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DESIGN OF CABLE STRIPPING MACHINE AND STATIC ANALYSIS FOR PROCESS IMPROVEMENT

DISEÑO DE MÁQUINA PELADORA DE CABLES Y ANÁLISIS ESTÁTICO PARA MEJORA DE PROCESO

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Design of cable stripping machine and static analysis for process improvement

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ABSTRACT

This article presents the design and static analysis of a copper cable stripping machine to improve recycling processes' efficiency. Currently, copper extraction from electrical cables represents a challenge due to the presence of insulating materials, which limits productivity and generates material losses. This project focuses on developing a mechanized system that replaces the manual process, optimizes time, reduces physical effort, and ensures precise cutting. To achieve this, SolidWorks was used to model and simulate the machine structure, ensuring its mechanical viability through static analysis. Factors such as stresses, displacements, and the safety factor in the blade supports were evaluated, determining that the design is structurally safe with a maximum stress of 29.8 MPa and a safety factor of 18. The results confirm the possibility of improving the design to reduce weight without compromising its integrity. This study represents a breakthrough in copper recycling methods, promoting efficient and sustainable solutions in the applied region.

***Keywords*:** mechanical design, static analysis, safety factor, copper recycling

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Diseño de máquina peladora de cables y análisis estático para mejora de proceso

RESUMEN

Este artículo aborda el diseño y análisis estático de una máquina peladora de cables de cobre, con el objetivo de mejorar la eficiencia en los procesos de reciclaje. Actualmente, la extracción de cobre a partir de cables eléctricos representa un desafío debido a la presencia de materiales aislantes, lo que limita la productividad y genera pérdidas de material. Este trabajo se centra en el desarrollo de un sistema mecanizado que sustituya el proceso manual, optimizando el tiempo, reduciendo el esfuerzo físico y garantizando un corte preciso. Para ello, se utilizó SolidWorks para modelar y simular la estructura de la máquina, asegurando su viabilidad mecánica mediante análisis estático. Se evaluaron factores como esfuerzos, desplazamientos y el factor de seguridad en los soportes de la cuchilla, determinando que el diseño es estructuralmente seguro con un esfuerzo máximo de 29.8 MPa y un factor de seguridad de 18. Los resultados confirman la posibilidad de mejorar el diseño para reducir peso sin comprometer su integridad. Este estudio representa un avance en los métodos del reciclaje de cobre, promoviendo soluciones eficientes y sostenibles en la región aplicada.

***Palabras clave*:** diseño mecánico, análisis estático, factor de seguridad, reciclaje de cobre

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INTRODUCTION

Metal recycling plays a fundamental role in reducing environmental impact and optimizing the use of resources (Nakajima et al., 2014). Copper, a material widely used in the electrical and electronics industry, is one of the most recycled metals due to its high demand and possible reuse without significant loss of properties (Liu et al., 2023). However, the process of recovering copper from electrical cables presents significant challenges due to the presence of insulating materials that must be efficiently removed to maximize metal recovery.

Traditional cable stripping techniques, whether manual or using essential tools, present limitations regarding efficiency, safety, and precision. In the recycling industry, modernizing these processes is key to improving productivity and ensuring optimal copper utilization. The factory Mecánica Hidráulica de Precisión Dos S.A. de C.V., located in Veracruz, Mexico, faces the challenge of improving copper extraction from electrical cables, given that the current technology employed at the plant is based on low-performance manual tools.

This study proposes the computer-aided design and improvement of a copper wire stripping machine that incorporates technological improvements to increase its efficiency, reduce manual effort, and ensure a safer and more precise process. Analyzing current technologies and implementing a mechanized system aims to modernize the recycling process and contribute to the industry's sustainability. The main objective of this article is to design and analyze a wire stripping machine in SolidWorks that will increase process efficiency. To this end, the following key aspects will be addressed:

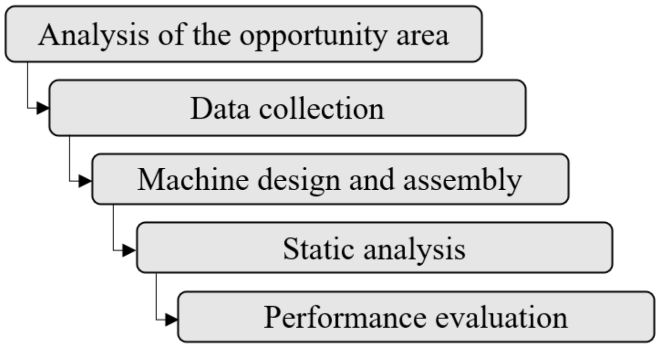
1. **Process automation**. Integrate a motorized system that replaces the manual peeling mechanism, reducing the time and effort required for copper extraction.
2. **Design optimization.** Develop a model that guarantees cutting precision, minimizes material loss, and ensures the quality of recycled copper.
3. **Static analysis**. Perform analysis of the main component, specifically the cutting disc support, to ensure the efficiency of the system's stresses, displacements, and safety factor.
4. **Improved operational safety**. Reduce the risks associated with using hand tools, ensuring safe working conditions for operators.

Various works involving design and stress analysis have been carried out using different approaches. For example, García & Martínez (2019) designed a mechanical transmission for a materials testing machine, performing static analysis to evaluate its structural performance and ability to withstand specific loads. Another relevant work is that of Pérez & Gómez (2022), who achieved satisfactory results by improving the design of an experimental 3D printer, applying static analysis to increase its stability and precision during printing. Likewise, an article shows the design of a machine for tensile and compression testing on materials, applying static analysis to validate its strength and operation under biaxial loads (Rodríguez, 2018). On the other hand, the study by David & Madukauwa (2016), analyzes the mechanical behavior of an innovative composite platform under static loads using numerical simulations. Damage from bolted fasteners in E-glass beams and the impact of embedded optical sensors were evaluated. The results showed damage thresholds and minimal impact on structural rigidity. Finally, Miranda-Molina et al. (2020) developed a CNC mechanical system for machining and 3D printing, evaluating its accuracy and functionality through static and dynamic analysis to ensure its structural performance. Like this proposal, the previous works emphasize the application of mechanical design and static analysis in developing and optimizing various machines and components, guaranteeing their functionality and resistance under operating conditions.

METODOLOGÍA

The methodology combines a technical approach and structural analysis to ensure the proposed solution is viable, efficient, and applicable. The steps are shown in Fig. 1 below.

Figure 1. Methodology proposed for this study



Analysis of the opportunity area

The company where the case study was conducted faces limitations in copper extraction due to manual peeling machines. This process requires significant physical effort, is inefficient, and generates material losses, highlighting the need for an optimized machine to improve productivity and operational safety.

Data collection

The data for this study were collected through direct observation, operator interviews, measurements, and documentary analysis. The objective was to evaluate the efficiency of the manual cable stripping process and inform the design of an optimized machine.

1. **Direct observation of the current process.** Operations were monitored, and the techniques used, the amount of physical effort required, and the speed of the process were documented.
2. **Interviews with operators**. Interviews were conducted with workers who manually operated the peeling machine. Their experiences regarding process difficulties, ergonomic risks, and suggestions for improving the machinery were collected.
3. **Measurement**. At this point, the machine components were measured so they could be modeled in 3D software, assembly, and static analysis.
4. **Document analysis.** Current industrial solutions for cable stripping were investigated, including automated or motorized machines, cutting tools, and safety systems used in the recycling sector.

The detailed analysis of these stages allowed us to establish a solid basis for the design and optimization of the prototype, ensuring that the proposed improvements responded to the real needs of the case study.

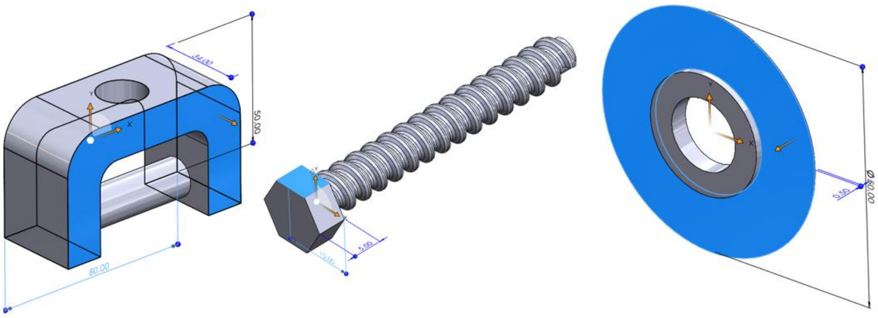
Machine design and assembly

The initial component design was carried out using SolidWorks (SW) as the primary tool. This process allowed for the development of an accurate three-dimensional model, which facilitated the identification of structural and functional improvements. To begin the design in SW, detailed measurements were taken of the existing manual peeling machine. Both the external and internal dimensions were evaluated, ensuring that the digital model represented the actual equipment as accurately as possible (Fig. 2).

Figure 2. Example of manual wire stripping machine head and designed model

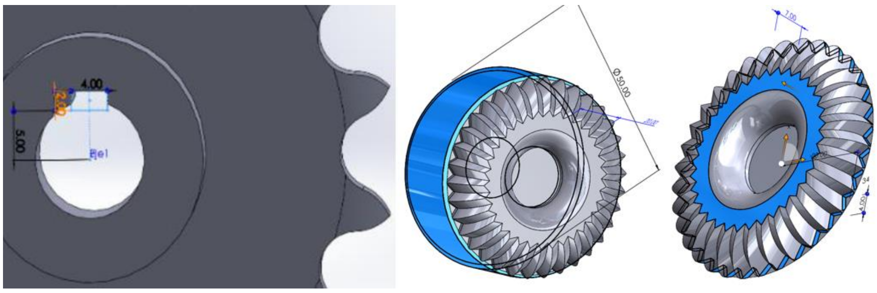
The next step was to model the box containing the internal mechanisms. The blade support was then designed, as shown in Figure 3. The structure had to provide stability and allow the blade to be adjusted to fit different cable diameters.

Figure 3. Modeling of support, motion transmission screw, and cutting disc



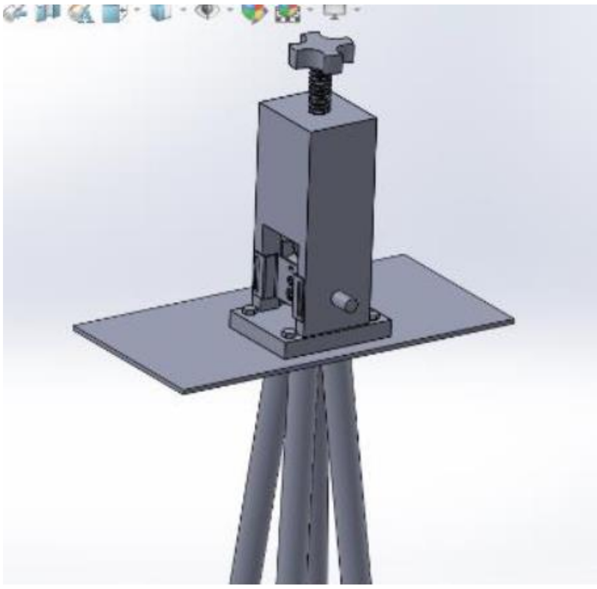
The transmission shaft was modeled, and the gears necessary for the machine's operation were defined (Fig. 4).

Figure 4. Sample pinion design



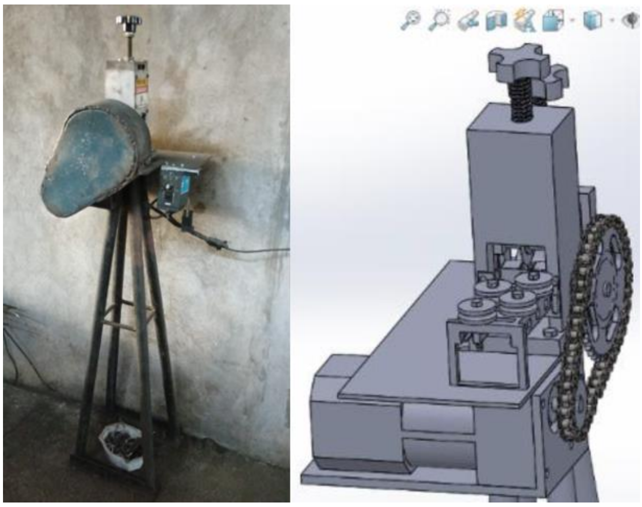
Finally, SW simulations were performed to evaluate the strength of the materials and improve the design. Stresses and deformations at critical points were analyzed to ensure the stability and safety of the equipment.

Figure 5. Design in approximation to the actual machine



In Figure 6, it can be seen that including a motorized system was one of the main improvements of the proposed design.

Figure 6. Real machine vs. Final design with integration of engine and transmission components

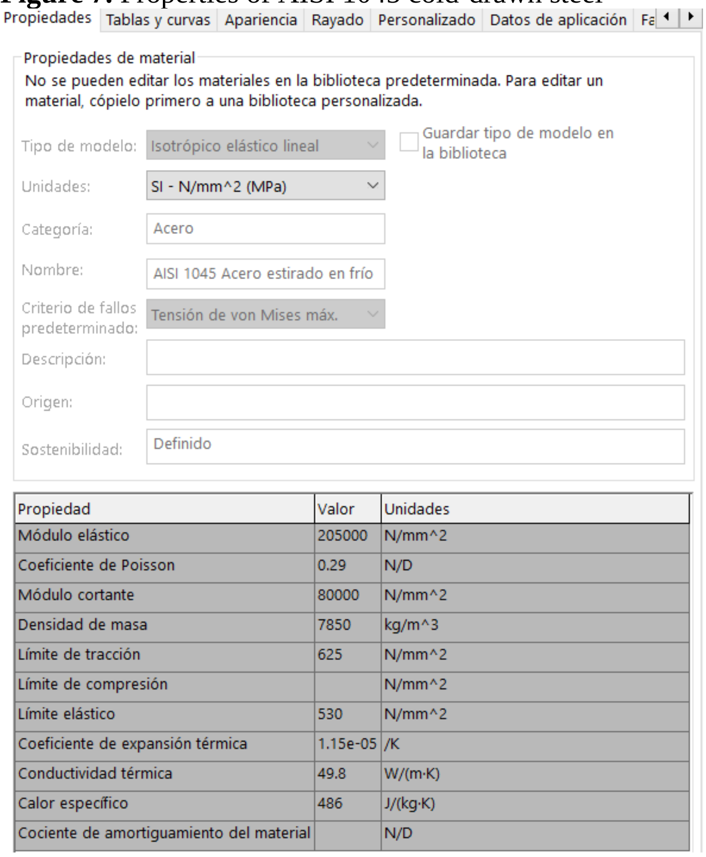


Static analysis and calculation of the safety factor in the blade support

Statics analyzes bodies at rest, evaluating forces and moments to maintain the equilibrium of physical systems. According to Awang (2016), these mechanical component analyses are essential to ensuring the integrity and functionality of mechanical components under specific loads. The shearing blade or shearing system is the mechanical component that receives the most significant stress. This element is responsible for separating the insulating material from the copper conductor and is subjected to high mechanical loads due to the insulation's resistance and the friction generated during the stripping process. For the purposes of this study, a static analysis is performed on the blade supports because they must withstand the pressure exerted during the shearing process and maintain the stability of the mechanism.

The material assigned to the piece for static analysis is AISI 1045 cold-drawn steel, which provides greater mechanical strength, better precision, and a better surface finish than its hot-rolled version (TYASA, 2024). In addition, it allows the supports to maintain their structural stability, reducing premature wear and ensuring a longer component lifespan. Figure 7 shows the material data as shown by SW.

Figure 7. Properties of AISI 1045 cold-drawn steel



Propiedad	Valor	Unidades
Módulo elástico	205000	N/mm^2
Coeficiente de Poisson	0.29	N/D
Módulo cortante	80000	N/mm^2
Densidad de masa	7850	kg/m^3
Límite de tracción	625	N/mm^2
Límite de compresión		N/mm^2
Límite elástico	530	N/mm^2
Coeficiente de expansión térmica	1.15e-05	/K
Conductividad térmica	49.8	W/(m·K)
Calor específico	486	J/(kg·K)
Cociente de amortiguamiento del material		N/D

Friction-free contact is created between the lower surfaces of the part, which is connected to the flat base of the head. To achieve this, the fixture is created under the standard conditions. The workpiece clamps are then finalized at the bottom, where the blade force is set. This is the proper way to constrain the part to represent the real system best and obtain reliable results.

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To estimate the load in Newtons (Kilograms-force, Kgf) that the blade supports receive, the cable diameter, the insulation resistance, and the approximate shear force are considered. Using (1), the blade contact area is calculated:

$$A = \pi * d * t$$

where $d =$ cable diameter and $t = 2$ mm represents the estimated thickness of the insulation.

$$A = \pi * 18 * 2 = 113.09 \text{ mm}^2$$

Force required considering τ for PVC ($\tau \approx 8$ N/mm²):

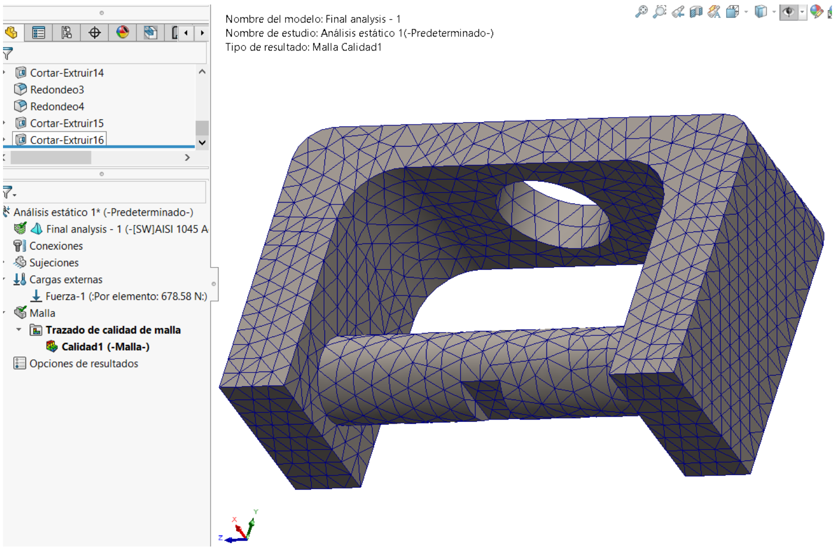
$$F = 18 * 113.09 = 2035.76\ N$$

Regarding the load transmitted to the blade supports and if we consider that the supports distribute the load on three support points, each support will receive approximately:

$$Dis = \frac{402.12}{3} = 678.58\ N$$

The meshing, also known as discretization, involves dividing a problem into more minor, more manageable finite elements, which can be used to model complex shapes and behaviors (Ziolkowski, 2017). For this study, the standard mesh recommended by SolidWorks for the part was selected (Fig. 8).

Figure 8. Standard mesh generation



RESULTS, CONCLUSIONS AND DISCUSSION

According to Pal et al. (2023), stress analysis in mechanical components allows for detecting potential failure zones by evaluating how stresses are distributed and concentrated. This analysis is essential for avoiding structural failures that could have consequences.

Figure 9. von Mises stress analysis, Mpa

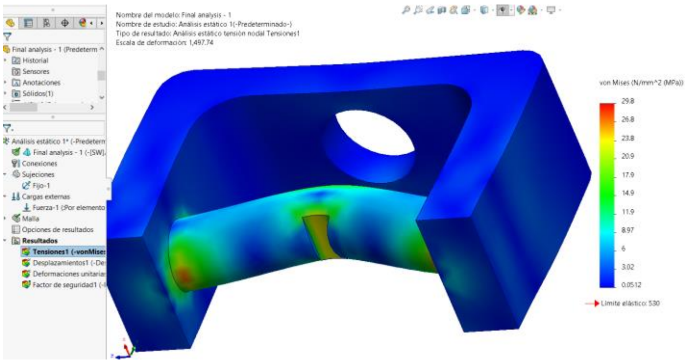
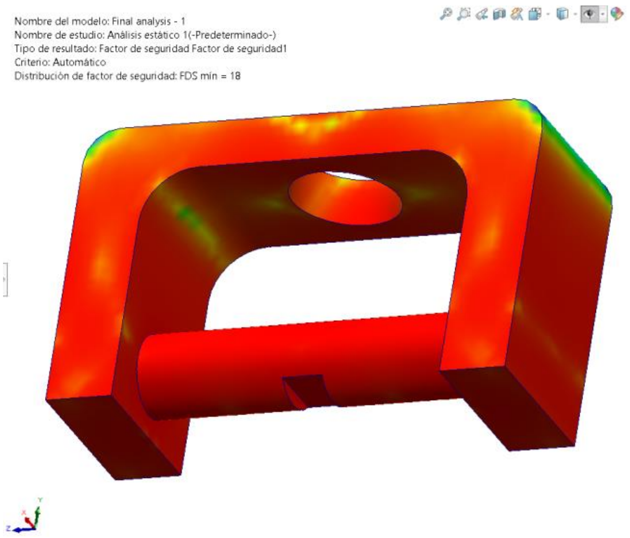


Figure 9 details the applied stress analysis confirming that the blade support is structurally safe and strong, with a maximum stress of 29.8 MPa, which is well below the yield strength of the material (530 MPa). However, the design can be optimized to reduce weight and improve efficiency without compromising its mechanical integrity. It is important to note that Figure 9 shows the software's automatic animation, but the actual animation barely shows the stresses generated by the applied forces. The factor of safety (SF) is a crucial parameter to ensure the structural integrity and reliability of engineering designs. It quantifies the margin of safety by comparing the actual stress or load with the maximum allowable stress or load (Dyson & Tolooiyan, 2018).

Figure 10. Estimation of the safety factor



Finally, the analysis in Figure 10 shows that the blade support is highly safe, with a minimum SF of 18, meaning there is no risk of failure under current conditions. However, due to its oversizing, the design can be optimized to reduce weight without compromising structural safety.

A copper wire stripping machine's design and static analysis demonstrate the feasibility of optimizing the recycling process through a more efficient and safer mechanized system. Using SolidWorks allowed us to evaluate the structural strength and stress distribution, ensuring the stability of the mechanism. The results confirm that the blade support, made of AISI 1045 steel, offers adequate strength, with a maximum stress of 29.8 MPa, well below the material's yield strength. Furthermore, the minimum safety factor of 18 suggests an opportunity for optimization to reduce weight without compromising structural integrity. This study highlights the importance of static analysis in industrial equipment design and its role in improving recycling processes, contributing to operational efficiency and environmental sustainability. Future studies could include dynamic analysis and experimental testing to optimize the structure further and evaluate its behavior under long-term use.

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BIBLIOGRAPHIC REFERENCES

Awang, M., Mohammadpour, E., & Muhammad, I. D. (2016). *Non-linear finite element analysis of nanotubes*. In *Engineering Materials* (pp. 107-131). Springer Science and Business Media B.V. https://doi.org/10.1007/978-3-319-03197-2_6

David Madukauwa-David, I., & Drissi-Habti, M. (2016). Numerical simulation of the mechanical behavior of a large smart composite platform under static loads. *Composites Part B: Engineering, 88*, 19-25. https://doi.org/10.1016/j.compositesb.2015.10.041

Dyson, A. P., & Tolooiyan, A. (2018). Optimisation of strength reduction finite element method codes for slope stability analysis. *Innovative Infrastructure Solutions, 3*(1), 38. https://doi.org/10.1007/s41062-018-0148-1

García, P., & Martínez, L. (2019). Diseño y análisis de transmisión mecánica para máquina de ensayos de materiales. *Memorias de la SOMIM 2019*, 43.

Khoshgoftar, M. J., & Abbaszadeh, H. (2021). Experimental and finite element analysis of the effect of geometrical parameters on the mechanical behavior of auxetic cellular structure under static load. *Journal of Strain Analysis for Engineering Design, 56*(3), 131–138. https://doi.org/10.1177/0309324720957573

Liu, L., Zhang, L., Jiang, S., Yuan, Z., & Chen, J. (2023). Global copper cycles in the anthroposphere since the 1960s. *Resources, Conservation and Recycling, 199*, 107294. https://doi.org/10.1016/j.resconrec.2023.107294

Miranda-Molina, L., Quinayas-Ortiz, A., & Peña-Rodríguez, G. (2020). Diseño y simulación de un sistema mecánico para el mecanizado de piezas e impresión en 3D (x, y, z). *Revista UIS Ingenierías, 19*(4), 115–122.

Nakajima, K., Otsuka, Y., Iwatsuki, Y., Nansai, K., Yamano, H., Matsubae, K., Murakami, S., & Nagasaka, T. (2014). Global supply chain analysis of nickel: Importance and possibility of controlling the resource logistics. *Metallurgical Research and Technology, 111*(6), 339-346. https://doi.org/10.1051/metal/2014036

Pal, R., Mitra, S., Rahul, & Kanaujia, N. (2023). Modelling and stress analysis of connecting rod using Fusion 360. En R. Sharma, R. Kannojiya, N. Garg, & S. S. Gautam (Eds.), *Lecture Notes in Mechanical Engineering* (pp. 235-247). Springer Science and Business Media Deutschland GmbH. https://doi.org/10.1007/978-981-99-3033-3_21

Pérez, J., & Gómez, M. (2022). Diseño mecánico para optimización de una impresora 3D CNC de tipo experimental. Revista de Ingeniería Mecánica, 35(2), 45–53.

Rodríguez, J. (2018). Diseño mecánico de una máquina de tracción y compresión biaxial. [Tesis de maestría, Universidad de Sevilla].

TYASA. (2024). *Ficha técnica: Acero SAE-AISI 1045 pelado y pulido*. Talleres y Aceros S.A. de C.V. Recuperado de https://www.tyasa.com

Ziolkowski, P. (2017). Processing of point cloud data retrieved from terrestrial laser scanning for structural modeling by finite element method. International Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management, SGEM, 17(23), 211-218. https://doi.org/10.5593/sgem2017/23/S10.026