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Sustainable Storage – Use of metallography as a solution for the development of a new device

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Abstract— *Wooden pallets are the most used resources in the storage of tools in the pressing area, in which components for the automotive industry are modeled. The objective of this work was to develop a metallic rack in carbon steel SAE 1020 to store the set of cutting, drilling and folding tools. The methodology used in the execution of this project was the microstructural characterization of the SAE 1020 materials by metallography techniques, hardness, mechanical modeling and simulation, development of the metallic Rack design by technical detailing in 2D via AutoCad® for the prototype, sometimes in 3D through virtual modeling Cliever Lab (Pro)® with Mock-up Create Buildings. The result achieved so far through the development of the Metal Rack has been a reduction in environmental liabilities, greater security in storage and reduction in tooling movement time.*

I. INTRODUCTION

For any type of company, logistics requires some care in relation to its costs, since storage requires basic investments for industrial operation. For Moura [1], when it comes to storage systems, racks become very important items to compose these structures. For they can be adapted for the most diverse functions, such as pallet boxes, pallets and platforms, for example, in the same way they adopt subdivisions of detachable racks, wire racks, shelves, pallet racks, among other products which facilitate transport, movement and storage of products.

It can be said that, when it comes to industrial production, the waste which can occur along the processes is 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 the manufacturing flow in quantity of finished product.

At this juncture, a research line is inserted: Product Project of the Stricto Sensu Postgraduate Program in Design, Technology and Innovation, Professional Master's Degree from the Teresa D'Ávila University Center, the current project aims to develop an industrial rack in AISI1020 steel for storage of set of cutting, drilling and bending tools in an industry in metallurgical component sector, located in Vale do Paraíba.

The project aimed to develop an industrial metal rack in AISI 1020 steel for storing the set of cutting, drilling and folding tools. Thus, it is possible to characterize the material via optical microscopy, material resistance via 3D and real modeling; develop a set of metallic racks within product design standards and their strategic alternatives in production management; maximize the setup time in movement and change of tools in the factory environment and reduce the environmental liability (Wood) and maximize the ergonomic occupational safety of the worker in the tooling movement process.

The aim was the notorious reduction and safety in the movement of tools and the improvement in setup time, extinguishing wood residues, making the company increasingly sustainable. It has been also tried to standardize the way of storing tools in order to expand this project to other areas and, in the future, to international companies, encompassing: cutting, drilling and shaping tools, generating a maximization of results and, in the short term, a reduction in the costs of transporting and moving the tools. Would the development of a tool storage device in AISI 1020 carbon steel reduce the environmental liability with more safety in the movement and storage of tools?

II. MATERIALS SELECTIONS

Carbon steel

According to Chiaverini [2], steels have a relatively complex structure, they are not only characterized by their carbon composition or by a set of other components which make the steel have different mechanical properties. Under these conditions, for a simple classification, it is possible to establish threshold percentages of carbon (C) present in the chemical composition of the steel, ranging from 0.008% to 2.11% C.

- Low carbon steel, carbon less than 0.3%;
- Steel with medium carbon content, carbon between 0.3 and 0.7%;
- Steel with high carbon content, carbon greater than 0.7%.

According to Callister [3], steels are extremely important for the industrial sector, in the manufacture of cars, trucks, buses, buildings, electronics and throughout the production chain. He also emphasizes the choice of steel for a given task indicates success and complement of the final objective of developing a given process.

According to Chiaverini [2], the main goals of thermal and thermochemical treatments are usually to promote:

- Changes in residual stresses;
- Increase or decrease in hardness;
- Increase in mechanical strength;
- Improved ductility;
- Improve in wear resistance;
- Improve in machinability;
- Modification of electrical and magnetic properties.

SAE 1020 steel

According to Luz [4], SAE 1020 steel is one of the most common carbon steels used as steel for carburizing, with an excellent cost-benefit ratio compared to more alloyed steels for the same purpose. It has excellent plasticity and weldability.

SAE 1020 steel is indicated for screws, hard drawn, chassis, wheel discs, parts in general for machines and vehicles subjected to small and medium efforts. The highly tenacious SAE 1020 steel, particularly suitable for the manufacture of parts which must receive surface treatment to increase hardness, mainly cementation. SAE 1020 steel is still used for shafts, in general, forged. For SAE 1020 steel to have these characteristics, it must follow specific chemical compositions. SAE 1020 Steels have Low hardenability, excellent forgeability and weldability, nevertheless its machining is relatively poor.

It can be applied in cementation. SAE 1020 Steels have, as ideal application, products such as: Screws, nails, shafts, components forged without greater requirements, distribution bar, case-hardened part and welded tubes [5].

Chart 1: Composition of SAE 1020

SAE/AISI	c	mn	P Max.	S Max.
1020	0.18-0.23	0.30-0.60	0.040	0.050

Source: Majewski [5]

Metallography

According to Colpaert [6], metallography is a method of studying materials in their smallest details, in order to observe their structures, in particular their physical properties, process and composition, in order to show how the material behaves under a certain force or application.

Marmontel [7] mentions that properties such as toughness, fragility and resilience are characterized in the material and can be seen and analyzed by means of metallography.

According to Fasano [8] and Rohde [12], metallography seeks to associate the structure of material with its function, showing its real performance, in the midst of its process and purpose in the productive sector, in which a certain force is exerted on this material.

These authors demonstrate metallography aims to analyze the material before its process so that it can have a favorable performance in the process it is performing. Thus, metallography has the role of bringing security and confidence in the search for the appropriate basis for choosing and analyzing material for process of production, creation, etc.

For Silva and Avanzi [10], Metallography is the study of structural characteristics or constitution of metals and their alloys, in order to relate them to their physical, chemical and mechanical properties.

According to Coutinho [11], metallography makes it possible to analyze the real property of material for purposes of material reduction, in order to make the product lighter so that it reduces gases that damage the atmosphere.

Such a detailed analysis of the material's structure with the naked eye would be practically impossible. In this case, it is necessary to have the aid of a microscope for a more specific analysis of the material, which is known as a micrograph. By means of macrography and micrography, it is possible to analyze and observe several characteristics of material, such as cracks, failures, strengths and weaknesses, discrepancies and ruptures [6].

Coutinho [11] says that by means of metallography it was possible to select possible materials to be used in automotive area, such as high resistance and no corrosion. The most used elements are Cu, Mg, Si, Mn, Fe, Ti and others, forming sustainable and resistant systems.

According to these authors, macrograph and micrograph analyzes are extremely important for elaboration of a product, with the purpose of providing the maximum quality possible in obtaining a satisfactory quality result in the finished product.

Macrographic Essay

According to Colpaert [6], micrography is the study of metals with the aid of a microscope, aiming at a detailed analysis of their composition and texture. In this process, it is necessary to clean the area to be examined and use a chemical reagent.

According to Colpaert [6], in the macrographic process, the sample to be analyzed is defined; selects the flat and sanitized part in the process; the use of chemical reagent in the area to be used; use of the microscope to observe the material by means of photographs.

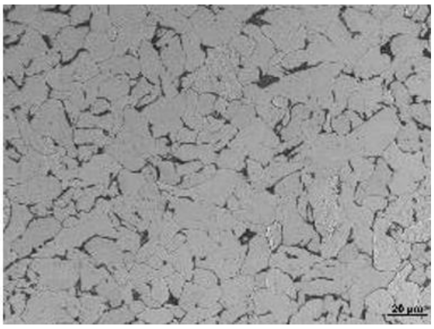

Fig.1 - Micrograph of a hot rolled 1010 Steel.

Source: Rohde [12]

Rack Design and Development

According to Fascioni [13], 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 artisans at that time. Through this thought, several artists came together in order to conceptualize the term Design, with the purpose of transporting the largest number of products in a simple and efficient way.

For Mozota [14], the word design comes from the Latin "designare", which means to draw or designate. No Inglês, o termo tem dois significados que pode ser intenção, projeto, plano, modelo, motivo, decoração, motivo, composição visual dependendo do contexto. Professional training in Brazil takes place by means of 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 who is in charge of designing systems of visual information, objects and systems of use objects by means of a disciplinary approach, considering the characteristics of the user and his socio-economic-cultural context, as well as the potential and economic and technological limitations of the productive units in which the information systems and objects of use will be produced [15].

According to Fascioni [13], in design thinking, ergonomics plays a fundamental role in the development of new products, and ergonomics is the Science which studies the behavior of man by means of his workplace, and bionics is also taken into account, which is the science that studies living systems in order to create new techniques and technological principles, it is also necessary to consider proxemics, which is the science that studies the theories and observations of human beings in their environment, besides the techniques of product development and lighting in the process.

III. METHODOLOGY

The development of this product project is based on Baxter's methodology [16], which proposes that the product development process is characterized by visual aspects, prototypes, market needs, ecological concern, reliability and cost reduction. It aims to integrate marketing points of view with engineering, as well as the identification and satisfaction of consumer needs. Therefore, the search for four steps in product development are:

- Preliminary ideas: generating ideas;

- Specifications: define opportunities and specify the project;
- Configurations: run tests, analyze change alternatives, structural calculation, material analysis, manufacturing process and adjustments;
- Production: detailing of product process, elaboration of technical drawing of a product ready for production.

Product design

The project setup starts with the chosen concept and ends with the prototype developed and tested. The proposal for the new product must start with the generation of ideas, in which all possible forms of manufacturing are explored. For the generation of ideas, Baxter [16] defines elements for the creative process:

- Thinking only about ideas: forgetting practical restrictions;
- Look for ideas outside the normal problem domain.

Baxter [16] suggests using techniques for problem reduction, problem expansion and problem digression, such as function analysis, morphological analysis, analogies and metaphors, clichés and proverbs.

In the technique of developing Metal Rack, several Sketchings were made, to start the creative process for the elaboration of the prototype. After an idea formed, a drawing was created in AutoCAD 2016® which develops a 2D drawing to visually aid the perspectives of the project.

The activities were carried out in the Materials, Modeling and Textures Laboratory "Prof. Wilson Kindlein Junior" at UNIFATEA, Figure 2.

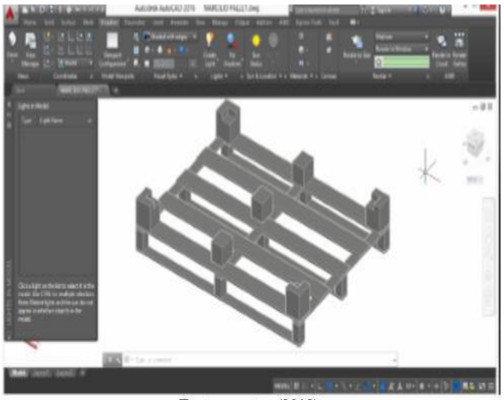

Fig.2: AutoCAD 2016 interface.

Source: The authors (2018).

A mark-up was developed using the 3D printer in the laboratory which used the Cliever Lab (pro) software on X, Y and Z axes.

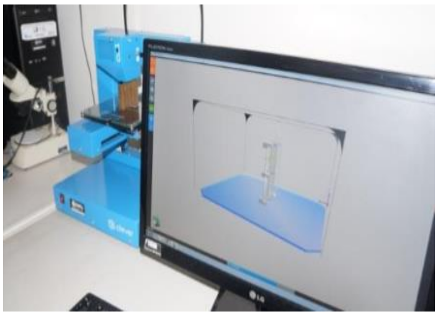

Fig.3: Software Cliever Lab (pro).

Source: The authors (2018).

To develop the mark-up, a 3D printer of the Cliever® model was used in order to establish a pre-project view in relation to ergonomics, shape, geometry, interchangeability, usability and the arrangement of the tooling on a reduced scale.

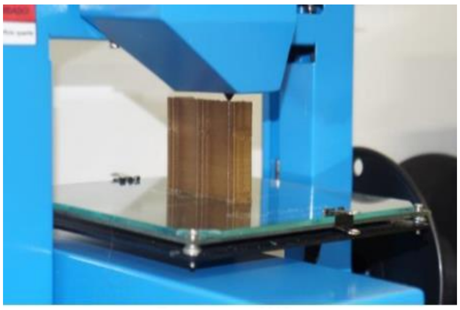

Fig.4: 3D Printer Cliever.

Source: The authors (2018).

IV. RESULTS AND DISCUSSION

Economic and Technical Feasibility

The wooden pallet exchange time is approximately 6 months, the average cost of wooden pallets is US$ 10.00 (ten dollars), totaling an annual cost of US$ 20.00 (twenty dollars). The Cost of Metallic Rack in steel 1020 is approximately US$40.00 (forty dollars), this value was defined by adding the value of the steel that was made available from the partner company and also the value of labor in the manufacture of the Metal rack.

With the use of the wooden pallet for 3 (three) years, the company accounts for an expense of US$59.00 (fifty nine dollars) and the cost of the wooden pallet was higher than the one of the metallic rack. It is noted that the metal rack can have a useful life of approximately 15 years, with proper maintenance and the partner company will have a cost reduction in the amount of US$293.00 (two hundred and ninety-three dollars) in this period.

Chart 02: Comparativo de custos

MATERIAIS	1 ano	15 anos
Pallet	R$ 104,00	R$ 1.560,00
Rack aço AISI 1020-sucata	R$ 206,00	**

Source: The authors (2018).

The partner company has approximately 1,000 (one thousand) tools. This information gives the company a cost reduction of approximately US$292,135.00 (two hundred and ninety two thousand one hundred and thirty-five dollars) already accounted for, in this amount, the value of the metallic rack. Costs indexed to the steel rack construction factor represent the manufacturing cost and direct labor of the company, Chart 3.

Chart 3: Development costs with reused material AISI 1020

LISTA DE MATERIAL

				DIMENSÕES						
ITEM	DENOMINAÇÃO	QUANTIDADE	MATERIAL	ESPESSURA	LARGURA	ALTURA	COMPRIMENTO	PESO	R$/KG	VALOR R$
1	VIGA LONGITUDINAL	3	SAE 1020	3	45	76	1300	18,55	R$ 0,80	R$ 14,84
2	VIGA TRANSVERSAL	6	SAE 1020	3	45	76	1080	30,83	R$ 0,80	R$ 24,66
3	VIGA DE REFORÇO	3	SAE 1020	3	45	76	1080	15,41	R$ 0,80	R$ 12,33
4	PLACA DE FECHAMENTO	24	SAE 1020	3	37	-	74	1,55	R$ 2,20	R$ 3,40
5	ALÇA	6	SAE 1020	8	37	-	447	6,23	R$ 2,20	R$ 13,71
								72,57		R$ 68,95

CUSTO DE FABRICAÇÃO

ITEM	OPERAÇÃO	TEMPO "h"	Valor hora maquina	Valor hora homem	Valor Operação
1	DESMONTAR 03 RACKS (SUCATA)	1	-	R$ 22,73	R$ 22,73
2	CORTAR VIGAS NA MEDIDA	1	-	R$ 22,73	R$ 22,73
3	DESEMPENAR VIGAS	1,5	-	R$ 22,73	R$ 34,09
4	CORTAR PLACA DE FECHAMENTO E ALÇA (TESOURA)	0,25	R$ 75,00	-	R$ 18,75
5	MONTAR PALLET	1	-	R$ 22,73	R$ 22,73
6	SOLDAR PALLET	1	-	R$ 22,73	R$ 22,73
					R$ 143,75
				VALOR TOTAL	R$ 212,70

Source: The authors (2018).

Microstructural characterization of material used in construction of metallic rack

For microstructural characterization, the optical microscopy technique was used, it was observed that micrographs with a magnitude of 500x in AISI 1020 steel show, in the light regions, the presence of ferrite, and in the dark regions, the presence of perlite in its grain contour.

These micro-constituents translate, to the material and structure of the Rack, ease in workability, in the manufacturing process and in ductility.

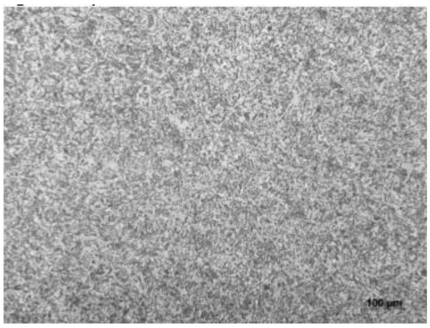

Fig.5: AISI 1020 Carbon Steel with Nital, 500x

Source: The authors (2018)

Product Design and Metallic Rack Design

In the Rack development process, the dimensional of the tooling was analyzed, in which it has a length of 1300 mm, width 1100 mm and height 215 mm.

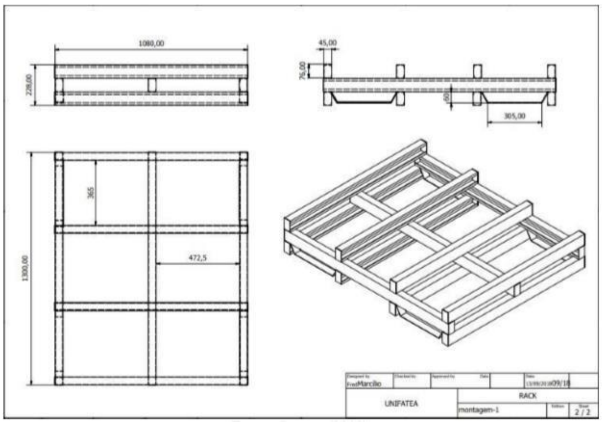

Fig.6 - Technical drawing of metallic rack.

Source: The authors (2018).

The metallic rack was produced from the technical drawing to perform the task analysis and to be tested in a real situation in the factory environment, Figures 7 and 8.

Fig.7 - Finished metal rack in AISI 1020 steel

Source: The authors (2018).

Fig.8 - Metal rack with set of cutting, drilling and bending tools

Source: The authors (2018).

V. CONCLUSION

With this work, the feasibility of storage and logistics systems can be analyzed. For research development, besides the use and bibliographic research with the theoretical foundation of pioneer and contemporary authors in several covered sectors, it is characteristic of this product creation method according to Baxter's methodology.

With the development of the Metal Rack, it was possible to reduce the movement and setup time by around 10 minutes, maximizing production time and removing the bridge from the process, bringing greater convenience to forklift truck drivers and employees who change tooling.

According to results obtained by means of this project, it was raised, in a quantitative way, indices of improvement of productive activities, logistics and warehousing. It can be seen that the company, which is the focus of the study, will be able to maximize productivity and, consequently, its profits, using the storage device, being of the Metallic Rack type, in which, by means of the application of design concept, it provided and improved several aspects which affect production, logistics and the product's value chain.

It is concluded that the objective of this project was achieved, since the model presented, when compared to the current concept of storage devices, presents numerous productive, logistical, occupational, environmental and financial advantages, in which the income from the use of the Rack Metallic impacted great savings for the company. Results were obtained by reducing environmental liabilities, standardizing the tooling storage sector, maximizing setup time and reducing cost estimating.

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