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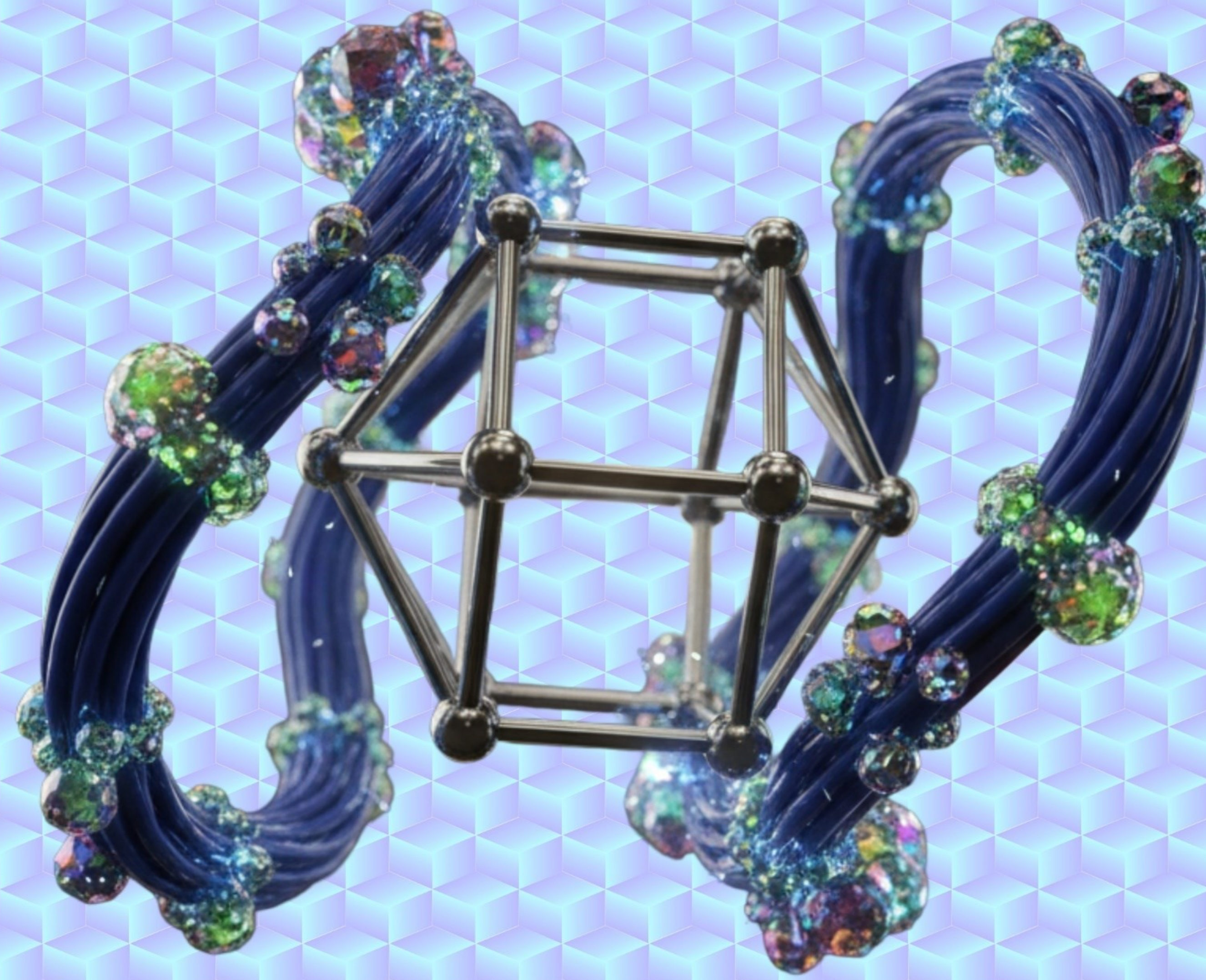

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Ecodesign of a Bar Transfer Equipment that Reduces the Environmental Impact at the Tenaris Tamsa Company in Veracruz

Dr. Vicente M. Diaz de Leon Santiago
Technological Institute of Veracruz
vicente.ds@veracruz.tecnm.mx
https://orcid.org/0009-0002-3689-1135

PhD. Alfredo Gutiérrez García
IECCMEXICO
ingalfredogutierrezgarcia@gmail.com
https://orcid.org/0000-0002-8197-8144

Juan Manuel Bucio Ballado
Technological Institute of Veracruz
juan.bb@veracruz.tecnm.mx
https://orcid.org/0009-0001-8701-2113

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*** Corresponding Author:** *vicente.ds@veracruz.tecnm.mx*

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ABSTRACT

This article presents the eco-design of a bar-type load transfer system for Tenaris TAMSA in Veracruz, Mexico, with the aim of reducing the environmental impact associated with the use of conventional hydraulic systems. The project, developed in collaboration between faculty and researchers from the Veracruz Institute of Technology and mechanical and mechatronics engineering students, proposes replacing the hydraulic actuators with an electromechanical system based on a four-bar crank-connecting-rod-rocker mechanism. The methodology employed included analyzing the existing system, generating design alternatives using CAD tools (SolidWorks and AutoCAD), applying the Brodell and Soni graphical synthesis method for kinematic dimensioning, and selecting a commercially available geared motor (Nord brand model SK9086.1/52-160MP/4 TW). The results demonstrate the technical feasibility of replacing the hydraulic system with an electromechanical one, achieving a significant reduction in the risk of oil spills, lower maintenance costs, greater reliability, and improved process sustainability. This proposal not only optimizes the operational performance of the equipment on the FAT-2 production line but also represents a successful application of ecodesign in the metalworking industry, aligned with the principles of the circular economy and environmental responsibility.

KEYWORDS

System analysis and design; Design engineering; Computer integrated manufacturing; Mechanical factors; Mechanical systems; Mechanical engineering; Environmental factors; Manufacturing processes.

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INTRODUCTION

Ecodesign has become a fundamental strategy in modern engineering for addressing the environmental challenges associated with industrial processes. This philosophy promotes the development of products and systems that, from their inception, minimize environmental impact throughout their entire life cycle, integrating criteria for sustainability, energy efficiency, and waste reduction [1]. In this context, the metalworking industry faces significant challenges stemming from the use of traditional hydraulic systems, whose maintenance involves risks of oil spills, high operating costs, and a considerable ecological footprint.

In September 2021, Tenaris TAMSA, located in Veracruz, Mexico, established a collaboration with the Veracruz Institute of Technology (TecNM) to develop a short-term improvement project (four months) focused on optimizing a critical piece of equipment on its production line: the bar load transfer system at the FAT-2 facility. The original system, based on four hydraulic cylinders acting on unloading cams, presented recurring problems related to hydraulic fluid leaks, intensive maintenance, and low operational reliability. Due to pandemic restrictions, the entire project was developed remotely, based on technical drawings, specifications provided by the company's Maintenance Director , Darío Chávez Gutiérrez, and the support of digital collaboration tools.

This work addresses the ecological redesign (ecodesign) of the transfer system by replacing the hydraulic system with an electromechanical alternative, aligned with the principles of the circular economy and industrial environmental responsibility. The participation of mechanical and mechatronics engineering students, guided by research professors, not only generated a viable technical solution but also strengthened university-industry collaboration and enriched professional training through the practical application of theoretical knowledge.

DEVELOPMENT

The eco-design of the bar load transfer system at Tenaris TAMSA represents a comprehensive approach to transforming a conventional industrial system (based on hydraulic technology) into a more sustainable, efficient, and environmentally responsible alternative. The core problem stems from the use of four hydraulic cylinders acting on discharge cams to transfer approximately 3.5 tons of steel bars to a roller conveyor. While functional, this system presents several operational and environmental disadvantages: recurring hydraulic oil leaks, costly maintenance, low reliability, and the risk of soil and industrial environment contamination.

Faced with this scenario, the research team proposed two redesign alternatives: (1) the direct replacement of the hydraulic cylinders with electromechanical linear actuators, and (2) the implementation of a four-bar linkage mechanism of the crank-connecting rod-rocker type driven by a geared motor. After a technical, economic, and environmental analysis, the second option was selected due to its greater compatibility with the existing infrastructure, its mechanical simplicity, and its potential for reusing current components, such as the already installed rocker arm.

The technical development of the mechanism was based on the Brodell and Soni graphical synthesis method, a recognized approach in the kinematics of planar mechanisms, implemented using SolidWorks modeling. This approach allowed for the dimensioning of the mechanism's links (crank, connecting rod, and rocker arm) to achieve the required range of motion, ensuring efficient power transmission from the gearmotor shaft to the cam system. It was verified that the available space in the FAT-2 facility allowed for the integration of the new system without significant structural alterations.

Additionally, the most suitable commercial gearmotor was selected, considering torque, speed, service factor, and compatibility with the industrial environment. The chosen model was the Nord SK9086.1/52-160MP/4 TW, which guarantees continuous operation, low maintenance, and high energy efficiency. This choice reinforces sustainability objectives by completely eliminating the need for hydraulic fluids, reducing the equipment's environmental footprint, and improving its operational reliability.

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The use of CAD tools (SolidWorks and AutoCAD) not only facilitated the visualization and validation of the design, but also allowed for the simulation of near-realistic operating conditions, accelerating the decision-making process and reducing risks during the implementation phase. This methodological approach demonstrates how ecodesign, supported by digital technologies, can generate innovative solutions that align industrial productivity with environmental responsibility.

GENERAL OBJECTIVE AND SPECIFIC OBJECTIVES

General Objective

To propose an ecological design for the bar transfer system in the FAT-2 line of the company Tenaris TAMSA , replacing the hydraulic actuators with an electromechanical mechanism that reduces the environmental impact, improves operational reliability and decreases maintenance costs.

Specific Objectives

- Technically evaluate the current hydraulic system of the bar load transfer system to identify its operational and environmental limitations.
- Propose design alternatives based on electromechanical technologies that meet the functional requirements of the original equipment.
- Select and dimension a four-bar crank-connecting rod-rocker mechanism using kinematic synthesis techniques (Brodell and Soni graphical method).
- Integrate a commercial gearmotor (model SK9086.1/52-160MP/4 TW from Nord) as the power source for the new system.
- Validate the proposed design through modeling and simulation in CAD environments (SolidWorks and AutoCAD), ensuring compatibility with the existing infrastructure.
- To contribute to the comprehensive training of mechanical and mechatronics engineering students through their active participation in a university-business linkage project with a focus on sustainability.

OBJECT OF STUDY

The subject of this research is the bar transfer system on the FAT-2 production line at Tenaris TAMSA , specifically the mechanism responsible for actuating the unloading cams that transfer approximately 3.5-ton steel bars to a roller conveyor for subsequent heating. This system, originally operated by four hydraulic cylinders (two on the east side and two on the west side), is a critical unit whose operation impacts both the efficiency of the production process and the environmental performance of the plant.

The study focuses on the ecological redesign (ecodesign) of this system, with an emphasis on replacing the hydraulic actuators with an electromechanical alternative based on a four-bar linkage mechanism (crank-connecting rod-rocker arm) coupled to a geared motor. This approach allows for the analysis not only of the equipment's technical and functional aspects, but also its environmental, economic, and maintenance implications within a real-world industrial context.

METHODOLOGY

For the development of the eco-design of the busbar load transfer system at Tenaris TAMSA, the Process-Based Methodology was applied. This approach allows for structuring the engineering work into sequential and coherent stages, aligned with the project objectives and the limitations of the industrial environment. This methodology facilitates the identification, analysis, redesign, and validation of technical solutions in real-world contexts, ensuring traceability, replicability, and a focus on continuous improvement.

The process was carried out remotely between September 2021 and November 2022, in coordination with the Maintenance Director of Tenaris TAMSA, Darío Chávez Gutiérrez, and with the support of digital collaboration tools (Microsoft Teams). The basic technical information (plans, operational specifications, and spatial constraints) was provided by the company, which allowed working with real data from the existing system.

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The main tools used were:

SolidWorks and AutoCAD, for three-dimensional modeling, kinematic analysis and graphical representation of the proposed design.
Brodell and Soni 's graphical synthesis method, for dimensioning the links of the four-bar mechanism (crank-connecting rod-rocker arm).
Technical catalogs from manufacturers, especially the Nord brand, for the selection of the appropriate commercial gearmotor (model SK9086.1/52-160MP/4 TW), considering torque, speed, service factor and environmental compatibility.
The methodology allowed for a comparison of two redesign alternatives: (1) electromechanical linear actuators and (2) a four-bar linkage with a geared motor. After a technical and functional evaluation, the second option was selected due to its simplicity, reuse of existing components (such as the rocker arm), and lower environmental impact.

This methodological approach ensures that any researcher or engineer can replicate the process in similar industrial contexts, since the selection criteria, the tools used, and the design parameters were clearly documented.

PHASES OF DEVELOPMENT

In accordance with the Process-Based Methodology adopted in this study, the development of the ecodesign of the busbar load transfer device was structured in the following sequential phases, each aligned with the principles of ecological design and the objectives of the project:

1. Identification and characterization of the problem

The process began with the collection of information provided by Tenaris TAMSA, including technical drawings, specifications of the current system, and an operational description of the transfer switch on the FAT-2 line. It was determined that the original system, based on four hydraulic cylinders, resulted in oil leaks, costly maintenance, low reliability, and environmental risks. This phase was conducted entirely remotely through virtual meetings with the Maintenance Director, Darío Chávez Gutiérrez.

Figure 1
Photograph of the real model to be optimized

Note: A photograph of the current state of the system is shown. Source: Tenaris TAMSA, 2022.

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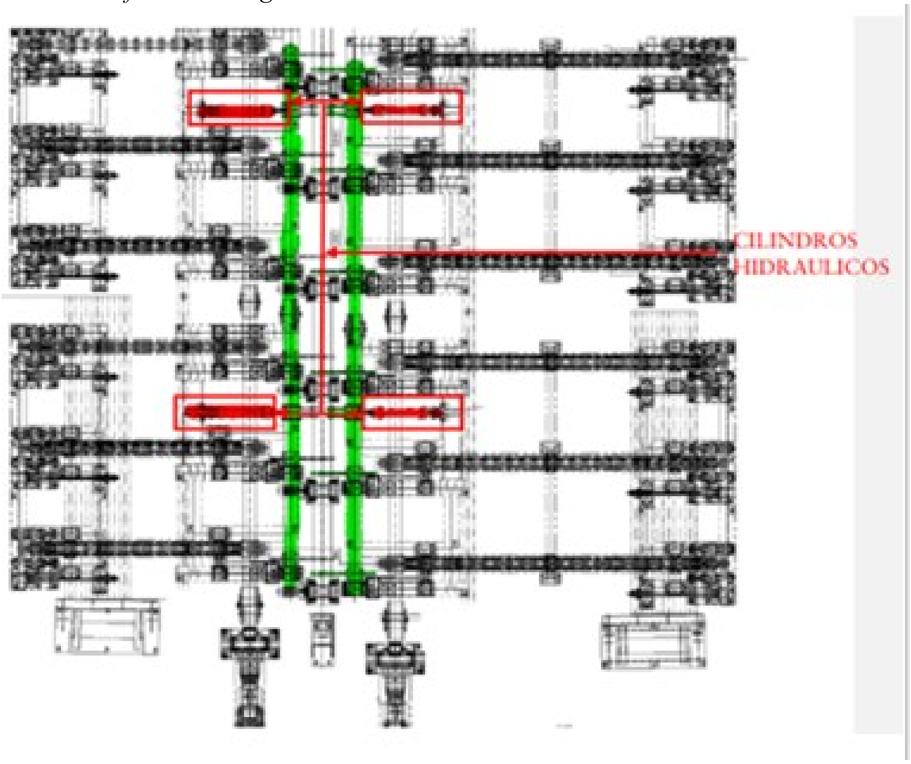
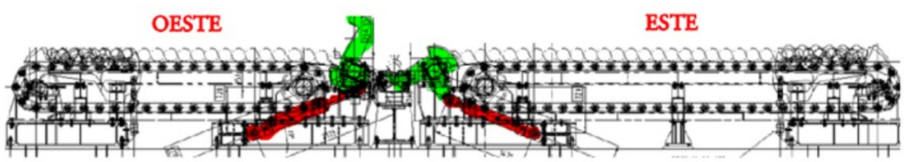
Figure 2
Plan view of the discharge bar cams.



Note: The plan view of the bar discharge cam area is shown. The actuator system (cam-bar) is shown in green, and each hydraulic actuator (system to be modified) is shown in red. Source: Tenaris TAMSA, 2022.

2. Generation of alternative solutions
The working group, made up of professors and students of mechanical and mechatronics engineering, proposed two technical alternatives:

Alternative A: Direct replacement by electromechanical linear actuators.
Figure 3
Side view of the bar discharge cams.



Note: The side view of the bar discharge cam area is shown; the actuator system (cam-bar) is shown in green, and each hydraulic actuator (system to be modified) is shown in red. Source: Tenaris TAMSA, 2022.

Figure 4.
Electromechanical actuator proposal.

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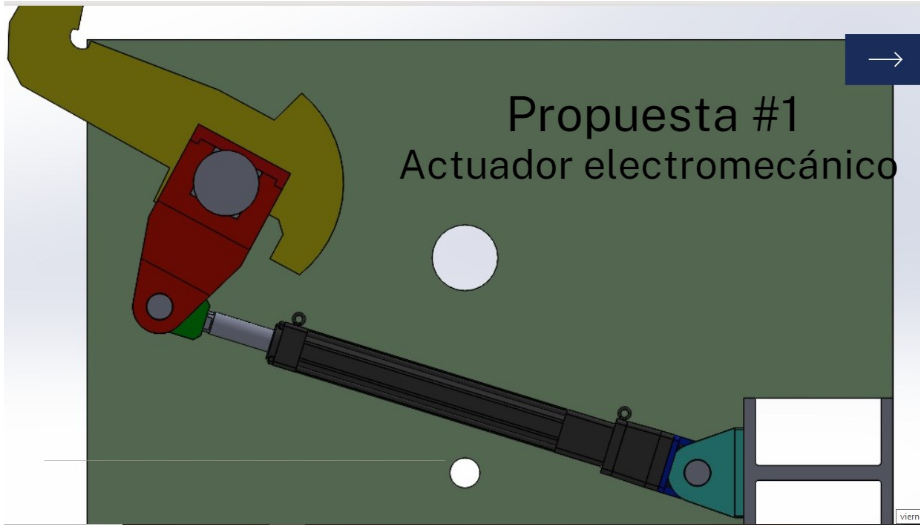
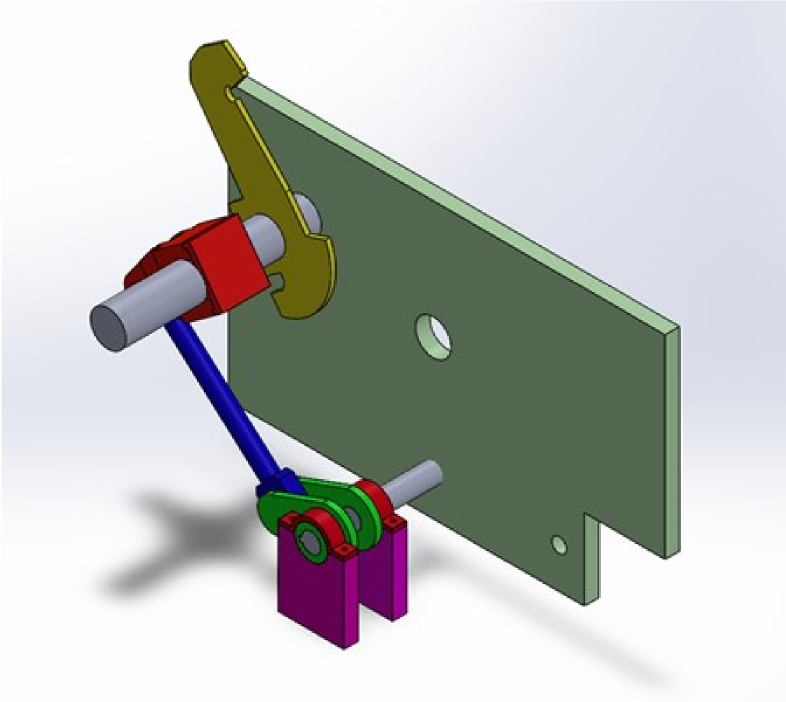


Note: Proposal #1 for an electromechanical linear actuator with electrical drive, designed in SolidWorks, is shown. Source: Author's own work.

Alternative B: Implementation of a four-bar crank-connecting rod-rocker mechanism driven by a geared motor.

Figure 5
second proposal design



Note: Proposal #2 for an electromechanical linear actuator with electric drive, designed in SolidWorks, is shown. Source: Author's own work.

Both options eliminated the use of hydraulic fluids, but were evaluated based on technical feasibility, cost, compatibility with existing infrastructure and potential for component reuse.

3. Selection and analysis of the optimal solution

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Following a comparative evaluation, Alternative B (four-bar linkage) was selected due to its mechanical simplicity, lower integration complexity, the possibility of reusing the existing rocker arm, and greater energy efficiency. It was verified that the available physical space in the plant allowed for the installation of the new system without major structural modifications.

4. Detailed design of the electromechanical system

Brodell and Soni graphical synthesis method was applied to dimension the mechanism's links (crank, connecting rod, and rocker arm). This process was carried out in the SolidWorks CAD environment, allowing for a precise graphical approximation of the required movement. Simultaneously, a commercial gearmotor (Nord brand model SK9086.1/52-160MP/4 TW) was selected that met the torque, speed, and service factor requirements for the approximately 3.5-ton load.

Table 1

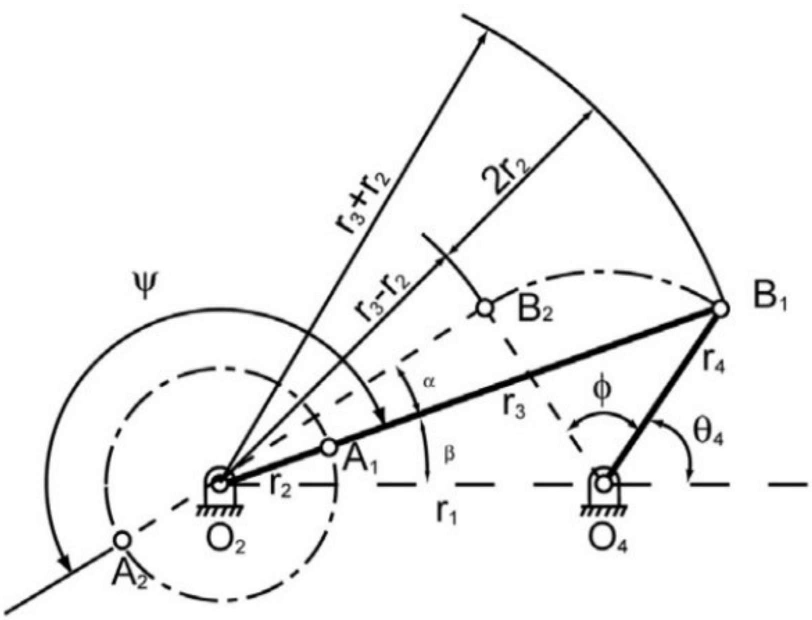
Model features SK9086.1/52-160MP/4 TW

Indicator	Equivalence
Power	15 hp
Output speed	4.1 – 7.5 rpm
Output pair	126063 – 231549 lb-in
Weight	2159 lb

Note: The specifications shown are for the Nord brand model SK9086.1/52-160MP/4 TW. Source: Nord Gear Motors sf

Figure 6.

Brodell and Soni graphical synthesis method



Note: The procedure used in the kinematic synthesis of mechanisms is shown, specifically for designing a four-bar crank-rocker (or crank-oscillator) mechanism that meets a unit time ratio and a specific rocker oscillation angle. Source: University of A Coruña, n.d.

5. Modeling, simulation and validation

A complete virtual assembly of the proposed system was generated in SolidWorks and AutoCAD. Kinematic compatibility, component interference, and mechanism functionality were verified under simulated operating conditions. This phase allowed for anticipating potential adjustments before physical implementation, reducing risks and costs.

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6. Documentation and preparation for implementation

The necessary technical documentation for the manufacture and installation of the new system was prepared, including detailed drawings, a bill of materials, and gearmotor specifications. The project was completed in November 2022 and is ready for commissioning at the Tenaris TAMSA plant, with a clear focus on sustainability, efficiency, and the professional development of the students involved.

RESULTS AND DISCUSSION

The project successfully developed a viable and environmentally responsible technical solution by redesigning the busbar transfer system on Tenaris TAMSA 's FAT-2 line. The most relevant results are summarized below:

Validation of the four-bar linkage:
A crank-connecting rod-rocker mechanism was successfully implemented, transmitting power from a geared motor to the discharge cam system. This design allows for the reuse of the existing rocker arm, minimizing structural modifications and adaptation costs. The geared motor's complete rotation efficiently translates into the oscillating motion required to actuate the cams, fulfilling the hydraulic system's original function.
Dimensioning using graphical synthesis:
Using the graphical method of Brodell and Soni, the appropriate link lengths for the mechanism were determined in the SolidWorks modeling environment (Figure 6). This approach allowed for a quick and visual approach to kinematic design, avoiding complex calculations in the initial stages and facilitating collaborative iterations between teachers and students.
Selection of the electromechanical drive:
The Nord SK9086.1/52-160MP/4 TW gearmotor was selected, meeting the torque, speed, and service factor requirements for a load of approximately 3.5 tons. This choice completely eliminates the need for hydraulic fluids, significantly reducing the risk of spills, the generation of hazardous waste, and the costs associated with preventive and corrective maintenance.
Virtual modeling and simulation:
The use of SolidWorks and AutoCAD allowed for the virtual assembly of all components (Figure 5), verification of the absence of mechanical interference, and validation of the system's functionality under simulated operating conditions. This stage was crucial for making informed decisions without the need for physical prototypes, accelerating the development process in a remote work environment.
Discussion
The proposed solution aligns with ecodesign principles, as it not only resolves an operational problem but also reduces environmental impact by eliminating the use of hydraulic oil. Compared to the alternative of electromechanical linear actuators (Figure 4), the four-bar linkage proved more suitable due to its simplicity, robustness, and compatibility with the existing infrastructure—a finding consistent with previous studies highlighting the efficiency of articulated mechanisms in high-load industrial applications [1], [2].

Furthermore, this case demonstrates how university-industry partnerships can generate high-value technical and educational solutions. The participation of engineering students in a real-world problem strengthens their professional competence, while simultaneously offering industry an innovative alternative with clear economic and environmental benefits.

Although detailed stress calculations, material selection, and fatigue analysis are not included in this article (these are reserved for a future publication), the preliminary results are sufficient to affirm the technical and sustainable feasibility of the proposed design.

CONCLUSION

The eco-design of the bar load transfer system for Tenaris TAMSA represents a significant contribution from both a technical and environmental perspective. Replacing the original hydraulic system with an electromechanical mechanism based on a four-bar crank-connecting rod-rocker system, driven by a commercial gearmotor (Nord model SK9086.1/52-160MP/4 TW), achieves the stated objectives: eliminating the use of hydraulic oil, reducing

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environmental impact, lowering maintenance costs, and improving the operational reliability of the equipment on the FAT-2 line.

This redesign not only solves a real industrial problem, but also demonstrates the feasibility of applying sustainability and circular economy principles in contexts with high mechanical demands, such as the steel industry. Furthermore, the use of digital tools like SolidWorks and AutoCAD allowed for the remote development, validation, and optimization of the solution, under the restrictions imposed by the pandemic, reinforcing the value of digital methodologies in modern engineering.

From an academic perspective, the project strengthened university-industry partnerships and provided mechanical and mechatronics engineering students with an authentic learning experience aligned with the challenges of the industrial sector. The system's implementation in November 2022 marked a milestone in the transition to cleaner and more efficient processes at the Veracruz plant.

Future work includes the detailed publication of material strength calculations, structural profile selection, kinematic and dynamic analysis, and field tests of the implemented system. These steps will consolidate the knowledge generated and serve as a basis for future research in ecodesign applied to heavy handling systems in the metalworking industry.

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