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Design and Simulation of Carbon Steel-based Band Saw Frame

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ABSTRACT

Frame design is an important factor in ensuring optimal performance of the band saw machine due to the dynamic loads that occur during the cutting process. This study discusses the design and simulation of a band saw machine with a focus on the analysis of the strength and stability of the machine frame using carbon steel with varying thicknesses, namely 1 mm, 2 mm, and 3 mm. Simulations were performed using finite element analysis (FEA)-based software to evaluate the stress, deformation, and safety factors of each variation of steel thickness. The simulation results show that material thickness has a significant effect on the frame's ability to withstand loads. Carbon steel with a thickness of 3 mm has the best structural performance in terms of stiffness and resistance to deformation, while steel with a thickness of 1 mm shows greater deformation at the same load. Thus, choosing the right thickness is very important to ensure the efficiency and durability of the band saw machine in industrial applications.

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1. Introduction

In the manufacturing industry, material selection and cutting tool design play a crucial role in increasing production efficiency. One of the tools often used in material processing is the band saw machine. This machine is widely used to cut a variety of materials, ranging from metal to wood. However, to achieve optimal performance, the right design and strong and durable materials are required. This article discusses the design and simulation of a band saw machine made of carbon steel, which is known to have high strength and resistance to wear.

Research on the design and development of band saw machines has been widely carried out, especially in efforts to increase machine efficiency and durability. For example, research conducted by Smith et al. [1] examined the optimization of band saw blade design to cut metal materials with greater precision, using a finite element-based simulation approach. The results showed that modifying the band saw tooth profile can reduce cutting forces by up to 15%, thereby extending the life of the blade. In addition, research by Liu and Zhang [2] focused on blade material selection and found that carbon steel provided better cutting performance than other materials, such as alloy steel. These studies form the basis for the development of more efficient and durable band saw machines, especially in the selection of materials and blade designs that are appropriate for specific applications.

Recent research on the design and simulation of band saw frame continues to grow along with the need to improve the efficiency and durability of the structure. Balighate and Dhanal [3] conducted a finite element analysis (FEA) on a swing frame of a band saw machine to compare the existing design with the new design, which showed an increase in structural stiffness. Han et al. [4] developed a mechanical model to improve the service life and cutting accuracy of the machine using stress and fatigue analysis approaches. Meanwhile, Chen et al. [5] optimized the complex structure of a cross-cutting saw machine through modal resonance analysis to reduce vibration and deviation during processing. Chen et al. [6] also applied DEFORM™ 3D simulation to understand the effect of cutting parameters on stress distribution and blade wear in the aluminum cutting process. In the context of lightweight materials, Cheng and Wei [7] analyzed the relationship between vibration and cutting performance of a band saw machine on a honeycomb structure, utilizing parameters such as motor current and shear stress. Additionally, research by a team from Mechanics & Industry [8] modeled a dynamic feed drive system for a frame saw and demonstrated that the use of high-stiffness components can improve feed response and reduce speed fluctuations.

In addition to research on band saw blades, various studies have also been conducted on the design of band saw machine frames, especially using steel materials. One significant study is the work of Thompson et al. [9], which explored the use of carbon steel in the manufacture of band saw machine frames to increase structural strength and reduce vibration during operation. This study used the finite element analysis method to simulate the stress distribution and deformation in the frame. The results showed that carbon steel, with the right design combination, can increase the stability and service life of the machine by up to 20% compared to frames made of lighter materials such as aluminum. On the other hand, research by Kumar and Patel [10] emphasized the importance of selecting steel thickness and frame connection design. They found that varying the steel thickness in certain parts of the frame can significantly reduce stress concentrations, thereby increasing the frame's resistance to high workloads. This study aims to evaluate machine performance through simulation and analyze the effect of using carbon steel in order to improve cutting quality and tool life.

2. Method

The research method used in this study is experimental research based on numerical simulation. This study focuses on the development and evaluation of the structural design of an engineering product, namely a band saw frame, by utilizing CAD software and finite element analysis (FEA) to obtain quantitative data on the mechanical performance of the design. The methods used in this study includes several main stages, starting from data collection, CAD model design, structural simulation, to result analysis. This process is carried out in stages to produce an optimal frame design that is resistant to work loads. The initial step is to collect technical data from literature and industry standards regarding band saws, including standard dimensions, material types, and typical workloads. In addition, carbon steel material selection is carried out based on its mechanical properties such as tensile strength, modulus of elasticity, and resistance to deformation. After the data is collected, the band saw frame is modeled using CAD (Computer-Aided Design) software such as SolidWorks or Autodesk Inventor. The design takes into account ergonomic factors, structural strength, and ease of manufacture. The designed 3D model is then exported into simulation software such as ANSYS or SolidWorks Simulation to be analyzed numerically using the finite element method. The analysis is carried out to evaluate the distribution of stress, deformation, and safety factors against various anticipated loads during operation. The simulation results are compared with the material strength limits to determine whether the design meets the safety requirements.

3. Results and Discussion

3.1. Model design of band saw

Band saw machine design is a crucial step in ensuring optimal performance and durability of the machine during cutting operations. The design process includes material selection, blade configuration, and frame structure, all of which affect the efficiency and stability of the machine. To maximize performance, the band saw machine blade is designed with a tooth profile that is tailored to the material to be cut, while the machine frame must be able to withstand dynamic loads and vibrations without significant deformation. The design of the band saw machine can be seen in Fig. 1.

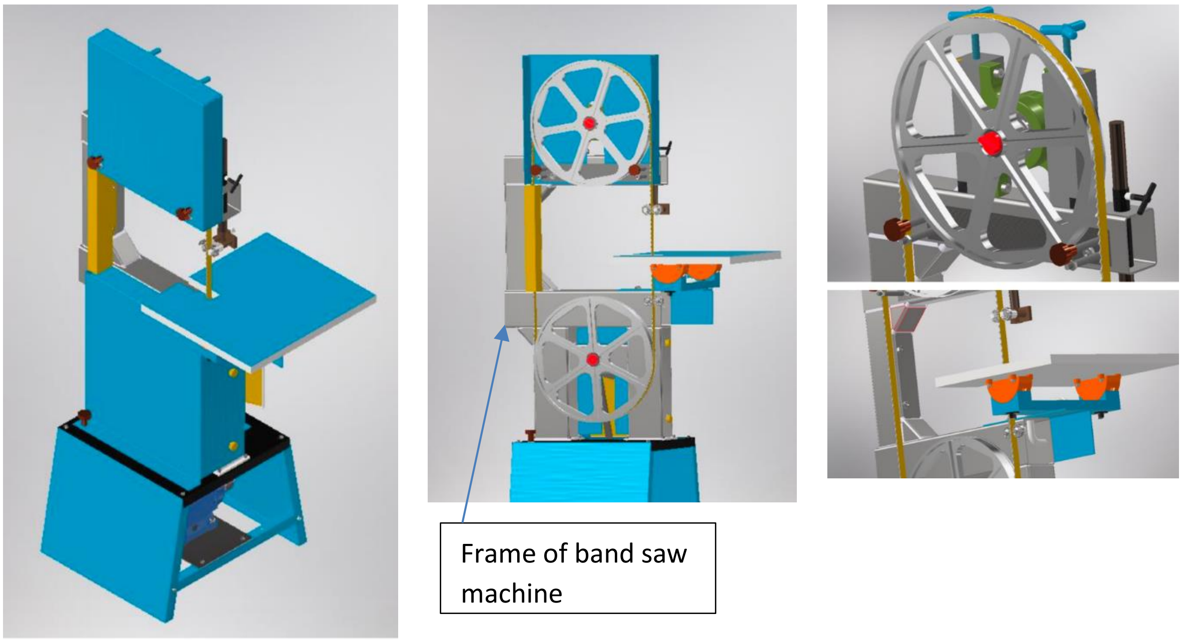

Fig. 1. Design of band saw machine.

The frame design of the band saw machine plays an important role in maintaining the stability and overall performance of the machine during the cutting process [11]. A strong and rigid frame is able to withstand various dynamic loads that occur due to vibrations and cutting forces, and maintains the alignment of the band saw blade for high-accuracy cutting. Frame materials, such as carbon steel, are often chosen because they have high tensile strength and are able to withstand deformation. In addition, the frame design must pay attention to the even distribution of loads to avoid stress concentrations that can cause cracks or damage to the joints.

The band saw machine frame uses hollow carbon steel material with dimensions of 8 x 6 mm and 10 x 10 mm, offering an ideal combination of strength and material efficiency. Carbon steel is known to have high tensile strength, which enables it to withstand dynamic loads and vibrations during cutting operations without experiencing significant deformation. The use of hollow carbon steel with dimensions of 8 x 6 mm and 10 x 10 mm provides good structural rigidity, but remains lightweight, thus reducing the overall weight of the machine. This is very important in industrial applications where energy efficiency and machine mobility are factors to consider. The main advantage of using hollow carbon steel is its ability to withstand compression and tension forces optimally, while reducing the material used compared to solid profiles. In addition, the cavity inside the hollow provides flexibility in the design of lighter, but still sturdy joints.

3.2. FEM on band saw frame.

To improve the accuracy and durability of the design, the FEA method is often used [12]. Through FEA, stress distribution and deformation can be modeled in detail, allowing designers to identify potential areas of high stress concentration that could lead to structural failure. In addition, this analysis allows optimization of materials and frame shapes, resulting in lighter, stronger, and more durable machines. The use of FEA also helps in estimating component life and minimizing production costs by reducing the need for repeated physical tests.

3.2.1. Stress analysis of the frame on various thicknesses

Fig. 2 shows a simulation of a band saw machine frame that is analyzed for strength through von mises stress with a load of 100 kg and details of the stress that occurs in the frame section that suffers from excess stress. Variations in plate thickness of 1 mm, 2 mm, and 3 mm are applied in FEA to obtain a picture of the stress that occurs at each point in the frame structure.

Based on the stress supported by the structure, it is then used as a reference for comparison with the allowable strength of carbon steel material so that the optimal plate thickness in this structure can be determined.From the results of the FEA, a frame with a thickness of 1 mm, 2 mm, and 3 mm has a maximum stress of 98.8 MPa,39.2 MPa, and 23 MPa, respectively. When compared to the allowable stress of carbon steel of 150 MPa, all maximum stresses obtained from the FEA analysis are below the safe limit. This means that in each case of thickness (1 mm, 2 mm, and 3 mm), the machine frame is still within the safe limit and will not experience material failure due to excessive stress during operation.

However, the difference in maximum stress values between the various thicknesses shows that the frame with a thickness of 3 mm provides the largest safety margin compared to the thicknesses of 1 mm and 2 mm. The smaller the stress generated compared to the allowable stress of the material, the lower the risk of permanent deformation or damage in the long term. Some considerations in selecting the thickness of the band saw machine frame are as follows:

- Frame with 1 mm thickness: The maximum stress of 98.8 MPa is still below the allowable stress of carbon steel (150 MPa). However, with a stress approaching 100 MPa, this frame is more susceptible to damage when used under high loads.
- Frame with 2 mm thickness: The maximum stress of 39.2 MPa provides better safety than 1 mm thickness. This frame is strong enough to withstand standard workloads and still has a fairly good safety margin.
- Frame with 3 mm thickness: The maximum stress of 23 MPa shows that this frame has optimal safety. The margin for allowable stress is very large, so this frame will be very stable and have high durability in the long term.

The study by Abambres and Arruda [13] emphasized the importance of ensuring that the maximum stress calculated through FEA remains below the allowable stress limit to prevent material failure and ensure structural safety. In addition, the study by Chen et al. [14] showed that increasing the thickness of the steel plate significantly improves the load-bearing capacity and stiffness of the structure, especially in the elastic-plastic stage after the yield limit is reached.

Furthermore, the study by Cheng and Wei [15] revealed that increasing the thickness of the structural component can reduce vibration and improve the cutting performance of the band saw machine, which is in line with the finding that a thickness of 3 mm provides the largest safety margin. Thus, the FEA results showing that all thickness configurations are within the safe limit, and that a thickness of 3 mm provides the largest safety margin, are supported by the literature that emphasizes the importance of maintaining stresses below the allowable limit and the benefits of increasing thickness in improving structural performance.

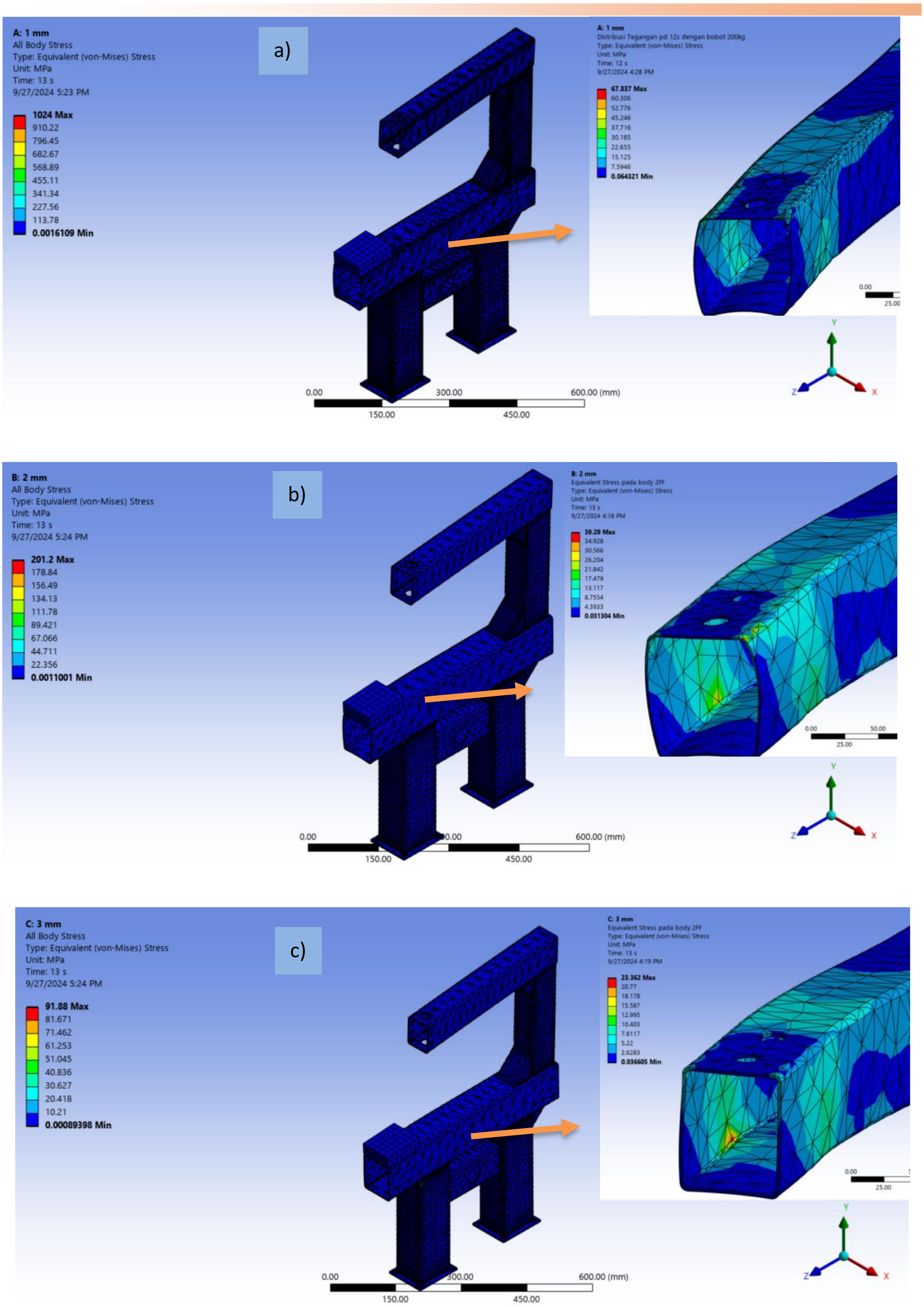

Fig. 2. FEA analysis on frames with thickness: a) 1 mm, b) 2 mm, c) 3 mm.

3.2.2. Evaluation of deformation of the frame on various thicknesses

Deformation analysis using the FEA method is very important for the band saw machine frame to ensure performance and structural durability during operation. Excessive deformation of the frame can cause changes in the position of the band saw blade, which ultimately affects the accuracy and quality of the cut. By performing FEA deformation analysis, the load distribution and frame response to dynamic forces can be predicted accurately, so that areas that have the potential to experience critical deformation can be identified early on. The results of the FEA deformation analysis with plate thicknesses of 1mm, 2mm and 3mm can be seen in Fig. 3.

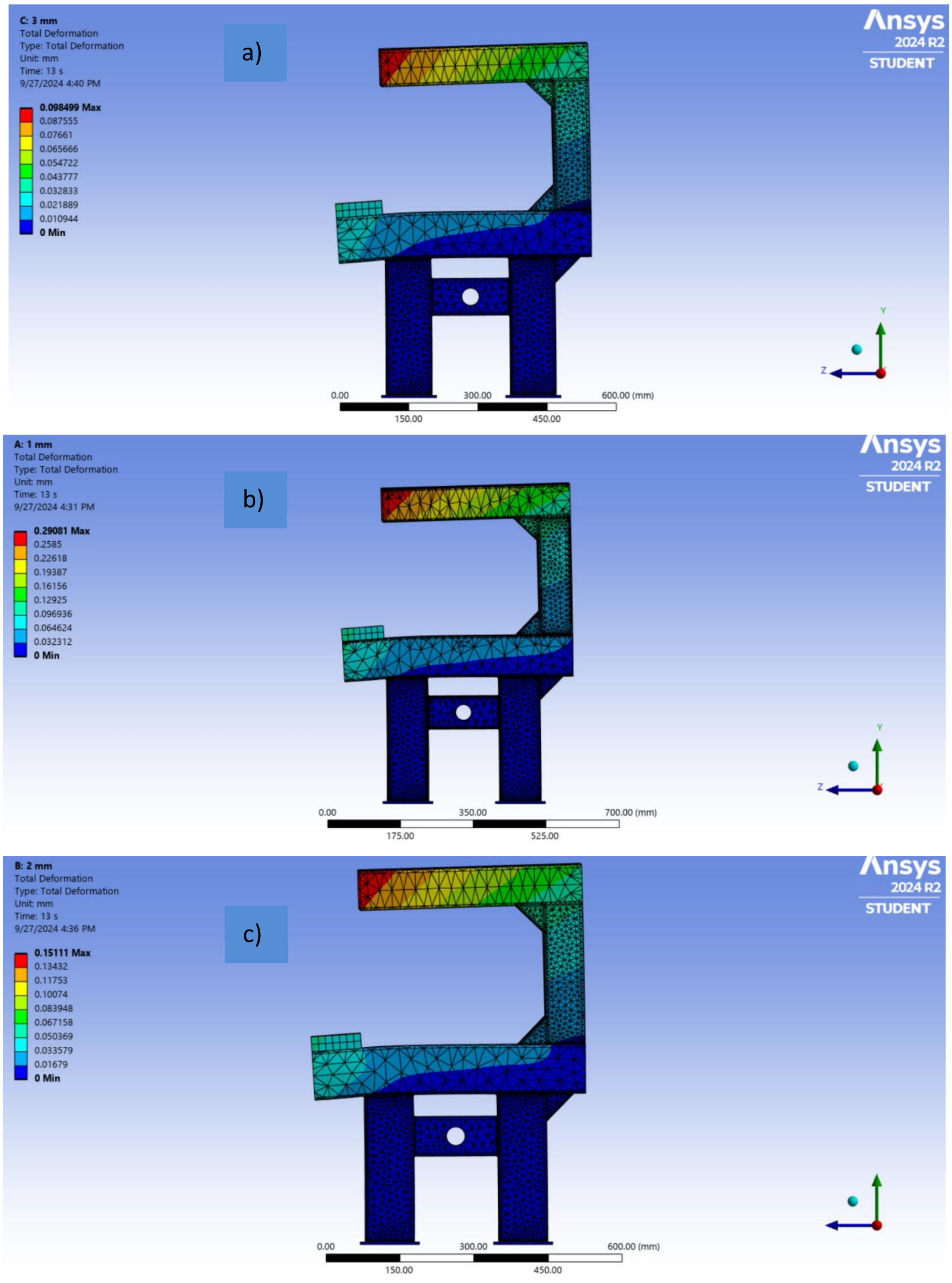

Fig. 3. FEA deformation analysis with frame thickness: a) 1mm, b) 2mm and c) 3mm.

The results of deformation analysis using the FEA method on the band saw machine frame show variations in deformation based on the thickness of the material used. On a frame with a thickness of 1 mm, the maximum deformation recorded was 0.29 mm, which indicates that the frame is more easily deformed when receiving workloads. At a thickness of 2 mm, the maximum deformation was significantly reduced to 0.15 mm. The frame with a thickness of 3 mm showed the best performance, with a maximum deformation of only 0.09 mm. This means that the frame is stiffer and able to withstand dynamic loads and cutting forces with minimal deformation.

When compared to the allowable deformation of carbon steel of 1-3 mm, all maximum deformation values obtained from the FEA results (0.29 mm, 0.15 mm, and 0.09 mm) are far below the safe limit of permissible deformation. This shows that the machine frames with a thickness of 1 mm, 2 mm, and 3 mm all operate within the safe limit of deformation, so there is no risk of permanent deformation or structural failure caused by the machine's workload.

However, the deformation results also indicate that the 1 mm thick frame, which experienced a maximum deformation of 0.29 mm, was more susceptible to deformation than the 2 mm and 3 mm thicknesses. This larger deformation can affect cutting accuracy, although it is still within the structurally safe limits. The 2 mm (0.15 mm) and 3 mm (0.09 mm) thick frames showed smaller deformations, which means the frame is stiffer and provides better stability, especially in precision cutting applications. For structural applications such as band saw frames, where stability is critical, a thicker steel frame (3 mm) is recommended to maintain minimal deformation and ensure durability under load [12].

This finding is in line with the study by Venkatesh et al. [16], which shows that the increase in steel profile thickness from 1.2 mm to 2 mm increases stiffness and reduces significant vertical deformation, based on numerical analysis using Abaqus software. Likewise, Ibrahim and Najem [17] found that the increase in the thickness of the steel plate in the steel shear wall increases stiffness and reduces lateral deformation, which is important for structural stability. In addition, Bahlol et al. [18] report that an increase in the thickness of the steel tube from 2 mm to 3 mm in the concrete composite beam increases the bending capacity and reduces slip at the maximum load, showing an increase in structural stability. Overall, this literature supports that increasing steel thickness in structures such as the SAW band machine frame can increase stiffness, reduce deformation, and increase stability, which is important for precision cutting applications.

4. Conclusion

All frame designs with thicknesses of 1 mm, 2 mm, and 3 mm are safe to use based on comparison with the allowable stress of carbon steel. However, the frame with a thickness of 3 mm provides the best performance in terms of strength and service life, because it has the lowest maximum stress compared to other thicknesses. All frame thicknesses (1 mm, 2 mm, and 3 mm) produce deformations that are well below the allowable deformation limit of carbon steel, indicating that the frame is safe and will not experience structural failure due to excessive deformation. However, the frame with a thickness of 3 mm provides the best results in terms of minimal deformation, making it ideal for applications requiring high accuracy and stability.

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