (1), 1-42.

Rathgeber, F., Ham, D., Mitchell, l., Lange, Luporini, F., Mcrae, T., Teodor G., Markall, B. And Kelly, P. (2016). Firedrake: Automating the Finite Element Method by Composing Abstractions, ACM Transactions on Mathematical Software, _43_(3), 2-27.

Rivin, E. (2008), Conceptual Developments in Design Components and Machine Elements, The American Society of Mechanical Engineers, 117(8), 33-41.

Robertson, A. (1981). Las innovaciones tecnológicas y su repercusión social, Revista internacional de ciencias, _33_(3), 471-488.

Roschuni, C., Agogino, A. and Beckman, S. (2011). "The DesignExchange: Supporting the Design Community of Practice," International Conference on Engineering Design, International Conference on Engineering Design (ICED '11), 6_8_(8), 255–264.

Jung, T., Park, Y., Kim, Y. And Cho, Ch. (2017). Integrated approach to an optimal automotive timing chain system design, International Journal of Automotive Technology, _18_(6), 1037–1045.

Vinayak, H., Khatawate, M., Dharap, R. And Moorthy (2016). Stress and strain concentration factors for flat plate with opposite side U-shaped notches under tension, International Journal of Design Engineering, _6_(3), 173-178.

Ward, C. and Seering, W. (2008). Quantitative Inference in a Mechanical Design 'Compiler', Journals of mechanicals design, 115(1), 29-35.

Yucheng Liu; Vipul Meghat; Benjamin Machen (2017). Design and prototyping of an in situ system to clean a cylinder head conveying line following an engineering systems design approach, International Journal of Design Engineering, _7_(2),106 – 122.

Zou H., Abdel, K., Malek, J. And Wang, J. (2007). Design Propagation in Mechanical Systems: Kinematic Analysis, Journals of mechanicals design,_119_(3), 338-345.