ISSN 2278-3091
Volume 9, No.5, September - October 2020
International Journal of Advanced Trends in Computer Science and Engineering
Available Online at http://www.warse.org/IJATCSE/static/pdf/file/ijatcse218952020.pdf
https://doi.org/10.30534/ijatcse/2020/218952020

Simulation In Classroom: Development Mini Computer Numerical Control (CNC) Milling Machine for G Code Movement

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ABSTRACT

Most of the conventional milling machine follows the same machining process as CNC milling machines. The different CNC Milling is utilized numerical control programming language code (G codes) to control all the machining processes such as tools, cut and shape the material. Based observation studies on the subject of Computer-Aided Machining Technology show that students are not able to develop codes of programming for easy programming topics contained in the syllabus of the subject. This means that the students do not understand and can't imagine the G codes movements and to develop easy G codes for CNC even after a semester they are studying it. Therefore, this study aims to design and develop a mini CNC milling machine for simulating the movement of the G code by using the ADDIE model. The use of the ADDIE model in this study is described in detail in five phases namely the analysis, design, development, implementation, and evaluation phases. The respondents were selected using purposive sampling. The findings of this study found that the development of teaching aids the movement of the G code CNC milling machine as a whole it was developed based on the scope and objectives of the study. As a result, using the simulation is expected to help the teaching staff in the implementation of the teaching and learning process more effective and important is to encourage students to improve understanding of the code G-code CNC milling machine.

Key words : Simulation, G codes, CNC Milling machine, ADDIE model

1. INTRODUCTION

The concept of tool cutting using the machine works when the feed occurs during the tool's rotation [1]. The concept of cutting is the same as conventional or using a computer numerical control (CNC) machine. Generally, there are three-axis directions available on the grinding machines X, Y and Z. For the X and Y axes, the horizontal motion is determined. The X-axis represents the left and right movements while the Y-axis moves forward and backward. The Z-axis, for example, represents the vertical and vertical movements. CNC milling machines use numerical control programming languages. Numerical control interpretations contain command codes, which are code G and code M. For code G, it is to regulate the movement of the tool. These codes can be generated using Master Cam software [2]. The order of the code is in the order of starting from the datum set process to the finish of the machining process.

In most educational institutions, conventional method is still an option in the teaching and learning process [3]. Using the conventional method in technical subjects especially CNC G code makes students hard to understand the movement of the tools. An initial survey was conducted to look at the state of the learning process for the subject of computer-aided machining technology followed by a cohort of 4 Bachelor of Vocational Education (General Machines) with honors. As a result of this observation, students cannot develop programming codes for the Easy Programming topics contained in the subject syllabus. In the five topics in the subject of computer-assisted machining technology, students will learn CNC Simple Programmers. One of the sub-topics in this topic is numerical control operations. This sub-topic introduces simple CNC programming codes such as G codes and M codes. Interviews were conducted to identify problems faced by students in this subject. According to the lecturers who teach on this subject even though the information has been provided, the students have difficulty understanding and thus developing the CNC programming code. He added that students also find it difficult to insert or apply simple CNC

programming code into a real machine. According to [4], the CNC's simple programming code G and M code need to be understood before machining. Once students have mastered the CNC's simple programming code, the student can operate a CNC machine. According to [5], understanding the basic concepts CNC is fundamental to meeting the challenges of IR 4.0 [5].

Practical teaching enables students to gain skills and learn something through direct experience [6]. He added that the content or learning material needed to be mastered by students to gain knowledge and skills in a field. According to [7], Students' understanding of some learning processes is through direct observation. Thus, on these subject students will learn about machine learning programming code which is a prerequisite for Computer-Aided Machining Skills. Students will learn simple CNC programming such as G code and M code. [4] states that the importance of CNC simple programming code is to give the machine instructions to execute the machining process according to the design required. According to [7]., the process of inserting simple programming code into CNC grinding machines requires high skill. The process of movement that should be generated should not have any problems during the machining process on the machine [8]. The use of the wrong programming code on the workpiece is defective and will impair the machining process [9]. Besides, CNC machines are sometimes too sensitive and vulnerable [10]. Therefore, losses will be incurred by the workshop if this problem occurs frequently.

The difficulty in understanding CNC's simple programming learning was evidenced by the scores of three cohort students who had taken up the subject of Computer-Aided Machining last semester. Score comparisons are taken based on the number of points obtained by students through the final examination questions. There are 4 questions contained in the examination paper. 1 out of 4 questions is a question related to simple CNC programming. The total score for that question is 25. However, the total score obtained by students is only between 8 and 13 marks. This stated that students still do not understand how to develop CNC simple programming codes even after one semester of studying.

An interview was conducted by The York College Mechanical Engineering. The response from the industry is that students need a better understanding of how the machining process works. Besides, a study was conducted on a Diploma in Mechanical Engineering Diploma students in polytechnics. According to [10], the responses obtained from employers indicated that students lacked the level of mastery in CNC machine handling skills. Additionally, relatively long learning times and deep interest are required to master machine operations. The process of generating a simple CNC programming code is one of the machining processes that influence the process of designing a product. Therefore, to ensure good teaching quality, practical teaching can help students become more knowledgeable and guide students in the machining process that will be used while in the job industry [11]. Simulation of the G-code was developed in the form of mini and portable CNC milling machines to facilitate class clarification. Therefore, this study aimed to design and develop mini CNC spinning machines for simulation of the G-code movement.

2. METHODOLOGY

This study used the ADDIE model to design and develop a mini CNC blade machine for simulating the movement of the G. The respondents were selected using purposive sampling. The use of the ADDIE model in this study is described in detail in five phases namely the analysis, design, development, implementation, and evaluation phases.

2.1 Analysis phase

In the analysis phase, the researcher analyzed the students' needs in the subject of computer-assisted machining. During this phase observations and interviews were conducted to identify the problems faced by the students.

2.2 Design phase

Researchers design three product sketches to assist in the selection of product designs and consult the experts. Design selection is accomplished through several studies of the design of the model to be developed.

2.3 Development phase

The development phase uses Arduino software to operate the ABBM model. The development phase begins with the process of making a skeleton followed by the installation of electronic parts.

2.4 Implementation phase

Three experts evaluated the functionality, design, and design of the materials used through the questionnaire, while two experts evaluated the worksheet.

2.5 Assessment phase

Perform ABBM demonstrations on students and disseminate questionnaires to assess the functionality of the design and design of materials used.

3. FINDINGS

3.1 Analysis phase

The observation and interviewing phase were conducted to identify the problems faced by the students in computer-aided machining subjects. This phase is important to ensure that the

next phases are implemented properly and efficiently to achieve the objectives of the study.

3.2 Design phase

The design phase is one of the most important phases. This is because this phase will determine the product being developed to meet the objectives of the study. Not only that, but even this phase will also ensure that the research questions are answered correctly. For the design phase, several studies were conducted on the design of the model will be developed. Studies were conducted on early ideas; idea analysis and refining ideas are done. However, there are some specifications and criteria that should be taken into consideration in the development of a product. The most important thing is the aspect of security. A product developed must be free of any kind a possible accident. Accidents can happen in any situation if no precaution is taken. Furthermore, this product has a power generation and will be used during the teaching and learning process. Therefore, the electric part will be wrapped with insulation and trimmed to prevent short circuits. Next is the endurance aspect. Longevity is the advantage that a good product can have. Therefore, the product produced must be durable the high end will last longer than the product emphasis on endurance aspects. To ensure this aspect is practicable in this product, the selection of materials used to develop the product selected can withstand strength and stainless so the product can be used for a long time. The ergonomic aspect is determined to be sure it is appropriate for the student or teacher's situation to use it. This is because the model should be able to be carried anywhere for convenience teachers to bring to class for the process of teaching and learning and so on easy operation. Once all the above aspects are considered, the last is an aspect of cost. Cost plays an important role in the production of a product. The cost created should include either optimum or minimum manufacturing cost without compromising the quality of the product generated. However, other things to consider during the design phase of the design are the initial ideas.

The first idea that came out during the development of this model was the CNC grinder. The movement resulting from the CNC milling machine comes from codes that are machine language. Code G is for regulating the movement of the tool points only. The movement of the tool points will be controlled through the Arduino system which is a microcontroller board that can be programmed using the software. Next is the selection section of product design. This phase starts with a production of at least three sketches that can be a guide in choosing the right design. Expert authorization is required to choose the right design. Tasty the shape with the highest-grade value will be chosen as the design will be developed. The choice of this design is based on the evaluation as well as an appointment made with a specialist to determine the right design for was developed as a teaching tool.

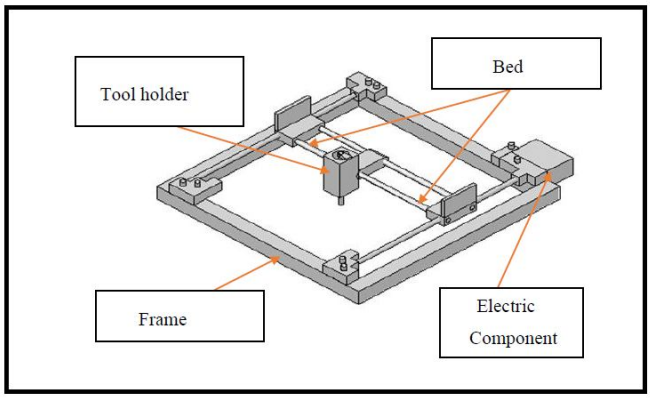

Figure 1: Sketch A

For this design sketch, the entire material uses soft steel. This design only moves the tool holder. Thus, the holding part of the workpiece is stationary and will remain in position. To bind component components separate use of screws is required. Other than the mechanism mechanical, the use of the electronic mechanism is also used to generate movement through the Arduino platform. Design A will put the mechanism in place electronics on the sides of the model that place the motors for movement machine. All electronic and motor elements will be in one place. The wires used will be securely fastened around the machine. That component used as shown in Table 1.

Table 1: The quantity of material for sketch A

No.	Part Name	Quantity	Material Type
1.	Frame	4	Mild steel
2.	Tool holder	1	Mild steel
3.	Bed	4	Mild steel
4.	Electrical components	1	Mild steel

Table 3.1 shown that there are 4 parts the key features of this sketch are the frame, tool eye holder, rails and electrical components. For this sketch, all materials used are used mild steel.

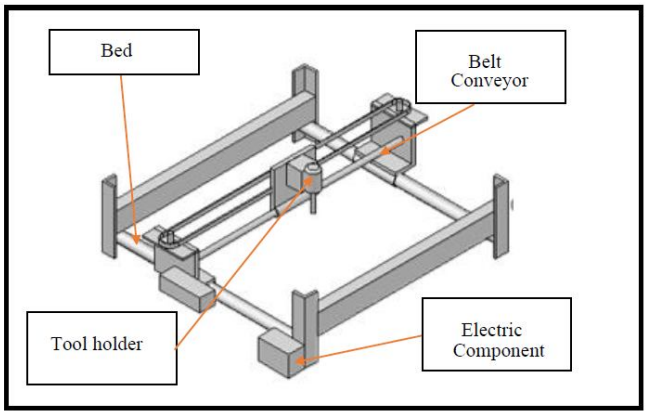

Figure 2: Sketch B

There are many differences significantly compared to design drawings A. The first difference is from the material used to make the track or movement. For sketch A, the use of solid soft steel substrates for moving parts moving however for design B the use of conveyor rope is required. The conveyor

belts is connected using a bearing that will cause X and Y-axis movements. The next difference is in terms of the material used to produce this product. The material used for the frame is a perspective. This is due to the main features of this material is lightweight and flexible. This can help to carry the product because for lightweight and easy to bring to class for teaching and learning theory. However, for a sketch, the shape of B is the same as design A is like a mechanism electronics on the sides of the model are also mounted with the motor for the art movement of the workpiece. The motor that moves the tool points will be on the side tool eyes. The components used are as shown in Table 2.

Table 2: The quantity of material for sketch B

No.	Part Name	Quantity	Material Type
1.	Frame	4	Perspex
2.	Tool holder	1	Mild steel
3.	Bed	4	Mild steel
4.	Electrical components	1	Perspex
5.	Conveyor belts	1	PVC

Table 2 shows the quantity of material sketch B. For sketch B there are 5 main parts, include frame, tool eye holder, rails, electrical components, and conveyor ropes. For structural parts and electrical components, the material used is perspective. Whereas the tool and trackers, soft steel is used. The conveyor belt uses materials from PVC.

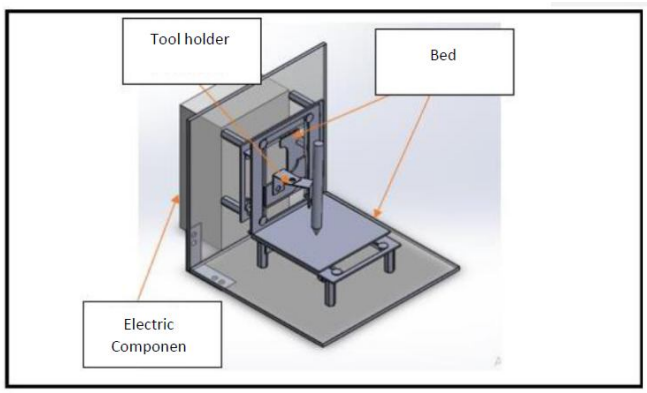

Figure 3: Sketch C

The last idea for this product was created is the sketch C. Improvement process has been done for this process. For the sketch, the C shape, the workpiece and the tool point are moving. Move both sides this is using a foundation. Using soft steel for foundation of the product because soft steel is a metal that does not rusty. This will ensure that the movement does not occur encountered any interruptions during the process. The material used is the same as design B, using the part on the other side on the runway. However, mechanical parts such as motors and the electronic machines will be located at one end of the product. This section is closed to ensure the product's durability is visible. This design sketch looks more ergonomic than the previous sketch lightweight as a result of using this perspective will facilitate energy instructors are easy to take this product anywhere to customize on the teaching and learning process. The components used are as shown in Table 3.

Table 3: The quantity of material for sketch C

No.	Part Name	Quantity	Material Type
1.	Frame	2	Perspex
2.	Tool holder	1	Mild steel
3.	Bed	4	Mild steel
4.	Electrical components	1	Perspex

Table 3 shows the quantity of material for sketch C. For sketch C there are four main parts, include frame, tool eye holder, rails, and electrical components. For this sketch, only two types of materials, namely frame, and electrical components used Perspex tool eye holder and rails used mild steel. The outcome in this phase, it can be concluded that the selection of experts is sketch C, the calculation matrix of this design is given to experts to get their opinions and insights they are about the design to be developed. The criteria contained in this scoring section is more than just a slap in the face aspect of evaluating the design already provided. Also, many criteria are Also important are safety criteria, portability, and more. These criteria are an important part of developing a business teaching aids. The sum of the scales marked by the expert is calculated and so on will make which design the expert choice for design the form was developed.

Table 4: The expert choice for three sketches

Design criteria	Sketch A					Sketch B					Sketch C				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Material selection on each component is appropriate			1	2				2	1					1	2
The material used is safe			2	1				2	1					2	1
The materials used are easy to maintain				3				3						3	
Product packaging		1							3					3	
Portability			2						3						3
The ABBM design fits the design of the actual machining equipment				3					3					1	2
Portable ABBM design				3					3						3
Ergonomic ABBM design				3			1		2						3
ABBM design is safe to use				3					3						3
Amount	77					99					106				

Table 5: Matrix used for design selection

Scale	Description
1	Not good
2	Poor good
3	Good enough
4	Good
5	Very good

To get the right number of scores, a scale is needed to make it easy for experts to score their opinions on a scale given.

3.3 Development phase

The development of the CNC simulation machine of this grinding machine involves 3 main things:

a) Hardware (CNC milling machine mini)

b) Controller (Arduino)

c) Software (Mastercam and GBRL)

The hardware part CNC milling machine mini is the part used to place the X-axis, Y and Z. the skeleton is made from a perspective. Perspectives are used because of the characteristics the main ingredient for this ingredient is light. This can be helpful to make this model is lightweight and easy to bring to class for teaching and learning theory. Also, perspective is noticeable due to its translucent nature. Use screws, bolts, and nuts as well are required for CD-ROM connectivity processes representing X, Y and Z axes. The use of CD-ROM in the production of this product because of its availability on CD-ROM has track and motor. This can save you money as well as time in product development.

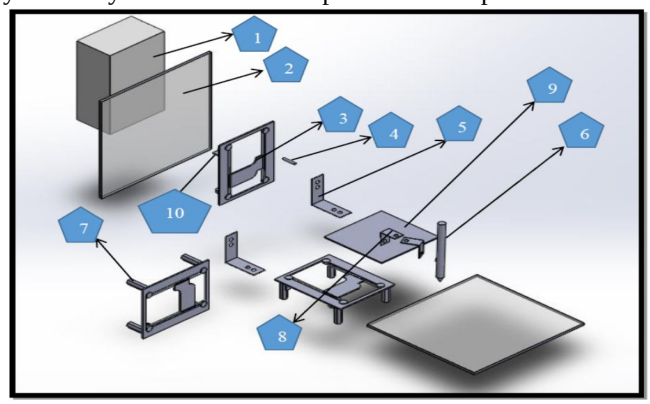

Figure 4: The CNC simulation machine

Table 6: Quantity of Material

No.	Component Name	Quantity	Material type	Unit Size	Unit Size
1.	Electronic boxes	1	Plastic	152 x 95 x 56	mm
2.	Frame	1	Perspective	192 x 187 x 4	mm
3.	CD ROM	1	Iron	115 x 95 x 2	mm
4.	Screw	1	Iron	M6 x 13	mm
5.	L large angles	2	Iron	20 x 50 x 1	mm
6.	Pen	1	Plastic	10 x 110	mm
7.	Threaded Tube	8	Iron	10 x 30	mm
8.	L small squares	2	Iron	15 x 25 x 1	mm
9.	Plywood	1	Perspective	100 x 100	mm
10.	Shaft and motor	1	Iron	10 x 7	mm

In table 6 show that the materials used to develop the mini CNC grinder machine. The second part is installation controller at the product which is the electronic part. This part is also the main component as this part of the product will move using several electronic components. Among the electronic components used are Arduino Uno, Easy Stepper Motor Driver, and Switching Power Supply 5 Volt 5 ampere. Arduino Uno is a device that will control all electronic components of this product. However, the Arduino Uno is not able to control alone, it requires support in the process of controlling the motor directly. Therefore, the use of Stepper Motor Driver is needed to help drive the existing motto on the CD-ROM. Switching Power Supply 5 Volt 5 ampere components that will control excess electrical current into the Arduino Uno. Only 5 Volt electrical power can enter the parts. This is to avoid damage due to excessive electrical power being applied to the product.

While, Mastercam software used to draw objects that are required so that the code can be generated. G code is entered in GBRL software downloaded from the internet so that the movement g code can be executed on the hardware.

3.4 Implementation and Assessment phase

Table 7: Product Suitability Section

No.	Item	Score	Percentage
1.	The design of appropriate teaching aids to be used for activities involving simple programming	110	91.67 %
2.	The design of teaching aids similar with the design of the actual machining equipment	110	91.67 %
3.	Design of portable teaching aids	115	95.88 %
4.	The design of teaching aids that are easily handled by students	110	91.67 %
5.	Design of interesting teaching aids	111	92.5 %
6.	Design of teaching aids of the right size	112	93.33 %
7.	Design of safe teaching aids	114	95 %

Results showed that the simulation can be carried out properly and following pre-programmed instructions. In table 6 show that the findings of this study done by experts to evaluate matters related to the design of teaching aids. 7 items were analyzed based on the added score for percentage. The first item, the design of teaching aids, is suitable for use in activities involving easy programming with 91.67% approval. Next is that the 91.67% percentages agree that the design of the teaching tool is similar with the design of the actual machining equipment. The design of portable and easy-to-use teaching aids was 95.88% and 91.67% respectively. The study also found that 92.5% agreed that the design of teaching aids was attractive and 93.33% stated that

the design was a suitable size. While 95% of respondents agreed that the design of teaching aids was safe.

Table 8: Suitability Analysis of Design Tools Teaching Aids

No.	Item	Yes	No
1.	Hardware to function properly	3	0
2.	The movement of the tool is the same as instructed in the software	3	0
3.	The movement shown is smooth	3	0
4.	The movement has shown just as real CNC milling machine	3	0
5.	The movement is easily seen by students	3	0
6.	The movement is easily understood by students	3	0

Functional Outcome is the third objective. The functionality of this product has been tested using a simple CNC programming code with real drawings. The process of entering the CNC programming code was done and the pen movement according to the drawing was successful. To further strengthen this support from the expert through expert evaluation. According to product experts, it can help educators to understand the concept of CNC machines. Moving all three axes works well at first. However, there is a slight disadvantage when used too often so the platform used to move the axis is slightly disturbed. This causes the runway to be manually moved in advance to ensure the smooth movement of the runway when the movement after entering the code runs smoothly. Next is an analysis of how this teaching tool product can save code in training students to understand the movement of CNC machine code G. This is because buying a CNC milling machine requires a very high cost. The resulting teaching aids can, therefore, show students the ability to see the CNC codes themselves.

5. CONCLUSION

One possible conclusion is the Model Development of teaching aids Movement of CNC Grinding Machine G Code it was developed based on the scope and objectives of the study. With the production of this teaching tool product hopefully help the teaching staff in the effective implementation of the teaching and learning process and it's important to be able to encourage students to improve the understanding of the G codes of CNC milling machines.

ACKNOWLEDGEMENT

The authors would like to thank the Ministry of Higher Education, Malaysia. This research was partially supported by University Tun Hussein Onn Malaysia, Johor using Scheme Program Pensiswazahan Guru (PPG) Vot No. K024. In addition, the authors also wish to thank the students of University Tun Hussein Onn Malaysia. Batu Pahat, who had given their full cooperation to ensure the success of this study.

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