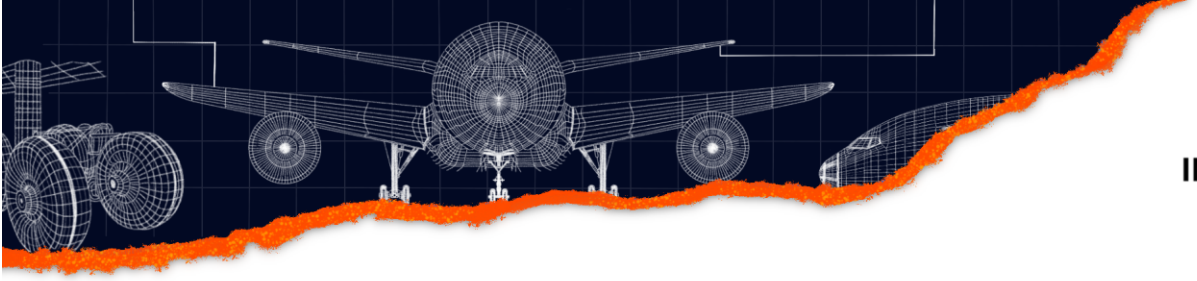

IMPACTO CIENTÍFICO
EDITORA

DESIGN OF AN ALIGNER AND QUICK HITCH FOR THE TRACTOR DRAWBAR

CONCEPÇÃO DE ALINHADOR E ENGATE RÁPIDO PARA BARRA DE TRAÇÃO DO TRATOR

DISEÑO DE ALINEACIÓN Y ENGANCHE RÁPIDO PARA BARRA DE TIRO DE TRACTOR

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ABSTRACT

Agricultural mechanization has been essential in promoting greater efficiency, safety, and productivity in the field. However, operations such as hitching and unhitching implements to the tractor drawbar are still performed manually on many farms, leading to operational risks and time losses. This work proposes the conceptual development of a quick hitch device with an automated aligner for agricultural tractors, based on a design methodology that allows revisions and iterations with previous stages for corrections and improvements when necessary, in compliance with Regulatory Standard NR 31. Technologies such as directional valves, electro-hydraulic, electropneumatic, and electric actuators were explored with the goal of eliminating the need for manual operator intervention. The results indicate a feasible solution adaptable to different tractor models, which can significantly improve ergonomics, safety, and the standardization of agricultural operations. The study also highlights the importance of innovation in the field through automation and the use of structured product development methodologies.

Keywords: Quick Hitch. Automation. NR-31. Agricultural Mechanization.

RESUMO

A mecanização agrícola tem sido fundamental para promover maior eficiência, segurança e produtividade no campo. No entanto, processos como o acoplamento e desacoplamento de implementos à barra de tração dos tratores ainda são realizados manualmente em muitas propriedades, o que acarreta riscos operacionais e perdas de tempo. Este trabalho propôs o desenvolvimento conceitual de um dispositivo de engate rápido com alinhador automatizado

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para tratores agrícolas, com base em uma metodologia de projeto que permite revisões e iterações com as etapas anteriores para correções e melhorias quando necessário e em conformidade com a Norma Regulamentadora NR 31. Foram exploradas tecnologias como válvulas direcionais, atuadores eletro-hidráulicos, eletropneumáticos e elétricos, com o objetivo de eliminar a necessidade de intervenção manual do operador. Os resultados apontam para uma solução viável e adaptável a diferentes modelos de tratores, que pode melhorar significativamente a ergonomia, segurança e padronização das operações agrícolas. O estudo também reforça a importância da inovação no campo por meio da automação e do uso de metodologias estruturadas de desenvolvimento de produtos.

Palavras-chave: Acoplamento de Implemento. Automação. NR-31. Mecanização Agrícola.

RESUMEN

La mecanización agrícola ha sido esencial para promover una mayor eficiencia, seguridad y productividad en el campo. Sin embargo, procesos como el acoplamiento y desacoplamiento de implementos a las barras de tiro de los tractores aún se realizan manualmente en muchas explotaciones agrícolas, lo que genera riesgos operativos y pérdida de tiempo. Este trabajo propuso el desarrollo conceptual de un dispositivo de enganche rápido con un sistema de alineación automatizado para tractores agrícolas, basado en una metodología de diseño que permite la revisión e iteración de pasos previos para realizar correcciones y mejoras cuando sea necesario, de conformidad con la Norma Regulatoria NR 31. Se exploraron tecnologías como válvulas direccionales y actuadores electrohidráulicos, electroneumáticos y eléctricos, con el objetivo de eliminar la necesidad de la intervención manual del operador. Los resultados indican una solución viable, adaptable a diferentes modelos de tractores, que puede mejorar significativamente la ergonomía, la seguridad y la estandarización de las operaciones agrícolas. El estudio también refuerza la importancia de la innovación en el campo mediante la automatización y el uso de metodologías estructuradas de desarrollo de productos.

Palabras clave: Acoplamiento de Implementos. Automatización. NR-31. Mecanización Agrícola.

1 INTRODUCTION

Agricultural mechanization represents one of the pillars of the modernization of the agricultural sector, promoting increased productivity, efficiency, and safety in field operations. Among the mechanized operational processes, the coupling of implements to the tractors' drawbar stands out, a procedure that, although routine, is still carried out manually on many properties, which compromises both the safety of operators and operational agility.

Regulatory Standard No. 31 (NR-31), specifically in its chapter 12, determines that the coupling of agricultural implements must be carried out by means of quick coupling systems and, preferably, without the intervention of third parties, ensuring greater safety for operators (BRASIL, 2005). However, as observed on a large farm during technical visits, none of the tractors had quick coupling systems on the drawbar, making the process time-consuming, unsafe and highly dependent on the operator's experience.

The development of devices that automate or facilitate the coupling and decoupling of implements is not unprecedented. Souza (2021) developed a device for assembling forestry implements that resulted in significant gains in ergonomics, safety, and reduction of physical effort in the manufacturing process. Similarly, Mattos (2022) proposed the concept of an autonomous precision seeder, highlighting the positive impact of technological solutions in increasing operational efficiency in the field. Koenig (2019), when designing a portable electric vehicle for urban mobility, used the methodology of Pahl et al. (2005) to guide the creative and technical process of the project, demonstrating the applicability of this approach in different areas of engineering.

In the same sense, Borges and Rodrigues (2010) reinforce the importance of Pahl and Beitz's methodology when addressing improvements that increase safety in product development, pointing out that failures in the early stages of the project can significantly compromise the performance and reliability of the final product.

In addition, safety in the operation of agricultural machinery is a critical aspect, involving the proper use of personal protective equipment (PPE), regular maintenance of machinery, and adequate training of operators (AMG Saúde, 2023).

Hydraulic and pneumatic systems play a crucial role in the automation and efficiency of agricultural machinery. Hydraulic systems are ideal for applications that require high force at moderate speeds, while pneumatic systems are more suitable for high-speed applications with moderate force (Farquar, 2023).

Thus, the proposal aims to fill a gap identified in the field, contributing with innovative solutions for the national agricultural sector. In addition, it is expected that the designed device can be adapted to different tractor models, promoting standardization and facilitating

the dissemination of safe and efficient practices in the use of agricultural machinery. In this context, the general objective of the present work is to develop a conceptual device for quick and safe attachment of implements to the tractor drawbar according to NR 31.12 of 2005, optimizing the coupling/uncoupling time and increasing operational safety.

As specific objectives, the following are: (1) To understand the requirements of NR 31.12 regarding the attachment of implements to agricultural tractors; (2) Identify solutions used and propose possible improvements; (3) Develop the conceptual design applying the product design methodology, in order to enable the definitive design of the quick coupling.

1.1 BACKGROUND

According to NR 31, in chapter 12, which deals with Safety at work in Agricultural Machinery and Implements, the coupling of implements must be done by means of a quick coupling and without the help of third parties to ensure safety in operation (NR-31).

Another important point is the coupling and uncoupling time of the implement. Without the quick hitch, the operator needs to get off the machine, remove the clamping pin, return to the tractor cab, align the tractor drawbar with the implement hitch head, align the holes, exit the cab, place the clamping pin, lock the pin and put on the chain. And for the decoupling the situation occurs with the reverse chronology.

With the device to be developed, the machines would meet the standard required by NR 31, reduce the coupling/uncoupling time, ensure greater safety in operation, in addition to greater reliability in coupling.

2 LITERATURE REVIEW

2.1 NR 31.12

Regulatory Standard number 31, which deals with Safety and health at work in agriculture, livestock, forestry, forestry and aquaculture, has an exclusive chapter to deal with the safety at work of agricultural machinery and implements, the chapter in question is number 12.

This chapter establishes guidelines to minimize risks and ensure the integrity of workers. Here are the key points focused on secure coupling:

- Training and Qualification – Workers must be properly trained to operate and couple agricultural machinery and implements, knowing in detail the correct safety procedures.
- Inspection Before Coupling – Before carrying out the coupling, it is essential to check the general condition of the equipment, including couplings, shafts, attachment points

and hydraulic systems, in order to identify possible defects or wear that may compromise safety.

- Safe Procedures – Coupling must be performed with the engine off, brake on and on flat ground to avoid unexpected movements that may cause accidents.
- Use of Protective Devices – The cardan shaft and other moving parts must be protected by guardrails or devices that prevent direct contact, preventing injuries.
- Personal Protective Equipment (PPE) – It is mandatory for workers to use appropriate PPE during the coupling process, such as gloves, safety boots, helmet, goggles and appropriate clothing, to reduce the risk of accidents and exposure to dangers.
- Safe Distance – During docking, other people must keep a safe distance from the danger zone to avoid accidents resulting from involuntary movements of the equipment.
- Preventive Maintenance – Agricultural machinery and implements must undergo regular inspections and maintenance to ensure their safe operation and prevent failures during operation.
- Communication and Signaling – Operators must maintain efficient communication and utilize standardized signals to ensure safe coordination during the mating process.

These measures ensure that the coupling process takes place safely, preventing accidents and protecting workers.

2.2 DRAWBAR

The drawbar is one of the main connection points between the agricultural tractor and the towed implements. Its function is to transmit the traction force generated by the tractor, ensuring the mobility and proper functioning of the implements during field operations.

There are different types of drawbars, the most common being:

- Straight bars - with fixed height in relation to the ground;
- Step bars - which allow adjustment in the height of the coupling point.

In both bars mentioned, the cylinder head can be screwed to form the "wolf's mouth".

The correct position of the drawbar is essential to ensure stability, reduce mechanical efforts and prevent accidents. According to a study by Silva et al. (2021), many tractor models do not comply with the dimensions and positioning required by the NBR 7811 standard, which can compromise ergonomics and safety in agricultural operations.

The drawbar terminal, which is composed of the bar and the head where the mechanical fitting occurs with the implement header by means of a fixing pin. This component is designed to withstand tensile stresses and impacts during field work. On modern tractors, the head may feature self-locking devices, which facilitate quick engagement, reducing the need for manual intervention.

According to Prado et al. (2022), the drawbar with a cylinder head must be properly aligned with the header of the implement to avoid excessive wear and ensure secure coupling. Also according to the same author, its shape facilitates the positioning of the pin, but requires care regarding alignment, especially on uneven terrain.

Drawbar efficiency is influenced by the tractor's power-to-weight ratio and the load exerted on the connection. Anselmo et al. (2021) highlight that balanced ratios and adequate loads ensure higher yield and lower fuel consumption. In addition, the correct use of the head bar reduces operator effort, improves ergonomics and increases safety during attachment and decoupling of attachments.

2.3 EXISTING DEVICES

A similar device was identified on the John Deere tractor, model 7J. In the video available on YouTube with the title "Drawbar - Technical Delivery TR 7J (Maqcampo | John Deere)", the technician responsible for the technical delivery mentions that it is a safety device that eliminates the need for the operator to get off the tractor to couple it with the implement. However, for decoupling, it is still necessary for the operator to descend and remove the pin manually. During the video, which lasts approximately 1 minute and 30 seconds, it is possible to see that the device is activated by a button located at the bottom of the drawbar head. This button mechanically triggers the release of the part that locks the pin at the time of attachment of the implement to the tractor's drawbar.

It is also possible to mention, as an example of similar technology, the automatic couplings used in vehicle cargo combinations, such as rodotrens, which use the so-called "dolly" – intermediate equipment that connects the trailer to the rear semi-trailer. Popularly known as the "Romeo and Juliet" system, this type of coupling is widely used in the road transport sector because it allows automatic coupling between modules, increasing the efficiency and safety of the operation. According to the Department of Roads of Minas Gerais (DER-MG), the dolly provides greater flexibility of articulation and facilitates maneuvers, contributing to the flow of traffic and operational safety on highways. These systems, which do not require direct operator intervention between the coupling points, serve as a technical reference for the development of similar solutions in agricultural tractors.

In a search carried out on the websites and manuals of the main suppliers of agricultural machinery, no other similar devices were found that completely automate the process of coupling and uncoupling implements.

2.4 RISKS AND ACCIDENTS IN THE COUPLING AND UNCOUPLING OF AGRICULTURAL IMPLEMENTS

The attachment and uncoupling of implements to the tractor's drawbar represents one of the most critical operational steps in the context of agricultural mechanization. When performed manually and without the support of automation devices, this process exposes operators to significant risks, such as crushing, falling, amputations, and rollovers, mainly due to the need to exit the cab for manual adjustments and positioning.

Data from the International Labor Organization (ILO) indicate that Brazil registers, annually, about 3,000 deaths involving agricultural tractors, and approximately one third of these accidents result in permanent disabilities. In certain regions, such as the valleys of the Rio Pardo, Jacuí and Taquari (RS), 42.5% of deaths related to rural work are associated with accidents with tractors.

More specifically, the technical literature points to the inadequate attachment of implements as one of the main causes of serious and fatal accidents. According to Cultivar Magazine (2020), practices such as the incorrect use of coupling points contribute to the increase in rear rollovers, a recurring phenomenon among fatal occurrences with agricultural tractors. In addition, the lack of training of operators is a recurring aggravating factor. Research published by Gonçalves et al. (2019) reveals that 60.74% of the tractor operators interviewed have never participated in operation or safety courses at work, which compromises the safe execution of the hitch and unhooking of implements.

The Regulatory Standard NR-31.12 (BRASIL, 2005) reinforces the obligation to carry out the coupling of implements by means of quick coupling systems and without the direct intervention of the operator between the connection points, aiming to reduce the risk of accidents and promote adequate ergonomic and safety conditions.

In view of this panorama, the importance of developing and adopting technological solutions that automate and standardize the coupling of implements, such as the device proposed in this work, is emphasized. The implementation of these technologies can contribute significantly to mitigating risks, increasing operational safety, and improving the efficiency of agricultural operations.

2.5 INDUSTRIAL PROPERTY OF SIMILAR DEVICES

A search in the databases of the INPI, Google Patents, Espacenet and Patentscope revealed the existence of nine patents related to hitch devices for agricultural tractors. Among them, five patents stand out that present innovative solutions applicable to automated coupling. All classified under IPC B60D codes, which deal with traction connections and couplings with specific functions.

Patent BR 10 2018 001677 6 B1 describes a pin drop hitch assembly assembly with spring retention mechanism. The system allows the pin to be kept in a retracted position until the activation occurs for its automatic locking in the engagement. This configuration aims to increase operator safety by reducing the need for manual intervention (INPI, 2025).

Patent BR 10 2018 001671 7 B1 presents a similar method, with variation in the activation of the fixing pin, allowing the control of the hitch by different operating positions. The solution is aimed at efficiency in repetitive agricultural operations, where coupling and uncoupling occur frequently (INPI, 2025).

Patent BR 10 2018 001673 3 B1 introduces a third position to the pin: in addition to the extended (locked) and retracted (free) positions, there is an intermediate position that allows fine adjustments at the time of coupling. This feature is especially useful in situations of uneven ground or misalignment between tractor and implement (INPI, 2025).

More advanced, patent BR 102018001668-7 A2 incorporates an alignment member that mechanically moves the pin receiver to align its opening with the drawbar bore. In addition, it has a viewing window, allowing the operator to verify that the drawbar is correctly positioned within the receiver cavity, thus increasing the reliability of the coupling (INPI, 2025).

Finally, patent BR 102014021089-0 A2, owned by Forage Innovations B.V., describes a coupling assembly assembly with relative rotation capability between the implement header and the tow vehicle. This rotational movement facilitates coupling on uneven terrain or with position variations, adding flexibility to the system (Google Patents, 2025).

These patents demonstrate the continuous effort of industries in the development of solutions that promote greater efficiency, safety and autonomy in the process of coupling agricultural implements. The technical principles presented in these inventions served as a basis for the conception of the device proposed in this work.

2.6 POSSIBLE WAYS OF ACTUATING THE HITCH PIN

The actuation of the hitch pin and agricultural implements can be carried out in several ways. Currently, in most equipment, this process is still performed manually, requiring the

operator to step down from the tractor cab to align the drawbar holes with those in the implement header and insert the clamping pin. The same procedure is required for the trip.

Some more modern models, such as the John Deere 7J tractor, have automatic activation for locking the pin by means of buttons on the inside of the head, but the decoupling process continues to require manual action from the operator.

In order to modernize and automate this process, alternatives such as the use of directional valves, microcontrollers, electro-hydraulic, electropneumatic or electric linear actuators are considered. These technologies have been applied in agricultural automation, with positive results in safety and efficiency.

Directional valves control the flow of fluid in hydraulic or pneumatic systems, and are characterized by the number of ways and positions, type of drive (manual, electric, hydraulic or pneumatic), type of return and flow. They are indispensable in electrohydraulic and electropneumatic circuits (Danfoss, 2024).

Linear actuators perform rectilinear movements and can be operated by electric, hydraulic or pneumatic force. Single-acting actuators use springs to return to the starting position, while double-acting actuators exert force in both directions. The possibility of integration with embedded electronic systems has expanded its application in automatic coupling mechanisms (Kyntronics, 2020).

These solutions eliminate the need for the operator to leave the cab, increasing productivity and reducing the risk of accidents.

2.7 PAHL'S METHODOLOGY

The development of the concept of the quick coupling device on the drawbar followed the methodological design approach proposed by Pahl et al. (2005). This methodology organizes the process into four main phases: Task Planning and Clarification, Design, Development, and Detailing. The method is iterative, allowing continuous reviews to improve the solution.

In the planning phase, the objectives and constraints of the project are defined, resulting in a list of requirements that will be updated as development progresses. The design phase deals with the generation of initial solutions, through the functional analysis of the problem. At this stage, different alternatives can be explored with representations such as diagrams, flowcharts, or sketches.

This work considers only the first two stages of the methodology, focusing on the formulation of the list of requirements and the proposition of preliminary solutions for the problem under study.

3 PROJECT DEVELOPMENT

The concept of the quick coupling device was based on the requirements identified in a large farm, observing the absence of automated solutions, and supported by the guidelines established by NR-31.12. The process of developing the conceptual project was guided by the methodology of Pahl et. al (2005), thinking primarily about operator safety, mechanical simplicity and the feasibility of automation.

For this project, the development was divided into two stages, the fixation system and the aligner or receiver of the drawbar.

3.1 FASTENING SYSTEM

From the analysis of the problem, the following requirements were established, listed in Table 1:

Table 1

Requirements for the fastening system

Requisito	Tipo	Observações
Eliminar necessidade de saída da cabine	Funcional	Segurança do operador
Acoplamento seguro e automático	Funcional	Redução de tempo e esforço físico
Compatibilidade com tratores existentes	Técnico	Adaptável à barra de tração
Baixo custo de produção	Econômico	Possibilidade de fabricação nacional
Controle elétrico com botão	Operacional	Facilidade de acionamento

Source: Authors.

Aiming at an innovative solution with the aim of registering a patent, the search for new solutions and the possibility of automatic decoupling of the implement began, in order to reduce time and increase safety in operation. Searches were carried out through the use of keywords, such as: quick hitch, automatic hitch, coupling, drawbar, tractors, agricultural machinery and implements, drawbar aligner with head and the like. The main search sites were: Google Scholar, SciELO. Searches were also carried out in technical manuals of agricultural machinery dealerships such as John Deere, Massey Ferguson and New Holland. And patent searches on the INPI website, Google Patents, Spacenet and Patentscope.

Thus, three hypotheses were considered for the quick hitch fixing pin actuation system, presented in Table 2.

The choice fell on the electrical system, due to its simplicity and compatibility with the reality of medium-sized rural properties.

Table 2

Types of system for fixing the hitch pin

Sistema	Vantagens	Desvantagens
Eletropneumático	Rápido, silencioso	Requer compressor, mais complexo
Eletro-hidráulico	Alta força, robustez	Sistema pesado, manutenção complexa
Elétrico (escolhido)	Simples, compatível com 12V, fácil instalação	Força moderada, depende da qualidade do atuador

Source: Authors.

The concept of this device can consist of a movable pin driven by an electric linear actuator, controlled by a button in the cab. The signal is sent to a simple control center, which can be a relay or microcontroller, which commands the advance or retreat of the fixing pin.

3.2 ALIGNMENT SYSTEM

To facilitate the coupling system, a guided alignment system can be used, patents BR 102018001668-7 A2 and BR 102014021089-0 A2 already describe similar mechanisms. Patent BR 102018001668-7 A2 (Deere & Company) features an alignment member that moves the pin receiver to align its opening with the drawbar hole, and contains a viewing window that allows the operator to verify the correct fit. Patent BR 102014021089-0 A2 (Forage Innovations B.V.) describes a hitch assembly with rotational movement capability between the header and the tractor, allowing small position adjustments during coupling, which is ideal for sloping or uneven terrain.

Based on the aforementioned patents and in order to optimize the process, the concept of an aligner is proposed that allows the coupling even in conditions of uneven soils or with small dimensional variations of the implements. For the solution of this problem, it must be considered that the drawbar receiver must have a limited lateral linkage that allows to align the drawbar and the implement laterally, a male tapered guide on the drawbar and a female tapered guide on the implement header to perform the self-alignment responsible for centering the pin through-holes. For a more modern system, an alignment sensor can be inserted to signal that the implement is correctly positioned, but the cost of implementation and maintenance is high and requires specialized labor.

The system must have as requirements, automatic position correction, reduction of coupling time, less wear due to misalignment and greater operational safety. Table 3 shows the operational benefits that the device with these characteristics should have.

In addition to the benefits, this system can be adapted with simple and resistant materials, such as carbon steel or light alloy, and can even use scrap from agricultural implements and machinery, thus maintaining low manufacturing costs, which is in line with

the objective of the work to develop a viable solution for the national agricultural environment. However, SAE 4140 steel is widely used for the manufacture of the drawbar structure, the cylinder head and other components subjected to significant mechanical stress (Turatti; Birck; Toso, 2017).

Table 3

Relevant characteristics for the aligner

Característica	Benefício Operacional
Correção automática de posição	Reduz necessidade de manobras com o trator
Redução de tempo de acoplamento	Alinhamento mais rápido e eficiente
Menor desgaste por desalinhamento	Prolonga vida útil do pino e da barra
Maior segurança operacional	Reduz riscos de falhas no encaixe

Source: Authors.

3.3 MATERIALS AND METHODS

For the development of the conceptual design of the quick coupling device with automated alignment, approaches based on product engineering were adopted, using the methodology of Pahl et al. (2005) as the main guideline, as described in Section 2.5.

Although it is a conceptual project, the selection of materials and components considered the feasibility of practical application. The selection considered mechanical resistance, availability in the domestic market and compatibility with operating conditions in the agricultural environment. The main material elements of the project are:

- SAE 4140 steel: a medium-carbon alloy with the addition of chromium and molybdenum, classified as hardenable low-alloy steel. It features high mechanical strength, good toughness, fatigue resistance, and excellent performance in applications subject to torsion, impact, and wear. In addition, it responds well to heat treatments such as quenching and tempering, and is widely used in critical components of agricultural machinery, such as shafts, pins, and drawbars. Its application is recommended in situations that require structural robustness and durability in severe environments (Turatti; Birck; Toso, 2017).
- 12V electric linear actuator: responsible for the movement of the hitch pin, with force and stroke capacity compatible with the proposed system;
- Microcontroller (e.g. Arduino) or control relay: to activate the electric actuator from a cabin command; Activation button: installed in the tractor cab to activate the clamping system;
- Conical guides (male and female): used for self-alignment between the drawbar and the implement header;

- Fasteners: such as screws, pins, dowels and metal sheets.

The development of the project followed a systematic approach divided into two fronts: fastening system and alignment system. The methodological stages were:

1. Requirements gathering: based on observations carried out on a large farm, where the coupling of implements was still done manually and the analysis of the normative requirements of NR 31.12;
2. Technical and technological review: including analysis of patents, manufacturers' manuals and scientific literature;
3. Generation of conceptual solutions: with alternatives based on electromechanical and safety operating principles;
4. Selection of the ideal solution: based on criteria such as construction simplicity, estimated cost, operational safety and compatibility with national tractors;
5. Three-dimensional modeling of the parts: carried out in Onshape's CAD environment, which allowed the individual creation of each component;
6. Virtual assembly of the assembly: Done in SolidWorks, allowing you to verify the fit and operation of the parts together and generate exploded and detailed views of the virtual prototype.

4 RESULTS AND DISCUSSION

The analysis of the quick coupling systems was divided into two fronts: the fastening system and the implement alignment system, based on the requirements raised during the development of the work based on technical literature on agricultural mechanization.

4.1 FASTENING SYSTEM

Among the technologies analyzed, the fastening system with an electric linear actuator was chosen, operated by means of pushbuttons installed in the tractor cabin. The choice for the electric system is justified by its simplicity of implementation, compatibility with the standard electric structure of tractors (12VDC), lower cost and ease of maintenance when compared to hydraulic and electropneumatic systems.

According to Silva, Oliveira and Pereira (2024), electric actuators represent an effective alternative for the automation of implements in medium-sized properties, as they operate with low energy consumption, require minimal maintenance and can be easily integrated with simple controls, such as relays or microcontrollers. This makes them ideal for applications that demand low cost and high reliability, characteristics desired in rural areas.

In addition, Porto (2015) points out that, although hydraulic and electropneumatic systems offer high performance, their implementation in tractors that do not have specific infrastructure (such as compressors or proportional valves) is limited, in addition to requiring specialized technical labor for maintenance. Therefore, these systems are more viable in industrial environments or in properties with a high degree of mechanization.

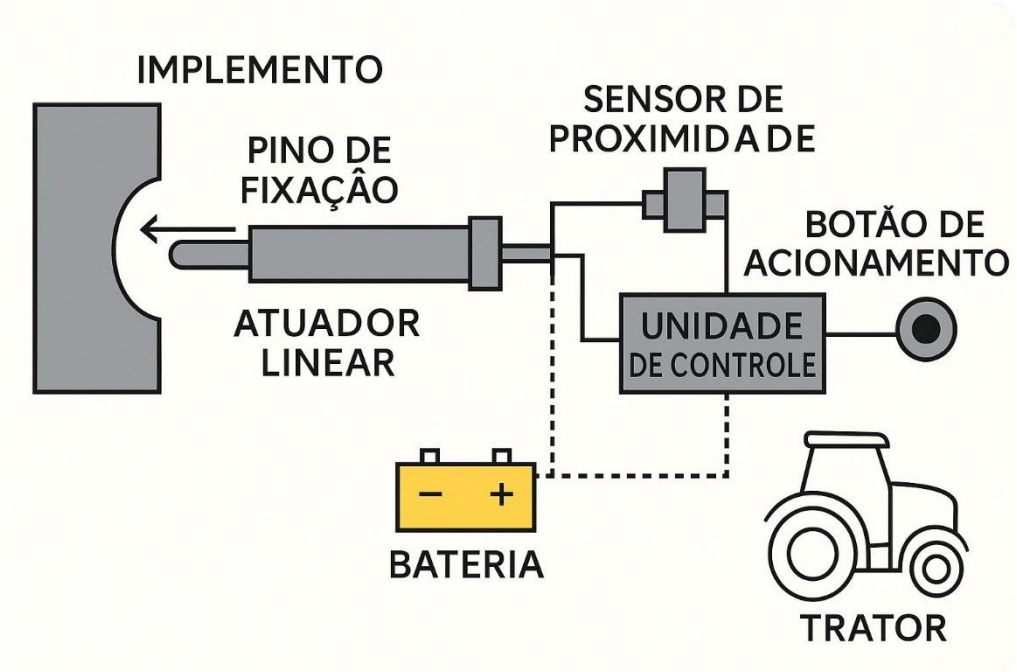
This approach is in accordance with the principles of NR-31.12, which determines that the operator should not be exposed to the danger zone during the coupling of implements (Brasil, 2005). By eliminating the need for the operator to descend for manual pin fixation, the proposed system contributes to the prevention of crushing and slipping accidents, as observed by Souza (2021) in similar projects.

Finally, the adopted concept is compatible with solutions already explored in the industry, such as patent BR 10 2018 001677 6 B1, which uses an internal mechanically actuated hitch pin retention system, also operated without manual intervention. Thus, the proposed system meets requirements of functionality, safety, ergonomics and economic viability.

Figure 1 illustrates the conceptual diagram proposed for this system. The actuation occurs from the command button, which activates the microcontroller or relay responsible for sending the signal to the linear actuator, which moves the fixing pin. This operating logic is often applied in modern implements and retrofit systems of old tractors (Porto, 2015).

Figure 1

Conceptual diagram of the hitch



Source: Author (2025).

It is worth noting that the actuator will not perform any external force, the only point to pay attention to are the forces suffered by the traction, compression and shear pin, but the material to be used may be the same as that already used to manufacture the conventional pin, since studies on the forces have already been carried out.

The reduction of the coupling time and also the reduction of the risk of accidents can be mentioned, since there will be no need for the operator to get out of the cab, meeting the requirements of ergonomics and occupational safety.

4.2 ALIGNMENT SYSTEM

To facilitate the engagement process, a mechanically guided alignment system was designed, based on the application of tapered male/female guides and joints with limited lateral movement. The objective is to allow the correction of common lateral misalignments during coupling on uneven terrain or with small dimensional variations between the drawbar and the implement header.

According to Prado et al. (2022), misalignment between hitch points can cause structural damage to the pull pin, make it difficult to couple, and increase component wear. The use of passive mechanisms, such as tapered guides and backlash-controlled hinges, promotes automatic centering of holes, reducing operating time and operator effort.

This principle is widely applied in coupling systems for larger road and agricultural implements, such as the "Romeo and Juliet" system with dolly, used in rodotrens. According to the DER-MG, this type of automatic connection increases safety and efficiency in maneuvers, which justifies its use as a technical reference for agriculture.

The proposal of this work incorporates elements described in patents BR 102018001668-7 A2 and BR 102014021089-0 A2, which present mechanisms of lateral alignment and visualization of pin positioning. Such solutions were adapted in a simplified way to ensure technical and economic feasibility. The proposed mechanical system can be built with materials such as carbon steel or reused parts of implements, aligning with the objective of proposing an affordable and efficient alternative.

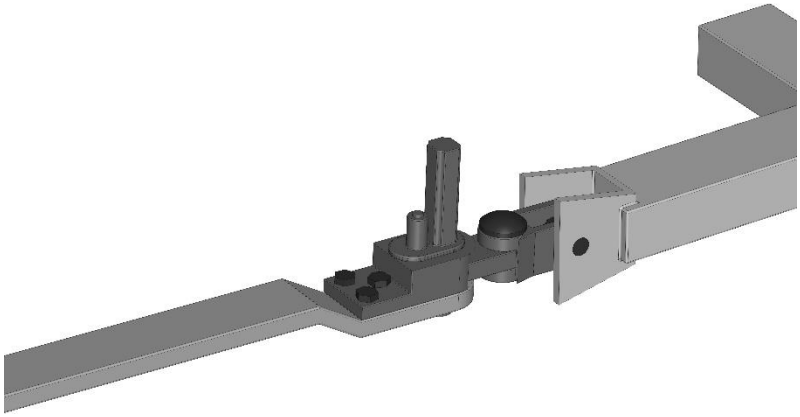
Therefore, the alignment system, in addition to being functional, contributes directly to the reduction of operational errors, increased durability of components and improved safety, consolidating itself as a viable and replicable solution in the context of Brazilian agricultural mechanization.

4.3 MODELING

The three-dimensional modeling of the pieces was carried out based on the concepts developed in the previous sections. Figure 2 shows the complete assembly of the quick coupling and, in Figure 3, the exploded view of the assembly is observed.

Figure 2

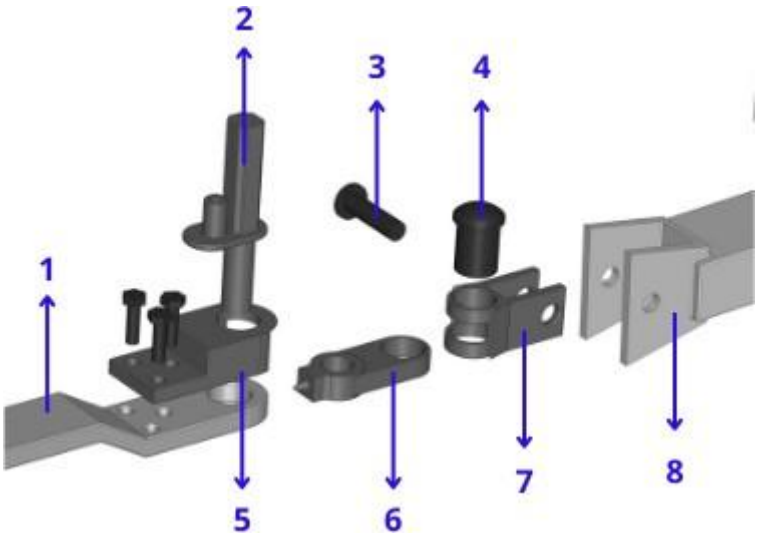
Modeling of the quick coupling assembly



Source: Author (2025).

Figure 3

Detailed view of the set



Source: Author (2025).

1. Drawbar;
2. Electric linear actuator;
3. Vertical joint axis;
4. Lateral/horizontal joint axis;
5. Cylinder head with clamping chamber;
6. Lateral/horizontal joint, with pin fixing hole and male tapered guide;

7. Support of the lateral/horizontal, vertical joint and clamping on the header;
8. Implement Header.

The drawbar head was adapted to receive a clamping chamber with chamfering, which, together with the tapered guides, facilitates the attachment of the implement. Figures 4 to 5 show the elements responsible for articulation and fixation.

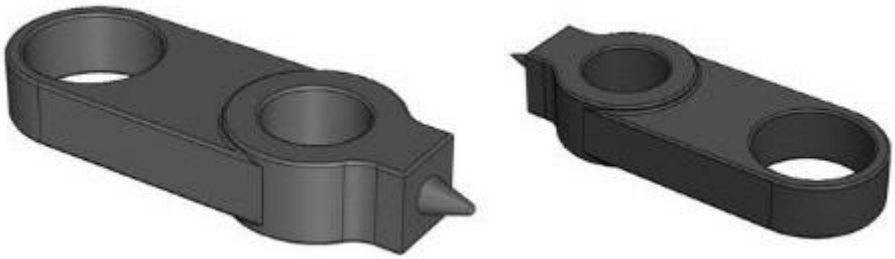
Figure 4

Conceptual diagram of the hitch

Source: Author (2025).

Figure 5

Conceptual diagram of the hitch



Source: Author (2025).

This solution was designed to be simple, low-cost, and can be implemented with recyclable materials, such as scrap or carbon steel parts. This contributes to the feasibility of application in medium-sized rural properties, respecting the principle of technological adequacy to the reality of the Brazilian farmer.

The head with the clamping chamber and the seat of the female tapered guide is depicted in Figure 4. The clamping chamber consists of the sides of the adapted head together with the surface of the drawbar. The sidewalls and top of the head have a chamfer to help align the linkage that has the hole for the pin engagement. In yellow is represented the female conical guide.

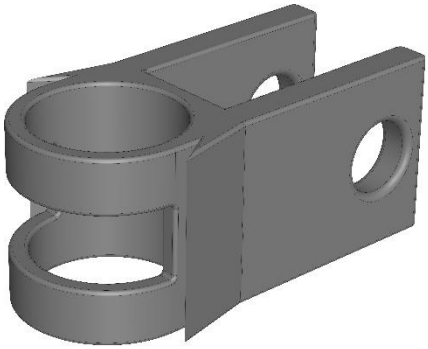
The joint that performs the lateral movement, represented in Figure 5, has its rotation limited by the support of the lateral/horizontal joint, represented in Figure 6. The end of the

joint that has the fixing hole is the same as the male tapered guide, at the other end is the hole for the side joint axis.

In Figure 6, which represents the support of the lateral/horizontal and vertical articulation and fixation in the header, it is possible to observe the lateral limiters, fixation holes in the header, articulated pin hole for vertical movement, represented in the details of Figure 3, item 8.

Figure 6

Support of the lateral/horizontal, vertical joint and fixation on the header



Source: Author (2025).

5 CONCLUSION

This work presented the conceptual development of an automated quick coupling device for agricultural tractors, focusing on improving safety, efficiency and ergonomics in the coupling and uncoupling operations of implements. The analysis carried out during the curricular internship showed the absence of quick hitch systems in the tractors of the evaluated property, in disagreement with the requirements of NR-31.

The proposed solution involved the application of linear actuators and directional valves, which enable the automation of the process, eliminating the need for the operator to get off the tractor. This reduces the risk of accidents, optimizes operating time, and contributes to the standardization of practices in the field.

In addition to presenting a viable technical alternative, the project highlights the relevance of applying systematized engineering methodologies, such as that of Pahl et al. (2005), to ensure greater effectiveness and safety in the development of innovative solutions for the agricultural sector. It is suggested for future work to build a functional prototype and carry out field tests to validate the performance of the device under real operating conditions.

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