Automation in the Food Industry: Design of a Machine for the Cutting of Native Potatoes

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Abstract. Due to the lack of technological development in the country's food industry, it makes sense to build an automated machine to obtain potato strips from native potatoes. The cutting of potato strips is a big problem for several companies. They are operated and processed manually, which results in the loss of part of the product in the peel, increased time for this operation, loss of money, work accidents, and the tiredness and fatigue of the workers in charge of the production. The design was developed to solve these problems. In the production process, the optimization of the synchronization of the described operations fulfils all production functions, but above all, it guarantees the quality of the final product, reduces losses caused by industrial accidents, and brings economic benefits to the company. Considering the design of the automated machine in the cutting process, the future development of the company aims to automate the entire processing plant as a first step for the cutting process by applying the mechanical design method. VDI 2221: This method goes deeper into the design process to find the best opportunities for research and development. It also concludes that, at the end of the process, an optimal machine has been designed that meets research and problem-solving requirements with regard to potato cutting.

1 Introduction

The design and development of automated machines for food production is a relevant topic in mechanical engineering. In this research work, the VDI 2221 methodology was used to design and evaluate an automated native potato-cutting machine. The mechanical design focused on optimizing the space in the processing plant, while the electronic design focused on the programming of automation stages [1]. An analysis of stresses and displacements in the cutting blades demonstrated their strength and ability to carry out the cutting process efficiently [2]. The use of materials such as stainless steel ensured the durability and safety of the machine in the food industry environment [3]. Also, the programming of the automated machine was carried out using TIA Portal V14 software, using the Ladder programming language [4]. Different cutting stages were programmed, and aspects such as speed, force, and position of the components were taken into account. In addition, Capacitive sensors were implemented to ensure accurate control during the process [5]. Therefore, the results obtained demonstrate the feasibility and effectiveness of the proposed design. It was possible to fully automate the native potato-cutting process, which reduced the time spent and increased productivity. It is recommended to carry out adequate preventive maintenance and cleaning of the machine to ensure its correct operation.

2 Materials and Methods

The mechanical engineering design method is the most suitable to develop the research work in progress until its final development, to determine the best alternatives for its final solution, and, to complement the design process, a study will be carried out. Therefore, the use of the VDI 2221 methodology [6] will help us to show detailed known levels and evaluation of components and types of materials in the calculation memory for its adequate final design. The purpose of this method is to find the appropriate solution among multiple alternatives proposed, as shown in Fig. 1.

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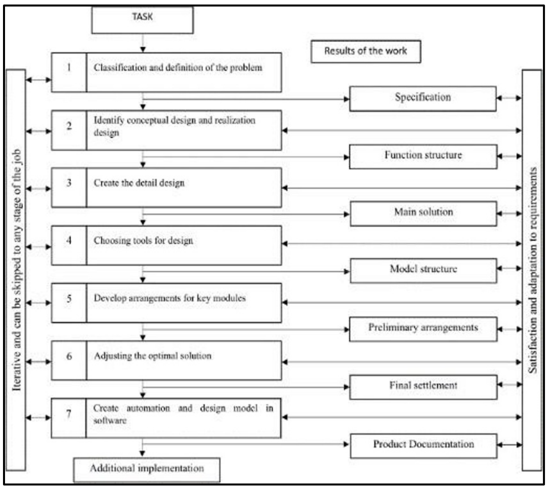

Fig. 1. VDI 2221 Methodology

2.1 Electrical design

The internal connection of the entire automation process was made in the electrical drawing on the plan, detailing each component to be used using the tools provided by the software used in the process. In Fig. 2, the servo motor is started in a vacuum state, for which it is essential to unlock it by means of an emergency push button. When the machine starts running, the push button is pressed, which activates the contactor, which in turn energizes the servo motor and starts the process.

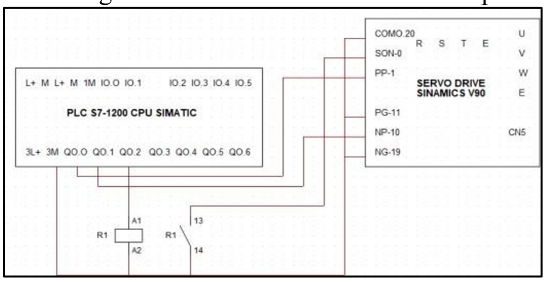

Fig. 2. Electronic design

The final design shows how the automated system can be connected to the presented devices, such as a PLC S7-1200 SIMATIC CPU, a SINAMICS V90 servo drive, and a 1FL6066 Servo motor as push buttons and capacitive sensors [7], to perform the native potato stick cutting. The design proposed in the diagram represents the main devices of the automated system that perform the main function of performing the cutting [8], as shown in Fig. 3.

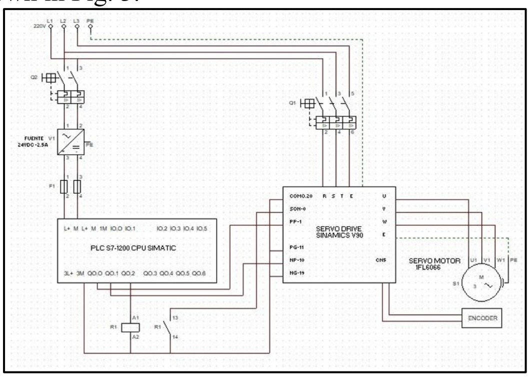

Fig. 3 Final electronic design

2.2 Mechanical design

An innovative mechanical design was carried out, combining the cutting of native potatoes in an upper and lower area, optimizing space resources within the processing plant, and then during the cutting process, a conduit was designed through which the cut potatoes are stored until they are supplied by an automatically controlled hopper; the material used was mostly stainless steel due to its great properties for use in the food industry.

In Fig. 4, the innovative mechanical design is shown. It was realized by combining the cutting of native potatoes at the top and bottom, optimizing the space resources in the processing plant, and then during the cutting, a channel was created where the cut potatoes will be stored in the process. Before the delivery of the automatically controlled containers, the material used was mainly stainless steel due to its excellent properties in the food industry [9].

The cutting process is carried out in the upper and lower parts of the structure, with internal feed and storage cavities. This design was chosen to increase productivity in both areas and minimize the usable area in this area of operations in the processing plant.

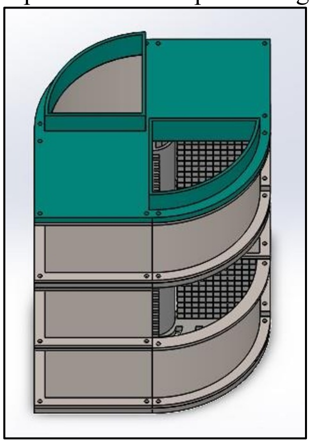

Fig. 4. Product cutting

Therefore, the automated cutting process uses a servomotor controlled by a programmable logic computer to ensure the movement and rotation of a central shaft connected to a polypropylene compressor in charge of pressurizing the potatoes. The blade pierces and cuts with precision, and the combination of a servomotor shaft and a cutting shaft is responsible for transmitting power through bevel gears [10], as shown in Fig. 5.

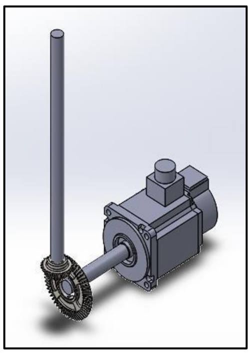

Fig. 5. Servo motor design

Thus, the basic structure is formed by a rectangular tube of 50x30x2.6 and a square tube of 20x20x2.0, both made of AISI 304 stainless steel, welded to the metal sheet in the upper and lower areas where the cutting area is located and which will be the base of the transmission system, as shown in Fig. 6.

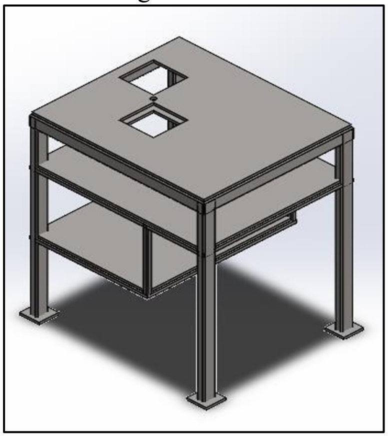

Fig. 6. Basic structure

Therefore, the assembly of the native potato feeding area will arrange the feeding pipes in the four sections created in the cutting area so that the automatic machine is continuously fed to cut the local potato sticks, as shown in Fig. 7, and four points are set to improve the productivity of the machine.

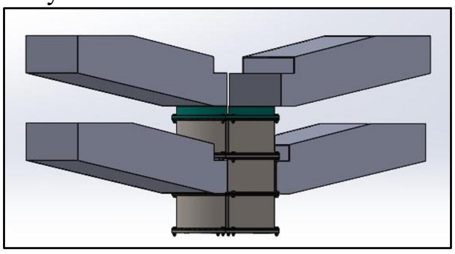

Fig. 7. Feeding zone

It shows the assembly of all the stages offered by the automated machine, such as the native potato feeding section, the cane cutting section, and the storage of the processed products. All these stages are combined into one basic structure. In Fig. 8, it is shown that stainless steel is used in the feeding pipes, the cutting areas, and the storage areas. In addition, this automated machine has its own distinctive innovations in design and manufacture.

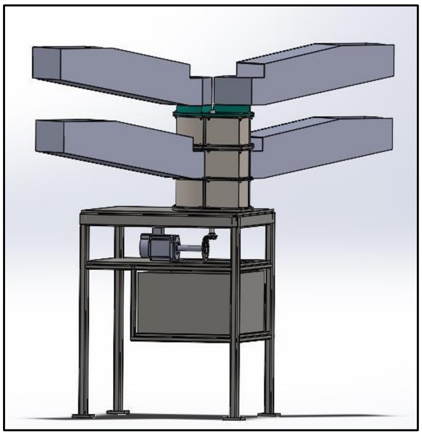

Fig. 8. Potato slicer design

3 Result

Validating the design of an automated machine to produce cut potato strips involves calculations made on the design of each element that makes up the machine and the type of material required, thanks to a simulation process using CAD software that verifies each functionality and element without functional risk during the cutting process

3.1 Detachable cutting blades

Von Mises stress is a physical measure used in structural engineering as an indicator to evaluate the strength of ductile materials in the context of failure theory. A Von Mises analysis was carried out on the four cutting blades used in the machine design to understand how the part would behave. The blade matrix has a yield strength of 1700 e+08 N/m2.

Static analysis differs from dynamic analysis in that static code analysis is performed without running the code, using various analysis techniques that can be performed on the source code of the application to identify potential problems, so that the analysis is applied to the components that make up the machine that is designed to achieve the goal, as shown in Fig. 9.

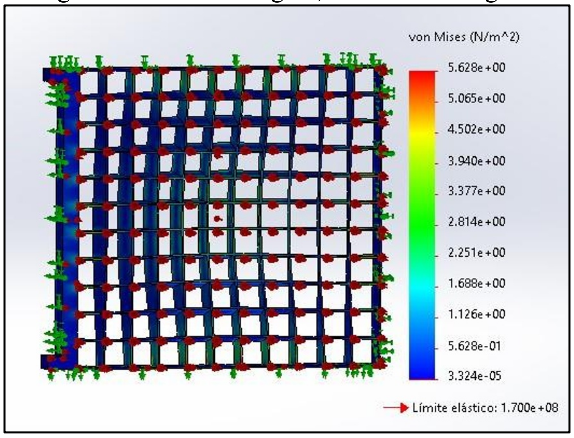

Fig. 9. Von mises of the cutter blade

The results of the stress analysis showed a stress concentration of 4.504 e-03 N/m2 in the roof profile connected to other parts of the structure where native potatoes are processed, 1.262 e-07 N/m2, as observed in Fig. 10

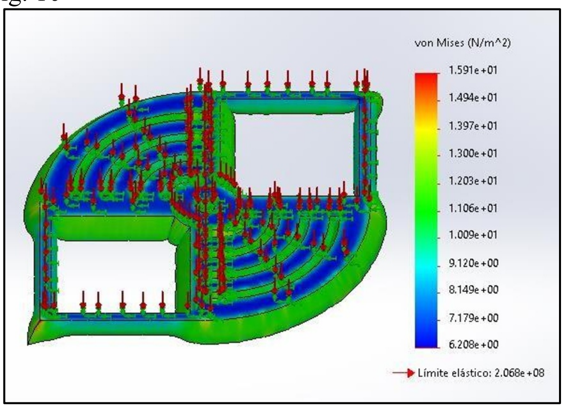

Fig. 10. Von mises of the processor

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The yield strength of the machine body or cutting area In most cases, the yield strength is used as the tensile strength. However, the software allows you to use yield or rupture stress limits or set your own stress limits, which ensures timely results when designing components. A hopper is a tank or container with a rectangular bottom whose task is to store or operate different types of products. By design, it is the final warehouse where processed products are stored for further distribution to the market, as shown in Fig. 11.

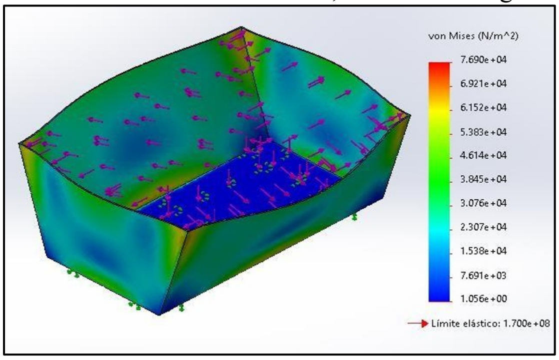

Fig. 11. Von mises of the hopper

3.2 Programming of cutting process automation steps

The programming of the different stages that make up the automated plant is carried out using the TIA Portal V14 software, starting with the creation of a project to be executed on the S7-1200 CPU. 12-14 DC-DC. In Fig. 12, the diagram shows the creation and selection of a PLC for a new research project on the design of an automated native potato cutting machine. Declaration of PLC variables in the TIA Portal software.

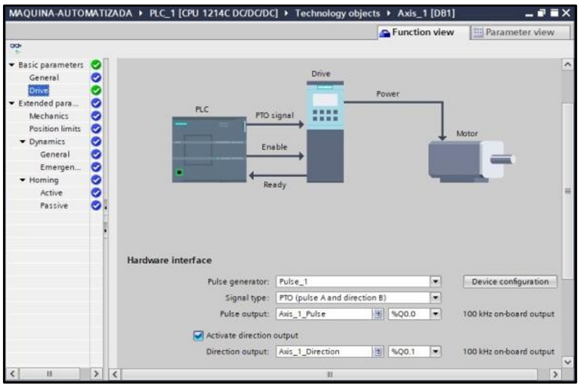

Fig. 12. Sample diagram

Also, the ladder diagram of the final system of the automation process The automation system can be programmed in Ladder Diagram programming language using PLCs and capacitive sensors such as motors and servo motors to provide local potato tube cutting as well as supply and inventory control throughout the production process. The programming takes into account important aspects such as the design of the cutting machine, the timing of each cutting operation, and its respective constant power supply to thesystem, making it an automated machine for the potato cutting process as shown in Fig. 13.

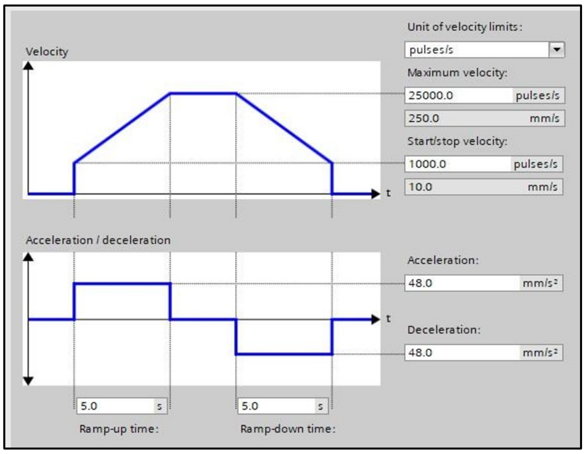

Fig. 13. Ladder diagram

The programming is done for the cutting of native potatoes. A servomotor represented as an adjustment coil is used to better explain the cutting process, as the servomotor operates with positioning, speed, torque, and force variables. After the previous step, where the product is brought to the cutting area, the process continues. In this cutting step, four capacitive sensors are placed in the cutting zone, and each sensor sends an acknowledgement signal to the computer. When all four capacitive sensors are activated, the signal is sent after two seconds. The rotation angle of the polypropylene compressor is 90°, which is transmitted by a bevel gear to the servomotor that activates it and cuts the bar, as shown in Fig. 14

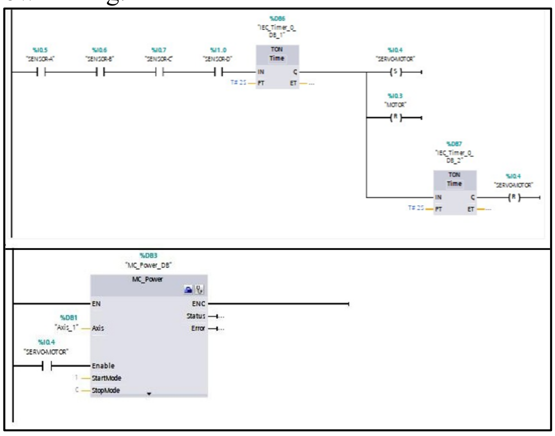

Fig. 14. Programming in TIA Portal

4 Conclusion

An automated machine for the production of native potato cuts is developed. Four steps are implemented in the cutting process of automated machines: the delivery stage, the cutting stage, the storage stage, and the final quality control inspection according to the standards for its production. Sufficient selection of the components that make up the machine and the automation system reduces the cost of purchasing the components of the cutting process.

Each step of the cutting process is automatically controlled by the Ladder diagram language programming software. The removable blade is designed in the automatic machine according to the company's requirements, and the cutting size of each potato stick is according to the production standard.

The final design of the proposed automatic machine for cutting native potato sticks reduces the time to obtain this product compared to the previously used methods. This design features an innovative cutting system not used in other machines to maximize the production line in a single operation with four dies, two of which are located in the main area and the other two in the secondary area. The process is specifically designed for sizes averaging 11.1 cm to 13.5 cm, 1° resolution, and 7.86 cm to 8.52 cm diameter. In particular, it is not allowed to cut local potatoes larger than these sizes.

5 Future Work

After designing the automated process for obtaining native potato cuttings into sticks, there are options to improve this process or to continue the process line after the washing and cutting stages. The final design presented in the study was allowed to evolve for further refinement based on a differentset of requirements and objectives. Then, in response to the work previously done, a number of current alternatives are proposed that could be addressed in the future, without considering some important points that the company did not address in the present research because they exceeded the original limitations and objectives.

- Manufacture and design a process for capturing and locating native potatoes after the first washing and peeling stage.
- Develop the design of the same system in the third cutting zone and chute for sorting native potatoes, as their stick cuts are different from the previous two operations.
- Apply the same design philosophy and approach to products other than native potatoes.
- Combine several production processes using a programmable logic controller.

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