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Design and Simulation of Mill Turn Vise

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Abstract: The design and development of a product are moving along with the rapid development of the machining industry. The development of this product plays an important role in providing exposure to researchers in the field of design and the use of jigs and fixtures. The purpose of this study is to design and perform FEA (Finite Element Analysis) to 3D model of Mill Turn Vise. This product focuses on the machining industry in particular and students who are in the field of machining in general. The design of this study is using the ADDIE model which consists of five phases namely analysis, design, development, implementation and evaluation. A form of data collection was also developed together to facilitate the technical data collection process. This product is expertly certified through instrument of design selection matrix and technical data generated through FEA analysis simulations using Solidworks software. Based on the data collected through two types of simulations (modal and structural) of three materials (aluminum, carbon steel and cast iron) and data collection forms, this product is practically safe to use in the precision industry as a preliminary exposure to the turning process that can be done on a CNC Milling Machine.

Keywords: CNC Milling Machine, Turning Process, Design and Development, Finite Element Analysis.

1. Introduction

The machining industry is one of the branches of mechanical engineering and manufacturing that is constantly evolving in line with the worldwide development of science and technology. The design and development of a product also move with the rapid development of the machining industry. According to Jalil (2000), design means the use of scientific principles, technical information and human imagination to create a new product. Besides, systematic and detailed design processes need to

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be in line with industry standards especially in the era of Industrial Revolution 4.0 (Sulaiman, Shapi, Hasan & Prabuwono, 2011). It is also driven by the problems and issues often encountered by industry players, students in mechanical engineering and manufacturing as well as hobbyists. Creativity and innovation, therefore, play a major role in generating new and fresh ideas in solving problems that are particularly prevalent in the machining industry.

Product design and development are also closely related to the functionality and mechanics of a process. Lately, researchers have emphasized and focused on understanding machining processes in the context of mechanics, functionality and design. The sophisticated machining technology with the features of High-Performance and High-Speed Cutting research has led researchers to improve the properties of tool points, jigs and fixtures as well as advanced materials usage. The machining process is also closely linked to aspects of tool handling to maximize productivity. According to Coelli, Rao, O'Donnell & Battese (2005), productivity refers to an overall productivity factor that measures all productivity factors, including work productivity at a factory and oil productivity at a power station. In the context of machining, activities and processes such as minimizing tool and object conversion time, position, movement and feed rate during tool cutting are in progress and the tool and system eye control system undergo a paradigm shift towards improvement to this system which is now a great addition to the machine tool variation in the manufacturing industry which indirectly increases the productivity of the work while generating double of the profit.

Therefore, as a Bachelor of Vocational Education (General Machining) undergraduate at UTHM, the development of this product plays an important role in providing exposure to researchers in the field of precision engineering in terms of jigs and fixtures design. Besides, it can also provide opportunities for researchers to design complex product development through sketching, computer-aided design, computer-aided machining and analyze the product through simulation which is also the SOP to develop the product. Hence, the study aims to develop a special fixture that can save time for the handling of tools and materials (in the context of this study, from CNC milling machines to CNC lathe). The researcher will also study in detail the background of the issues, and objectives of this holder developed through the process of product design and development as well as technical data analysis for future improvement.

According to the Malaysian Productivity Corporation (2017), statistics show that overall factor productivity in Malaysia from 2001 to 2015 was low with a cumulative growth rate of 2.3 percent compared to other Asian countries such as Thailand and Korea with both countries recording cumulative growth rate of 4.7 percent. This in fact proves and indicates that productivity levels in Malaysia are still low in percentage and need to be improved.

Additionally, tool handling is also one of the issues that have caught the attention of the researcher. According to researchers' observations after undergoing industrial training at Panasonic Manufacturing Malaysia Berhad back in 2016, the equipment used to hold the tool bit for the lathe process is a common vise used in a milling machine. Although the vise is mechanically stable and can absorb vibrations well, the vise does not have an adjustable angular feature. Hence, the operator of the milling machine has difficulty in setting up the tool bit. According to Nachtman (1989), the angles that need to be taken into account in setting up a lathe single-point cutting tool are the angle of release (12 degrees), clearance angle (6 degrees), edge rake angle (14 degrees), back rake angle (8 degrees), end cutting angle (20 degrees) and edge cutting angle (15 degrees). Therefore, the aforementioned angles are crucial to ensuring the surface finish quality of the workpiece. The three objectives of this study are:

- To design a 3D model of Mill Turn Vise
- To run simulations to a 3D model of Mill Turn Vise using Solidworks.
- To do a technical data analysis for functionality testing of 3D model of Mill Turn Vise

According to Narayana, Kannaiah and Reddy (2006), jigs and fixtures are a tool that supports and holds the workpiece and also guides the cutting tool during the machining process. They are widely used for hole drilling, threading, reaming and counter-boring operations. The jigs also do not need to be installed on a particular machine, more like an accessory rather than a permanent part of a machine. This statement is supported by Venkataraman (2015) who says that the development of jigs, fixtures and other accessories such as measuring gauge is aimed at producing components that meet the aspects of accuracy, interchangeability, repeatability and economic production rates.

The ADDIE model is a teaching model that serves as a guide for developing software and teaching materials based on student needs (Wang & Hsu, 2009). The early history of this model can be traced back to the 1950s but was widely recognized in 1975 by the Florida State University Center for Educational Technology and developed for use by the United States Army. Nevertheless, the ADDIE model can also serve as a guide in the development of a product. According to Stapa and Mohammad (2019), the five elements of the ADDIE model are analysis, design, development, implementation and evaluation. This model is also used because the approach used is very effective in solving problems early on (Ismail, Utami, Ismail, Hamzah & Harun, 2014). Apparently, this model is also suitable for product development. This is because according to Branch (2009), the processes involved in the ADDIE model still remain one of the most effective ways of producing a product.

Meanwhile, turning is a machining process that produces a cylindrical and rounded outer surface due to the action of a cutting tool on a symmetrical rotating object using a lathe machine (Davies, 1997). Some of the most common machining operations using the turning process including face turning, straight turning and taper turning. Face turning is an operation in which the facing tool is aimed at cutting perpendicular flat surfaces with the axis of rotation of the workpiece. Factors that can affect the quality and effectiveness of the cutting-edge operation include cutting speed and feed rate, material hardness, cutting tool size and how the workpiece is clamped (Davim, 2013). According to Lopez and Lamikiz (2008), straight turning is a lathe machining operation in which the points of the cutting tool move parallel to the axis of rotation of the workpiece. Taper turning is an operation of an array of machines where the diameter of the workpiece decreases from one side to the other and thus creates an angle to the workpiece. Basically, there are three main ways to create a taper; using compound rest, offset on tailstock or using taper attachment or forming tool. (Childs et al., 2000).

CADCAM (computer-aided design and computer-aided manufacturing) system is a complex application that requires both hardware and software (Zeid, 2004). This statement was supported by Groover (2004) who claims that computer systems related to product design are known as CAD (computer-aided design) systems. Design systems and software related to CAD systems include geometric modeling, engineering analysis packages such as Finite Element Modeling, design review and evaluation and automation drafting. Hashim, Yaakub and Ahmad (2007) has defined simulation as a situation created to resemble a controlled real situation. Finite Element Analysis (FEA) or sometimes known as Finite Element Method (FEM) is a computational technique used to obtain a significant value in engineering which must meet the differential equations and specific conditions of a given situation (Hutton, 2004). This is supported by Akin (2010), stated that the data generated by FEA analysis is very useful for engineers and applied mathematicians because the FEA simulation data can be obtained quickly and accurately. He also said the FEA was divided into a number of specific technical analysis areas such as stress analysis and structural analysis which included Von Mises Stress Tests, displacement and Safety Factor tests.

Hence, based on a literature review conducted, researchers have decided to design and develop a special fixture to aid turning process on a CNC Milling. In addition, this chapter is seen as a source of reference in assisting with the processes in the research methodology section. This chapter also covers the study of the concept of equipment that can be used when the researcher creates sketches and the initial concept and analysis is performed to test the durability of the Mill Turn Vise. Therefore, these guidelines will facilitate the whole process of research and provide a deeper understanding. The next chapter also discusses the journey of work and the processes involved in this study.

2. Methodology

The researcher selected the ADDIE Model to emphasize the study method to develop this product. The researcher made the initial observation during industrial training at Panasonic Manufacturing Malaysia Berhad. In addition, researchers have collected preliminary information and opinions from experts including lecturers and assistant engineers at the Faculty of Technical and Vocational Education (FPTV) as well as technicians and engineers working in the field of machining.

In addition, design is a very important process to ensure that the fabricated product is safe to use and high-quality guaranteed. Design is also not a process that can be done without detailed analysis. Therefore, to develop this product, the researcher used the ADDIE model as a guide in designing the workflow in the project methodology. The flowchart in Figure 1 shows the conceptual framework of designing, developing and simulating the three-dimensional model testing of the product.

2.1 Research Procedure

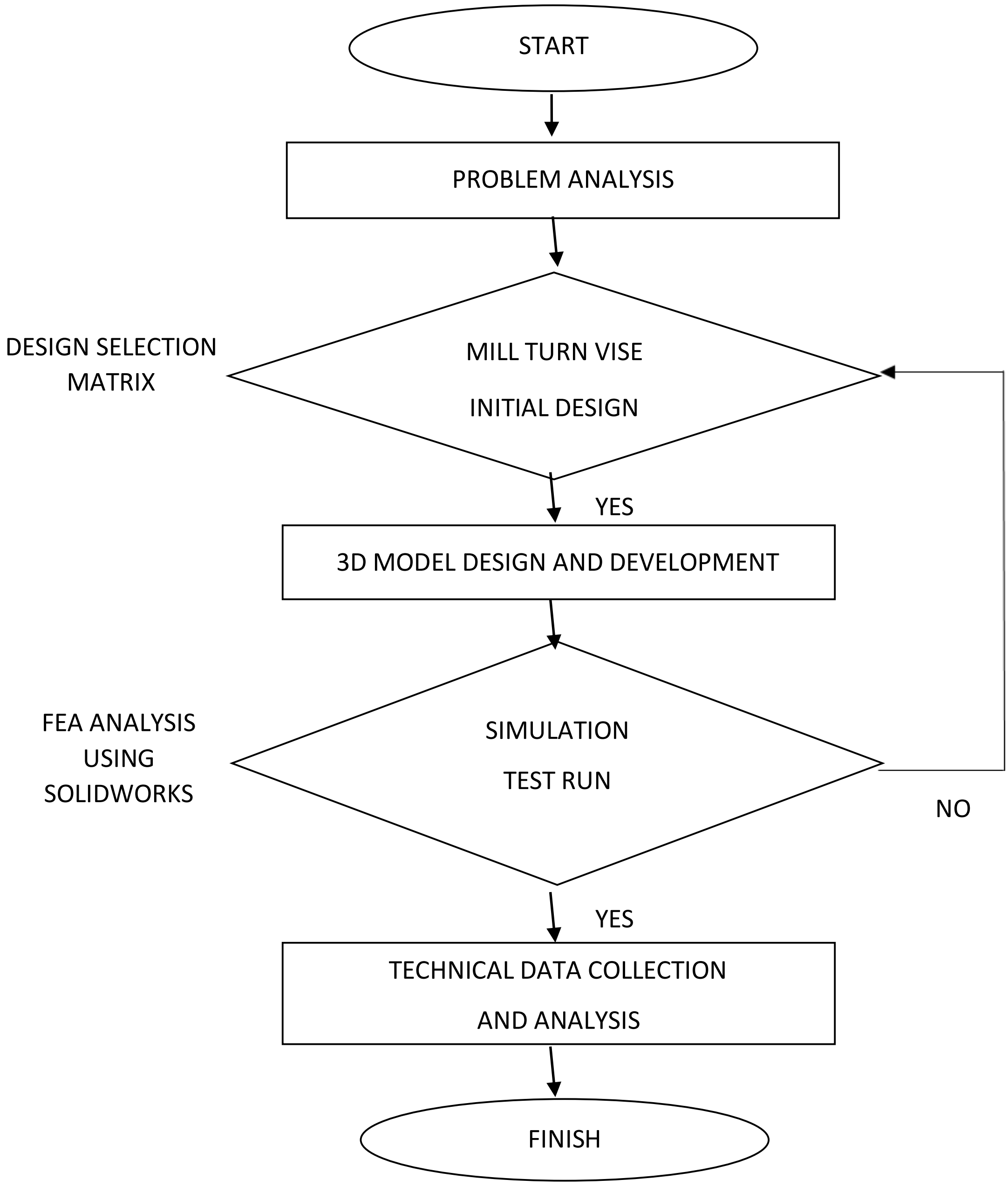

Figure 1: Conceptual framework of developing a Mill Turn Vise 3D Model and Simulation

3. Results and Discussion

3.1 Modal Analysis

This analysis was carried out by manipulating three types of materials namely carbon steel, aluminum and cast iron. Four modes are used in this analysis and the results of this simulation will show displacement in millimeters (mm) of units in the 3D model of Mill Turn Vise. Figure 3 below shows a graph of the modal analysis projection.

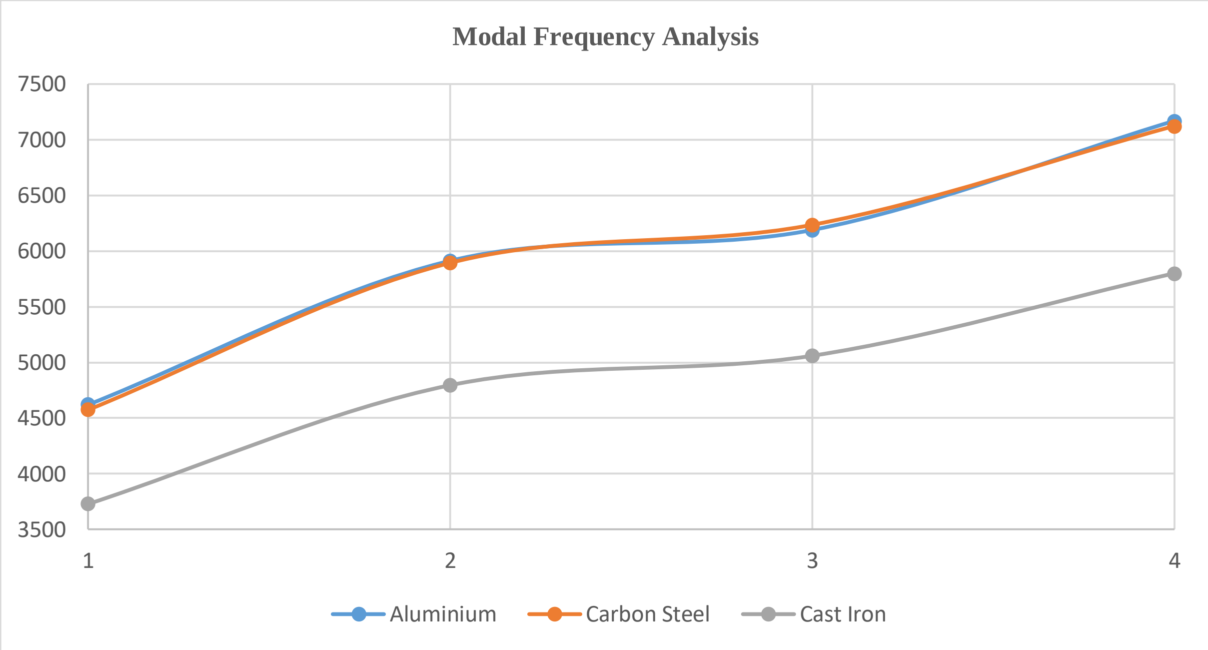

Figure 2: Result of Modal Analysis for All Three Materials

After undergoing modal analysis simulation, technically this 3D model of Mill Turn Vise is safe to use for any operation on a CNC Milling Machine. The graph shows that the 3D model has a similar modal frequency form from the first frequency mode to the fourth frequency mode although the researcher uses three different materials. It can also be seen from Figure 3 that the cast iron shows the lowest value of the frequency range of 3732 to 5800 Hz whereas for carbon steel and aluminum, both materials show very similar value ranges.

3.2 Structural Analysis

This structural analysis is carried out by manipulating three types of materials namely carbon steel, aluminum and cast iron. Researcher have applied five cutting forces on 3D models; 500, 1000, 1500, 2000 and 2500 Newton (N) for this analysis and the results of this simulation will show the occurrence of Von Mises stress (Von Mises Stress), displacement and safety factors in 3D model of Mill Turn Vise. Figure 4, 5 and 6 below show graphs of Von Mises stress analysis, displacement analysis and safety factor analysis respectively.

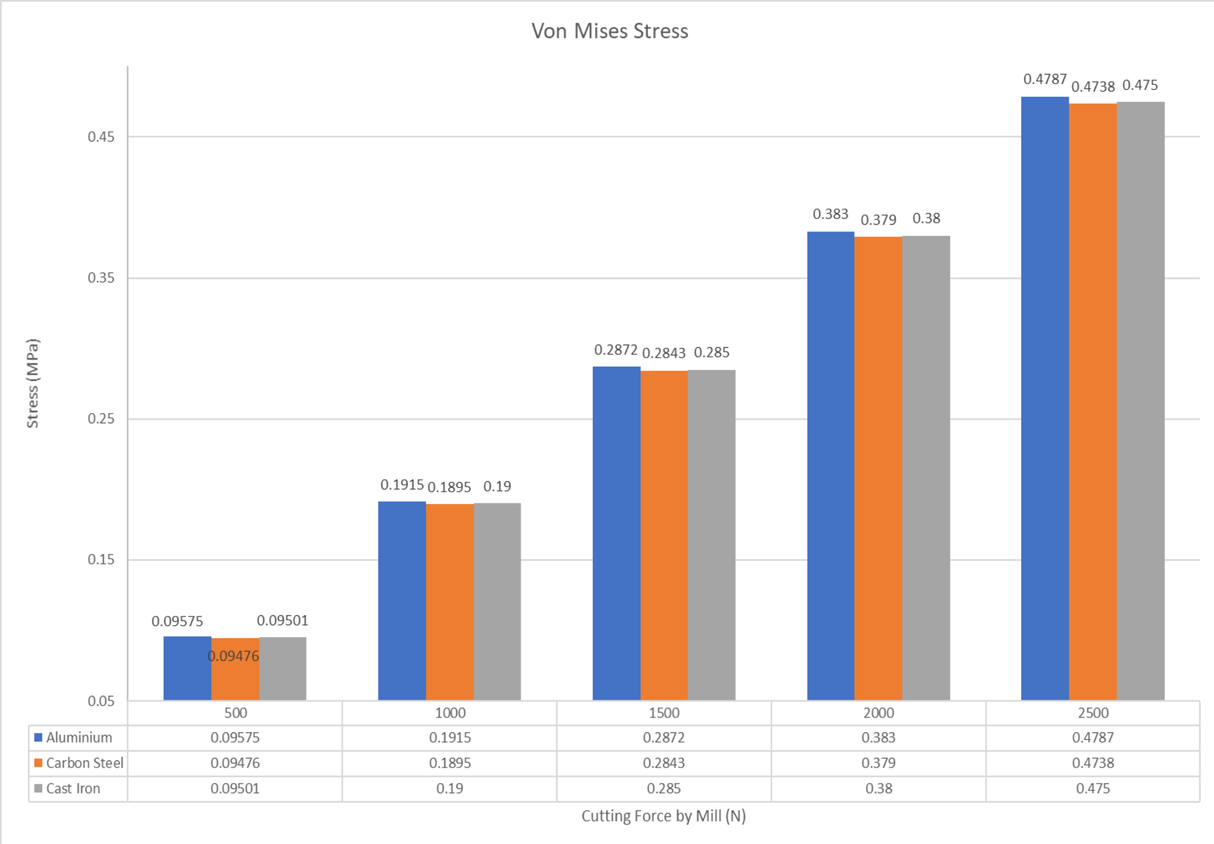

Figure 3: Result of Von Mises Stress Simulation for All Three Materials

As shown in Figure 4, when a cutting force of 500N is applied to a 3D model using aluminum material, the resulting Von Mises stress is as high as 0.09575 Mega Pascal (MPa). For carbon steel, the resulting Von Mises stresses were as low as 0.09476 MPa. The third material is cast iron, the resulting Von Mises stress is 0.09501 MPa. Furthermore, when the cutting force of 1000N was applied to the 3D model using aluminum material, the resulting Von Mises stress was as high as 0.1915 Mega Pascal (MPa). For carbon steel, the resulting Von Mises stresses were as low as 0.1895 MPa. The third material is cast iron, the resulting Von Mises stress is 0.19 MPa.

Then, when the cutting force of 1500N was applied to the 3D model using aluminum material, the resulting Von Mises stress was as high as 0.2872 Mega Pascal (MPa). For carbon steel, the resulting Von Mises stresses are as low as 0.2843 MPa. The third material is cast iron, the resulting Von Mises stress is 0.285 MPa. When the cutting force of 2000N was applied to the 3D model using aluminum material, the resulting Von Mises stress was as high as 0.383 Mega Pascal (MPa). For carbon steel, the resulting Von Mises stresses are as low as 0.379 MPa. The third material is cast iron, the resulting Von Mises stress is 0.38 MPa. Finally, when the cutting force of 2500N is applied to the 3D model using aluminum material, the resulting Von Mises stress is as high as 0.4787 Mega Pascal (MPa). For carbon steel, the resulting Von Mises stresses are as low as 0.4738 MPa. The third material is cast iron, the resulting Von Mises stress is 0.475 MPa.

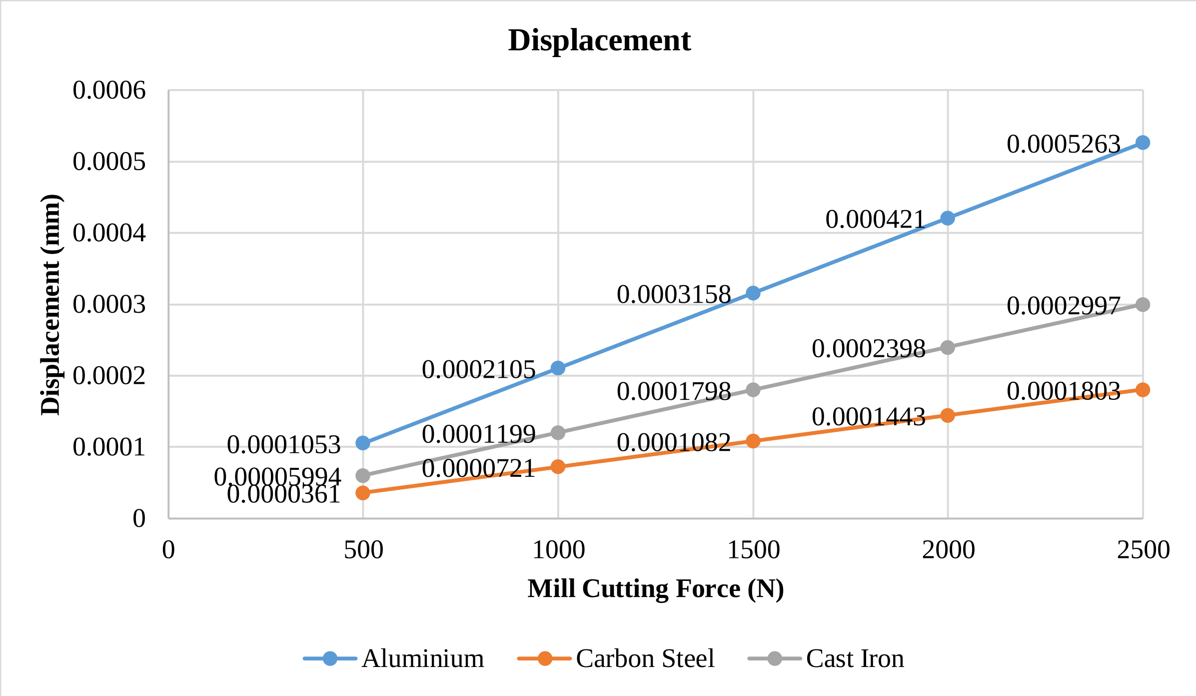

Figure 4: Result of Displacement for All Three Materials

As shown in Figure 5, when a cutting force of 500N is applied to the 3D model using aluminum material, the resulting displacement is as high as $1.053x10^{-4}$ millimeters (mm). For carbon steel, the resulting displacement is $5.994x10^{-5}$ mm. The third material is cast iron, the resulting displacement being the lowest $3.61x10^{-5}$ mm. Furthermore, when the cutting force of 1000N was applied to 3D models using aluminum material, the resulting displacement was as high as $2.105x10^{-4}$ millimeters (mm). For carbon steel, the resulting displacement is $1.199x10^{-4}$ mm. The third material is cast iron, the resulting displacement being the lowest of $7.21x10^{-5}$ mm. Then, when the cutting force of 1500N was applied to the 3D model using aluminum material, the resulting displacement was as high as $3.158x10^{-4}$ millimeters (mm). For carbon steel, the resulting displacement is $1.798x10^{-4}$ mm. The third material is cast iron, the resulting displacement being the lowest of $1.082x10^{-4}$ mm.

When a cutting force of 2000N was applied to a 3D model using aluminum material, the resulting displacement was as high as $4.21x10^{-4}$ millimeters (mm). For carbon steel, the resulting displacement is $2.398x10^{-4}$ mm. The third material is cast iron, the resulting displacement being the lowest of $1.443x10^{-4}$ mm. Finally, when the cutting force of 2500N was applied to the 3D model using aluminum material, the resulting displacement was as high as $5.263x10^{-4}$ millimeters (mm). For carbon steel, the resulting displacement is $2.997x10^{-4}$ mm. The third material is cast iron, the resulting displacement being the lowest of $1.803x10^{-4}$ mm.

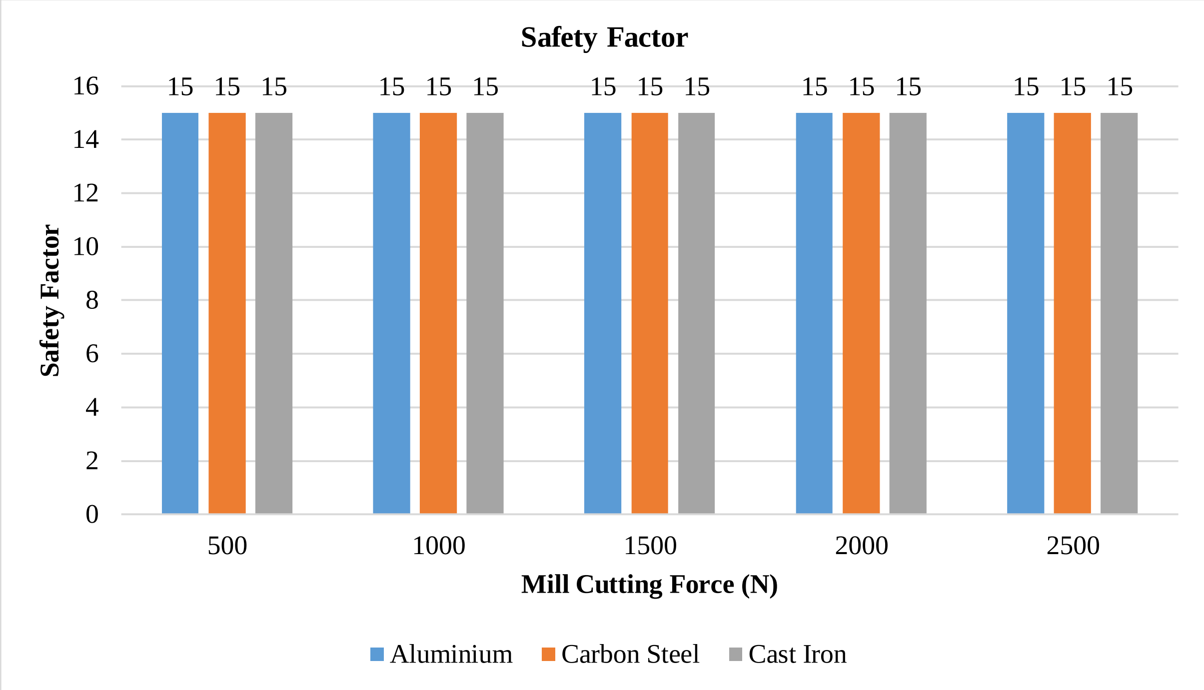

Figure 5: Result of Safety Factors for All Three Materials

As shown in Figure 6, when a cutting force of 500N is applied to a 3D model using aluminum material, the resulting safety factor is 15. For carbon steel, the resulting safety factor is 15. The third material is cast iron, the resulting safety factor also recorded a value of 15. This trend is seen to be continuous when four cutting forces are applied on the 3D model to three different materials (aluminum, carbon steel and cast iron) of 1000N, 1500N, 2000N and 2500N, all of them resulting in a safety factor of 15 when the simulation is performed.

3.3 Discussion

The results of the study are expected to benefit the machining industry in particular so that tool handling problems can be overcome as well as productivity levels can be improved. In addition, the issues and problems with the lathe tool handling, specifically in CNC milling machine are resolved. This is because the use of Mill Turn Vise emphasizes the concept of angle gradients of 15 to 20 degrees hence facilitating the tool setup for turning process on CNC milling machine. The development of this product is also intended to help Bachelor of Vocational Education undergraduates' especially General Machining students to understand the exciting process that can be done on CNC milling machines.

4. Conclusion

As a result, the researchers found that the Mill Turn Vise has good design and development features. This product is expected to help industry players especially the machining industry to help them solve the issues of tool handling and productivity among their workers. However, the research and development of this product still have the opportunity for future improvement to be an effective product. Therefore, it is hoped that improvements can be made as well as using the suggestions provided to produce a more efficient and secure fixture. The researcher also hopes that this study has provided a clearer and more detailed picture to future researchers about their research while improving the quality and functionality of this product.

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