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FEASIBILITY OF INTRODUCING A CNC MACHINE TO FRESHMEN AND INCOMING COLLEGE STUDENTS

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Abstract - *Having proper equipment and materials is the best way to ensure that students have all the necessary information and skills they need to be competent and promising future members of the professional field [11, 13]. Thus, the researchers conducted a study on the feasibility of introducing an alternate version of a Computer Numerical Control machine [15] to the students earlier than usual. To do this, a proposal for a portable CNC machine was made. And as evidenced by previous studies, it is possible to make smaller versions [22, 35] of machines and students are receptive to being introduced to new and novel equipment [22, 37, 38]. With the problems listed, the researchers went on with the research while keeping the objective and scope of the limitation in mind. Thus, after making a proposed model for the device and conducting the market survey research, several conclusions were made.*

Key Words: CNC Milling Machine, Lathing, Market Survey, Milling Machine, Work Piece

1. INTRODUCTION

Having proper equipment and materials has always been associated with better learning and immersion to the subject matter students need to understand. As with working on appliance repair, familiarization with the working tools necessary for each activity is as vital as knowing the theory behind repairing the appliance itself. This stands to reason that providing students with the appropriate equipment is important. However, a major issue with this concept is that some of this equipment and materials are far too expensive and acquiring them will be either be a massive investment from the educators part or a huge financial burden for the students who will use it.

In this regard, using cheaper alternatives is a great way to bridge the gap between the issues of finance and learning. As for Mechanical Engineering students, among the plethora of the most important machinery, they need to fully understand the CNC machine. This is milling equipment often used to cut metal, wood, and other solid materials that may be too difficult to lathe for the inexperienced.

This machine's unique advantages will be necessary for a students' learning. More than this, understanding the mechanisms behind how it works is a great introductory course to learning how to design, build, and operate more complicated machinery. Having this machine at an institution's disposal is desirable for the student and any other company that will hire them in the future.

However, as previously stated, this machine shares the same problem with almost any other; it is expensive. This is why the researchers propose designing a portable CNC machine that is much less expensive than conventional versions of the machine. In turn, the success of the product could well benefit academia immensely. Once the proposed machine is fully functioning, it can be introduced to more students, in this case, general engineering and senior high school students, without the need to burden any of the institutions stock holders financially.

In this research paper, the group will discuss the history, importance, uses, and future of the CNC machine to prove the need to expose more people to this equipment. The proposed design will also be presented and the feasibility of having this equipment compared to conventional CNC machines. Moreover, the possibility of introducing this machine to students outside mechanical engineering will also be explored. Lastly, the researchers will also survey the reception of different students from different fields to be given a chance to learn how to use a simplified version of the machine in question.

1.1 Statement of the Problem

Technology has undergone consistent and continuous developments in making it easier for billions of people to live a more convenient and comfortable life. And this has gone on for thousands of years. Among the results of these developments is the technological revolution that brought about the invention of the CNC machine. They are becoming an increasingly prevalent part of the manufacturing industry and have effectively reduced the need for manual human labor and its errors. This machine is the ideal equipment in manufacturing for several reasons, and its benefits easily extend towards academia.

However, the current versions of the CNC machine are not well suited for being put inside a learning institution for

several reasons. Alone, this factor is enough to make the accessibility rating for this machine low, but another reason is that its compatibility is also limited to large industries. Together, these further prove the need for a portable and affordable version of the CNC machine.

Table -1:

CNC MACHINE SIZE COMPARISON			
Model	Brand	Weight(kg)	Height(mm)
GX 1600	Hardinge	9800	2878
VMX50i	Hurco	8136	2959
AJMCV 300	Ajax	2,500	2,400
KTM-3VSF	Kent Industrial	1270	1828.4

To further emphasize the issue with affordability, above is a table (Table 1) it displays the manufacturer and dimensions of the CNC milling machines currently sold in the market. Reading the table shows that the machine is much larger than what a normal person can reasonably handle. Still, another issue is that there is no transparency regarding the price of these items, which are usually sold to companies directly and with contracts that may or may not stop them from announcing how much the machine was.

The major challenge of manufacturing is producing more products with less material, less energy, and less labor involvement. This reasoning makes it difficult for smaller developers and companies to fully use a CNC milling machine since these machines are generally too large, too heavy, and too difficult to handle and maintain for such companies [1]. To summarize, here are the three points that the researchers currently view as the most important and the ones they intend to tackle:

a. Lack of a smaller, easier to handle, and less expansive version of the CNC milling machine for academic purposes.

b. Finding out the feasibility of using the portable CNC milling machine designed by the researchers for small-to-mid range scale companies and academia.

c. Find out students' reactions to being introduced to a piece of new equipment as part of their curriculum.

To answer these questions, the researchers are proposing to make a design for a portable CNC machine that has reduced accuracy and function but will be much smaller and easier to set up and remove after use. The researchers expect to have the previously stated question through a methodology discussed further in the paper.

1.2 Objective of the Study

Having stated the problems currently experienced by the industry and the significance of solving them, the goals for the research are set. Other than the main objective of designing a portable CNC milling machine, this research has several goals that seek to reach.

The study aims to identify the properties that make for a functioning CNC milling machine that resembles the conventional versions of the machine. The principles that make the machine work will also be explored. Furthermore, given the information gathered through the former goals, the research aims to establish that it is possible to design a portable CNC milling machine with this information as a guide.

With that being said and done, the research will move on and start tackling the next problems the research seeks to solve. This portion of the research will be more theoretical and subjective. The reasoning for it will be discussed further in the paper.

As a general outline, this is the general outline the researchers will aim for as they progress through the study:

a. To understand the current CNC milling machines' properties, principles, and mechanisms.

b. To design a machine that functions as a portable CNC milling machine that can be built for a more reasonable price.

c. To determine whether or not the design can act as a precedent for making mid-scale CNC milling machines.

d. To establish that students want to learn how to operate a portable CNC milling machine.

1.3 Significance of the Study

As with any industry, the manufacturing business also continues to expand at a breakneck speed. And, as the demand for different products grows, the technology needed to make these products should also improve. Unfortunately, as time makes these machines better, they are also made more expensive, effectively making them less and less accessible to small-to-medium businesses and introducing these machines to students less and less attractive for academic institutions.

As previously stated, the absence of an affordable CNC milling machine is a huge factor that stops it from being used in more industries. Despite the availability of traditional

machinery, they are incapable of meeting the demands needed for higher productions and are also much less precise. The existing CNC milling machines also use a wider range of models and types that can work with difficult pieces in a fraction of the time it takes for traditional equipment to complete.

This is why the researchers propose introducing a version of the CNC machine that is portable, easily set up and removed, easier for the workers to operate, and time and space-saving. The successful launch of such a machine will amplify the benefits of knowing how to operate this machine. This will be done by making it easier to understand and operate.

a. Creating a working design for a portable CNC milling machine will make it more accessible for users from different fields.

Creating a portable CNC milling machine is an ideal solution for the need to bridge the student's educational needs and the issue of finding the finances for acquiring one of these machines. Furthermore, the implications of having made a successful portable CNC milling machine design will act as an ample precedent for designing a smaller and more affordable version of the conventional CNC milling machines currently used by the industry. This version of the CNC milling machine will be more affordable for educational institutions and make acquiring it a more attractive prospect than ever before. With this in mind, it stands to reason that adding learning how to operate this machine to a student's curriculum can improve their chances of finding work in the real world and may also inspire them to be a part of the mechanical engineering field if the machine is introduced earlier in their life.

b. Making a precedent for the design and manufacturing of a mid-scale CNC milling machine that is more affordable for small-to-mid-sized companies in the industry.

The success of designing a working portable CNC milling machine will be a great basis for designing a slightly larger version of the machine. After this research, the group is willing to allow other researchers to make this paper their basis for when they consider making a mid-scale version of the machine in question. If successful, the machine will be sold to smaller companies that do not require a CNC milling machine as large as conventional ones. The manufacturing of precisely milled products should grow exponentially as the number of companies using the new mid-scale CNC milling machine increases. Furthermore, with it being more affordable, the creation of new businesses that use this equipment is expected to be the next logical progression after these improvements in the technology.

c. Provide a clear reference stating that students are willing to learn about new equipment as part of their educational curriculum.

Other than this proof acting as a reference as to how students will react to having to learn how to operate new equipment, in this case, the portable CNC milling machine, it will also act as a preliminary survey that educational institutions can use when considering to add this machine to their repertoire of educational materials. As this is the secondary aim of the research, the design of the machine will be closely based on the feasibility of this happening.

1.4 Scope and Limitation

This study will focus on designing a portable CNC milling machine and the feasibility of introducing it as an alternative tool for helping students learn about the precision milling of different materials. A detailed scope of the research is provided below. These limitations will serve as a guideline to help streamline the dataset, interpretation, analysis, and conclusions that will be taken after the research.

a. The study will design a portable CNC milling machine instead of building one.

The estimated time for the product to be completed is longer than the time allotted to make this paper. Hence, the research will be limited to only designing the intended product instead of proving that the design works.

b. The basis for proving that the design can work will be compared with existing CNC milling machines.

As the research is only limited to designing the product, it is impossible to prove its accuracy. Therefore, the final design will be compared to existing CNC milling machines and other smaller versions of different equipment.

c. The conclusion regarding the feasibility of making the design will be based solely on theoretical data.

With the previously stated limitations, it stands to reason that the conclusion regarding the designed CNC milling machine will be purely theoretical.

d. The research on the possibility of designing a mid-scale version of the product will be purely analytical and will not be based on tested data.

The study will only deal with analysing the feasibility of using the design as a precedent for a bigger version of the design. This will be done through market analysis and by pulling conclusions from historical data that are already available. It will not include how to introduce the portable CNC machine to the market to introduce it to groups that will use it as a basis for a new design.

e. The study will only include General Engineering students and Senior High School students for the market survey.

The researchers will only include select students from these two age groups for their research. The students do not necessarily need to come from the same institution.

f. The study will not involve the design of the software on which the CNC milling machine will operate on.

Given the time and resource limitations that are currently present, the researchers will not be developing software that will guide the machine as it mills. Neither will they delve into the topic of designing, coding, or maintaining software. This study will assume that the machine will operate with a functioning operating system, albeit limited in capability.

1.5 Hypothesis

The researchers hypothesize that it is possible to design a working portable CNC machine by basing on theory and the principles that make up conventional machines. Moreover, the group also hypothesizes that a reliable comparison between the proposed design and other successful portable designs is possible, and that this can be done through correlational methods.

As for the first target of the research, making a precedent for the design of a mid-scale version of the machine, the researchers hypothesize that it is feasible to make the proposed design as a basis. Moving on, as for the second target of the research, the group hypothesizes that the participants of the study will have a positive reaction to being introduced new machines as part of their curriculum.

Overall, the research hypothesis that is also the most ideal result would be to make a working portable CNC milling machine design that can be feasibly built. However, realistically, the researchers hypothesize that this proposed design will not be used as a basis for future researches on the matter.

2. REVIEW OF RELATED LITERATURE

One of the most influential and flexible types of machinery in the manufacturing business is the milling machine. It is a machining operation where the material is removed from a work item using a cutter with numerous cutting edges. This machine tool is responsible for around 85% of the total material removal process [2]. CNC machining has become a standard part of many industries' manufacturing processes. This is since CNC machines improve output. Compared to manually operated gear, it also provides for a greater range of applications [3].

Milling machines were created to make hand-filing more efficient. They first appeared in the early 1800s (1814-1818), though the exact history is difficult to follow because there was so much development in tiny stores at the time. For decades, milling machines have had a significant impact on the world of production and industry. Countless ideas would have never seen the light of day if it hadn't been for them. At its most basic level, a milling machine employs revolving cutters to remove material from a solid block by feeding the cutter along the block [4].

For operating directives, controllers switched from punch cards to software. From punch card-indicated coordinates that showed the start and finish locations along two axes to today's technology that can produce highly complex three-dimensional components by moving tools along five axes, the usefulness of the machine has also grown. While the manufacturing sector prefers to stick to tried-and-true technology, CNC machines have become a modern invention that many firms are now adopting. CNC devices are a far superior option to previous NC machines or manual machining due to improved precision, quicker speeds, and higher output capacities provided by computerized control [5].

CNC machining has several advantages for today's organizations. With a high rate of output and fewer errors in the resultant components, CNC machines more than make up for their initial expenses. Operators also require less training and may learn how to run a CNC machines in a virtual environment, reducing the requirement for training work pieces [6]. An engineer does not need to be a construction specialist to produce a perfect design; instead, she needs only copy her concept on the computer and have the CNC machine make it. Because the blueprint is still on the computer, any shape changes may be made rapidly simply by repeatedly performing the machining process for a new model and doing it repeatedly after [5].

CNC machining, a type of precision machining, differs from other types of precision machining in that it is automated, allowing for high CNC accuracy and extreme precision. CNC machining not only allows for a level of complexity and intricacy that traditional precision machining technology cannot — cutting to 0.001" or roughly 1/4 the width of a human hair — but it also saves money when making complicated products [6].

To supervise the output of numerous CNC machines, just one skilled person is required. The technology underlying these robots has progressed to the point where one person can sit and watch them work for hours after they've been programmed. Companies that employ these devices may pass on the cost savings from fewer personnel to their customers [7]. The G-code-based software will update itself as needed. CNC machines don't require much maintenance beyond changing the cutting implements at the appropriate intervals and minor cleaning. Regular maintenance does not need expert assistance, saving money [8].

On the contrary, there are some negatives to switching on today's technology. Although CNC machines are more expensive than manually controlled machines, the costs are gradually decreasing. A CNC machine operator just requires

basic training and abilities, which are sufficient to oversee numerous machines. Compared to manually operated equipment, CNC machines require fewer personnel to operate. As a result, CNC machines can cause a lot of unemployment [9].

Many mechanical engineers are concerned that students may lose their manual machining abilities by emphasizing the use of CNC machines in the classroom. These physical abilities, such as facing, turning, grooving, and polishing using a lathe, give important mathematics and technical knowledge [10].

With the global economy continuing to expand, machine tool consumption will increase by more than 3.0% in 2019, propelling the worldwide CNC machine tool industry, which had an output value of $70 billion in 2018, to continue to rise gradually. China, being the world's top manufacturer and user of CNC machine tools, had a CNC rate of 29.7% in 2018, much lower than Europe, America, Japan, and other industrialized nations (Japan: over 90 percent; Germany: above 75 percent; the United States: beyond 80 percent). Metal cutting machine tools had a CNC level of 39.0 percent, which was greater than metal forming machine tools (only 9.9 percent) [11].

MESCO was the first company in the Philippines to launch numerous important machining technologies. In fact, in 1973, the business introduced the Philippines' first CNC machine tool. MESCO was also incorporated into MESCO Inc. at this time [12].

Due to the high cost of training for highly specialized skills such as CNC Machining, CNC Programming, manufacturing engineering, and CNC machine repair and maintenance, which are at the higher-level technology and still relatively uncommon in the Philippines, there are only a few skilled CNC Machinists available. Hence, making learning it a viable path towards a more in-demand profession in the future. Especially considering that there is a huge lack in people in the country who are able to use this machine effectively [13].

In a study conducted by Guiming, he found that while many machine tool manufacturers pay attention to the production of machine tools, they are losing the genuine beauty of how they can produce a tool with a great structure. In the method of CNC machine tool industrial intelligent production, the significance of industrial design intelligence to CNC machine tool should acknowledge by the designers, the traditional concept must be amended, and even the balances in functions and forms should be transformed [14].

The numerical control machine tool manufacturing industry is thriving, and the main producing countries with absolute advantages are Asia, America, and the European Union. China, Japan, and Germany. In 2019, 31.5% was recorded in China for the scale of CNC Machine tool while 0.6% in Japan. Effective integration in automatic control intelligent technology and traditional manufacturing technology will turn the construction into higher efficiency, operates easily, and supports the operating system with lower difficulty [14].

Through a prepared program involving coded alphanumeric data, the Computer Numerical Control was being controlled. Manufacturing with high accuracy, short time in production, manufacturing with greater flexibility, simplex fixturing, contour machining and decreasing human errors. The drawbacks are expensive cost, maintenance, and the necessity of skilled part programmers. CNC has a wide range of benefits in the machine tool category, including lathe, drill press, milling machine, grinding unit, laser, sheet-metal press working machine, tube bending machine, and many more. Turning centers and machining centers are highly automated machine tools that can change the cutting tools automatically. On the other hand, CNC in the non-machine tool category also has other functions, welding machines, coordinate measuring machines, tape laying and filament winding machines for composites and many more are included in CNC applications [15].

The core manufacturing equipment is the Computer Numerical Control (CNC) machine tools, wherein the important part of intelligent manufacturing workshops is collected and monitored. Refinement of production with the competency of enterprises and remove information islands that served as great importance [16].

Milling machines are developing, the machine is built to become even better, and the desired outcome is a machine capable of working with stock materials that include plastic, wood, and light materials such as aluminum and bronze. When you use it with metals, it will make the CNC machine benefitted over 3D printers. Metals are intended to create durable parts when using plastic in 3D printers [17].

With the use of shelf-component stepper motors with drivers, Arduino open source, microcontroller, and open-source motor control software low-cost three-axis CNC machine was developed. The author developed the low cost of the CNC Machine, and the purpose is for education [18].

Many manufacturing processes are now using computerized machines that lead to high production. Unfortunately, it is not a problem when it comes to inspection. To have an advanced swiftly that can produce in fast processing, CNC must use, where it is able in manufacturing parts that speed is high and can make manual inspection into a bottleneck [19].

CNC price chart data was obtained in 2018 to determine low, high, average, and brand pricing based on CNC type (Table II). Suppliers saw how many manufacturers and machinists were looking for prices and decided to compile statistics based on our inventory and sales from the previous year.

Table -2:

CNC MACHINE PRICE BY CNC TYPE (ROUNDED DATA FROM CNCMACHINES.NET AS OF 12/2018)				
CNC	DESCRIPTION	PRICE USD$		
		Lowest	Highest	Average
CNC Lathe	Lathe	10,000	430,000	80,000
CNC Mill	Mill	6,000	300,000	60,000
CNC VMC	Vertical Machining Center	6,000	275,000	50,000
CNC HMC	Horizontal Machining Center	15,000	350,000	89,000
CNC HBM	Horizontal Boring Mill	50,000	300,000	125,000
CNC VTL	Vertical Turret Lathe	25,000	385,000	166,000

Material milling CNC mill machines are available in two basic configurations: vertical and horizontal. The milling tool descends and collides with the material on the table. Milling tools are positioned horizontally on horizontal machining centers, and the workpiece is impacted to a vertical surface. The cost of a transaction rises as the number of alternative moves increases [20].

Due to the investment costs of machine tools, a direct purchase only makes sense if the workload is high. Therefore, for smaller companies to get the maximum benefit from these technologies, they will likely need to develop a strong outsourcing policy. SMEs should not see these practices solely as the domain of large organizations; they are good at adopting and adapting such strategies to give themselves a competitive advantage [21].

Small and medium-sized enterprises (SMEs) located at the third or lower level of a supply chain in manufacturing remain more labor-intensive and focus on short-term operations rather than long-term strategic issues, as they don't have many resources. This continuous improvement process can last a long time, at least until the market is saturated or until an innovation with a competitive advantage enters the market: cheaper, easier to use, more reliable, and better. Most mature, everyday products are cheaper today than when they were first introduced and are undoubtedly more reliable. [22].

One of the several factors small-medium enterprises (SMEs) and large companies when purchasing CNC Machines is the size of the machine. The production area is different in a large manufacturing company and SMEs manufacturer. However, for a machinist who performs their job at their workstation most of the time, a small space brought by the machine may create discomfort due to feelings of confinement [23]. CNC machines have different types of axes available in the market. 3 to 5-axis machines centers and 2 to 8-axis turning centers are the machines you can find in a manufacturing company. Selecting CNC Machines is important in manufacturing companies. Business owners will save money when they can choose the correct machine needed in their business project [24].

In 2020, Campbell wrote an article about CNC machines and came to think that one factor that should be considered is your budget. Machining services and equipment are expensive yet do not meet your company's requirements. However, with a well-thought-out strategy and sufficient expertise, you may select a service that meets all of your requirements while remaining within your budgetary constraints. As a result, when choosing a provider, be as precise as possible about your expectations. Also, because VMC (vertical machining center) machines are less expensive than HMC (horizontal machining center) equipment, they may be less expensive to hire. Note that pricing differences should not be the sole factor to consider [25].

A decent CNC machine can do a lot of work. You need an as little downtime and maintenance as possible to get maximum output. DMS machines, with a few exceptions, lubricate themselves automatically. Even the few pieces of equipment that need manual lubrication may be maintained at one of three sites. While some machines may require hours of rest each day, we propose a simple monthly checkup to guarantee optimal performance. DMS devices require less maintenance and downtime [26].

Performance testing of CNC units and mechanical components is becoming more significant; nevertheless, testing of merely CNC units cannot improve the performance of full systems since they interact with other mechanical components like ball screws and bearings. The CNC units must also be tested after the entire machine tool is produced, which is expensive and time-consuming. Furthermore, the performance test would be harmed by too many noises emitted by each component [27].

The interpolation and speed (acceleration/deceleration) control methods used by the CNC significantly impact the machine tool's speed and accuracy. Furthermore, the CNC's interpolation and speed control technology is a black box based on processing unique to each CNC maker [28].

The key to bearing safety is a design that incorporates excellent thermal management, ensuring heat generation and dissipation are balanced within the system [29]. There is

certainly that rolling bearings play a key role in the spindle system of a CNC vertical milling machine since their mechanical qualities have a significant impact on the spindle system's dynamic behavior and stability. Furthermore, the bearing clearance is an important design parameter to compensate for the thermal deformation of the spindle system in CNC vertical milling machines to avoid the bearing from jamming [30].

Choosing the proper material is the first step in having an ideal completed item. The most appropriate and cost-effective material can be chosen by limiting the sorts of machining materials that are best suited for the item. When choosing a material, make sure that its melting point is lower than the machining process's working temperature. Furthermore, any variations in operation temperature must be considered. The material must sustain the temperatures for an extended period without warping, distorting, or breaking down [31].

This is one of the most important factors to consider when choosing a material for CNC manufacturing. Different materials are required for different applications. An aeronautical part must be lightweight compared to a part for structural support in a building. Aluminum 3.3211, for example, is widely utilized in the aerospace sector due to its high strength-to-weight ratio. The application area will determine the physical qualities of the material, such as tensile strength, strength to weight ratio, crack resistance, stiffness, and flexibility [32].

Temperature deformations occur due to this temperature effect, resulting in a change in the position of the work piece relative to the tool and, as a result, errors. Every CNC machine tool is subjected to temperature impacts during operation and in sleep mode, both uniform and uneven. This will be particularly noticeable if we concentrate on the stability of the machined dimension in the case of a smaller number of work pieces while keeping the shape and position faults defined on the machined parts in mind [33].

From a structural standpoint, the positioning accuracy of CNC machine equipment causes machining mistakes. The machine tool's feed system is the most important factor affecting its positioning precision. The mechanical transmission system in the structural design is linked to positioning precision. Using position sensing devices, CNC machine tools can typically prevent positional variations in the primary components of the feed system, such as ball screws, in a closed-loop system. Positioning and monitoring are impossible in open-loop systems due to the numerous influencing factors and the intricate environment [34].

3. METHODOLOGY

Given the scopes and limitations of the research, other research design types cannot be used for the research. However, it also presents two clear alternatives. The researchers will utilize a quantitative and correlational research design for the study.

The researchers will use a quantitative research design for the market survey portion of the research. This allows the researchers to transform data gathered into easily understandable stats and numbers. This will also make way for a casual-comparative sub-research using the same data set.

As for the feasibility of making the product as a basis for designing a mid-scale version of conventional CNC milling machines, a correlational research design will be used. This will be achieved by comparing the design and the principles used in proposing previously made machines. This will ensure that little to no resources are wasted in making this research.

As for the overall process of the research, the data collection to make the data will be based solely on observational and correlational methods to make the most optimal design for the proposal. The proposal will go under a feasibility study that will quantify the statistical grade of the designed machine. Moving on, the other data that will be required to draw out the conclusion will also is treated similarly to the other data collected in other parts of the research.

This method should allow for a reliable supply of data and information that will prove sufficient for the interpretation aspect of the study. This should provide a reliable and systematic pattern that other researchers can follow if they want to improve the design proposed by the group.

3.1 Data Gathering and Collection

As discussed in the conceptual framework of the research, the process that will be followed to complete this research will be based on that diagram. In summary, the researchers will use different existing references to make their designs. Then a series of trials for the design's feasibility will be conducted until an optimal design that meets all the criteria they laid out is met. The proposed design will then be compared to other existing designs to ensure that it is up to par with standards and can be used as a basis for future designs. Furthermore, the researchers will also survey to ensure that the proposal of teaching operating this machine will be well received by students and other possible users of the expected product.

Given the limitations laid out by the researchers in earlier chapters, the researchers will not be making a physical version of the product. However, the research design they chose should prove a viable alternative to proving whether or not the design would work. If necessary, peer reviews of the proposal may also be done to ensure that it would function as intended. Regardless, the data gathering for the second objective of the research will be limited to theoretical discussions.

As for the survey, the researchers will use google forms as a convenient way of getting information from students from all walks of life and a wider range. This will allow for a truly random set of participants that are always ideal for research like this. Once done, the data will be tabulated and analyzed through excel to ensure that the relationships between the variables and the answers are laid out for interpretation.

The data analysis procedure that the researchers will follow will be based on the research's previously discussed research design and conceptual framework.

As data gathering from different sources and designs of the CNC milling machine is the first step of the study, the data gathered from that portion of the research will be processed quantitatively, and all the design principles and properties that overlap will be used for the proposed design. As the researchers expect, following this method should result in the most optimal design that blends all the mechanical elements of a CNC milling machine to become a complete functioning machine. This mechanical design will act as a balancing factor for the machine's stiffness, strength, reliability, and accuracy. All of these are necessary to make the machine acceptable in academia and different industries.

Once done, correlational data gathering procedures will be utilized to compare the proposed product's effectiveness compared to other smaller prototypes of huge machines used in the industry. By correlating whichever portion of the proposed design overlaps with other designs made successfully through this research method, a conclusion should be made available to the researchers.

As for the market survey, which is the part of the research where students will be asked whether or not they want to learn about CNC's in their classes, the data will be gathered through a survey along with other data that may be helpful for the research. Their answers will then be collected and compiled into easily understandable figures to add context to their answers.

Together, the data gathered from the research should be enough to make a suitable conclusion and recommendation that can be sent to the school institution and small-to-medium businesses regarding the feasibility of a CNC milling machine.

3.1 Mechanical Design

The machine comprises a frame that houses a plane that allows for X-Y axes movements through table motions, and the Z-axis milling is adjusted through the spindle cutter. The CNC control card and computer are the machine's control units. Stepper motors are also attached to provide an easier revolution of the material. These are attached to a sturdy base to make sure that the machine stays as stable as possible.

The functional and derived requirements are the most important design requirements as with any machine. The functional requirements are a collection of derived criteria that must be met to complete the machine's design. The CNC milling machine mainly consists of the mechanical components, including the structure, the electrical system and the control or computing system to position the tip of the milling cutter at the required position. These are also the base requirements the researchers used for making the design.

The machine's mainframe is made from aluminum tubes that can easily be interchanged and adjusted, making the machine even easier to assemble and disassemble when needed. Since the material is light, the machine is much less expensive to build. The stepper motors of the machine are mounted on the X-Y axes allowing for movement on this plane, and are coupled through a shaft connected to the system through lead screw axes.

A shaft coupling is used to connect the lead screw end to the stepper motor using a key lock to transmit the required power to cut through the material used. The speed of the motor in each axes is controlled through the stepper motor. This electromechanical part was devised to convert electrical control signals into the rotational mechanical movement milling requires. The stepper motors are also brushless for a more precise milled product.

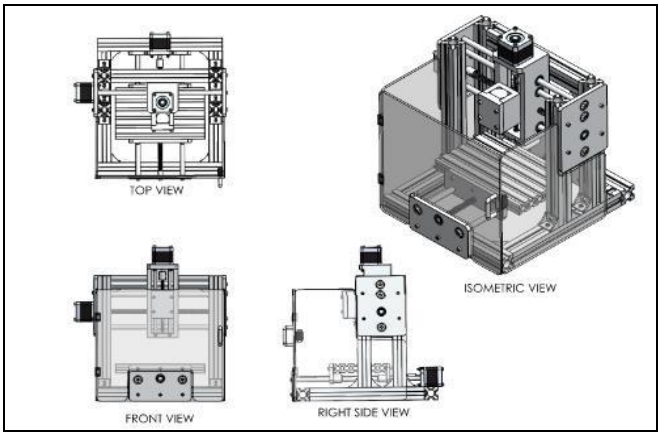

Fig -1: Proposed Portable CNC Milling Machine Design

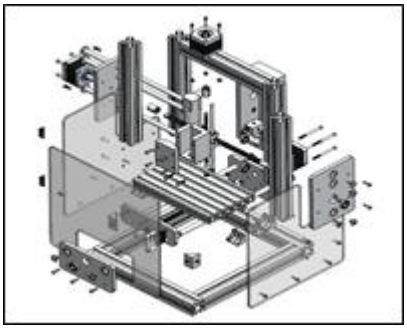

Fig -2: Exploded View of the Proposed Portable CNC Milling Machine

Above is an exploded view of the proposed portable CNC milling machine. The image showcases the aluminum base, acetate barrier, lead screws, stepper motor, etc. This design view is meant for future research regarding making the machine and, hopefully, improving it.

Despite most CNC milling machines in production being completely automated, this design will require a little more attention to make us of properly. Since it's an introductory item that most students are meant to use, it was decided that it's best to make the process of using the machine more immersive if the student so chooses. This is the reason for the variable speed for the motor, so they can better observe how their digital designs are being transformed or etched into/onto 3D objects.

4. CONCLUSIONS

The research established that understanding what makes a CNC milling machine run is necessary for making a proposal for a portable version of the machine. The research also concludes that it is possible to make more economical version of the CNC milling machine, and such a machine is more than enough to get students interested in learning about the machine.

Moreover, as the number of people who are aware of the machine increases, the possibility of seeing improvements in the future also increases, similarly to what was alluded to by the research conducted by Sarwar (2013). The market study of the research established that students are willing to learn about different machines if they are given the opportunity; this conclusion was supported by Doney and Wegerif's (2017) research. It was also concluded that it is possible that improvements on the CNC machine can be produced by the interest of students in the future.

The correlational comparison with other machines of the machine, especially with its close design to that of Haji (2013) supports the possibility of making a functional portable CNC milling machine.

Here is a summarized list of the conclusions the group derived from the research.

- Understanding what makes a CNC milling machine run will help in making a proposed design for a portable CNC milling machine
- It is possible to make a portable CNC milling machine at a more economical price. However, the capabilities of this machine will be greatly limited.
- The proposed design can serve as a basis for making a mid-scale version of the CNC milling machine, so long as interest in the machine is increased.
- Students are receptive to having CNC milling as part of their curriculum, and they are generally willing to learn how to operate the machine.

Overall, the researchers conclude that it is feasible to introduce a proposed portable CNC milling machine to a wider audience.

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REFERENCES

[1] G. Chryssolouris, Laser Machining, 1st ed. New York, NY: Springer New York, 1991, pp. 85-103.

[2] A. Kumar, "Milling Machine: Definition, Parts, Operation, Working Principle, Application, Advantages", themechanicalengineering.com, 2020. [Online]. Available: https://themechanicalengineering.com /millingmachine/. [Accessed: 16- Jan- 2022].

[3] "What Is a CNC Machine? An Overview of CNC Machining • Prototech Asia", Prototechasia.com, 2020. [Online]. Available: https://prototechasia.com/en/what-is-a-cnc-machine. [Accessed: 16- Jan- 2022].

[4] "The History and Design of Milling Machines.", Plethora, 2017. [Online]. Available: https://www.plethora.com/insights/the-history-and-design-of-milling-machines. [Accessed: 17- Jan- 2022].

[5] "The Evolution of CNC Machines | American Micro Industries", AmericanMicroIndustries, 2021. [Online]. Available: https://www.americanmicroinc.com/resources/evolution-cnc-machines/. [Accessed: 12- Jan- 2022].

[6] Oracle-Precision. (2015). Advantages of CNC Machining. Retrieved February 16, 2022, from https://www.oracleprecision.co.uk/news/advantages-of-cnc-machining, 2015. [Online]. Available: https://www.oracleprecision.co.uk/news/advantages-of-cnc-machining. [Accessed: 16- Feb- 2022].

[7] S. Waak, "5 Ways CNC Precision Machining Can Make or Break Quality and Performance", www.steckermachine.com, 2021. [Online]. Available: https://www.steckermachine.com/blog/quality-cncprecision-machining. [Accessed: 03- Feb- 2022].

[8] C. Metals, "What are the Advantages of CNC Machining?", CAMM Metals, 2017. [Online]. Available: https://inbound.cammmetals.com/blog/what-are-the-advantages-of-cnc-machining. [Accessed: 03- Feb- 2022].

[9] B. Reed, "Advantages of CNC Machining vs Conventional Machining", Fairlawn Tool, Inc., 2016. [Online]. Available: https://www.fairlawntool.com/blog/advantages-cnc-machines/. [Accessed: 03- Feb- 2022].

[10] "The Disadvantages and Advantages of CNC Machining", Prime Engineering, 2019. [Online]. Available: https://www.primeengineering.com.au/the-disadvantages-and-advantages-of-cncmachining/. [Accessed: 03- Feb- 2022].

[11] "Global CNC Machining Center (5-axis) Market Growth 2022-2028 : ReportsnReports", Reportsnreports.com, 2022. [Online]. Available: https://www.reportsnreports.com/reports/5299487-global-cnc-machining-center-5-axis-market-growth-2022-2028.html. [Accessed: 02- Feb- 2022].

[12] A. P. M. E. News, "MESCO: Driving Machining Technology Evolution," Asia Pacific Metalworking Equipment News | Manufacturing | Automation | Quality Control, Oct. 10, 2019. https://www.equipment-news.com/mesco-driving-machining-technology-evolution/ [Accessed Dec. 03, 2022].

[13] Baldoz, "CNC Machinist: One of the Most In-Demand Jobs Today", OFWguide.Com, 2013. [Online]. Available: https://www.ofwguide.com/article_item-1914/CNC-Machinist--One-of-the-Most-In-Demand-Jobs - Today.html. [Accessed: 02- Feb- 2022].

[14] Q. Guiming, Research on Intelligent Technology of CNC Machine Tool Industrial Design. 2021.

[15] R. Sundaramoorthy, "(2016). A Literature Survey on Machining with Different Types of Materials by CNC Milling Machine.," ijesrt.com, 2016. http://www.ijesrt.com/issues%20pdf%20file/Archive-2016/February-2016/64_A%20LITERATURE%20SURVEY%20ON%20MACHINING%20WITH%20DIFFERENT%20TYPES%20OF%20MATERIALS%20BY%20CNC%20MILLING%20MACHINE.pdf?fbclid=IwAR2yoC5U7QicEbYfraj6zHOQS23f19Pis82mOM505rXXQOBQEABX42JpArk (accessed Feb. 02, 2022).

[16] Y. Guo, Y. Sun, and K. Wu, "Research and development of monitoring system and data monitoring system and data acquisition of CNC machine tool in intelligent manufacturing," International Journal of Advanced Robotic Systems, vol. 17, no. 2, p. 172988141989801, Mar. 2020, doi: 10.1177/1729881419898017.

[17] Spilling, "Self-Improving CNC Milling Machine." 2014, [Online]. Available: https://core.ac.uk/download/pdf/30873518.pdf?fbclid=IwAR24XFMtRhP5vuTi0zsVS49pMSOTcZKLaLHkZvTHeSPvvLKRHP6Ka_PFZyg [Accessed: Feb. 02, 2022.]

[18] M. Patil, "Literature Review for Designing of Portable CNC Machine," IJIRST, 2017. Accessed: Feb. 2AD. [Online]. Available: http://www.ijirst.org/articles/IJIRSTV4I6010.pdf

[19] Tiwari, "Automated Inspection using Database Technology within the Aerospace Industry," 2008, Accessed: Feb. 2AD. [Online]. Available: https://core.ac.uk/download/pdf/14343184.pdf?fbclid=IwAR3v_dAzOTM015nDWlbjiWPS3gzkAfploAccx88JFvTd_34-aTgsw0AJrnA.

[20] "2018 Used CNC Machine Price: Average CNC Machine Price | ManufacturingTomorrow," manufacturingtomorrow.com. https://www.manufacturingtomorrow.com/article/2018/12/2018-usedcnc-machine-price-average-cnc-machine-price/12676/ [Accessed: Feb. 02, 2022].

[21] PRIME Faraday Partnership, "Machining Technology Developments," LBoro UK, 2001. https://www.lboro.ac.uk/microsites/mechman/research/ipmktn/pdf/Technology _review/machine-technology-developments.pdf [Accessed: Feb. 02, 2022].

[22] "Invention and innovation: an introduction: View as single page," Open.edu, 2019. https://www.open.edu/openlearn/ocw/mod/oucontent/view.php?id=3440&printable=1.

[23] "Factors To Consider When Choosing CNC Machines | purshoLOGY," https://www.purshology.com/. https://www.purshology.com/2020/07/factors-to-

consider-when-choosing-cnc-machines/ [Accessed Feb. 02, 2022].

[24] Admin, "7 Steps to Choosing the Right CNC Machine Tool - Hwacheon Asia Pacific Pte. Ltd.," Jun. 04, 2018. https://hwacheonasia.com/7-steps-choosing-right-cnc-machine-tool/ [Accessed Feb. 02, 2022].

[25] R. Campbell, "5 Important Factors To Consider While Choosing A CNC Machining Service," BitRebels, 2020. https://bitrebels.com/technology/5-important-factors-considerchoosing-cnc-machining-service/ [Accessed Feb. 03, 2022].

[26] Diversified Machine Systems, "Eight Things to Consider Before You Buy a CNC Machine," dmscncrouters, 2020. https://dmscncrouters.com/blog/eight-things-to-considerbefore-you-buy-a-cnc-machine/ [Accessed Feb. 03, 2022].

[27] C.-H. Lee and G. Khim, "Performance Evaluation Method of CNC Units using Torque Curve Patterns," 2008 International Conference on Smart Manufacturing Application, Apr. 2008, doi: 10.1109/icsma.2008.4505646.

[28] T. Otsuki, H. Sasahara, and R. Sato, "A Method for Evaluating the Speed and Accuracy of CNC Machine Tools," 2017, pp. 40–55.

[29] J. Takabi and M. M. Khonsari, "On the thermally-induced seizure in bearings," 2015.

[30] H. Miao, C. Li, C. Wang, M. Xu, and Y. Zhang, "The vibration analysis of the CNC vertical milling machine spindle system considering nonlinear and nonsmooth bearing restoring force," Mechanical Systems and Signal Processing, vol. 161, p. 107970, Dec. 2021, doi: 10.1016/j.ymssp.2021.107970.

[31] S. Mein, "Selecting the Right CNC Machining Materials for the Part," www.firetrace.com. https://www.firetrace.com/fire-protection-blog/cnc-machining-materials.

[32] Xometry Europe GmbH, "Factors To Consider When Choosing Materials for CNC Machining," Xometry Europe, 2021. https://xometry.eu/en/how-to-choose-materials-for-cncmachining/ [Accessed Feb. 04, 2022].

[33] J. Marek, M. Holub, T. Marek, and P. Blecha, Geometric Accuracy, Volumetric Accuracy and Compensation of CNC Machine Tools. IntechOpen, 2020.

[34] "CNC Milling," Suzhou Longkai Electromechanical Technology Co., Ltd. https://www.cnc-longkai.com/cnc-drilling-and-milling-machine/cnc-milling.html [Accessed Jan. 29, 2022].

[35] "The History of Portable X-Ray Machines SOmatech - Search," www.bing.com. https://www.bing.com/search?q=The+History+of+Portable+X-Ray+Machines+SOmatech&qs=n&form=QBRE&sp=-1&pq=the+history+of+portable+x-ray+machines+somat&sc=1-44&sk=&cvid=092C3EFB622B4CC0BB904CBF381E4EC4 [Accessed Jan. 10, 2022].

[36] S. Haji, "Design and Fabricate of Portable CNC Milling Machine," Thesis, Faculty of Mechanical Engineering UNIVERSITI MALAYSIA PAHANG, 2013.

[37] M. Sarwar, "Impact of Smartphone's on Society.," European Journal of Scientific Research, 2013.

[38] J. Doney and R. Wegerif, Measuring Open-Mindedness. Tony Blair Institute for Global Change.

[39] Deans for Impact, "The Science of Learning," Deans for Impact, Austin, TX, 2015.