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Original Article

Ginger Post-Harvest Cleaning Machine by Spraying Pressurized Water

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Abstract - *The following research work developed a post-harvest ginger washing machine to conserve and improve the quality of ginger in the province of Satipo. The harvest needs to go through a washing process to remove impurities and other residues, so the main objective of this research project was to design a ginger washing machine with an improved pressurized water system, with a horizontal drum that has turning paddles and a sample drawer for quality control, reusing the water by filtering it through a sand trap. This work was carried out by developing an adaptation of the VDI 2221 and VDI 2225 standards, resulting in 4 phases to develop the project: the first, gathering information; the second, defining the solution concept, which seeks the solution to the problem; the third, the development and design; and finally, the design/modeling of the machine using software to validate its operation. The results in the design phase determined that it should have a feeding hopper, a horizontal drum, which should handle a maximum production of 40 [kg/min], a small sample drawer at one end to check the quality of the ginger, a 4.5 hp motor reducer that is in charge of the shaft rotation drive; the recirculation and washing by means of constant pressure are handled by a ½ HP motor-pump which expels the water through an injector tube that has cuts in the shape of a cross.*

Keywords - *Ginger, Machine, Pressure, Quality, Washer.*

1. Introduction

Ginger is presented as a potential safe therapeutic agent thanks to its bioactive compounds; what stands out the most is its efficacy and its economic price. It can be used for various health conditions, providing an alternative to conventional treatments [1].

For this reason, in the last year, it has increased its exports to 28% compared to last year, having as main destinations the United States, the Netherlands and Canada [2].

This presents an opportunity for farmers in the areas of Chanchamayo and Satipo, where it stands out because they contribute 95% of ginger production in Peru [3].

The traditional and rudimentary process for post-harvest washing is based on spreading the ginger on the ground on top of sacks where it is watered with a hose that sprays pressurized water, then rubbed with a soft bristle brush [4] some farmers also wash using the streams in the area as shown in Figure 1.

Fig. 1 Traditional and rudimentary ginger washing in the province of Satipo

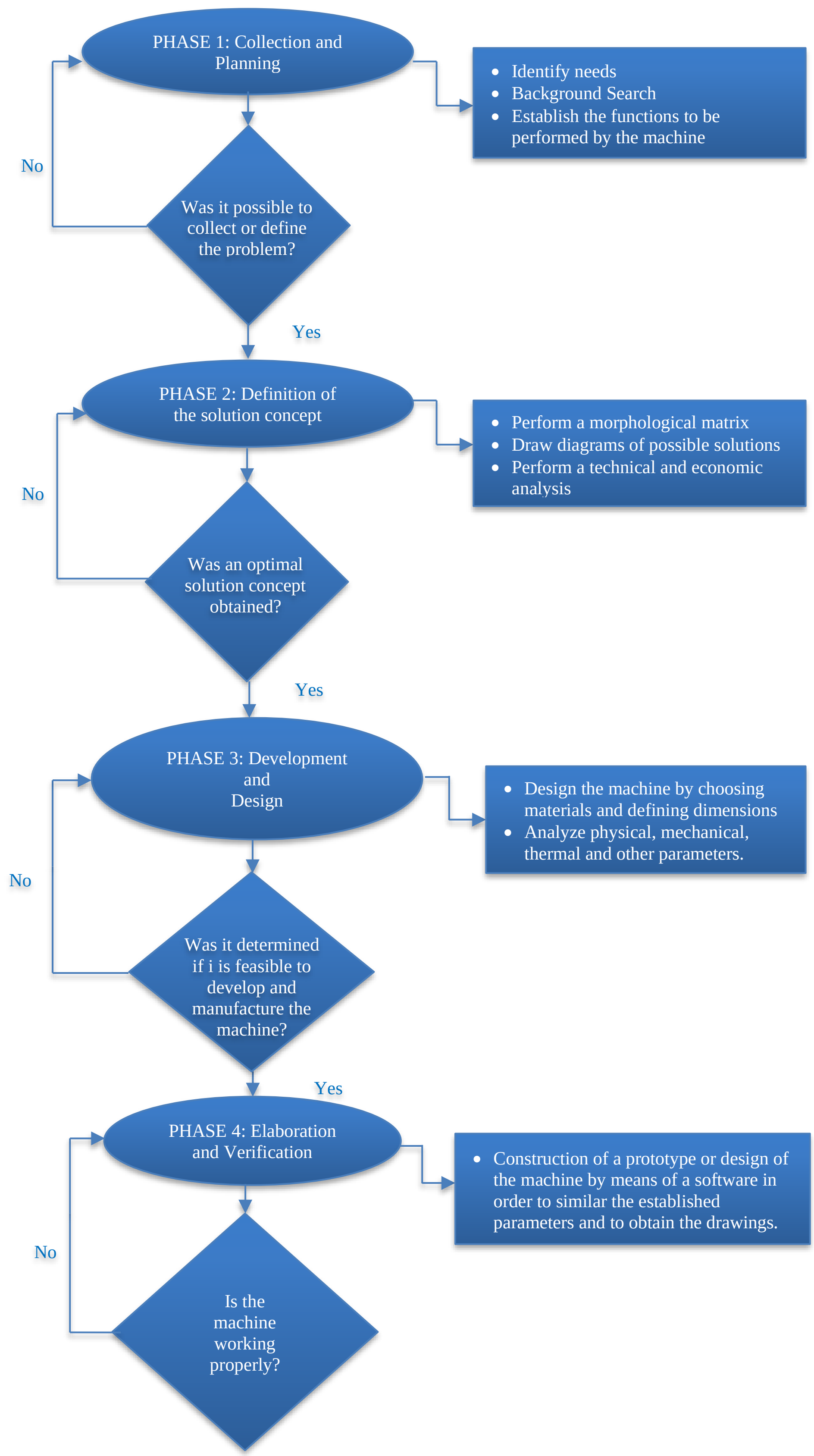

Fig. 2 Diagram of phases and processes of own design based on VDI 2221 and VDI 2225.

As in the ginger peeling machine [5], the use of a horizontal drum is very effective in dealing with soft products and, therefore, causes little damage to ginger. It is also widely used for other root vegetables, such as carrots, potatoes, and sweet potatoes, among others, with a washing capacity of 500-1000kg/h. Cleaning operations are an essential part of food production. [6] where the efficiency of the operations carried out has an enormous influence on the final quality of the product, as a precondition for a pressure washing process must be regularized standards of cleanliness - quality. The ginger washing and peeling machine [7] has a production capacity of 13.86 kg/h and has a design that washes by means of rollers, but these also fulfil the function of peeling for which they use rollers with hard brushes; however, through other works observed previously, these rollers do not always peel the product well when using hard brushes they damage the quality of the ginger causing them to lose edible material. The ginger cleaning machine [8] uses horizontal drums with small holes; the washing procedure is done on top of a tank where water is stored. This water accumulates dirt for each wash, which must be changed constantly, which delays the production and otherwise affects the quality of ginger.

According to Garzón [9], the machines whose main function is washing, as an objective of the tubers, put their main emphasis on the presentation of the product; therefore, the design of a potato washing machine with a pressure of 6.5 hp, a drum with a length of 1.75 m and a diameter of 40 cm; all this taking into account the engineering parameters, in order to improve the quality and presentation which will influence the final value of the product. The pressure cleaning machines [10], unlike other types of washing machines, allow deep cleaning, gentle elimination of waste water and also the possibility of reusing the water.

Because of this, the ginger washing machine will be performed in a way that will improve the quality after harvest and increase productivity in order to compete with other producers. Reviewing the information given by the company Mclanahan [11] to determine the correct equipment for the washing function, it must be determined what type of contamination is to be removed, as the product to be washed is soft and the material to be removed is soil or other residues remaining after its harvest, the appropriate equipment is the use of a drum with paddles that help to remove the residues. For this reason, the design of a post-harvest cleaning machine is made to offer ginger an added value to improve the quality of the final product for export, complying with quality standards.

In this research, it was chosen to use a quantitative approach in sequential and evidential order, which means that each of the stages will be followed if presiding any; these were obtained taking as reference the VDI 2221 standard [12] complemented with the VDI 2225 standard [13]. These methodologies were used to design one of their own (Figure 2.), having as the main focus the technical and economic analysis. Additionally, the sequence of operations is shown in detail (Figure 3), establishing the order of the processes. As part of the process, knowledge such as mechanics of materials, fluid mechanics and turbomachinery was applied in the development of the project, which contributed significantly to preventing errors in the design and the different calculations that were carried out.

The materials proposed in the design of the project were selected according to the function of each system. These materials can be changed as the situation requires. These materials are identified in Table 1.

2. Materials and Methods

For the solution of the problem, a scheme (Figure 2) with the phases to be followed in order to reach the objective was drawn up (Figure 2).

In phase 1, the problem is defined by looking for the needs to be covered, which in this work was to increase the production of ginger while preserving and/or improving the quality of the product. To do so, background information is sought on everything related to the production of ginger, the importance of the final presentation of the product, as well as projects related to the main objective.

In phase 2, the optimal solution is sought, for which the sequence of operations (Figure 3) was carried out to establish the procedures to be performed by the machine; after this, the morphological matrix is developed, where the possible alternatives are sought by selecting either materials or parts which are considered the most suitable for the design of the machine. The possible designs were subjected to different analyses such as technical and economic; after the tests, the design with the highest score was chosen.

In phase 3, the procedures and mathematical calculations were developed to define the different parameters, such as mechanics, dimensions, and quantities, among others; the results obtained are shown in Table I below.

Table 1. Materials selection according to the system

Item	Material
Power supply system	AISI 304 stainless steel
Washing system	4.5 Hp Geared Motor
Drive system	SAE 1045 cold welded stainless steel
Recirculation system	½ Hp electric pump
Structure	ASTM A36

The procedure for obtaining the results shown in Table 1 can be seen in detail.

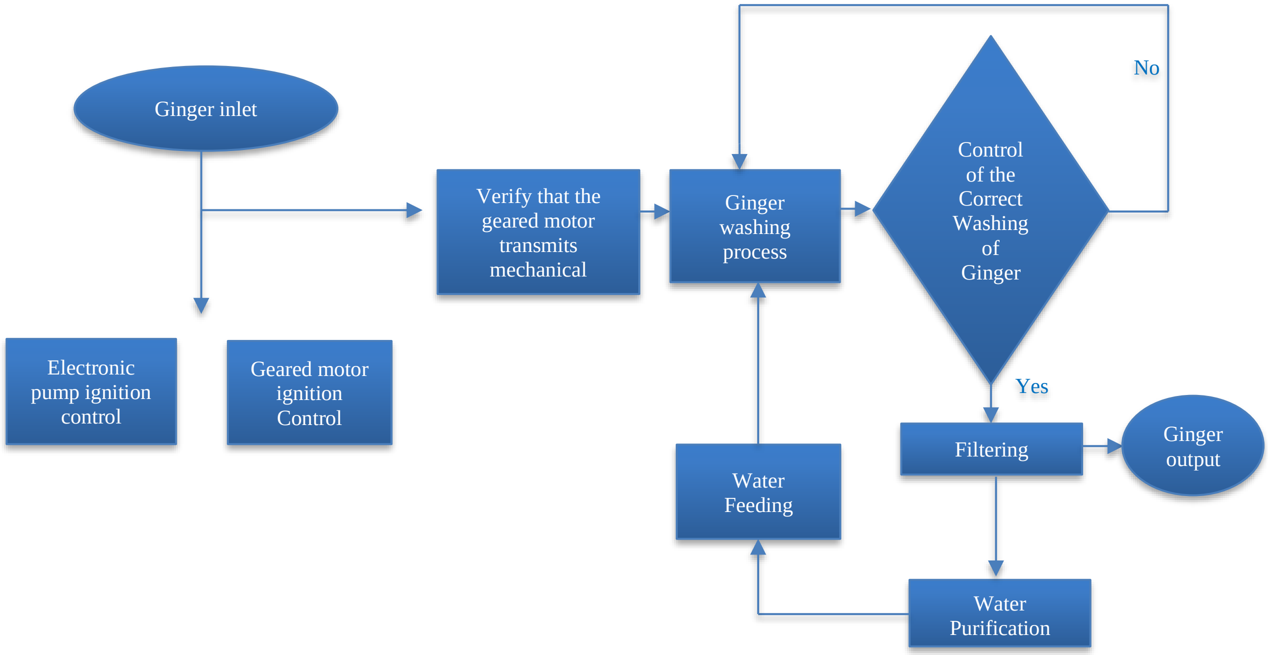

Fig. 3 Sequence of operations

Finally, phase 4 is about testing the operation of the machine; this will depend on the objective or what is proposed in the work; the testing can be done by building the machine and seeing its operation; you can also design the machine in a software and performing the corresponding checks and simulations.

The first design (Figure 4) consisted only of a rotating drum with internal paddles to help distribute and turn the ginger.

Subsequently, the design was improved (Figure 5), concluding with the systems shown in Table 1.

Fig. 4 First design

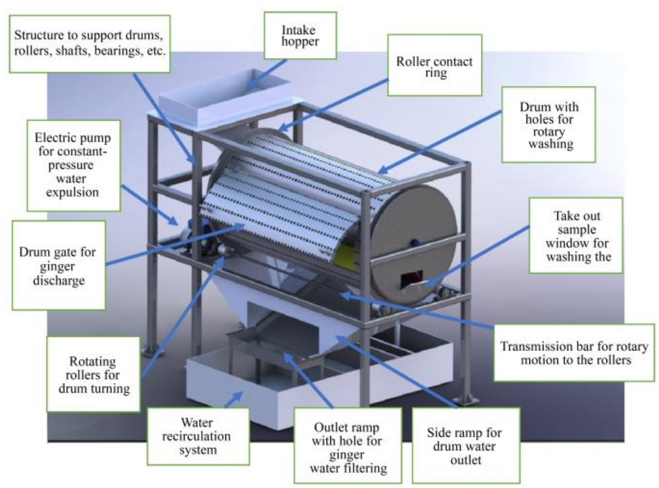

Fig. 5 Current design

3. Results and Discussion

3.1. Power Supply System

The Feeding System in Figure 6 consists of a pyramidal hopper with a rectangular-shaped opening which is located on top of the structure. Its function is to dose the amount of ginger in order to maintain the required amount. The results of the calculations, along with their parameters, are shown in Table 2.

Table 2. Inlet hopper

Parameters	Results
Thickness	2mm to 3mm
Height	300 mm

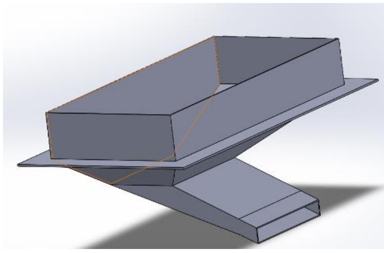

Fig. 6 Intake hopper

3.2. Washing System

The washing system consists of a horizontal drum with paddles inside, and the drum has multiple conical holes. This system rotates thanks to a gear motor that transforms electrical energy into mechanical energy. The analysis of moments of inertia was carried out in order to choose the power of the motor; the angular velocity was taken into account, and it was decided that the drum should rotate approximately 30 rpm. (3.14 rad/s) (n_{tambor}); this, together with other equations, gave us the result that the motor should have a power of 4.5 Hp. The data are shown in Table 3.

Table 3. Drum

Parameters	Equation	Results
Ginger moment of inertia	Value issued by SolidWorks	$I_P = 410\text{Kg} * m^2$
Motor Stabilization Time		$t_m = 2s$
Drum rotation speed		$N = 3.14\, rad/s$
Angular acceleration of the drum	$\beta = \frac{N}{t_m}$	$\beta = 1.57 rad/s^2$
Angular Moment of ginger inside the drum	$M_{TP} = \beta * I_J$	$M_{TP} = 643.7\, N * m$
Geared motor power	$Pot = M_{TP} * N$ $PotD = Pot * C_1/\eta$	$Pot = 2021.22\, W$ $PotD = 3284.48\, W \approx 4.5\, Hp$

3.3. Drive System

The drive system comprises a drive shaft and a secondary shaft, and the drive shaft will be attached to the geared motor, which will be responsible for rotating the entire washing system; the shafts have a pair of nylon rollers Figure 7, its parameters are shown in Table 4, these are responsible for supporting and rotating the drum through some channels that it has. The design was made based on the formulas established in Shigley's book. [14] The first step was to select the material and the diameter that the shaft must have; these data are shown in Table 5.

Table 4. Roller

Parameters	Equation	Results
Diameter	D1	100mm
Inner Diameter	D2	21mm
Long	L1	50mm

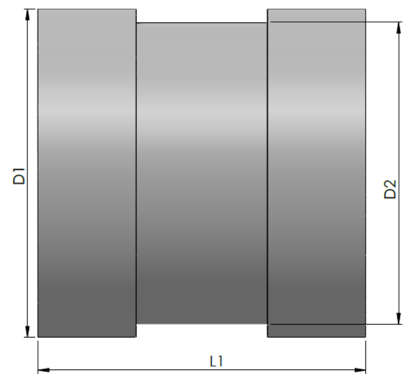

Fig. 7 Nylon roller

Table 5. Axis design

Parameters	Equation	Results
Torque	$T = F * r$	$T = 5.341\, N.m.$
Moments	$M_A = \sqrt{M_{A_{xy}}^2 + M_{A_{xz}}^2}$	$M_A = 26.942\, N.m$ $M_B = 27.237\, N.m$ (Critical Point)
Material		SAE 1045 steel -Cold welding
Creep Resistance	According to table	$S_y = 531\, MPa$
Ultimate Strength	According to Table	$S_{ut} = 627\, MPa$
Hardness	According to Table	$Dureza = 179\, HB$
Stress co-concentration factors	According to Table	$K_t = 2.2$ $K_s = 3$
Notch Radius	Estimate	$r = 0.5m$
Fatigue stress concentration factor	$K_f = 1 + q(K_t - 1)$ $K_{fs} = 1 + q_{cortante}(K_{ts} - 1)$	$K_f = 1.768$ $K_{fs} = 2.56$
Shaft diameter	Von Mises Equation $d = \{\frac{16n}{\pi S_y}[4(K_f M)^2 + 3(K_{fs}T)^2]^{1/2}\}^{1/3}$ $\frac{D}{d} = 1.2$	$d \cong 20\, mm$ $D \cong 24\, mm$

Table 6. Pump selection

Parameters	Equation	Results
Flow rate	$Q = v * A$	$Q = 0.003\,\frac{m^3}{s}$
Flow rate	$V_s = \frac{Q}{A_S}$ $V_d = \frac{Q}{A_S}$	$V_s = 0.365\ m/s$ $V_d = 1.384\ m/s$
Reynolds number	$N_{Rs} = \frac{Ns * Ds * \rho}{n}$ $N_{Rd} = \frac{Vd * Dd * \rho}{n}$	$N_{Rs} = 0.287 * 10^5$ $N_{Rd} = 0.559 * 10^5$
Friction factor	$f = \frac{0.25}{[\log(\frac{1}{3.7\left(\frac{D}{\varepsilon}\right)} + \frac{5.74}{N_R^{0.9}})]^2}$	$fs = 0.033$ $fd = 0.0235$
Losses	$h_1 = h_{fricción} = fs(\frac{Ls}{Ds})\frac{Vs^2}{2g}$ $h_2 = h_{codo\ de\ descarga} = 5k(\frac{Vd^2}{2g})$ $h_3 = h_{válvula} = k(\frac{Vd^2}{2g})$ $h_4 = h_{fricción} = fd\left(\frac{Ld}{Dd}\right)\frac{Vd^2}{2g}$ $h_5 = h_{codo\ succión} = k(\frac{Vs^2}{2g})$	$h_1 = 0.00285m$ $h_2 = 0.278m$ $h_3 = 0.631m$ $h_4 = 0.0312m$ $h_5 = 0.0388m$
Loss Equation	$h_{L_{1-2}} = h_1 + h_2 + h_3 + h_4 + h_5$	$h_{L_{1-2}} = 0.98185m$
Total pump load	$h_A = 0.82 + 0.98185$	$h_A \approx 1.80m$
Pump Family (F) and Power(Pb)	According to the Hidrostal brochure	Family 40 - 125 $P_b = \frac{1}{2}Hp$

3.4. Recirculation System

The recirculation system deals with the recirculation of water, starting with the use of water to wash the ginger, then filtering, storing and cleaning the water for its reentry back into the washing system to be used again; this system consists of a water tank that functions as a sand trap, at the end of which there is a set of pipes that by means of an electric pump sucks the water into it and is expelled through an injector pipe. For the adequate selection of the pump power, the Hidrostal pump family was chosen [15]. The parameters and equations are shown in Table 6.

After completing the corresponding calculations, the simulation was performed in SolidWorks software using Flow Simulation.

The static analysis was performed on the drive shaft to verify if both the shaft design and the material chosen are adequate; Figure 8 shows the result that by means of the VON MISES analysis, the maximum elastic limit is 274.49 MPa which is below the static limit that the material of which the shaft is made can withstand.

The test was carried out by placing a higher force than the one used in the calculations for the design of the shaft in order to check if there was overweight; as a result, the safety factor gives a result of 1.9, which indicates that if there is an the overweighing shaft is able to withstand it without deforming.

3.5. Structure

For the structure, it was decided to use a metal capable of withstanding the pressure of all the systems mentioned above. In addition to being resistant to oxidation by water, ASTM A36 metal was chosen as the best option. To check the strength of the structure, a static analysis was performed with the material proposed in the Solid Works software Figure 9, in which none exceeds the static limit that the structure's material is capable of withstanding (ASTM A36).

The safety factor results in 3.2 which is within a comfortable range in which to work.

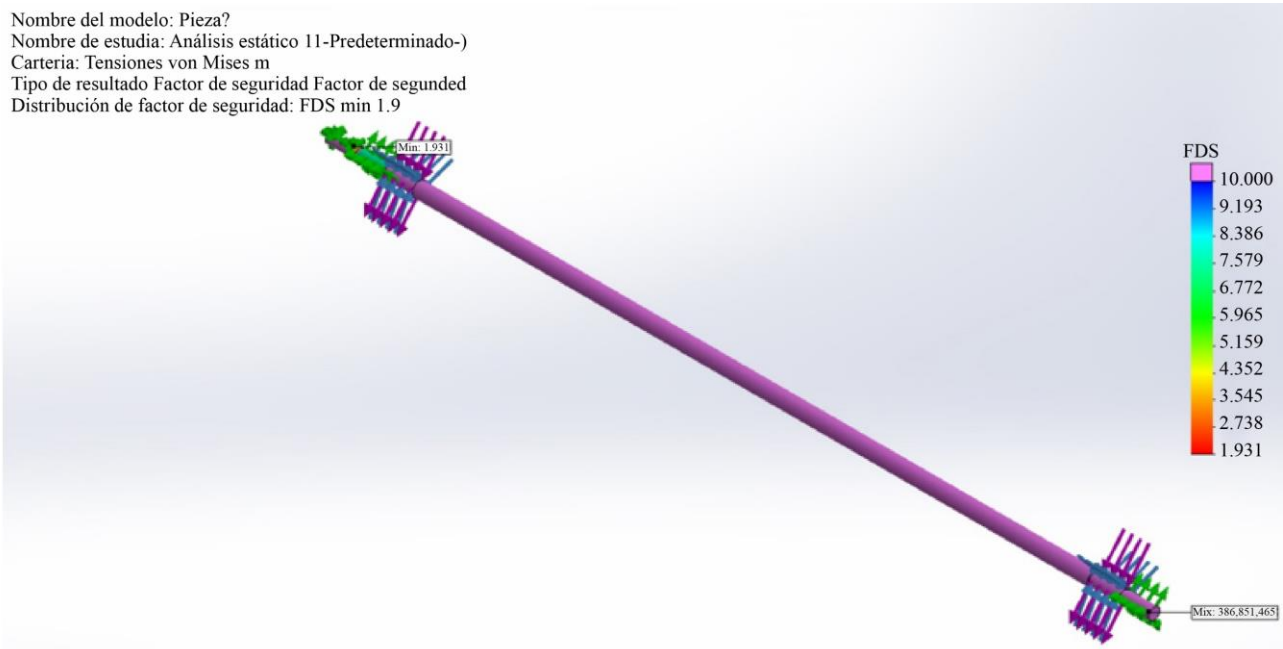

Fig. 8 Simulation of the static analysis of the shaft using Solid Works 2021 software

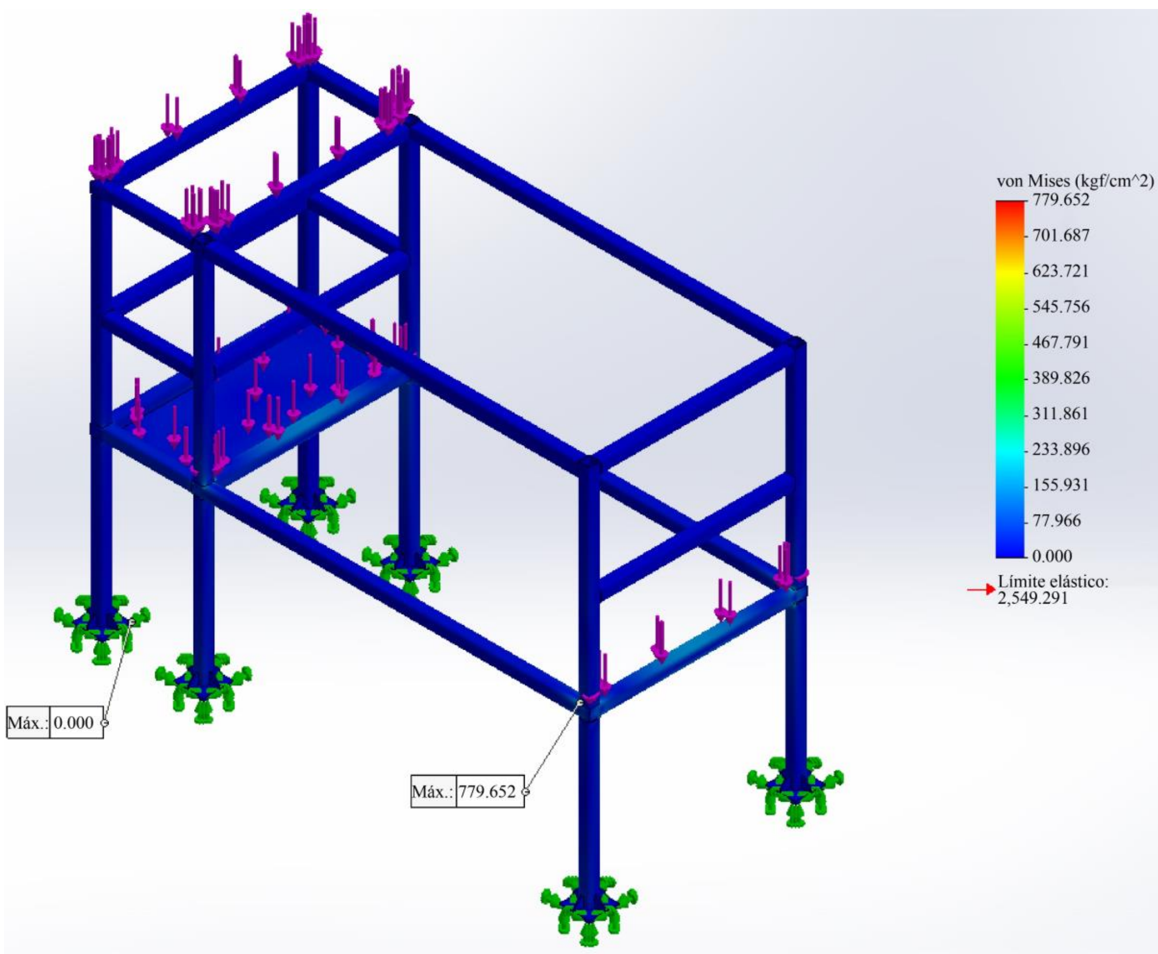

Fig. 9 Simulation of the static analysis of the structure using SolidWorks 2021 software

3.6. Discussion of Results

The post-harvest ginger cleaning machine using pressurized water spraying has several significant advantages, while the peeling machine [5] is a one-way cleaning machine and, therefore, lacks quality control of the final product since there is no re-entry.

Compared to the first design Figure 4, which is of a single washing direction, it was considered that the washing efficiency will improve by 30% because the incoming ginger will be removed after checking its proper washing. This will ensure that the product meets the high-quality standards for export also that the production increases to 40kg/min, which is higher compared to other machines [7].

The water used in the washing process falls directly into the desanding tank located under the structure, which ensures that the quality of the ginger is not affected compared to machines [5] and [8], where the washing process is done directly on the tank where the water is stored but this can affect the quality as it is still in contact with the residual again. The machine has a water filter, where the used water is stored in a desanding tank, in order to clean the impurities from the water to be used again, something that is not present in many of the machines seen since the water used is emptied on the ground or goes directly to the drain.

In addition, it is estimated that water consumption will be reduced thanks to the water recirculation system, which reduces operating costs and also reduces the environmental impact.

4. Machine Description

The machine is composed of an inlet system, a washing system, a drive system, a recirculation system and the structure in charge of supporting all of the above.

The structure consists of ASTM A36 galvanized tubes of 5 to 6 mm thickness, and the structure is welded firmly by an electric arc using electrodes covered with carbon steel 6011. The structure is designed to resist rust, vibration and high pressure.

The inlet system of the machine consists of a rectangular hopper made of a 3mm thick plate, the hopper is designed in a “v” shape for the effective entry of the rhizome into the drum.

The washing and drive system consists of a horizontal drum, a gear motor, a pair of shafts and rollers. The drum is made of a metal plate (steel and chrome alloy) with a thickness of 8 mm, a diameter of 600 mm and a length of 1250 mm; the drum is provided with conical-shaped holes, with paddles incorporated inside the drum to adequately distribute the ginger, two chutes located at both ends and with two lids, one of which is equipped with a sample taker to check the quality of the washing. For the rotary movement of the drum will be used a 4.5hp single-phase motor reducer that performs a reduction of 3 to 1. This motor will drive the shafts that are made of SAE 1045 steel - cold welded 22.8x1380mm; these shafts support the drum through the rollers, these rollers are made of synthetic nylon that make contact with the drum through the channels 25.4mm thick located in it.

The 1/2hp electric pump generates a flow that sucks the water from the tank located under the structure through a foot valve with a basket and a suction pipe; the water is expelled through a discharge pipe to redirect the water flow into the drum where the ginger is washed by spraying pressurized water, which is expelled through a standard ASTM metal pipe which is cut with bladed cuts in different directions. The washed ginger is discharged through a gate located in the drum, and the ginger will be directed through an exit ramp that is welded to a structure with grids where the water will be filtered into the tank, where a desander will filter the impurities to make its use again.

5. Conclusion

- A ginger post-harvest cleaning machine was designed by spraying pressurized water in order to preserve and improve the quality of ginger in Satipo according to the producer’s needs.
- According to the methodology Figure 2 proposed above, it was determined the different systems that the machine must have: the feeding system is composed of a rectangular hopper; the washing system has a drum that is made of AISI 304 with conical holes inside the drum has two pairs of paddles (1 pair. The drum can wash between 30 - 40 kg/min. The drum is placed on a shaft which rotates by means of 100X50 nylon rollers that are counted by means of troughs located at both ends of the drum; the shaft drive system, which is made of cold welded SAE 1045 stainless steel, is driven by means of a 4.5 hp motor reducer; the machine has a washing system that is made of stainless steel SAE 1045.5 hp; the machine has a water recirculation system that through a ramp located under the drum the water is collected and passes through a cleaning system by means of a dewatering system, the recirculation is carried out by a ½ hp motor pump of the 40-120 family. Everything is supported by a structure made of ASTM A36 galvanized pipes.
- The material of the shaft can be changed for one of higher resistance in case it is required to work with a higher weight being higher than 50 kg/min.

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in the Academic School of Mechanical Engineering. His extensive experience as a researcher and inventor, with publications like “Half face mask with continuous air flow regulation thermal stability system: Stabimask” and patents such as “Coffee roasting machine” (Industrial Property Registry No. 1463, Indecopi Peru), has been instrumental to this project’s success. As a registered Mechanical Engineer and member of the College of Engineers of Peru (CIP 85622), his expertise and dedication have significantly advanced our research.

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