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Desain dan Analisis Frekuensi Natural Rangka Mesin Penyiang Gulma Menggunakan Metode Finite Element Analysis

Design and Analysis of Natural Frequency Weed Weeding Machine Frames Using the Finite Element Analysis Method

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ABSTRAK

Rangka mesin harus didesain dan disbuat kokoh agar mampu menopang sebagian besar beban akibat komponen lain yang menempel pada rangka mesin penyiang gulma. Makalah ini bertujuan untuk menganalisis frekuensi natural rangka mesinn penyiang gulma dan mengetahui bentuk normalnya dengan menggunakan metode finite element analisis. Analisis ini sangat penting agar tidak terjadi resonansi akibat kerusakan pada komponen mesin penyiang gulma. Bahan rangka yang digunakan pada penelitian ini adalah mild steel dan dianalisis menggunakan perangkat lunak ANSYS. Hasil analisis frekuensi natural rangka mesin penyiang gulma untuk mode pertama hingga mode keenam secara berturut-turut sebesar 12, 366 Hz, 52, 109 Hz, 67,26 Hz, 85, 807 Hz, 174, 55Hz, dan 178, 97 Hz. Dan nilai deformasi maksimum rangka mesin penyiang gulma secara berturut-turut sebesar 18,708mm, 26,758mm, 19,869mm, 13,912mm, 16,312mm, dan 18, 458 mm. menggunakan ANSYS, analisis modal dapat mempersingkat siklus desain dan menurunkan biaya pembuatan desain. Desain rangka mesin penyiang gulma sesuai dengan spesifikasi desain dan layak digunakan untuk mesin penyiang gulma.

Kata Kunci: Rangka Penyiang Gulma, Frekuensi Natural, Analisis Modal, Ansys

ABSTRACT

To be able to sustain the majority of the loads created by other components linked to the frame of the welding machine, the machine's frame must be designed and built with sturdiness. The objective of this study is to employ the finite element analysis technique to investigate the natural frequency of the weed-wacker machine frame and establish its normal form. This examination is crucial to ensure that resonance doesn't happen as a result of weeding machine component damage. ANSYS software was utilized to assess the mild steel employed in the study's frame. The investigation of the weeding machine frame's natural frequency yielded the following results: 12, 366 Hz, 52, 109 Hz, 67.26 Hz, 85, 807 Hz, 174, 55 Hz, and 178, 97 Hz. The wedding machine frame's maximum deformation values are 18,708mm, 26.758mm, 19,869mm, 13,912mm, 16.312mm, and 18,458mm. Utilizing ANSYS, modal analysis can shorten the design cycle and lower design expenses. The weeding machine's frame is designed in accordance with the design requirements and can be used as the weeding machine frame.

Keywords*: Weed Wedding Frame, Natural Frequency, Modal Analysis, Ansys*

1. INTRODUCTION

Every three months, when the rice plants reach the ages of 15 days and 30 days, weed control is done twice in paddy fields. Weeds are plants that coexist with other plants and compete with them for resources like sunshine, food, water, and space (Upendar et al., 2018). Farmers use 30% of the expenditures allocated for managing paddy fields to control weeds (Pandey et al., 2019).

Currently, there are four different approaches to controlling weeds: manually, mechanically, chemically, and biologically (Upendar et al., 2018). The manual control approach faces many challenges, such as the time and labour requirements that it entails (K.T., 2019). Environmental contamination is impacted by chemical control. An alternative is to use mechanical weed control, which is more efficient and labour-intensive (Kumar & Mohankumar, 2019).

The advantage of mechanical weed control is that it keeps the soil surface looser, allowing for improved water penetration into the soil (Prasad et al., 2019). Figure 1 depicts the weeding machine prototype in broad strokes. The design of the claws, their number, and their degree of inclination while working are a few variables that determine the outcomes of weeding. To assist farmers in efficiently and effectively weeding sugar, it was decided to design a prototype weeding machine.

Figure 1. Weed weeding machine

The engine frame is a machine's most crucial part since it serves as the foundation for mounting other parts including the engine, tiller cultivator, and claw cultivator. To be able to sustain the majority of the loads created by other components linked to the weeding machine's frame, the frame must be designed and constructed with sturdiness. Aesthetics, safety, convenience, and ease of use are a few considerations that must be taken into account before designing the weed weeding machine. Component safety factors must also be taken into consideration, notably the weed weeding machine structure (Awwaluddin, 2019).

The determination of the load is an important factor to take into account when designing a weed weeding machine. It is vital to understand the force operating on the power weeder machine. A designer must therefore take the load application into account. The power weeder tool is made to remove weeds from the muddy ground. This could result in an excessive push and load. There will be an inertia force acting on the entire frame if it has no mass and is moving quickly (Soden et al., 1986).

To reduce expenses caused by mistakes in the product design drawing process, the primary step in the machine production process is to create a design using CAD technology(Cekus et al., 2019; Chirende et al., 2019). Design optimization can also reduce design flaws (Vegad & Yadav, 2018). This is frequently used in businesses that deal with mechanics and other constructions (Gheorghe et al., 2018). ANSYS is a piece of software that can assist designers in finding solutions to technical issues (Al-Shammari & Abdullah, 2018).

Based on the above description of the issue, the goal of this study is to use numerical simulation to perform dynamic analysis, particularly the analysis of the natural frequency and normal mode on the parts of the weeding machine. The value of the natural frequency and the normal mode shape of a component or structure are both found using the modal analysis approach. an approach to fundamental dynamic analysis that is used to identify a structure or component's vibrational properties. One of the factors to consider while developing a component is the form of the mode and natural frequency. (Ari et al., 2022).

Previous research that used modal analysis to examine a 3D elevator computer desk entity revealed that the desk's strength and stiffness were in compliance with design specifications and that there was no resonance (Jinlong & Zhenqian, 2018). The next study also does a natural frequency analysis on engine parts (pistons). The findings of his study demonstrate that capital analysis can decrease design time and improve piston efficiency (Zheng, B. ; Zhang J.; Yao, 2019). The ANSYS software was used to carry out the modal analysis. Engineers and designers are already familiar with this program. Before a structure is employed, its dynamic features can be known and enhanced through this modelling.

2. MATERIAL AND METHOD

Many steps must be completed in this study, including pre-processing, processing, and post-processing (Prasetiyo & Fauzun, 2018).

1. Design and Material

First, SolidWorks 2022 software was used to create the frame for the weed-weeding machine, which was then saved in the *iges format. Figure 2 depicts the general design of the weed weeding machine frame. After that, enter the parameter data for the beginning conditions, gird distribution and frame material of the weed-weeding machine in the ANSYS program.

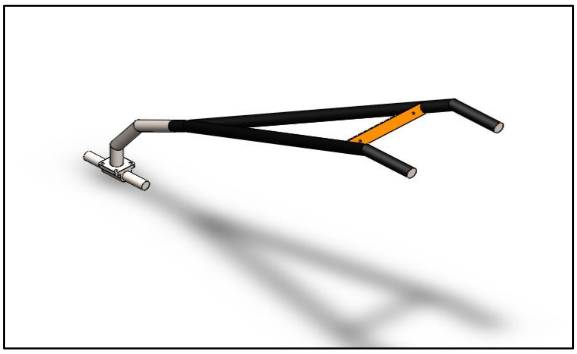

Figure 2. 3D Weed weeding machine frame

Mild steel was utilized as the study's frame material because it is widely available, reasonably priced, and has a high yield strength (Kubasad, 2018). Table 1 shows the simulation parameters in general.

Table 1. Material Properties Mild Steel

Description	Value
Young's Modulus	200 Gpa
Poison's Ratio	0.31
Density	7750
Tensile Yield Strength	320 Mpa
Tensile Ultimate Strength	400 MPa

2. Mesh and Initial Condition

Domain or mesh division has an impact on computational modelling when utilizing simulation techniques (Doustdar & Kazemi, 2019). Gird division is one procedure with a high level of intricacy (Sosnowski et al., 2018). Tetrahedral mesh, hexahedral mesh, and polyhedral mesh are some of the mesh types used in the simulation (García Pérez & Vakkilainen, 2019; Prasetiyo et al., 2019; Sosnowski et al., 2019).

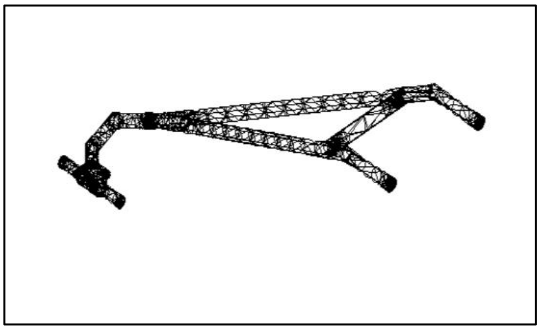

Figure 3. Weed machine frame mesh results

Figure 4 displays the capital analysis boundary conditions. Table 2 lists the FEM using ANSYS assumptions.

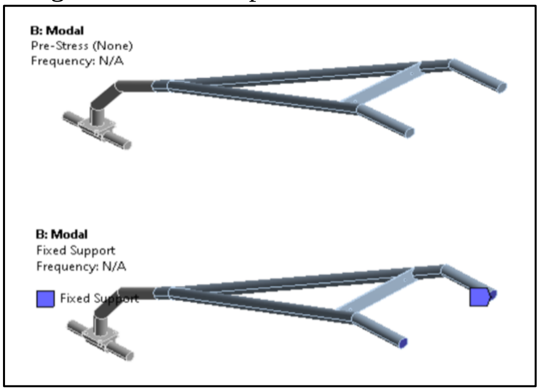

Figure 4. Simulation boundary conditions: pre-stress (top) and location of fixed support on the handle (bottom)

Table 2. Assumption FEM

Description	Value
Condition	Pre-Stress
Element	7183
Nodes	14148
Mesh Type	Tetrahedral

3. Modal Analysis Theory

As a collection of modal coordinates and modal parameters used to express independent equations, modal analysis is a differential equation of vibration on a linear time-invariant system of physical coordinates (Jinlong & Zhenqian, 2018). Determine the vibration properties of a structure, including its natural frequency and mode shape, using modal analysis alone(Al-Maliky & Albermani, 2018). The issue's dynamical equation of motion:

$$[M]\{\ddot{x}\} + [k]\{x\} = \{0\} \qquad (1)$$

Simple harmonic vibration makes up the structure's free vibration, and the displacement is a sine function.

$$x = x \sin \omega\, t \qquad (2)$$

For modal analysis, the vibration frequency ω_i dan mode Φ_i are calculated using the equation:

$$([K] - \omega_i^2[M])\{\Phi_i\} = 0 \qquad (3)$$

{x} is the displacement vector, and [K] is the stiffness matrix. The equation of the characteristic value of ω_i^2 is the circular vibrational frequency and the natural vibrational frequency of $f = \omega_i/2\pi$, with eigenvalue matching to eigenvector {x}i and vibration mode corresponding to π/2.

3. RESULTS AND DISCUSSION

To efficiently evaluate dynamic systems, the nodal analysis uses the properties of eigenvalues and eigenvectors (Ari et al., 2022). With the use of Ansys, modal analysis can be computed via numerical simulation. This numerical simulation was performed to identify the weeding machine's frame's inherent frequency and mode shape.

Table 3 displays the findings of the modal analysis performed using ANSYS for the first mode to the first mode. Additionally, Figure 5 shows the first vibration mode through vibration mode. Figures 6, 7, 8, 9, and 10 show several situations. The outcomes of the frame weeding machine's natural frequency values for the initial mode to the succeeding modes of 12, 366 Hz, 52, 109 Hz, 67.26 Hz, 85, 807 Hz, 174, 55Hz, and 178, 97 Hz.

Each vibration mode's natural frequency value varies, resulting in a distinct reaction. The deflection caused by the influence of material, configuration, a defect, and other factors causes the largest increase in natural frequency, which is an increase of 88.743 Hz, in the fourth to fifth order vibration mode (Ofrial, M, T, A; Noerochim, L ;Hidayat, M, I, 2017). Each substance has a different mode and more than one natural frequency (Endriatno, 2021).

Knowing natural frequencies is crucial to preventing harm to a system or component (Aritonang et al., 2018). If the frequency of the vibration is the same as the natural frequency, it will produce a strong enough vibration to be dangerous to the user (Rao, 2010).

Table 3. The results of the capital analysis of the weed weeding machine frame

Mode	Frequency Natural (Hz)	Deformation Maximum (mm)
1	12, 366	18, 708
2	52,109	26,758
3	67,26	19, 869
4	85,807	13,912
5	174,55	16,312
6	178,97	18,458

The first and sixth modes of the weeding machine's frame's maximum deformation are 18,708mm, 26.758mm, 19,869mm, 13,912mm, 16,312mm, and 18,458mm. This deformation's value is so great that it must be foreseen to prevent resonance. The elastic modulus (E) of the object and the position of the material against the support, which can also affect the vibration mode and the size of the vibration transfer value, are factors that affect vibration characteristics (Endriatno, 2022).

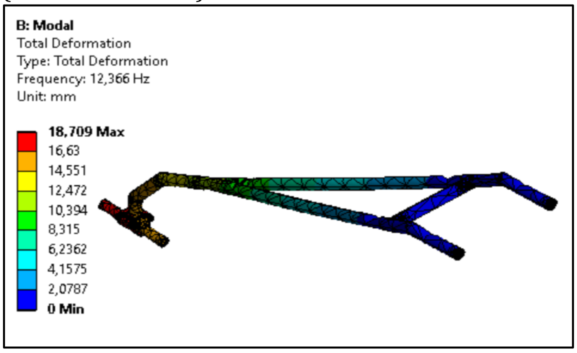

Figure 5. The first vibration mode of the weed weeding machine frame

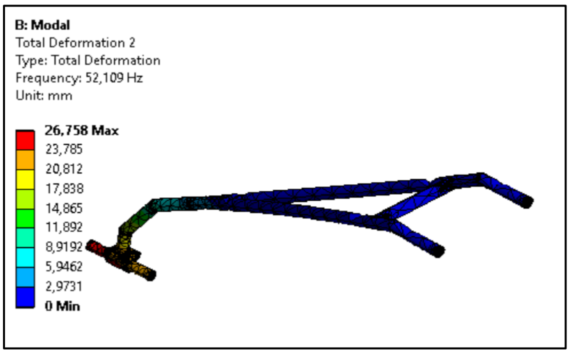

Figure 6. The second vibration mode of the weed weeding machine frame

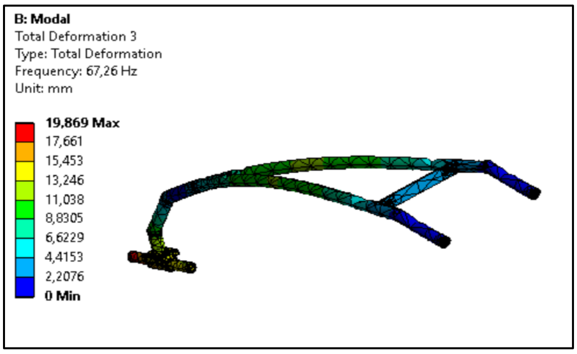

Figure 7. The third vibration mode of the frame of the weeding machine

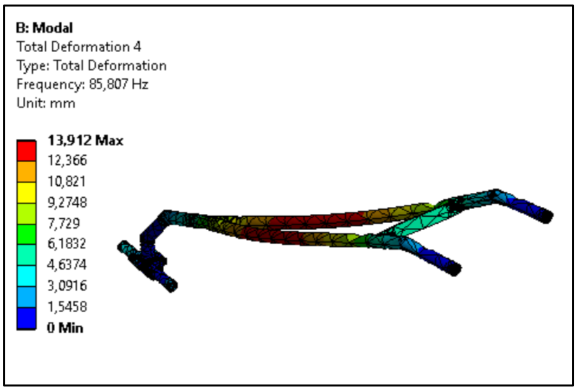

Figure 8. The fourth vibration mode of the weed weeding machine frame

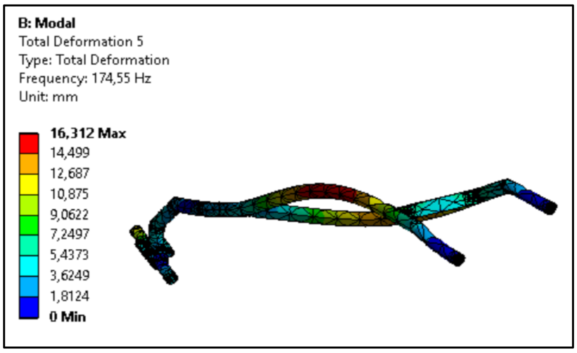

Figure 9. The fifth vibration mode of the weed weeding machine frame

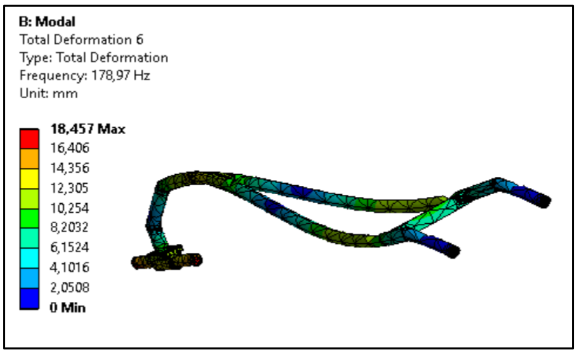

Figure 10. The sixth vibration mode of the weed weeding machine frame

The frame of the weeding machine is built using the findings of the modelling modal analysis of the framework mentioned above in order to avoid resonance and deep frequency in the actual work (Zhengshi, L.;Ronghui, and G; Enwei, 2011). Because the resonant frequency of the vibration effect at its peak has been supplied in modelling form, modal analysis is crucial. This is a reference that should be taken into account while choosing the weed weeding machine's frame design to prevent failure. The analysis and monitoring of vibration conditions in engineering machinery and structures will also benefit from understanding of vibration patterns in a design (Rao, 2010). The intricacies and shapes of the modes and frequencies can be utilized as a point of reference for further study in the harmonic and transient dynamic analysis that this modal analysis serves as a foundation for.

4. CONCLUSION

Using ANSYS software, the capital analysis of the weeding machine's parts led to make conclusion as follow:(1) The first through sixth modes' natural frequencies and vibrational frequencies are 12, 366 Hz, 52, 109 Hz, 67.26 Hz, 85, 807 Hz, 174, 55 Hz, and 178. 97 Hz. The frame of the weed weeding equipment is in good shape. (2) The weeding machine's frame can deform to a maximum of 18,708 mm, 26,758 mm, 19,869 mm, 13,912 mm, 16.312 mm, and 18,458 mm. (3) The design cycle can be sped up and costs reduced by using ANSYS software for collaborative simulation and analysis of the frame performance of weeding machines. (4) The weeding machine's frame is designed in accordance with the design requirements and can be used as the weeding machine frame.

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