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Strength Analysis of the Frame and Shaft of the Planting Media Mixing Machine With a Maximum Capacity of 100 kg/process

(Analisis Kekuatan Rangka Dan Aci Mesin Pembancuh Media Tanam Dengan Kapasiti Maksimum 100 kg/proses)

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Abstract

Cultivation of white oyster mushroom (Pleurotus ostreatus) is a relatively easy business because the raw materials for planting media are relatively easy to obtain, such as sawdust, rice bran (bran), calcium, and water. The increasing demand for oyster mushrooms is one of the reasons for the development of oyster mushroom cultivation. Mushroom growing media (baglog) can continuously harvest oyster mushrooms within 4-5 months. A mixer is needed to prepare the planting media to save production time. Ensuring the mixing machine can operate for a long time, it is necessary to analyze the strength of the components of the mixing machine, especially against the possible loadings. In this paper, the strength analysis is focused on the components of the engine frame and the mixing engine shaft because the probability of failure is quite large. The strength of the shaft and frame were analyzed using Ansys software. The growing media mixing machine analyzed has a maximum capacity of 100 kg per process, whereas one mixing process takes 12 minutes. The analysis using the Von Misses Stress showed a maximum of 121,8 Mpa on the upper side of the frame and 25.376 Mpa on the shaft for a stirring capacity of 100 kg.

Keywords: Oyster mushroom, planting media, mixer, strength analysis, shaft, frame.

INTRODUCTION

Oyster mushroom cultivation is a business that does not require a large area of land, the maintenance process is relatively easy, and the raw materials are easy to obtain and cheap. Although oyster mushrooms are not classified as basic food needs, they are in great demand by the public because of their high nutritional content and non-cholesterol (Egra et al., 2018; Sagaf et al., 2021). The breeding process is also relatively easy using planting media (baglog), whose ingredients are readily available. Conventional white oyster mushroom growing media is sengon wood powder (Paraserianthes falcataria), containing 49% cellulose, 26.8% lignin, 15.6% pentose, and 0.6% ash, and 0.2% silica (Kurniati et al., 2019). Mushroom growing media (baglog) can continuously harvest oyster mushrooms within 4-5 months. The process of processing planting media for baglog raw materials includes preparing raw materials, mixing, composting, baglog printing, sterilization, inoculation, incubation, and maintenance. In the conventional baglog production process, the mixing of these ingredients is stirred in a container such as a bucket so that it is evenly distributed using a hoe by several workers. The mixing process is carried out using a mixer driven by an electromotor or combustion engine.

Mixer performance is very influential in producing good quality baglog, which is very dependent on the homogeneity of the mixture. Based on the mixer model, the mixers consist of ribbon mixers, plough mixers, paddle benders, rotatable drums, V-blenders, and double cone blends. Based on the type of vessel, the mixer can be divided into a mixer with a rotating vessel and a fixed vessel.

This paper discusses the analysis of the strength of the baglog mixer machine components to ensure the machine is safe in operation and can be used for a relatively long period. In this case, the strength analysis is focused on components that are considered quite important, i.e., the shaft and frame.

SHAFT

The shaft is a machine element that functions to move rotation or support a load with or without transmitting power (Mott et al., 2011; Reddy, 2017). Shafts carry loads perpendicular to their axes. Such loads produce bending moments in the shaft, generating bending stresses. This flexural stress is normal stress, either tensile or compressive stress. The maximum bending stress in a shaft cross-section will occur at the farthest from the neutral axis of the cross-section (Mulyanto & Sapto, 2017). The deflection and torsion angle is used to determine whether the shaft is safe or not in machine construction.

FRAME

The frame is an essential element that cannot be separated in manufacturing a machine with a function as a support and a place for other components. The frame must have criteria that must be able to withstand the load from the components that hit it, be able to withstand vibrations that arise due to the working process of the machine and have alignment between the frame legs and the support for the engine components (Majid et al., 2019).

STRESS

Stress is the intensity of internal forces on structural elements as a reaction to deformation arising from the work of external loads. In practice, the stress that occurs in machine construction can be in the form of normal stress and shear stress. In practice, several stresses can work simultaneously in machine construction.

VON MISES STRESS

Von Mises's stress is an indicator that measures material failure by analyzing the resultant 3 main stresses or commonly called Principal Stress. A simulation is carried out by showing the value of Von Mises's stress to see the spread of stress in the material. Failure is predicted if the value of the Von Mises stress is greater than the material's yield stress.

$$\sigma_V > \sigma_y \quad (1)$$

Where:

σ_v = Von Mises Stress
σ_y = yield stress

METHODOLOGY

FLOW CHART METHODOLOGY

In this paper, the strength analysis is carried out on the machine shaft and baglog mixer frame with finite element analysis using Ansys software. There are several steps involved in this analysis, including:

1. Shaft and frame model drawing
2. Input data such as constraints, load, and material types
3. Running analysis
4. Analysis of the distribution of stresses, strains, and displacements on both the shaft and frame of the machine

For more details about the flow chart of this research can be seen in Figure 1.

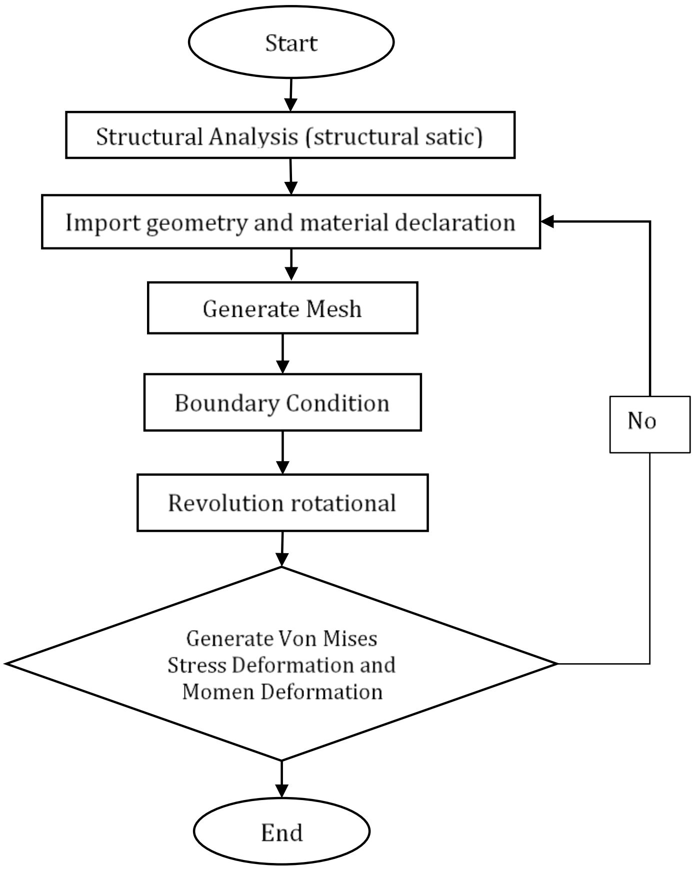

Figure 1. Research Flow chart

STIRRING SHAFT

The modelling for the stirring shaft and frame can be seen in Figure 2. The modelling drawing shows that the loading that occurs on the stirring shaft is the torsional moment, and the loading that appears on the frame is due to the weight of the components placed on the frame. The magnitude of the torsion moment obtained is the product of the farthest distance of the stirring blade and the tangential force Ft. The difficulty in getting the torque value is due to the irregular shape of the blade.

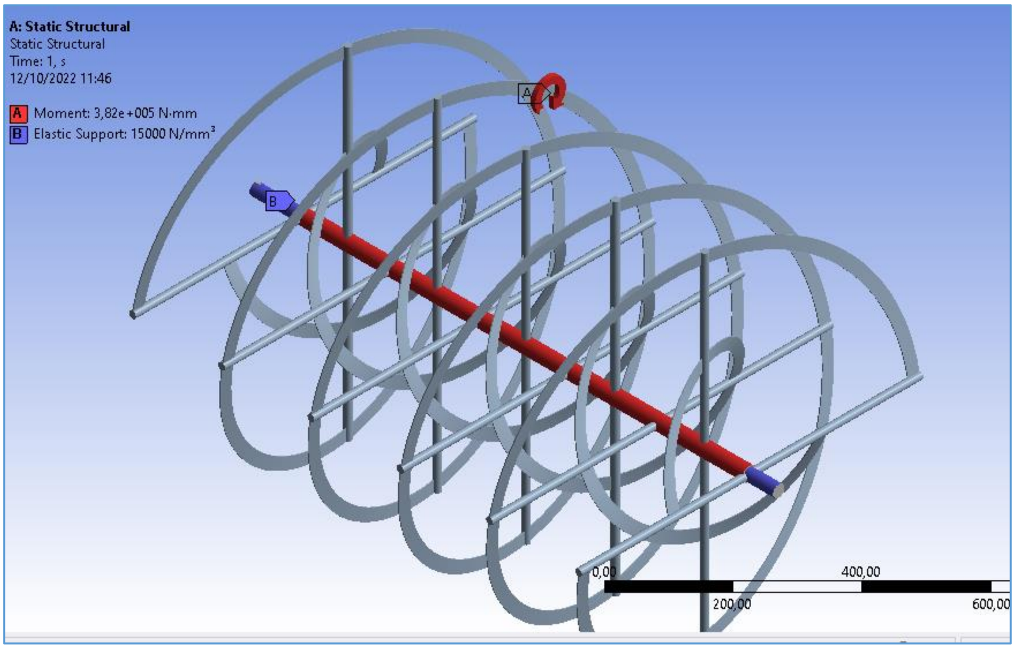

Figure 2. Stirring shaft model and structural mechanics' input

Based on the strength simulation carried out on the baglog mixing machine shaft, several results were obtained in the form of stress, strain, and displacement. On the working shaft, shear loading can be formulated due to tangential force on the stirring blade.

$$F_t = \mu . N \qquad (2)$$

Where: μ = coefficient of friction
N = normal force = mg

Therefore, the torsional moment acting on the stirring shaft is:

$$T = F_t . r \qquad (3)$$

Where: r = the outer radius of the stirring blade

Since the capacity of the baglog mixer machine is 100 kg/batch, Ft = 300 N is obtained. The shaft material is S50C carbon steel, which is a medium carbon steel group. The design simulation parameters for the stirring shaft can be seen in Table 1.

Table 1. Parameters used in the simulation of stirring shaft

Properties	Value
Mass Density	7850 kg/m^3
Yield Strength	343 Mpa
Ultimate Tensile Strength	569 Mpa
Young's Modulus	200 Gpa
Poisson's Ratio	0,3
Shear Modulus	76,923 Gpa

BAGLOG MIXING MACHINE FRAME

The modelling for the baglog mixing machine frame can be seen in Figure 3. From the modelling drawing, the loading that occurs frame is due to the weight of the components placed on the frame.

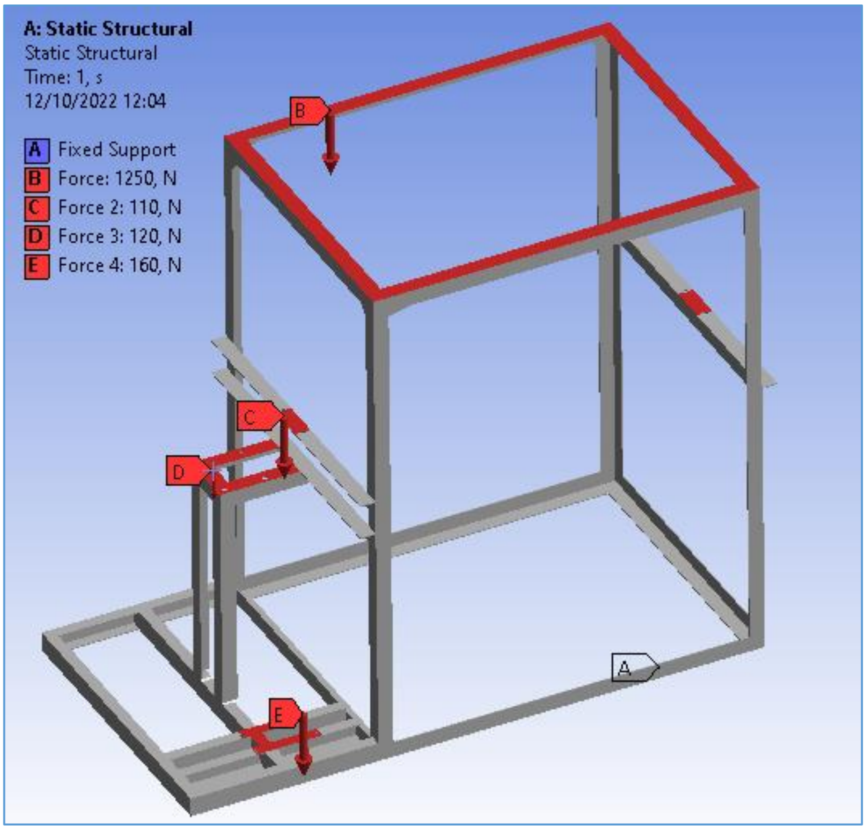

Figure 3. Baglog mixer frame model and structural mechanics' input

The calculation of the mass located above the baglog mixing machine frame can be seen in Table 2. Mass is obtained by counting and weighing the components directly.

Table 2. The results of the calculation of the mass above the frame

Part	QTY	Materials	Result
combustion engine	1	-	16 kg
gearbox	1	Cast Iron	12 kg
stirring shaft	1	St 37	7 kg
stirring knife	20	St 37	4 kg
vessel	1	St 37	25 kg
baglog	-	-	100 kg

The F1 force in Figure 2 shows the weight of the vessel plus the weight of the baglog mixture in the vessel. Meanwhile, the F2 style is the weight of the stirring shaft and stirring knife simultaneously. The forces F3 and F4 are the weight of the gearbox and the weight of the combustion engine, respectively.

Testing on the frame of the baglog mixer machine was carried out by analyzing the static load on the frame of the baglog mixer machine using the Ansys software. In the results of this design simulation, the data in Figure 4 is obtained as follows:

The design simulation parameters for the baglog mixing machine frame components can be seen in table 3.

Table 3. Parameters used in the baglog mixer frame simulation

Properties	Value
Mass Density	7850 kg/m^3
Yield Strength	300 Mpa
Ultimate Tensile Strength	370 Mpa
Young's Modulus	200 Gpa
Poisson's Ratio	0,3
Shear Modulus	76,923 Gpa

RESULTS

STIRRING SHAFT STRENGTH ANALYSIS

Testing on the stirring shaft is carried out by analyzing the static load on the agitating shaft using Ansys software so that the output of von mises stress, displacement and safety factor is obtained. The simulation results can be seen in table 4 below.

Table 4. Simulation result on stirring shaft

Name	Minimum	Maximum
Von Mises Stress	0,14173 MPa	121,8 Mpa
Strain	0,00000032367 mm/mm	0,0006283 mm/mm
Displacement	0,029864 mm	0,18633 mm
Safety factor	2,8161	15

Stress distribution on the shaft can be seen in Figure 4. From the distribution, we can see that maximum stress is located at the left support. Because the modelling is static, no iteration is needed to get the stress distribution in Figure 2. At least two trials and errors are performed in selecting the meshing quality to get the stress distribution. The distribution in the figure is obtained for the meshing quality 4.

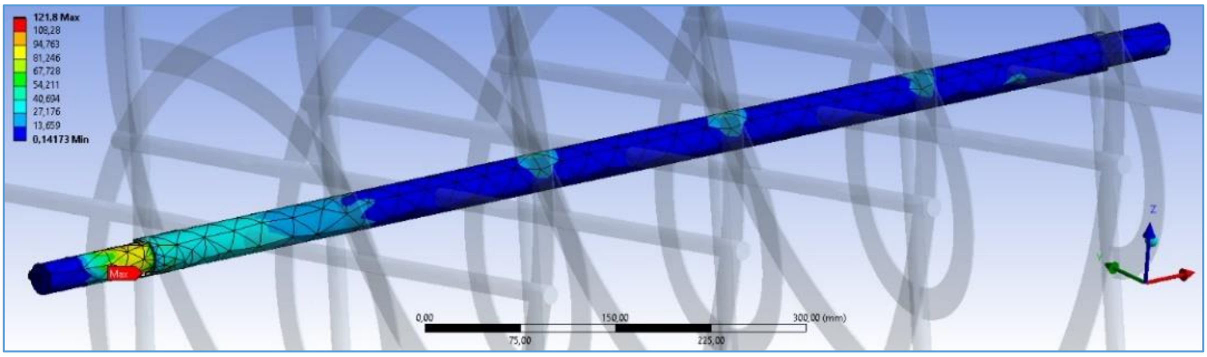

Figure 4. Stress distribution on the stirring shaft

The stress distribution results show that the highest stress value is at the left support of the shaft. This is because there was a keyway on the left axle support following the real object. If the meshing quality is increased to 5 from a maximum of 7, the maximum stress is obtained on the left and right sides of the shaft, but the time required to obtain the stress distribution is longer.

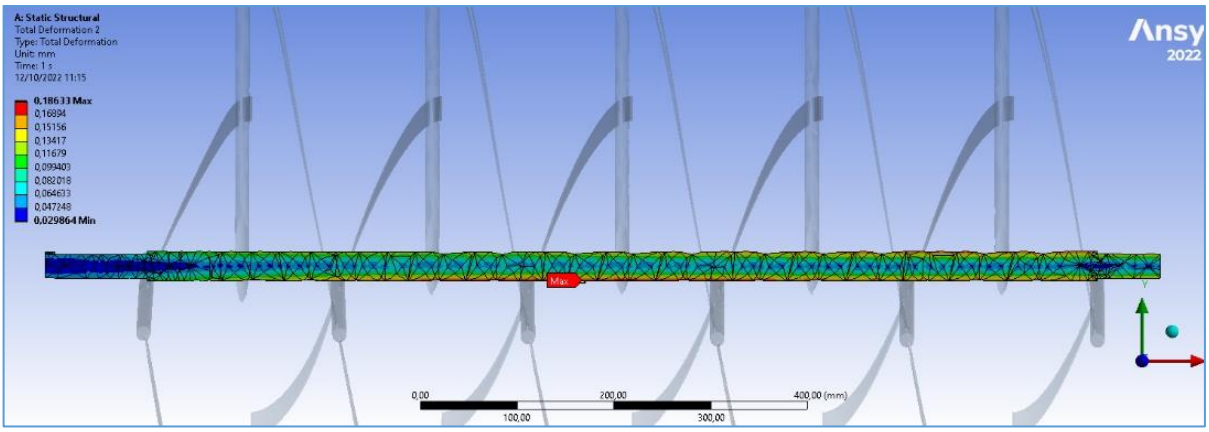

Figure 5. Deformation on the stirring shaft

STRENGTH ANALYSIS OF THE MIXING MACHINE FRAME

Testing on the frame of the baglog mixer machine was carried out by analyzing the static load on this machine frame using Ansys software so that the output of von mises stress, displacement and safety factor was obtained. The simulation results can be seen in Table 5 below.

Table 5. Simulation results of baglog mixing machine frame

Name	Minimum	Maximum
Von Mises Stress	0,0000029676 MPa	25,376 Mpa
Strain	$4,6195x10^{-11}$ mm/mm	0,00012698 mm/mm
Vertical Displacement	0 mm	0,52282 mm
Horizontal Displacement	0 mm	0,84185 mm
Safety factor	11,822	15

Stress distribution on the baglog mixing machine frame can be seen in Figure 6. From the distribution, we can see that maximum stress is in the middle of the upper frame. As with the stirring shaft, to get the stress distribution on the baglog mixing machine frame, a mesh quality of 4 is used from a maximum of 7.

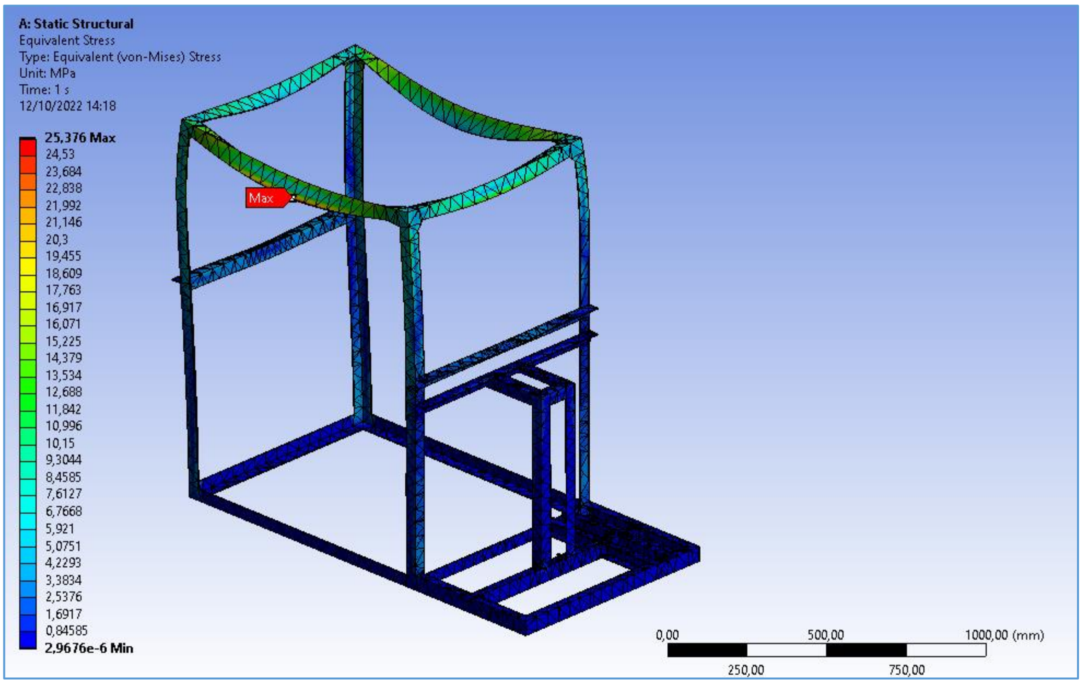

Figure 6. Stress distribution on baglog mixing machine frame

Horizontal deformation that occurs in the frame is shown in Figure 7 where the maximum deformation occurs in the middle of the upper frame. While the vertical deformation can be seen in Figure 8. Both figures show that the maximum deformation is located at the center of the upper frame. Ideally, the simulation results can be validated using experiments, but due to equipment limitations, this was not done in this study. If the von Mises stress occurs far above the material's yield stress, plastic deformation will occur, which in turn will cause the failure of the material.

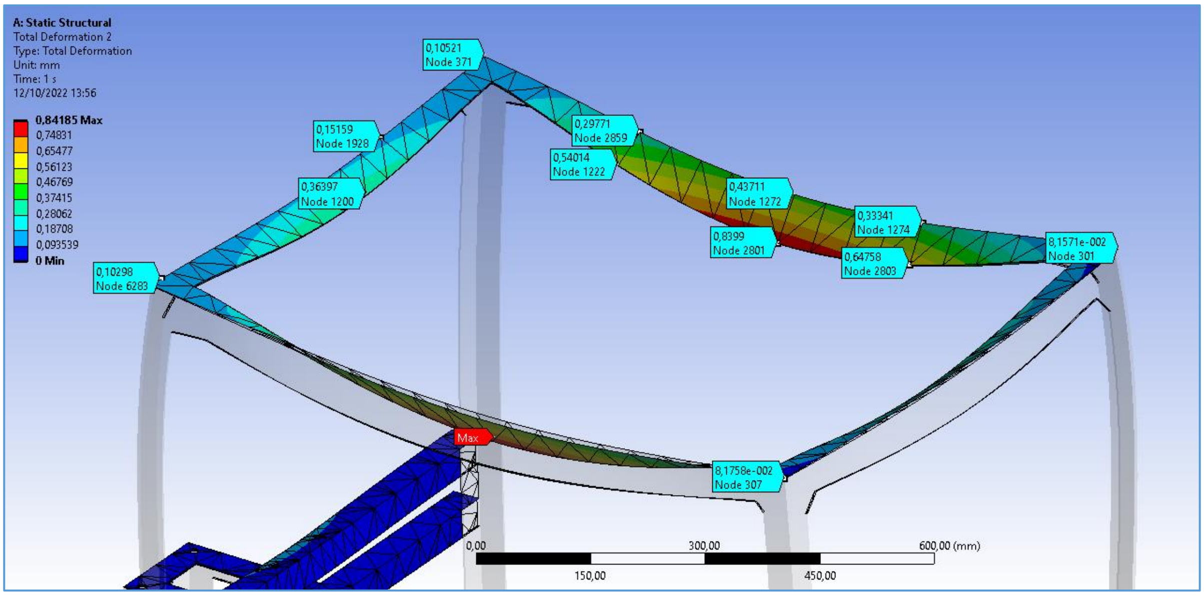

Figure 7. Horizontal Deformation on frame

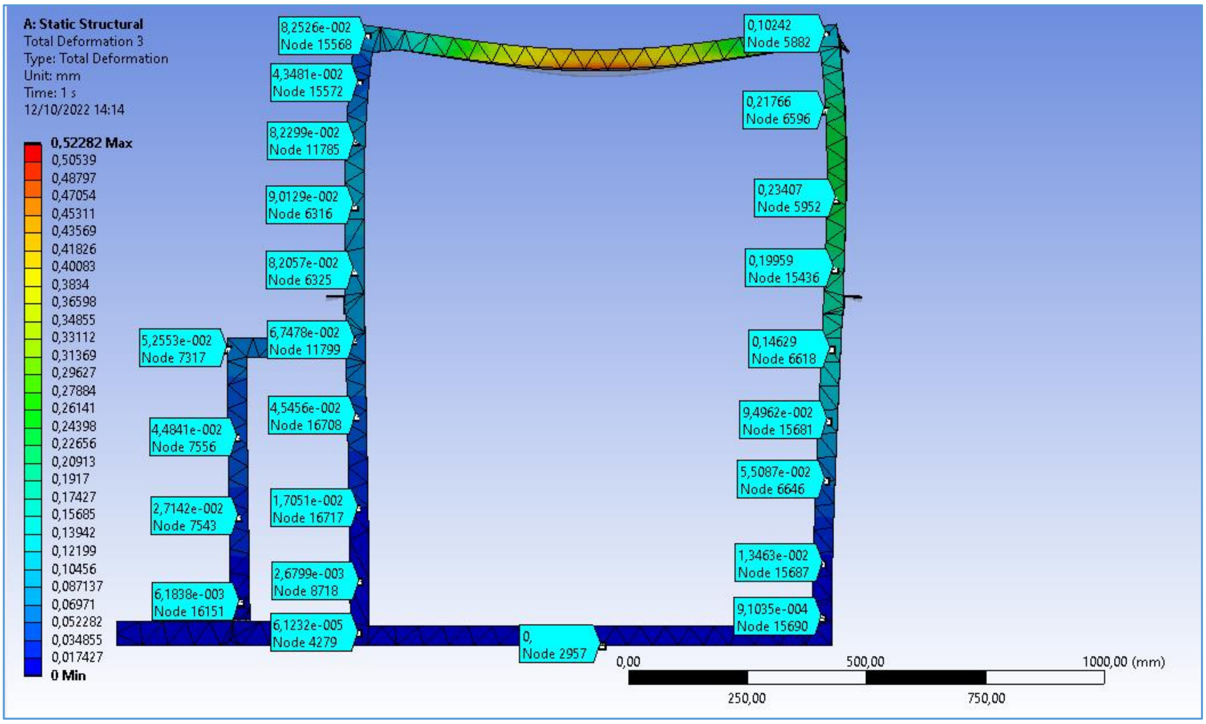

Figure 8. Vertical Deformation on frame

CONCLUSION

From the results and discussion above, we can conclude that the minimum and maximum stresses on the shaft are 0.14173 MPa and 121.8 MPa, respectively. While the minimum and maximum stresses on the frame of the mixing machine are 0.0000029676 MPa and 25.376 MPa, respectively. Maximum displacement on the shaft of 0.18633 mm indicates the shaft is safe to use for the applied load. It is recommended to perform dynamic strength analysis in future studies to obtain results that are close to the experimental values of stress.

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