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Analysis of The Influence of CNC Milling Macro Programs and Sub-programs Mazak on The Effectiveness Manufacturing Cover of Pressure Cylinder Using CAM

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***Abstract*— CNC machines allow computer programming to control the movement and actions of the machine, enabling more precise and repeatable production. However, in operating a CNC machine, good and efficient programming is essential. To optimize the use of CNC machines, it is necessary to optimize the number of NC program blocks that include the concept of macros and sub-programs. An effective CNC program, along with the proper use of macros and sub-programs, can speed up the production process, reduce human error, and increase accuracy. The research method used is comparative research by comparing using macro programs and manual programming, in this case comparing the number of solid trajectories and the number of program lines in the design using the simulation method using the Autodesk Fusion 360 application. So that the optimal number of movements will be obtained through the row value in the NC program. Macros and sub- programs allow users to easily change or modify CNC programs without having to rewrite the entire program. This increases flexibility in producing various types of products. It is concluded that optimization using macro and sub-programs provides a significant reduction in the number of program blocks in the case of the machining process for manufacturing the cover of pressure cylinder. This reduction in program blocks can help improve efficiency and sustainability in the development of modified machining processes.**

Keywords—component; CNC Macro Program, CNC Milling Sub-program, NC Program Effectiveness, Cover of Pressure Cylinder, CAM

I. Introduction

The rapid development of manufacturing technology and the increasing competition between manufacturers of manufactured products, the need for high quality products produced with high production speed (high speed manufacturing). Where at this time in the development and planning of products cannot be separated from the need for technology, with a very high need, an automation system was developed. Automation can be defined as a technology based on the application of mechanical, electronic and computer systems, so that the work of the development stage includes planning, preparation, assembly, installation, programming, inspection, commissioning.

The development of manufacturing technology has played an important role in improving efficiency, accuracy, and quality in the manufacturing process of machine components and other manufactured products. One technology that has become a major focus in the manufacturing industry is the use of CNC (Computer Numerical Control) machines. CNC machines allow computer programming to control the movement and actions of the machine, enabling more precise and repeatable production. However, in operating CNC machines, good and efficient programming is essential. To optimize the use of CNC machines, users often use programs that include the concept of macros and sub-programs. An effective CNC program, along with the proper use of macros and sub-programs, can speed up the production process, reduce human error, and improve accuracy. Therefore, this study aims to optimize CNC programs using a macro program system, and sub-programs in the manufacture of complex components/parts.

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II. Research Methodology

The research method used is comparative research by comparing using macro programs and manual programming, in this case comparing the number of solid trajectories and the number of program lines in the design using the simulation method using the Autodesk Fusion 360 application. So that the optimal number of movements will be obtained through the row value in the NC program. An efficient CNC program and the correct use of macros or sub-programs can reduce operator (human) errors, which can result in scrap or defective products. Macros and sub-programs allow users to easily change or modify a CNC program without having to rewrite the entire program. This increases flexibility in producing different types of products [1].

A. Product Design

CAD (Computer Aided Design) system is a computer software used to create product drawings. CAD can be used to produce 2D and 3D images. The utilization of CAD in the context of this research provides various advantages, including simplifying and accelerating the process of making and modifying product or component drawings [2]. In this research, CAD is used to design the geometry of the cover of the pressure cylinder in the Autodesk Fusion 360 application, which can be seen in Figure 1 below.

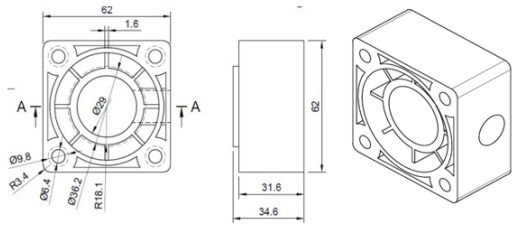

Figure 1. Geometry of cover of pressure cylinder

B. CNC Programming System

In this study, two different types of programming systems, absolute programming, and incremental programming, were used to set the cutting path for each design. The aim is to analyze the differences between the cutting paths generated by the two types of programming as well as the time differences that occur.

Absolute programming refers to the zero point of the work object when determining its coordinates. Meanwhile, incremental programming, also known as chain programming or relative coordinate system, determines the movement of the cutting tool from one point to the next with reference to the last stopping point of the cutting tool [3].

C. CNC Program Optimization

CNC program optimization through the application of macro programs and sub-programs is a highly relevant step in research methods in manufacturing and mechanical engineering. In the context of research, this approach provides the ability to test, analyze, and measure the impact of using this macro programs and sub programs (CNC programs) on the efficiency of the production process [4].

The use of program macros makes it possible to design complex programming algorithms and then test them in real situations. This makes it possible to study the effects of more concise and understandable programs on production time, accuracy, and reduction of human error. Macro programs also allow researchers to study the impact of changes in product design or production processes quickly and efficiently [5].

D. CAM (Computer Aided Manufacturing)

After designing the geometry of the workpiece, the next step is to convert the drawing into manufacturing mode using the Autodesk Fusion 360 application for the cutting tool movement path design process. This process is known as CAM (Computer Aided Manufacturing), which refers to the use of computers to convert technical designs into final products. The production process requires detailed planning and scheduling, which describes how the product is made, what resources are required, and when and where these resources will be used [6].

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In manufacturing systems with Computer-Aided Manufacturing (CAM), Computer Numeric Control (CNC) is used to carry out machining and design processes. In many cases, the CAM system will interact with CAD designs created in a three-dimensional (3D) environment. A CNC programmer is responsible for determining the required machine operations, and the CAM system is used to generate the corresponding CNC program.

In this research, the design and optimization of cutting paths for the CNC milling machining process only focuses on several types of toolpaths. The toolpaths named in this process are countour, pocket, and drill. In this design, there are three different schemes, where each scheme uses absolute and incremental programming systems with similar cutting parameters for each cutting path scheme used [7].

In this research, the material used is Aluminum 6061 [8]. Carbide cutting tools were used with uniform cutting parameters for each scheme, as listed in Table 1 [9].

Table 1. Machining parameters for material cutting

No.	Machining Process	Tools	Machining Parameters
1.	Outer Countour 	 Flat Endmill Dia. 10 mm	n = 2864.79 Rpm F = 90 m/min Dept = 2 mm
2.	Pocket Circle 1 	 Flat Endmill Dia. 10 mm	n = 2864.79 Rpm F = 90 m/min Dept = 2 mm
3.	Pocket Circle 2 	 Flat Endmill Dia. 10 mm	n = 2864.79 Rpm F = 90 m/min Dept = 2 mm
4.	Pocket Circle Side 	 Flat Endmill Dia. 6 mm	n = 4774.65 Rpm F = 90 m/min Dept = 1 mm
5.	Drill 	 Drill Dia. 6 mm	n = 4476.23 Rpm F = 90 m/min Dept = 38 mm

After all cutting parameters have been adjusted and the cutting path has been determined, the next step is to perform simulation. Simulation results for each cutting path design scheme.

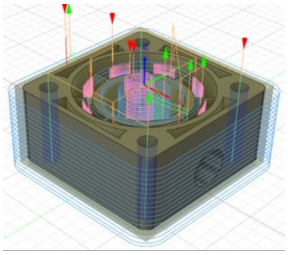

Figure 2. Schematic design of material cutting path

Figure 3. G-Code program cover of pressure cylinder

III. Results and Discussion

A. Data collection results

Through optimizing the CNC Milling machining process in manufacturing the cover of pressure cylinder by utilizing the Autodesk Fusion 360 application, a number of data were obtained based on three different types of programming.

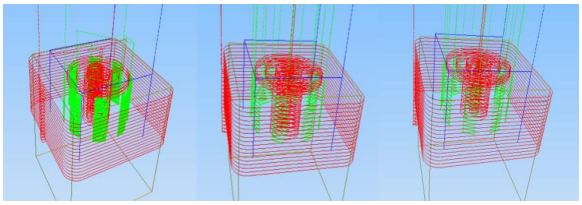

Figure 4. Direction of movement of material cutting tools

For complete details about the machining process of each tool path scheme, you can refer to Table 2.

Table 2. Machining parameters for material cutting

Program Type	Number of Blocks per Program Step				
	Outer *Countur*	*Pocket* Circle 1	*Pocket* Circle 2	Pocket Circle Side	*Drill*
CAM	348	71	217	3068	15
Macros	28	43	39	344	15
Sub-program	19	36	32	336	9

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Table 3. Total tool passes

Program Section	Program Type		
	CAM	Macros	Sub-program
Content	3719	469	138
Total with *Header/Footer*	3740	490	207

B. Effect of Using Macro Programs and Sub-programs on the Number of Program Blocks/Lines

Based on the table of data collection results, the value of the number of tool passes of the toolpath type of 3 types of NC program variations used is known. The presentation of data on the results of NC program optimization of each process in the form of graphs for the relationship between the type of program and toolpath is obtained as in Figure 4 below:

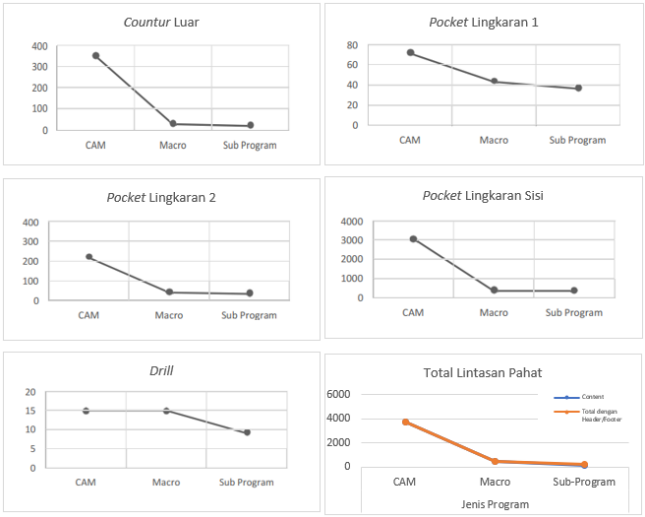

Figure 5. NC program optimization graph between machining process, program type and number of blocks/rows for manufacturing cover of pressure cylinder

Based on graph (a) shows the results of optimization using the macro program, which resulted in a reduction in the number of program blocks by 320 blocks. Meanwhile, optimization using sub-programs resulted in a reduction in the number of program blocks by 329 blocks. The results of graph (b) show that optimization using macro programs results in a reduction in the number of program blocks by 28 blocks, while optimization using sub-programs results in a reduction in the number of program blocks by 35 blocks.

In graph (c), the results of optimization using macro programs resulted in a reduction in the number of program blocks by 178 blocks, while optimization using sub-programs resulted in a reduction in the number of program blocks by 185 blocks. While in graph (d), the optimization results using the macro program resulted in a reduction in the number of program blocks by 2724 blocks, and optimization using sub-programs resulted in a reduction in the number of program blocks by 2732 blocks. Finally, in graph (e), optimization using macro programs does not result in a reduction in the number of program blocks (0 blocks), while optimization using sub-programs results in a reduction in the number of program blocks by 6 blocks.

It is important to note that in graph (f), the optimization results using macro programs result in a significant reduction in the number of program blocks, and the same is true for optimization using sub-programs.

IV. Conclusion

Conclusions are written in this part.

1. Based on the results of the research conducted, it can be concluded that optimization using macro programs and sub-programs provides a significant reduction in the number of program blocks in some machining process cases. This reduction in program blocks can help improve efficiency and sustainability in the development of modified machining processes.
2. The results also show that the choice between using macro programs or sub-programs in the optimization process should be carefully considered based on the characteristics and complexity of the program being analyzed.
3. In addition, although optimization using macro programs and sub-programs can provide significant program block reduction, small differences in program block reduction can also

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have a significant impact on the development of manufacturing processes on a larger scale. Therefore, choosing the right optimization method can play an important role in improving the software development process.

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