Device design for SAE 1020 steel tool storage applied to automotive industry

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Wood pallets are the most commonly used resources in tool storage in the press industry, where components are modeled for automotive industry. The aim of this work was to develop AISI 1020 carbon steel metal rack for storing the set of cutting, drilling, and folding tools. The collaborating company is a manufacturer of automotive components for buses, trucks and pickup trucks. It is located in the municipality of Cruzeiro, São Paulo and Metropolitan Sub-Region of Vale do Paraíba and Litoral Norte 4. Methodology used in the execution of this project was the microstructural characterization of (AISI 1020) by techniques of metallography, hardness, modeling and mechanical simulation, development of metal rack design by technical details in 2D via AutoCad® for prototype, or in 3D by means of virtual modeling Cliever Lab (Pro) ® to create a Mock-up. In production and operations management the average time of handling of forklifts was analyzed using the timer in the current logistic process in the forklift, crane, tool and pallet assembly. The result obtained so far by means of development of Metal Rack was the reduction of environmental liabilities, greater storage safety and reduction in time of tool movement.

Keywork: 1 Rack Design; 2 Design and Material Selection; 3 Product Design; 4 3D Prototyping.

1 introduction

For any type of establishment, the logistics require certain care with respect to its costs, since the storage demands basic investments for the industrial operability. For Moura (1998) when it comes to storage systems, racks become very important items to compose these structures. They can be adapted to a wide range of functions, such as pallet boxes, pallets and pallets, for example, in the same way as they adopt subdivisions of collapsible racks, wire racks, shelves, pallets and other products that facilitate transport, handling and storage of products.

In addition, when inserted in large stocks of goods, metallic racks are essential when you need to adjust the platforms in height, so that it is in accordance with the work questions, when one enters the question ergonomics.

It can be said that in the case of industrial production the waste that can occur along the processes are diverse, ranging from raw material to financial resources. However, raw material waste can be classified as the most urgent in this sector and also the most passive to be studied, since it directly impacts on the factory flow and the quantity of the finished product.

At this juncture, inserted a line of research : Product Project of the Stricto Sensu Post-Graduation Program in Design, Technology and Innovation, Professional Masters of Teresa D'Ávila University Center, the current project aims to develop an industrial AISI 1020 steel Rack for the storage of the set of cutting tools , drilling and folding in a metallurgical industry of component located in Vale do Paraíba.

Aimed at the notable reduction and safety in the movement of tools and an improvement in the setup time, extinguishing the wood waste, making the company increasingly sustainable. It was also tried to standardize the method of stocking tools with the objective of expanding this project to the other areas and future for international companies, including: cutting, drilling and modeling tools, generating a maximization of results and, in the short term , a reduction in the costs of transportation and handling of the tools. Would the development of a tool storage device made of AISI 1020 carbon steel reduce environmental liabilities more safely in the handling and storage of tooling?

1.1 General Objectives/Aims

The project aimed to develop an AISI 1020 steel industrial metal rack for the storage/warehousing of the cutting, drilling and folding tools.

1.2 Special Objectives/Aims

The specific purposes of the present study are:

a) Characterize the material via optical microscopy, resistance of the material via 3D and real modeling;

b) To develop a set of metallic Rack within the product design standards and its strategic alternatives in the management of the production.

c) Maximize setup time in the movement and exchange of tooling in the manufacturing environment.

d) Reduce the environmental liability (Wood) and maximize the occupational and ergonomic safety of the worker in the process of moving the tooling.

1.3 Situation- Problem Analysis

The study carried out in the present work had the purpose of analysis of the transport activities carried out in the productive environment of a pressing sector, verifying and analyzing procedures rooted in the company, observing the process and movement of tooling in cast steel for the modeling of parts for trucks and large buses.

In a production chain there are several stages of transformation and manufacturing between the sheet steel and the final product. However, for this to happen, there must be the commitment of several operators and they must be in line with the process. In this flow, the component needs to be modeled passes through the area of control and materials, reaching the quality and being released.

After this, the production sector is allowed to model the parts in presses from 250 tons up to 2,000 tons. For this to happen, the logistics have to contribute with the movement of tools, so that the presses can model the components, remembering that, for each component, a different tooling is needed.

Standardization is a very beneficial medium in the logistics business. However, in large companies it is extremely difficult to program and maintain this standardization, because for each type of tooling, different pallets are used and there is no identification for the correct pallet in the correct tooling, generating in addition to lack of standardization, lack of environmental liabilities, Figure 1.

Figure 1 : Wooden Pallets used in a factory environment
Source: The authors (2018)

In the concept of packaging standardization, it was also possible to observe the lack of inspection in the storage sector, in order to change the pallet at the end of its useful life, or as soon as some internal or external break occurs, Figure 2.

Figure 2 - Storage system with the tool set of wooden pallets.
Source: The authors (2018)

After the use of the wooden pallets in the storage process, it is sent to be stored, but there is no quality control in the storage, to select the appropriate pallets, Figure 3.

Figure 3 - Incorrect disposal of wooden pallets, after use in the factory environment
Source: The authors (2018)

The site is often not conducive to this storage due to the reason of disposal in open environments to recommend weather conditions, leading to degradation and reduction of the useful life of the material.

2 Functions of Packaging

Camargo and Negrão (2007) believe that the production of artisanal packaging lasted for a long time, only after the 17th century, through the industrial revolution that began the series production of packaging. Through this revolution we began the development of technology for the manufacture of more innovative packaging.

According to Pedelhes (2005), packaging has become essential in the daily lives of human beings and, above all, in the tasks of any industry. The process and storage carried human innovation, from the convenience of storage of several things in some packaging to aim at the own human development, began the mercantile activities and the propagation of the use of containers.

Mestriner (2007) points out that in Brazil, if the manufacture of packaging began after the arrival of the Portuguese royal family in 1808, after Don Bosco VI allowed the companies to explode in Brazil for the development of the economy at the time. With the technological advance, the first marketing function of the packaging emerged.

Understanding the importance of packaging for society, its relevant purposes are cited. According to Moura (1998), these are:

• Decrease in expenses per unit;
• Maximization of time;
• Clarity in usability, logistics and storage;
• Product protection;
• Reaching several areas of activity;
• Acting in accordance with the laws and regulations of consumer status;
• Maximizing sales.

According to Moura and Banzato (1997) it can highlight more objectives, such as:

• Control of the product: it has the purpose of stocking the product, that is, policing. Therefore, in planning the packaging, this purpose must be linked to the product that will be packaged;

• Preservation of packaged elements: this purpose must preserve the packaged product in a way to guarantee its protection, thus ensuring that attitudes of storage, logistics, handling and climatic conditions do not interfere in the quality of the product. This preservation must direct mechanical operations: vibration, shock, comprehension and physical-chemical: temperature, humidity, oxidation, among others;

• Informative: the packaging has the purpose of communicating by descriptions, colors, symbols, dimensions, etc .;

• Purpose: to interact between man and product, maximizing the usability of products purchased by the customer.

The relevance of the packaging can be noticed in the face of innumerable variations and methods related to the packaging, according to the planning of each organization, to show that the crucial purpose besides preserving the product, the packaging has several purposes, being attributed as being fundamental for the activities of the industrial sector (MANTOVANI, 2014).

2.1 Logistics and Lean Six Sigma

In the business environment, the handling of products, production and stock are organized through the logistics sector. It is a branch of the management in which the activities and handling of the products of a company or industry are administered. It includes practices of planning, operation and control of the flow of goods, materials and services inside the company "has the mission to put the right quantity of the right product, in the right place and at the right time, at the lowest cost and in the conditions desired by the other business activities, "(COSTA, DIAS & GODINO, 2010, p. 11).

For Ballou (2001, p.201)

> The location of inventories in warehouses directly affects the total material handling expense of all goods that are moved into the warehouse. What you are looking for the least is the balance between the cost of material handling and the use of the warehouse space. There are specific considerations about the storage space and the order separation in the internal design of a warehouse.

Logistics was developed with the main objective of developing techniques so that the products of a company were handled in a more structured way and also for its distribution to happen more quickly and efficiently. With this, logistics can integrate and rationalize the functions of the company from production to guarantee the competitive advantages of the company (COSTAS, DIAS and GODINO, 2010).

The Lean began in the Toyota production system in the 1980s focusing on the flow of the process; Six Sigma began in the same period Motorola focused on operational improvements. According to Mousa (2013), Six Sigma and

Lean have evolved together, that is, with the same goals despite different approaches, in order to complement each other.

According to Anbari and Hook (2006) Six Sigma originated at Motorola in 1980 and aims to increase profits and improve the efficiency and effectiveness of operations. Its methodology is based on the improvement steps of a process, these are known as DMAIC, which has the purpose of defining, measuring, analyzing, improving and controlling a process improvement.

According to Chen (2008) in Lean Manufacturing, its methodology consists of two goals: to eliminate tasks that do not add value and to add value in production, as much as possible, with less employees, less equipment, in less time, in strategic locations to achieve goals in production and the customer. The purpose of Lean is to create efficient processes that have value at the end of the chain, so its main purpose is to reduce waste and create value.

For Chen (2008) the combination of Lean with Six Sigma results in a greater capacity to solve difficulties caused by lack of competent management and its benefits can last for years. According to Mousa (2013) Lean Six Sigma is the latest methodological evolution in process improvement, building on previous philosophies and adopting the same benefits, enhancing existing ones for the purpose of improving the process more and more.

According to Anibari and Hook (2006), Six Sigma adopts tools to help complement its process in order to reduce processes that are not productive, some tools used are: SIPOC, chronoanalysis, process map, cause and effect diagram, matrix prioritization, Pareto diagram, stratification, among others. According to the Etymological Dictionary of the Portuguese Language by José Pedro Machado, the etymology of logistics comes from the Greek logistik which means the practical science of calculus. However, Heskett states in the preface to the book Tixier that logistics originates from the French logger, which means to accommodate or accommodate. (MOURA, 2006).

Logistics is developed based on data such as the history of the demand for products, as well as sales and suppliers history, so that the administration foresees the next production. In this way it is possible to monitor the orders, the deliveries, the costs involved, the delivery time, the seasonal periods and others. Because it is a form of management that seeks balance in business activities, it ends up contributing to the company's goal of increasing production and reducing profits. (COSTAS, DIAS and GODINO, 2010)

2.2 Rack Design and Development

According to Fascioni (2017) the word Design was created in the period of the industrial revolution, with the purpose of creating new products and packaging for the large-scale production of prominent craftsmen of that time. Through this thought several artists met with the purpose of conceptualizing the term Design, with the purpose of transporting the greatest number of products in a simple and efficient way.

For Mozota (2011) the word design comes from the Latin designare that means to draw or to designate. In English, the term has two meanings that can be intention, design, plan, model, motif, decoration, motif, visual composition depending on the context. The professional formation in Brazil, is through the training in the Graduate Course in Design, in accordance with the curricular guidelines of the Ministry of Education and Culture (MEC), which requires a profile:

The professional that deals with the design of visual information systems, objects and systems of objects of use through the disciplinary approach, considering the characteristics of the user and their socio-economic-cultural context, as well as the economic and technological potentialities and limitations of productive units in which information systems and objects of use will be produced (MEC, 2003, p.26).

According to Fascioni (2017) in design thinking, ergonomics plays a fundamental role in the development of new products, ergonomics being the science that studies the behavior of man through his workplace, also taking into consideration the bionics that is the science that studies living systems in order to create new techniques and technological principles, it is also necessary to consider the proxemics that are the science that studies the theories and observations of the human being in their environment, besides the techniques of product development and the lighting in the process.

2.2.1 Design Thinking

Lockwood, president of the Design Management Institute (DMI), defines design thinking:

> Essentially a human-centered innovation process that emphasizes observation, collaboration, rapid learning, brainstorming, rapid prototyping of concepts and concurrent business analysis, which influences innovation and business strategy (LOCKWOOD, 2009, p.11).

According to Martin (2009), design thinking is the activity of thought that provides change through knowledge. The author mentions that change occurs over a long period, but the benefits are incalculable.

According to Ilipinar et al. (2008), design thinking is a creative method supported in the development of ideas, making the use of technology vital in the business environment. Design thinking extinguishes the fear of making mistakes and increases the absorption of employees' knowledge in the process of problem solving within the manufacturing environment.

According to Brown (2009), design thinking begins with the skills that designers inculcate over time, such as assimilating the needs of individuals with the technological procedure accessible to systems, the instinct and competence to know the tasks and develop ideas that have both affective and functional justification.

According to Ambrose & Harris (2011), his studies are based on the methodology of design thinking that seeks to find a specific solution to a difficulty found in the process or development of a product, which most of the time starts in the task of finding the true problem.

The design thinking methodology is presented through several interfaces to facilitate the understanding of the reader and maximize the learning process. Vianna et al (2012) defines design thinking as three stages: immersion, ideation and prototyping.

2.3 Selections of Materials

2.3.1. Carbon Steel

According to Chiaverini (2010) Steel is a relatively complex metal, they are characterized not only by their carbon composition or by a set of other components that characterize the steel to have different mechanical properties. Under these conditions for a simple classification can establish percent carbon limits (C) present in the chemical composition of steel ranging from 0.008% to 2.11% C.

- Low carbon steel, carbon below 0.3%;
- Medium carbon steel, carbon between 0.3 and 0.7%;
- High carbon steel, carbon higher than 0.7%.

According to Chiaverini (2010), the main objectives of thermal and thermochemical treatments are usually to promote:

- Changes in residual stress;
- Increase or decrease in hardness;
- Increased mechanical resistance;
- Improvement of ductility;
- Improved wear resistance;
- Improved machinability;
- Modification of electrical and magnetic properties.

2.3.1.1. Steel AISI 1020

According to Luz (2018) AISI 1020 steel is one of the most common carbon steels used as a cost-effective carburizing steel compared to more bonded steels for the same purpose. It has excellent plasticity and weldability.

AISI 1020 steel is suitable for bolts, hard drawn, chassis, wheel discs, parts generally for machines and vehicles subjected to small, medium and highly tenacious efforts, particularly indicated for the manufacture of parts that must receive surface treatment for hardness increase , mainly cementation. The material has as an ideal application for products such as bolts, nails, shafts, forged components without major requirements, distribution bar, cemented piece, welded tubes (MAJEWSKI, 2017).

Board 1: Typical chemical composition of AISI 1020 Steel.

AISI/AISI	C	Mn	Max. P	Max. S
1020	0.18- 0.23	0.30-0.60	0.040	0.050

Source: Gerdau (2013).

3.0 Methodology

The development of this product design was based on the methodology of Baxter (2011), proposes that the product development process is characterized by the visual aspects, prototype, market needs, ecological concern, confidence and cost reduction. It aims to integrate the market views with engineering, as well as the identification and satisfaction of consumer needs. Thus the search for four stages in product development are:

• Preliminary ideas: generation of ideas;

• Specifications: define the opportunities and specify the project;

• Configurations: make tests, analyze change alternatives, structural calculation, material analysis, manufacturing process and adjustments;

• Production: detailing of the product process, preparation of the technical drawing and product ready for production.

According to Baxter (2011), "innovation is a vital ingredient for business success" and it generates a competition among companies in a fierce way in which they seek to continuously introduce new products so that they do not lose part of their market. Therefore, the development of new products is seen as an important but risky attitude. For the success of an innovation, it is necessary to establish goals, in which it must be verified that the product will meet the proposed objectives; whether it will be well accepted by the consumer; if it will have an affordable cost. (BAXTER, 2011).

3.4.3. Product Design

The design configuration starts with the chosen concept and ends with the prototype developed and tested. The proposal of the new product must begin with the generation of ideas, in which all possible forms of manufacture are explored. For the generation of ideas, Baxter (2011) defines elements for the creative process:

• Think only of ideas: forget about practical restrictions;

• Look for ideas outside the normal domain of the problem.

Baxter (2011) suggests using techniques for problem reduction, problem expansion, and problem digression, such as function analysis, morphological analysis, analogies and metaphors, cliches, and proverbs.

In the technique of development of the metallic Rack were made several Sketchings, to begin the process of creativity for the elaboration of the prototype. After an idea formed was an elaborate drawing in the AutoCAD 2016® that develops a 2 D design for the visual aid of the project perspectives.

The activities were done in the Laboratory of Materials, Modeling and Textures *"Prof. Dr. Wilson Kindlein Junior* "in UNIFATEA, Figure 4.

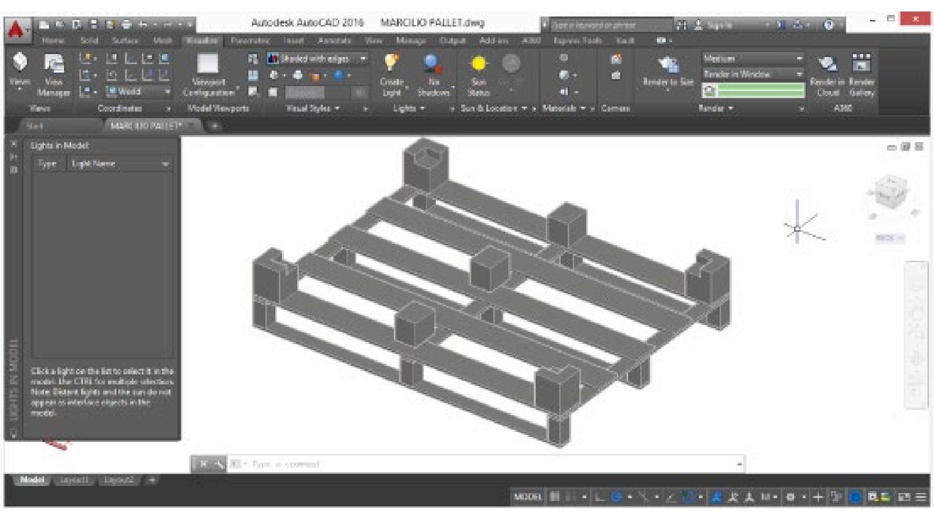

Figure 4 : Autocad Interface 2016
Source: The authors (2018)

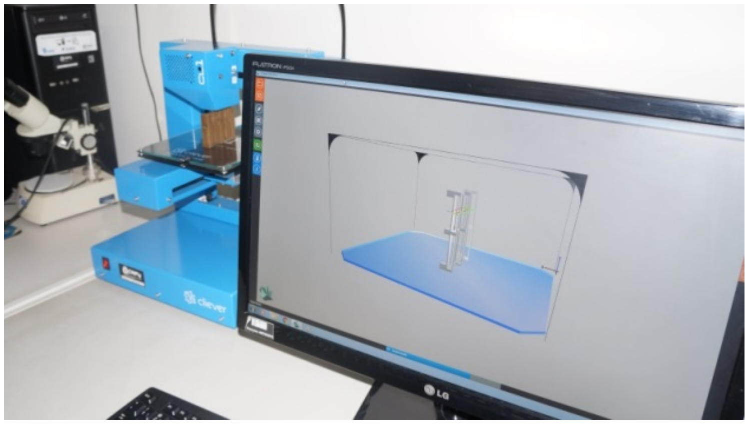

Figure 5: Software for prototyping in Cliever® Lab (pro).
Source: The authors (2018)

For the development of the mock-up, the 3D printer of the Cliever® model was used in order to establish a pre-project view regarding ergonomics, shape, geometry, interchangeability, usability and small-scale tooling.

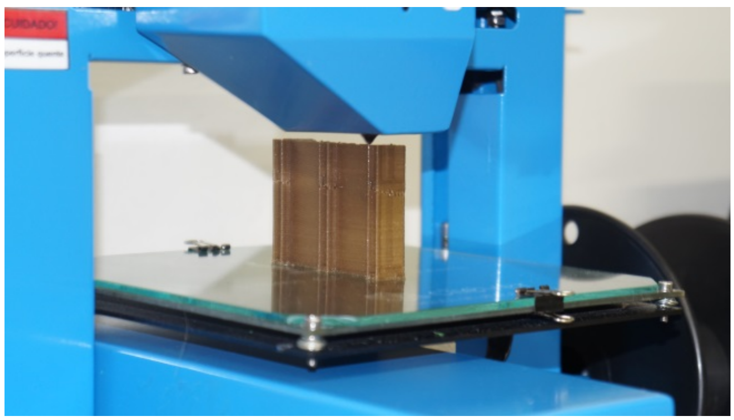

Figure 6: Prototyping 3D printer.
Source: The authors (2018)

4. Results and Discussion

4.1. Economic and Technical Viability

The shelf life of the wooden pallet is approximately 6 months, and the average cost of the same is U$ 14.85, totaling an annual cost of U$ 29.81. The Cost of Steel Rack 1020 is approximately U$ 58.85, this value was defined by adding the value of the steel that was made available to the partner company and also by the value of labor in the manufacture of Metal rack.

With the use of 3 (three) years of the wooden pallet the company counts an expense of U$ 89.14 and that the cost of the wooden pallet was greater than that of the metallic Rack. Note that the metal rack can have a service life of approximately 15 years with adequate maintenance and the partner company will have cost reduction in the amount of U$ 445,71 (one thousand, five hundred and sixty reais) in this period.

Table 1: Comparison of industrial costs

MATERIALS	1 year	15 years
Pallet	U$ 29.71	U$ 445.71
Rack steel AISI 1020-waste	U$ 58.85	**

Source: The authors (2018)

In the partner company has approximately 1,000 (one thousand) tooling this information that for the company the cost reduction of approximately U$ 445,714.00 already counted the value of the metallic Rack in this amount.

4.2. Microstructural characterization of the material used in the construction of the metal rack

For the microstructural characterization, the optical microscopy technique was observed in the micrographs with the magnitude of 500x in the AISI 1020 steel and presents in the light regions the presence of ferrite, and in the dark regions the presence of perlite in its grain contour. These microconstituents translate the material and structure of the Rack into ease in workability, manufacturing process and ductility.

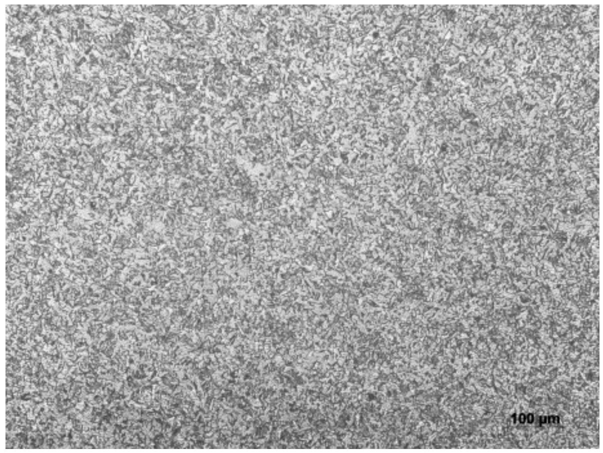

Figure 7: AISI 1020 Carbon steel etching with Nital, 500x
Source: The authors (2018)

4.1 Product Design and Metal Rack Design

The metal rack was produced from the technical drawing to carry out the task analysis and be tested in real situation in the factory environment, Figures 8 and 9. In the process of development of the Rack was analyzed the dimensional of the tooling, in that it has a length of 1300 mm, width 1100 mm and 215 mm height, Figure 10.

Figure 8 - AISI 1020 steel metal rack finished
Source: The authors (2018)

Figure 9 - Metal rack with cutting, drilling and bending tool set
Source: The authors (2018)

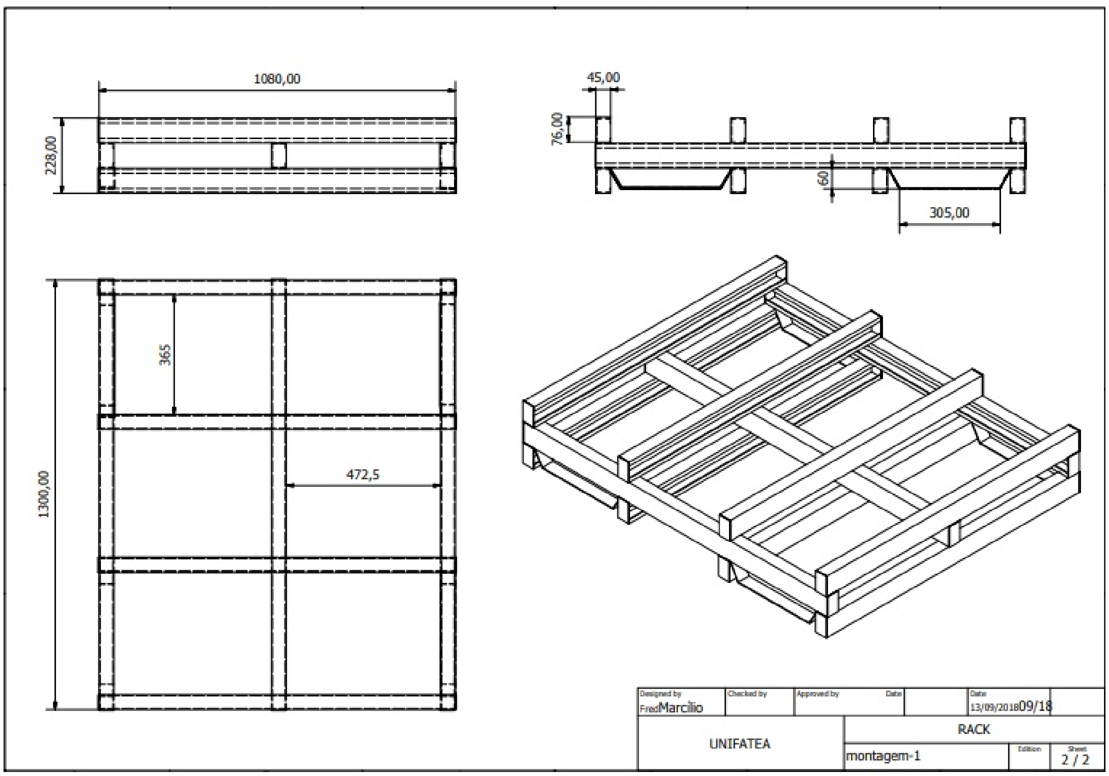

Figure 10 - Technical Drawing of the metal rack
Source: the author (2018).

5. Conclusion

With this work, one can analyze the feasibility of storage and logistics systems. For research elaboration, besides the use and bibliographical researches with theoretical basis of pioneering and contemporary authors in the several sectors approached, it is characteristic of it the product creation method by following the Baxter methodology.

It was developed a Storage Device (Rack) that meets the needs of the pressing industry using the optical microscopy techniques and ensuring strength and hardness of material by means of a structural calculation and testing in the factory environment.

It was highlighted, based on a theoretical and practical process, that the metallic steel rack has a great competitive advantage over wooden racks, aiming at a better process of ergonomics, transportation and material saving.

Risks that could occur with the use of conventional racks and technological opportunities that the development of a metal rack could bring by means of the use of design, technology and innovation were verified.

The materials and their structures were analyzed in order to guarantee resistance and its mechanical and chemical properties, giving to the metal rack safety and quality in the movement and storage of cutting, drilling and folding tools.

With the development of metal rack, it was possible to reduce the time of movement and setup in around 10 minutes, maximizing the production time and removing the process crane, bringing greater convenience to the stacker and to the employees who make the tool change.

According to results obtained by means of the accomplishment of this project, indexes of improvement of productive, logistical and storage activities were raised quantitatively. It can be seen that the company's focus may maximize productivity and consequently its profits, using the storage device being of the Metallic Rack type in which, by means of application of design concept, has improved several aspects that affect productive activity, logistics and the value chain of product.

It is concluded that the objective of project was reached, since the presented model, when compared to the current concept of storage devices, presents innumerable productive, logistical, occupational, environmental and financial advantages, in which the income with the use of Rack Metallic products impacted on a great economy for the company, the results were obtained by means of reduction of environmental liabilities, standardization of tooling storage sector, maximization of setup time and cost reduction estimating.

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