Article **Journal Computational Simulation**
December 2022, Vol.6 No.16 1-9

Structural analysis of stresses and deformations of a lump-sifting machine

Análisis estructural de esfuerzos y deformaciones de una máquina desterronadora – cernidora

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DOI: 10.35429/JCS.2022.16.6.1.9 Received: July 10, 2022; Accepted December 30, 2022

Abstract

In this paper, the 3D modeling and structural analysis of a lump-sieving machine is presented, using the Von Mises maximum distortion energy criteria. The study is carried out by the finite element method using the CAD design software SolidWorks. The objective of the study focuses on analyzing the structure of the machine, the blades, and the rotation axis of the clay lump breaker. The results show that the efforts and deformation in the trituration elements, the square axis of rotation and the structure of the machine, in addition to the resistive forces generated by the raw material which, in this case, is clay. According to the results obtained by the CAD software, the elements satisfy a safety factor greater than 1.5, it is verified that the pieces will not fail under normal working conditions. Therefore, the development of this machine will contribute to improving the process (time and quality of raw material) and reducing the physical exhaustion and tear carried out by the artisans of the municipality of Cohuecan.

Von Mises, Modeling, Structural analysis

Resumen

En este trabajo, se presenta el modelado 3D y el análisis estructural de una máquina desterronadora-cernidora, usando el criterio de máxima energía de distorsión de Von Mises. El estudio se realiza mediante el método de elemento finito usando el software de diseño CAD llamado SolidWorks. El objetivo del estudio se centra en analizar la estructura de la máquina, las aspas y el eje de giro de la desterronadora. Los resultados muestran los esfuerzos presentes y la deformación en los elementos de trituración, el eje de giro cuadrado y la estructura de la maquinaria, además, de las fuerzas resistivas generadas por la materia prima que, para este caso, es la arcilla. De acuerdo a los resultados obtenidos por el software CAD los elementos satisfacen un factor de seguridad mayor de 1.5 se comprobó que las piezas no fallaran bajo condiciones de trabajo normales. En consecuencia, el desarrollo de esta máquina contribuirá a mejorar el proceso (tiempo y calidad de materia prima) y a reducir el desgaste físico realizado por los artesanos del municipio de Cohuecan.

Von Mises, Modelado, Análisis estructural

Citation: AMARO-BALANZAR, Jovanni, SÁNCHEZ-TEXIS, Fernando, IBARRA-BONILLA, Mariana Natalia and EUSEBIO-GRANDE, Raúl. Structural analysis of stresses and deformations of a lump-sifting machine. Journal Computational Simulation. 2022. 6-16:1-9.

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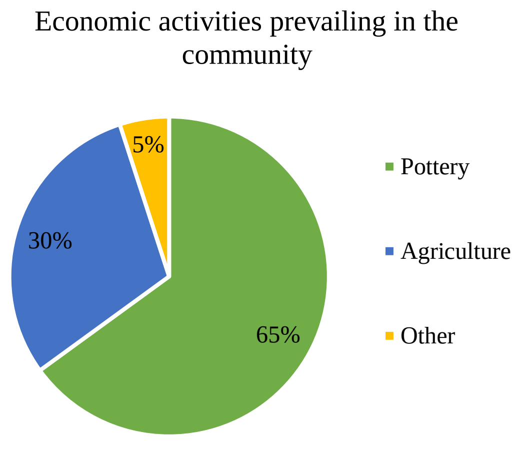
Introduction

Economic activities are called all those activities through which human beings satisfy their needs, and that generate profits within the market for their producers. (Cáceres, 2013)

We can distinguish primary, secondary and tertiary economic activities. Craft activities are secondary in their classification according to their function, modifying the raw material, and in the state of Puebla alone, it involves more than 50,000 people, who live from crafts as their first or second source of income. (Cáceres, 2013)

There are various craft techniques ranging from ceramics and pottery to jewelry. Pottery is the art of making clay pots and is considered the oldest industry; however, today this activity has an economic burden in different municipalities of the state of Puebla, among which is the municipality of Cohuecan.

Cohuecan is located in the center-west part of the state of Puebla where, according to the results of the 386 surveys applied by collaborators from the Higher Technological Institute of Atlixco (ITSA), the Higher Technological Institute of Acatlán de Osorio (ITSAO) and the University Technological Institute of Izúcar de Matamoros (UTIM), the main economic activity of its inhabitants is pottery with 65% (Graphic 1).



Graphic 1 Economic activity with the greatest impact in the municipality of Cohuecan
Source: Own elaboration

For the pots, plates, glasses, and an endless list of pieces to reach the hands of the final consumers, the potters need to carry out a whole previous process that basically consists of five stages: (Brito, 2017).

- Lumpy.
- Sifting.
- Making of the raw material.
- Kneading.
- Cut and flattened.

Currently (Figure 1), most of the families dedicated to pottery carry out the first phase of the process with the help of a basic lump-breaker with a maximum capacity of 5 kg or, in more limited conditions, the lump-breaking is done manually with the help of a shovel or a hammer mill. When they go to the sifting stage, they use a fine mesh sieve to separate the finest part of the clay once it has been clodded.

The other three stages contemplate the mixture of clay with water to prepare the raw material that, later, will be kneaded manually by the potters. Finally, the dough is cut and flattened according to the piece to be made and thus, the final craft is made.

Figure 1 Diagram of the process of making clay pieces in the municipality of Cohuecan Puebla
Source: Own elaboration

Although the pottery process consists of five stages, this article only focuses on the first two of the process, that is, the breaking up and sifting of the raw material. For this reason, the present work consists of presenting the mechanical design and static analysis of the structure of a lump-sieving machine to verify the viability of the materials to be used in its construction. Consequently, the article is divided into different sections where the material used, the methodology implemented, the results obtained, and conclusions are discussed.

ISSN 2523-6865

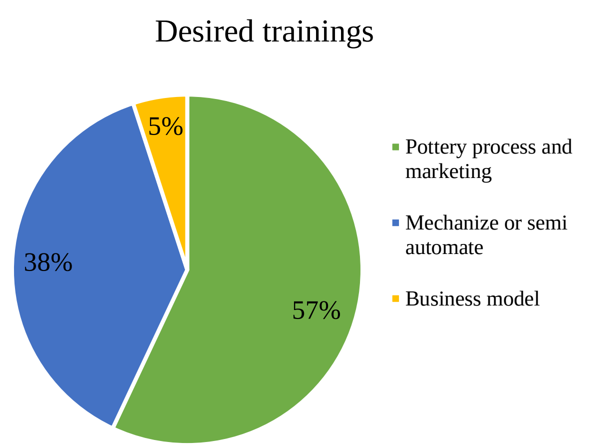
Lump breaker

Lump shakers are machines intended for the dissolution of lumps and agglomerations, they are always used when in a process, due to storage, sedimentation or pressure reasons, there are (in most cases) large pieces/lumps of product (unwanted) that must be crushed to certain sizes. (Armas, 2020)

Sifter

A sieve is nothing more than a machine that performs the function of a sieve, it serves to separate the powders, or in this case the clay, of different thicknesses. (Calderón, 2020).

There are independent lumping and sifting machines on the market, which have various advantages and disadvantages such as sound insulation and low vibration frequency; However, there is no general machine that can simultaneously carry out two stages of the artisanal process, such as the breaking up and sifting of the clay, and that, in addition, they are provided with training to be able to operate the machine since, According to the graph shown in figure 3, of the 386 people surveyed, 57% would like to be trained in the pottery process.



Graphic 2 Identification of the needs of the inhabitants of the municipality of Cohuecan
Source: Own elaboration

In addition to the above, the analysis of the mechanical elements, as well as the selection of the material, is sometimes not taken into account when these machines are designed independently. (Faires, 2003; Gómez, 2018).

Material

The material used in the structure of the machine is the galvanized steel PTR; because it is a very dense material it provides ease of welding and moderate cutting, molding and machining. Likewise, it has a greater weight, tenacity; it has a resistance to corrosion and extreme temperatures; and has superior machinability.

Table 1 shows the properties of galvanized steel of special interest for the project. (Hibbeler, 2011).

Property	Amount	Units
Elastic module	2e + 11	$\frac{N}{m^2}$
Poisson's ratio	0.29	$\frac{N}{D}$
Mass density	7870	$\frac{Kg}{m^3}$
Traction limit	356900674.5	$\frac{N}{m^2}$
Elastic limit	203943242.6	$\frac{N}{m^2}$

Table 1 Specifications of galvanized steel
Source: Own elaboration

Methodology

Structure

Simulation:

The following structure (Figure 2) will be subjected to a numerical analysis using the finite element method and a static stress-strain analysis using the Von Mises criterion.

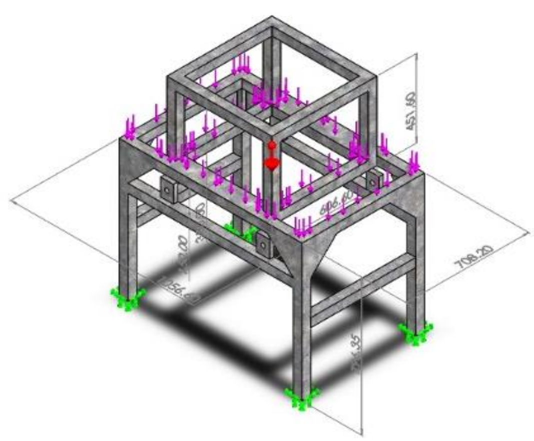


Figure 2 Structure
Source: Own elaboration

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Gravity:

In this part, our reference point is the plant (the structure, which is the part that receives the greatest force due to the sifting process), which is subjected to a gravity force of 9.81 m/s^2.

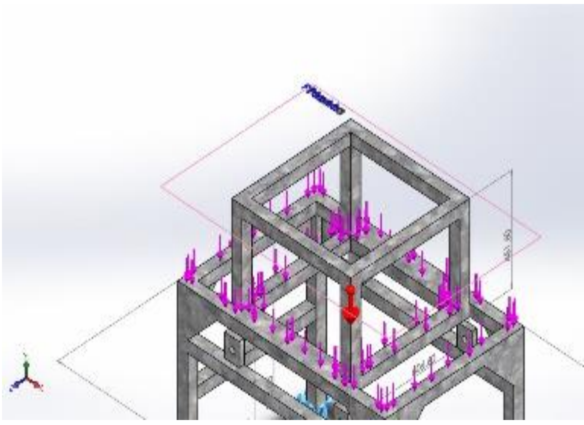

Figure 3 The red arrow in the image indicates the gravity applied to the structure
Source: Own elaboration

To apply the loads to the structure, two areas were chosen where the greatest amount of force is applied due to the back-and-forth movement that the sifting machine will perform once placed.

Load 1:

In figure 4 it can be seen in blue the first face of the structure subjected to a normal force of 1000 N; these loads (represented by blue arrows) are distributed along the selected face of the structure. In reality, the structure is designed to support up to 50 kg of clay (500 N of force), however, in the analysis a safety factor of 1.5 is being considered to limit the nominal load that it will actually support to 100 kg. its useful life the structure.

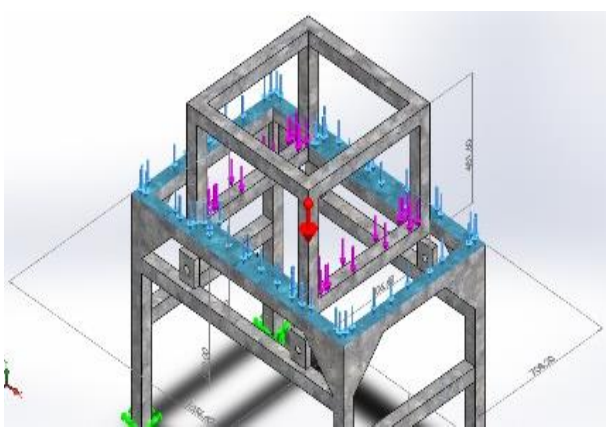

Figure 4 Distribution of forces on one face of the structure
Source: Own elaboration

Load 2:

For force two, the total subjected force of 1000 N is distributed to two faces of the structure as shown in the figure; these forces are also marked with blue arrows.

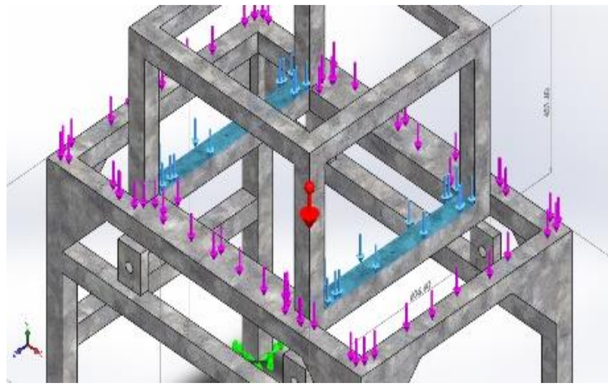

Figure 5 Distribution of forces in the second section of the structure
Source: Own elaboration

Numerical analysis

Figure 6 represents the resulting mesh after applying the numerical analysis by the finite element method with the computer software. The method can be applied in the resolution and diagnosis of structural analysis problems to obtain displacements, deformations and stresses. In this analysis, the entities can be in contact or at a small distance from each other, they are of various types, the one used is of the rigid union type and compatible meshing.

Thus, we have a standard solid mesh type, with an element size of 35.8595mm and a tolerance of 1.79298mm, as well as a total number of nodes of 15649 and a total number of elements of 7637.

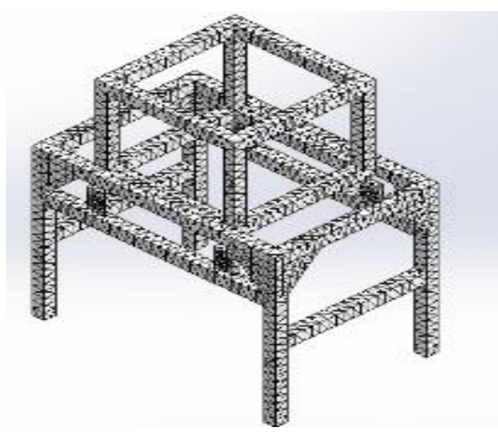

Figure 6 Numerical analysis by the finite element method of the structure
Source: Own elaboration

ISSN 2523-6865

Resultant forces

As can be seen in table 2, the forces are practically negligible in the X and Z axis due to the way in which the design is made in the software, contrary to the y axis, which practically receives all the force applied to the structure.

Selection	Units	Sum X	Sum Y	Sum Z	Resulting
All model	N	0.00976896	5275.17	-0.0487652	5275.17

Table 2 Resulting forces applied on the structure
Source: Own elaboration

Axis

Simulation

The following clamping axis (Figure 7) will be subjected to a numerical analysis using the finite element method and a static stress-strain analysis using the Von Mises criterion.

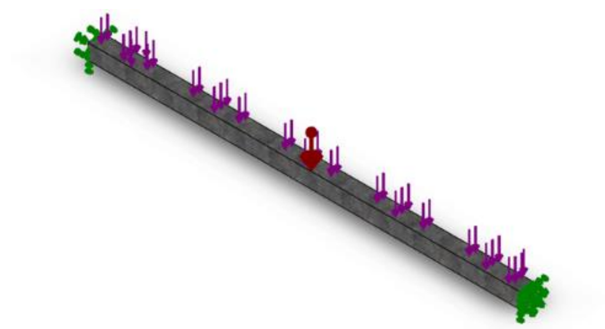

Figure 7 Clamping axis
Source: Own elaboration

Gravity

The reference point is the floor (the clamping axis), which is subjected to a gravity force of 9.81 m / s^2.

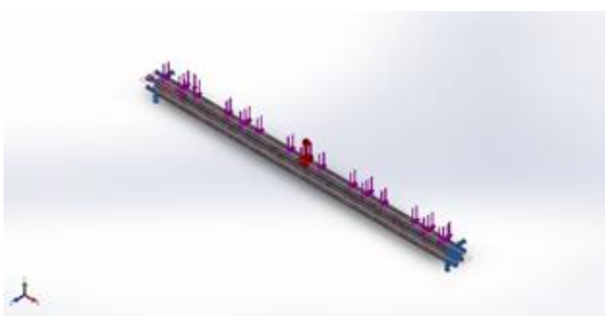

Figure 8 The red arrow in the image indicates the gravity applied to the axis
Source: Own elaboration

To apply the load to the shaft, an area was chosen where the greatest amount of force is applied due to the turning movement.

Load 1

It can be seen in blue on the first face of the structure subjected to a normal force of 750 N, (about 75 kg); these loads (represented by blue arrows) are distributed along the clamping axis. The maximum weight to support will be 50 kg, so the blades have a safety factor of 1.5.

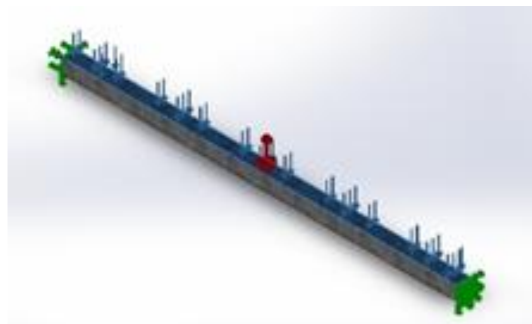

Figure 9 Distribution of forces on one face of the shaft
Source: Own elaboration

Numerical analysis

Figure 10 represents the resulting mesh after applying the numerical analysis by the finite element method with the computer software. The method can be applied in the resolution and diagnosis of structural analysis problems to obtain displacements, deformations and stresses.

In this analysis, the entities can be in contact or at a small distance from each other, they are of various types, the one used is of the rigid union type and compatible meshing.

Thus, we have a standard solid mesh type, with an element size of 11.4398 mm and a tolerance of 0.571988 mm, as well as a total number of nodes of 3244 and a total number of elements of 1551.

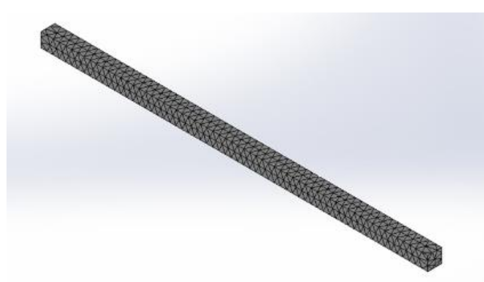

Figure 10 Numerical analysis by the finite element method of the clamping axis
Source: Own elaboration

ISSN 2523-6865

Resulting forces

As can be seen in table 3, the forces are practically negligible in the X and Z axis due to the way in which the design is made in the software, contrary to the y axis, which practically receives all the force applied to the structure.

Selection	Units	Sum X	Sum Y	Sum Z	Resulting
All models	N	-0.0956726	785.401	-0.0582352	785.401

Table 3 Resulting forces applied on the axis
Source: Own elaboration

Blades

Simulation

The next axis will be subjected to a numerical analysis using the finite element method and a static stress-strain analysis using the Von Mises criterion.

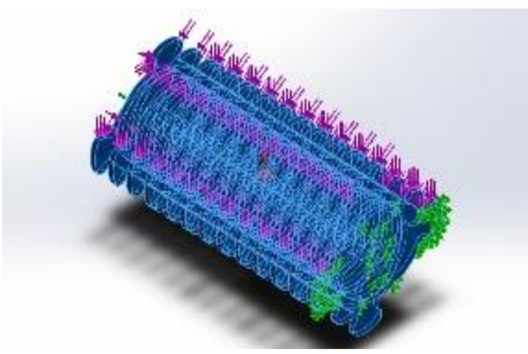

Figure 11 Holding shaft
Source: Own elaboration

Gravity

In this part, the reference point is the plant (the blades), which is subjected to a gravity force of 9.81 m / s^2.

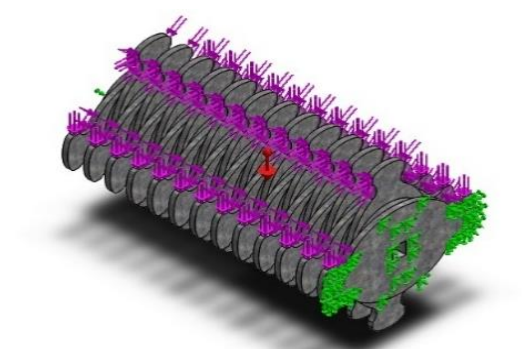

Figure 12 The red arrow in the image indicates the gravity applied to the blades
Source: Own elaboration

To apply the load to the blades, an area was chosen where the greatest amount of force is applied due to the turning movement.

Load 1

In figure 13 it can be seen in blue the first face of the structure subjected to a normal force of 750 N, (around 75 kg); these charges (represented by blue arrows) are distributed along the blades. Actually, the maximum weight to be supported will be 50 kg, so the blades have a safety factor of 1.5.

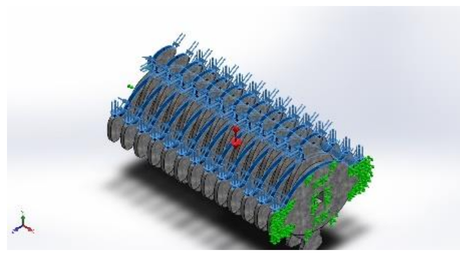

Figure 13 Distribution of forces to the faces of the blades
Source: Own elaboration

Numerical analysis

Figure 14 represents the resulting mesh after applying the numerical analysis by the finite element method with the computer software. The method can be applied in the resolution and diagnosis of structural analysis problems to obtain displacements, deformations and stresses. In this analysis, the entities can be in contact or at a small distance from each other, they are of various types, the one used is of the rigid union type and compatible meshing.

Thus, we have a standard solid mesh type, with an element size of 27.3413 mm and a tolerance of 1.36706 mm, as well as a total number of nodes of 23214 and a total number of elements of 11668.

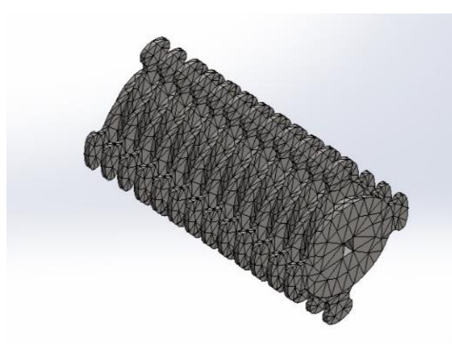

Figure 14 The red arrow in the image indicates the gravity applied to the blades
Source: Own elaboration

ISSN 2523-6865

Resultant forces

As can be seen in table 4, the forces are practically negligible in the X and Z axis due to the way in which the design is made in the software, contrary to the y axis, which practically receives all the force applied to the structure.

Selection	Units	Sum X	Sum Y	Sum Z	Resulting
All models	N	-4.73118	1485.07	61.3836	1486.34

Table 4 Resulting forces applied on the blades
Source: Own elaboration

Results

For the presentation of the results we will delve into a topic of great importance which is the Von Mises criterion, it will be of great importance to us to understand part of the results of the final structural analyses.

The Von Mises criterion, also called the maximum distortion energy criterion, is a static resistance criterion, applied to ductile materials depending on the material, it will not flow at the analyzed point as long as the distortion energy per unit volume at the point does not exceed the distortion energy per unit volume that occurs at the moment of creep in the tensile test. (Hibbeler, 2011).

Structure

Stress

As can be seen in Figure 15, in the Von Mises criterion presented by our structure, the minimum stress coefficient is $4.056e * 10^2 \frac{N}{m^2}$ and the maximum stress coefficient is $3.299e * 10^6 \frac{N}{m^2}$.

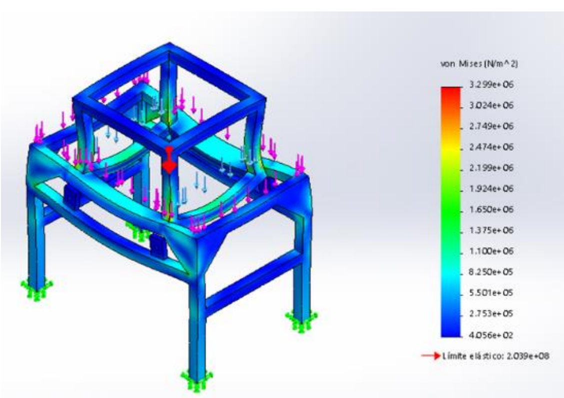

Figure 15 Von Mises stresses in the structure
Source: Own elaboration

Displacement

In Figure 16 we can observe the Von Mises criterion that our structure presents, the minimum displacement coefficient is 0 mm which makes it negligible and the maximum tension coefficient is $1.598e * 10^2\ mm$. Which in turn we can visualize due to the resulting displacement (URES). (Norton, 2011).

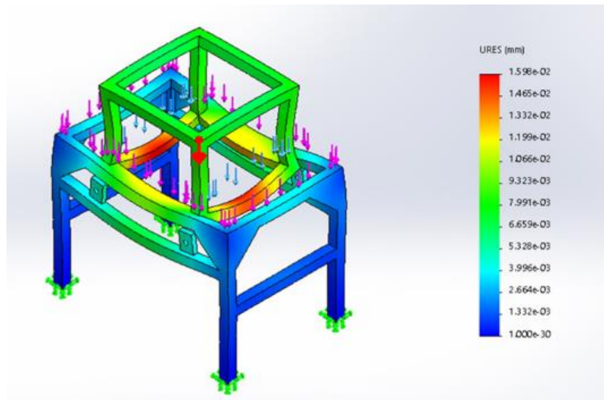

Figure 16 Displacements of the structure
Source: Own elaboration

Unitary deformations

Finally we can observe the equivalent unit strain of the structure whose minimum strain coefficient is $1.950e * -10^9$ which makes it negligible and the maximum stress coefficient is $1.063e * -10^5$.

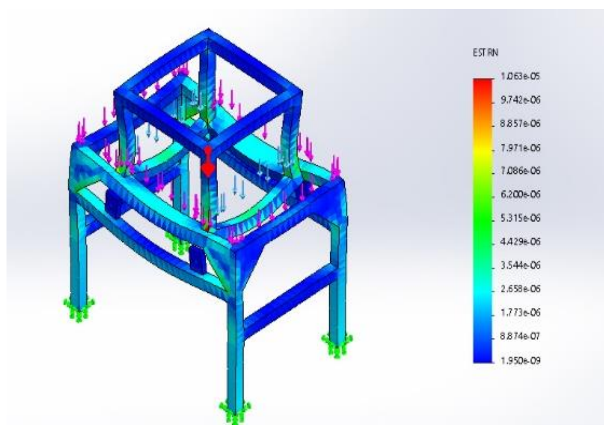

Figure 17 Unitary deformations of the structure
Source: Own elaboration

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Clamping axis

Stress

As can be seen in Figure 18, in the Von Mises criterion presented by our structure, the minimum stress coefficient is $1.847e * 10^4 \frac{N}{m^2}$ and the maximum stress coefficient is $1.623e * 10^7 \frac{N}{m^2}$.

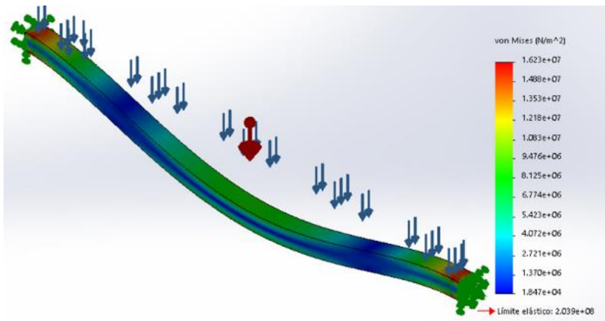

Figure 18 Von Mises stresses on the axis
Source: Own elaboration

Displacement

In Figure 19 we can see, in the Von Mises criterion that our structure presents, the minimum displacement coefficient is 0 mm which makes it negligible and the maximum tension coefficient is $1.063e * 10^{-1}\, mm$. Which in turn we can visualize due to the URES.

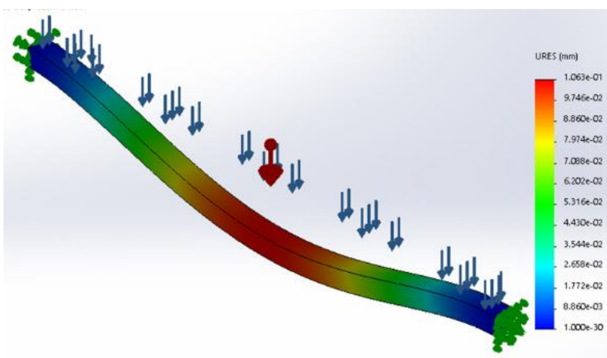

Figure 19 Axis displacements
Source: Own elaboration

Unitary deformations

Finally, we can observe the equivalent unit strain of the structure whose minimum strain coefficient is$1.861e * 10^{-6}$ which makes it negligible and the maximum stress coefficient is $5.808e * -10^{-5}$.

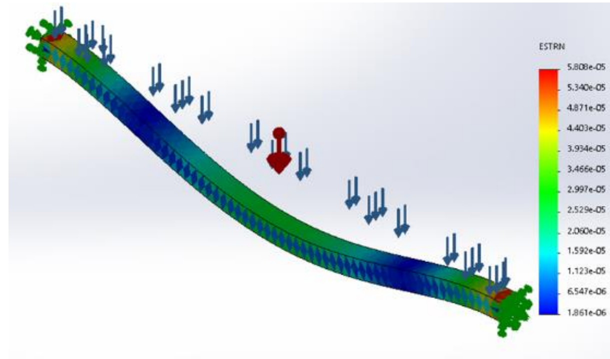

Figure 20 Shaft unit strains
Source: Own elaboration

Blades

Stress

As can be seen in the following table, in the Von Mises criterion presented by our structure, the minimum stress coefficient is $6.103e * 10^1 \frac{N}{m^2}$ and the maximum stress coefficient is $2.507e * 10^5 \frac{N}{m^2}$.

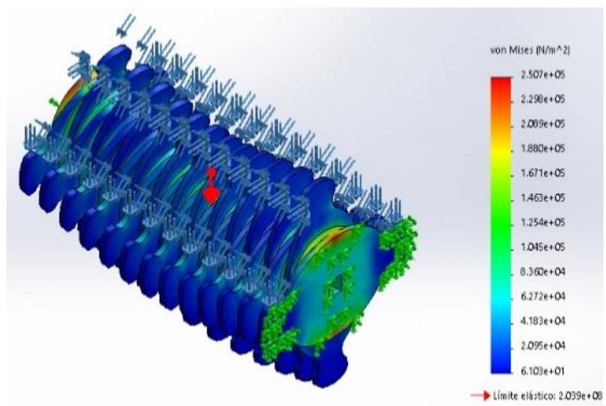

Figure 21 Von Mises stresses in the blades
Source: Own elaboration

Displacement

In this second table we can observe, in the Von Mises criterion that our structure presents, the minimum displacement coefficient is 0 mm which makes it negligible and the maximum tension coefficient is $2.045e * 10^4\, mm$. Which in turn we can visualize due to the URES.

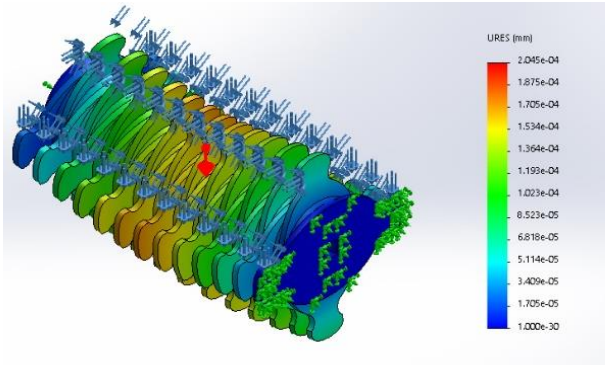

Figure 22 Displacements in the blades
Source: Own elaboration

Unitary deformations

Finally, we can observe the equivalent unit strain of the structure whose minimum strain coefficient is$6.989e * 10^{-10}$ which makes it negligible and the maximum stress coefficient is $9.142e * -10^{-7}$.

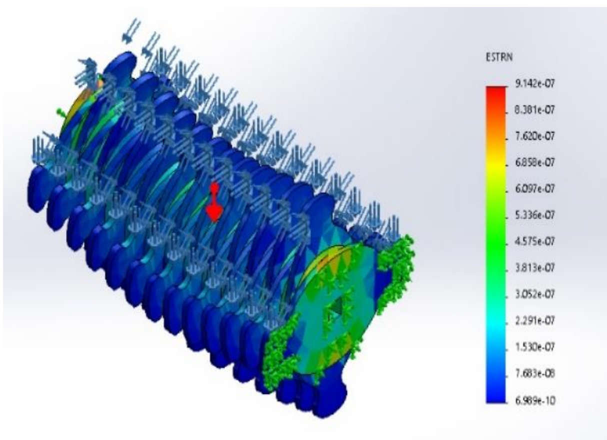

Figure 23 Deformations in the blades
Source: Own elaboration

Acknowledgement

The authors appreciate the support granted by PRODEP, for the realization of this work.

Financing

This project is financed by PRODEP through the Support Program for the Strengthening of CA with assignment document: M00/2250/2021.

Conclusions

The design of a joint system of two machines (lumps and sifters) was proposed, which, by working together, is expected to reduce work times and delivery of pottery products. Thanks to the proposal of this machinery, the artisans will have a decrease in the physical fatigue that comes with the manual work of breaking up and sifting the raw material.

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