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Comparative Study of Macro Program Machining and CAM 2.5D Machining for Press Dies Manufacturing

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ABSTRACT

The manufacturing industry extensively utilizes machining and casting processes for die fabrication. Due to the inherent dimensional inaccuracies and surface roughness of casting, machining is often required to achieve desired accuracy and finish. Traditional computerized numerical control machining relies on individual programming using macro programming or computer-aided manufacturing software for operations such as facing, which can be inefficient and prone to error. This study aims to evaluate and compare the efficiency and accuracy of macro programming and CAM 2.5D in CNC milling specifically for press die manufacturing. Macro programming is used for automating complex and repetitive machining by incorporating variables, expressions, and logic directly to machine whereas CAM 2.5D refers to programming using software in G-code format with capability to work not only two-dimensional planes but also limited vertical movement. Experimental results indicate that CAM 2.5D offers a time-saving advantage by about 2 hours while macro programming allows for greater accuracy in machining. Industries are encouraged to utilize both macro programming and CAM 2.5D to achieve a balance of speed, accuracy, and flexibility, optimizing their CNC machining processes for both large-scale and precision-focused operations.

1. INTRODUCTION

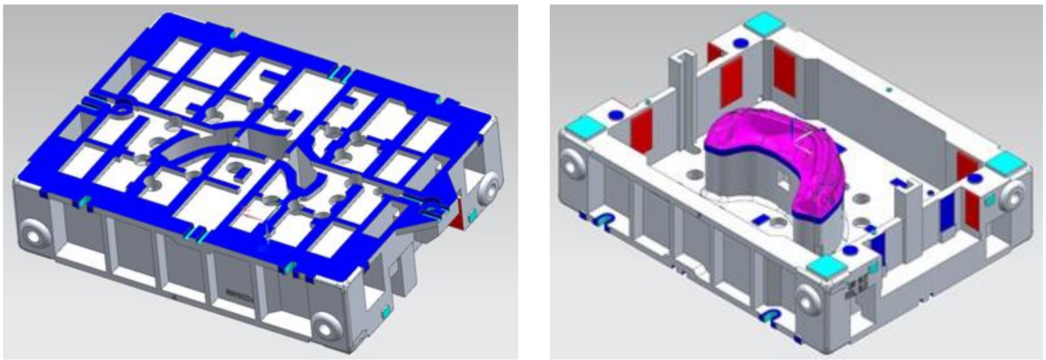
In dies fabrication, machining and casting are the common manufacturing processes. Some cases only depend on machining process whereas the other including casting process at the beginning. Involving casting process leads to inaccuracy in dimensions and the surface roughness of a cast part is inevitably. Therefore, usually a cast part requires some machining and facing will be the first step. There are a couple of options to do the facing in computerized numerical control (CNC) machine using macro programming or computer-aided manufacturing (CAM) software. At the beginning of modern CNC machines, very few users and programmers of CNC machines understood parametric and macro languages, and even fewer were those who could apply them for manufacturing purposes. Even though most CNC machines have this feature, users need to utilize the capabilities of their equipment fully. With this condition, the facing program for one workpiece cannot be used for another dimension. Macro programming offers a lot of simplicity in CNC machines, making it possible to develop a single program for workpieces of all dimensions. Hence, machining operations can be repeated under the same program for each part. It is proven that macro programming has performed well in reducing redundant work in product design, development, and production processes[1], [2], [3], [4], [5], [6].

Macro programing provides programming template that is used repetitively for the same facing process. Even though the effort of making program is reduced significantly, operator still needs translating the coordinate points of the workpiece from 2D drawing. As a result, machining operators should have a great Macro programming provides a programming template that is used repetitively for the same-facing process. Even though the effort of making the program is reduced significantly, the operator still needs to translate the coordinate points of the workpiece from 2D drawings. As a result, machining operators should possess a strong skill set to perform this work, including knowledge of implementing various data setting methods, CNC programming, machining skills, mathematics skills, and understanding of subprograms and system parameters. Additionally, the machining operators must fully understand every process and the objectives of the macro program. To the best of our knowledge, the most effective practice is to keep the drafting printed on A0 paper and input the macro program header as well as draw coordinates of the workpiece directly to the CNC machine. However, involving human interaction during these setups leads to error, and curative action is always needed. Machining operators must frequently review and verify the process by closely monitoring the tools and machine movements to ensure the program functions as intended.

Technology plays an important role in providing faster processes. Using computer-aided manufacturing (CAM) system in the milling process [7], [8], [9], [10], [11] can shorten the setup time in CNC machines. There are 3 types of CAM system: CAM 2D, CAM 2.5D, and CAM 3D. CAM 2D focuses on generating numerical control (NC) programs from 2D geometries to control tools' movement over the X and Y axes. On the other hand, CAM 2.5 D and 3D prepare NC programs from 3D geometries involving the X, Y, and Z axes, respectively. The main difference between CAM 2.5D, and 3D is the contour profile. CAM 2.5D is used for flat surfaces, whereas CAM 3D is utilized for non-flat contours. Moreover, advancement in this area has been explored in many works [12], [13], [14], [15], [16], [17]. The study done in [17] showed how macro programming performed in providing better root mean square error compare to CAM system in general using coordinate measuring machine (CMM). In this study, the performance of macro programming and CAM 2.5D will be evaluated under the same treatments, such as materials, press dies processes, cutting tools and tool parameters. The key of this study is to provide a wide range of options to achieve a fast and accurate machining process, especially for die press manufacturing.

2. METHODS

The CNC milling machining process consists of several works. The roughing process is well-known for removing excess material and cutting it roughly to create a finished product. Next, it is a semi-finish process; this work does the feeding movement at a certain range from the model. The aim is to provide better accuracy for the finishing process. The next process is finishing, in which the cutting tool moves slowly along the materials to produce the desired final shape. The tool speed will be reduced, whereas the spindle speed will increase to have a more accurate surface.



(a) (b)

Figure 1. lower press dies (a) bottom surface (b) top surface

Another process in CNC machining is milling construction. It is used to obtain great accuracy of contour. In order to do the machining over the press dies materials, it is necessary to know the machining area of the press dies parts. The part to be machined by the CNC machine is the lower press dies top and bottom surfaces. Designs of the press dies are shown in Fig 1. Marking is given to simplify the press dies machining process. Each marking color has a different type of roughness. Light blue represents a fairly smooth surface; it involves only a roughing process. The blue color indicates a smooth surface with the finishing process. The red color demonstrates a very fine surface, including roughing, semi-finish, and finishing processes, while the violet color shows a very smooth surface. In this study, we focus on machining the bottom surface of lower press dies using macro program and CAM 2,5D program.

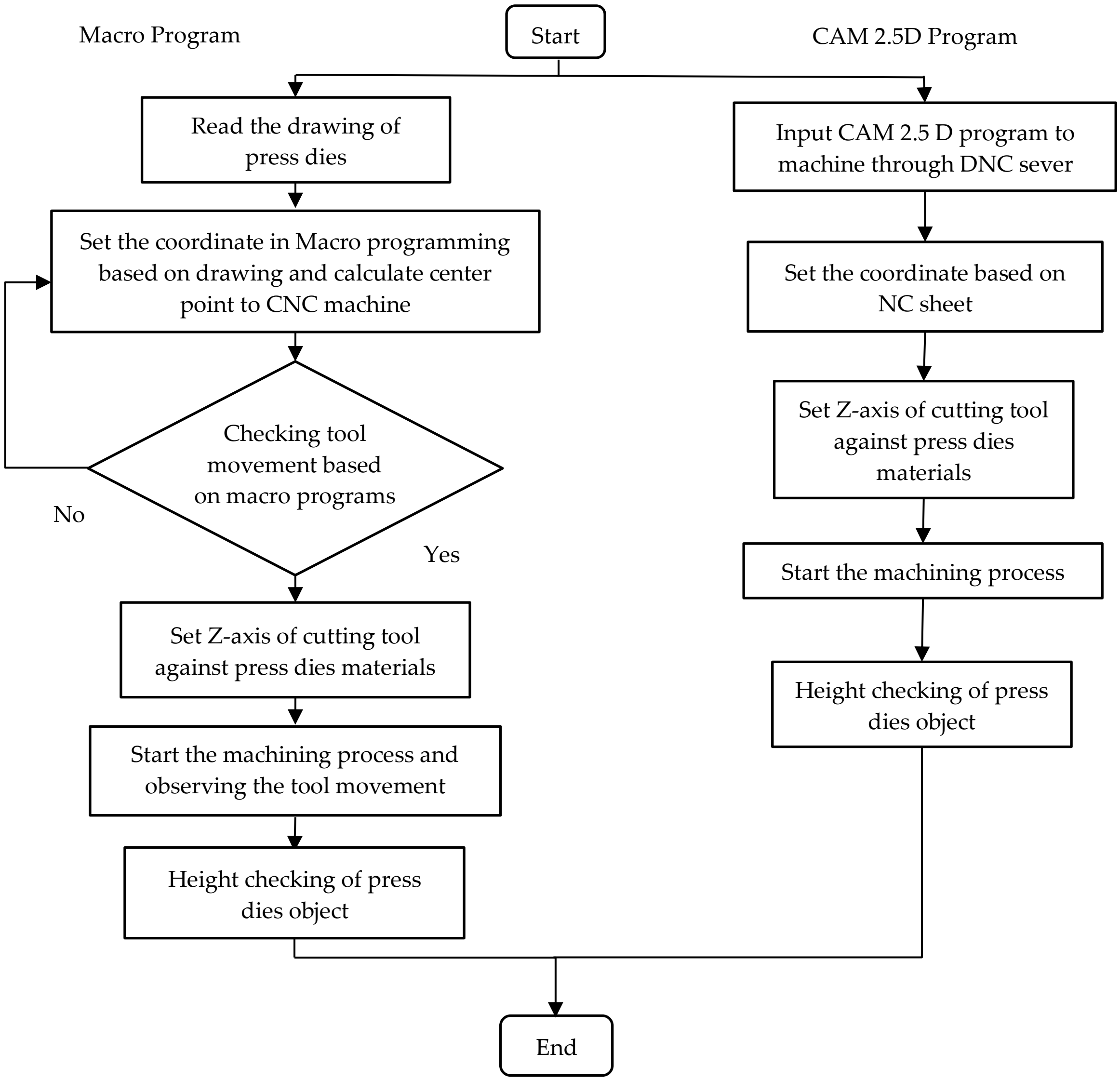


Figure 2. Flowchart of machining process between Macro programming and CAM 2.5 D

Figure 2 illustrates the flowchart of facing processes of macro programming and CAM 2.5D. The study is focused on the milling process in CNC machines. Hence, the process of making the CAM program is not considered in this paper. On the one hand, for macro programming processes, the sequence is firstly started by reading press dies drawing. The information available in the drawing includes drawing coordinate, feeding rate, tool diameter, datum, and feed rate, which are then computed to a macro programming template. The operator needs to ensure the tool's movement is correct according to the tool parameters. The following process is preparing press die materials on the CNC machines' beds. It is important to ensure the Z-axis is in proper position. Once the setup is finished, the operator starts the machining process while observing the tool movements at the same time. If there is no irregularity in the facing process, the operator will continue the work until the particular job is done. Otherwise, the operator needs to terminate the machine. Secondly, the operator needs to compute information again based on the drawing for the next machining process. It is repeated until all machining areas are finished. Finally, an inspection needs to be carried out to make sure the finished part has the same dimensions as its drawing.

On the other hand, the milling process using CAM 2.5D experiences different treatments. CAM 2.5D program is prepared earlier when using CAM software for all machining areas. Preparation includes determining details of the machining area, Z-axis position of lower press dies, simulation time results, and cutting tools and their parameters for every machining area. Once the program is created, it is transferred to the CNC machine. At this point, the operator's presence no longer hampers the milling process as the process starts automatically. For the experiment in CNC machine, cutting tool parameters are situated to be the same between Macro program and CAM 2.5D program that is not composed as per manufacturer's standard. This is a preventive action to reduce cutting tools of being broken during the operation. However, for simulation results of CAM system, the feed rate is set properly as per the manufacturer's standard as an ideal condition.

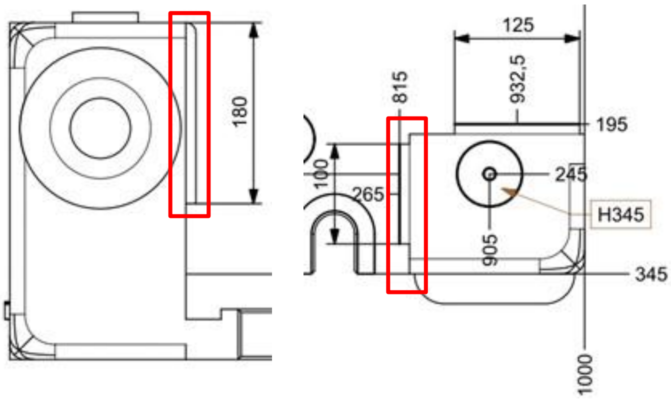


Fig 3. Example of coordinate points of drawing part

Table 1. Sample of Macro Header

Line No	Code	Remarks
1	VC85=2000.	Feeding rate declaration
2	VC2=1.	Start point Z is set to 1
3	VC86=63.	Tool diameter in mm
4	VC87=1.	Feeding (movement along X-axis and Y-axis)
5	VC88=0.1	Offset
6	VC89=10.	Feed Z+ (adding tool retraction for safety)
7	VC90=110	Feed wide
8	VC95=-185	Feed Z- (slide height as on drawing + 5 mm for safety)
9	VC96=2.	Escape (tool movement move 2 mm before retracting)
10	()	
19	N1 CALL OPRG PX=815. PY=-265. PA=-185.	Coordinate for roughing slide as on drawing.

To illustrate the macro program and NC program header, we will give sample programs for both of them based on the drawing part in Fig. 3. The program is a roughing slide for the area marked in red. From the drawing, it can be seen that the coordinate points are X-axis = 815, Y-axis =-265, and Z-axis =-180, respectively. These coordinate points are computed in the CNC machine by the machining operator. Table 1 provides the header of the macro program for roughing slides. Line 1 indicates the feeding rate that is set to 2000 while the tool diameter is 63, as provided in line 3. Coordinate points are computed in line 19 with the code starting with N1. The macro program can handle more than one machining process. If the machining process consists of 3 sequences, then there will be code N1, N2, and N3, respectively. Each N process should have different coordinate points that need to be computed in the macro header program.

Unlike macro programming, which requires computing tool parameters, the CAM 2.5D program works more simply. In general, the CAM 2.5D program structure consists of a header and G-code for all tasks. The header has information on the initial coordinate points of the tool to start the operation.

Coordinate points are positioned in the middle of dies, where the X-axis and Y-axis are 0, respectively. The Z-axis is positioned according to the height of the dies. If the height is 400 mm, then the Z-axis is 400. At this rate, the CNC machine can execute the G-code program automatically. Information on the cutting tool and its parameters is provided in the NC sheet. NC sheet is prepared for machining operator guidance.

3. RESULTS AND DISCUSSION

In an attempt to have a better comparison between macro programming and CAM system, machining features are situated to be similar. The tool parameters such as tool diameter, depth of cut, feed rate, and spindle speed are prepared to be matched with the macro program as depicted in Table 2. In fact, the CAM system can provide a higher feed rate and spindle speed as specified by the data sheet of the selected tools. Therefore, performance evaluation will compare the results of the milling process between macro and CAM system as well as simulation results of CAM 2.5D.

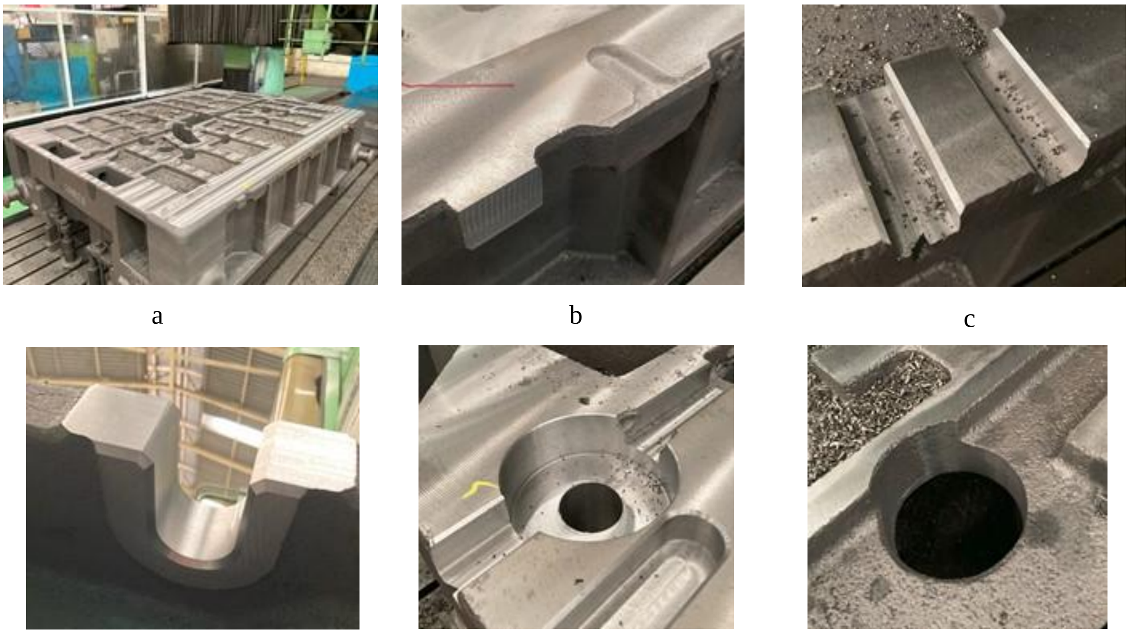
Table 2. Machining features for macro programming and CAM 2.5 D

Machining Area	Machining Operation	Rough/Finish Machining	Tool	Tool diameter (mm)	DOC (mm)	Feed Rate (min)	Spindle Speed (rpm)
Roughness bottom surface	Face milling	Rough	Face mill	63	9.5	2000	700
Roughness bottom surface	Face milling	Finish	Face mill	200	0.5	400	250
Datum lane	Face milling	2D milling	End mill	25	10	2000	700
Key + chamfering	Face milling	2D milling	End mill	25	10	800	700
Key + chamfering	Face milling	Chamfering	End mill chamfer	-	-	1000	170
U-slot + chamfer	Face milling	2D milling	End mill	25	10	800	700
U-slot + chamfer	Face milling	2D milling from bottom	T-Slot	120	-	380	550
U-slot + chamfer	Face milling	Chamfering	End mill chamfer	-	-	1000	170
Pilot cushion	Face milling	2D milling	End mill	25	10	800	700
Pilot cushion	Face milling	Chamfering	End mill chamfer	-	-	1000	170
Hole negashi cushion pin	Face milling	2D milling	End mill	16	10	380	550

DOC: depth of cut

The results show that the milling process using CAM 2.5D provides a slight improvement rather than macro programming. In general, this condition can be obviously predicted since macro programming requires the operator to set the die every time a process is completed. In contrast, the CAM system does not require this operation. Table 3 shows the comparison of machining results of the bottom surface of lower press dies in term of NC line as well as machining cycle time. For a machining area that is considered big and needs details such as roughness, a bottom surface, and a U-slot, CAM 2.5D tends to provide faster results for about an hour. For small machining areas, the results are similar between macro programming and CAM 2.5D programming. The datum line does not require a simulation process since it is prepared for the actual press dies coordinate point. CAM 2.5D tends to provide long program length compare to macro programming, making it difficult to be changing during real time operation. On the other hand, macro programming offers simplicity in term of program length, making it possible to be altered during operation.

Figure 5 illustrates the time consumed for macro programming, CAM 2.5D and CAM software simulation. The results show a slight difference of machining time between CAM 2.5D and macro programming. The CAM 2.5D shows 2 hours faster than macro programming. However, CAM simulation both for same tools parameter as macro and using cutting standard provide better estimation to complete machining of lower die that are stood at 6 hour and 10.5 hour respectively. The study conducted in [17] showed that under CMM measurement, objects machined with macro programming offer better accuracy compared to those machined with a CAM system. This presents a favorable trade-off, where macro programming can deliver higher accuracy while the CAM system can offer a slight improvement in processing time efficiency.



a b c

d e f

Figure 4. Machining area of lower press dies part: (a) roughness bottom surface; (b) datum line; (c) key + chamfering; (d) U-slot; (e) pilot cushion; (f) hole negashi

Table 3. Result of comparison Macro programming and CAM 2.5D program

Features of Comparison	**Roughing Bottom Surface**		**Key**		**U-Slot**		**Pilot Cushion Pin**		**Hole Negashi Cushion Pin**	
	CAM 2.5D	**Macro**	**CAM 2.5D**	**Macro**	**CAM 2.5D**	**Macro**	**CAM 2.5D**	**Macro**	**CAM 2.5D**	**Macro**
Number of Blocks/NC instruction lines	1917	28	1902	35	7025	23	3050	19	8678	42
Machining Cycle Time	5H 28M	7H 56M	58M 4S	1H 12M	1H 38M 58S	3H 11M	1H 18M	2H 56M	1H 37M	2H 7M

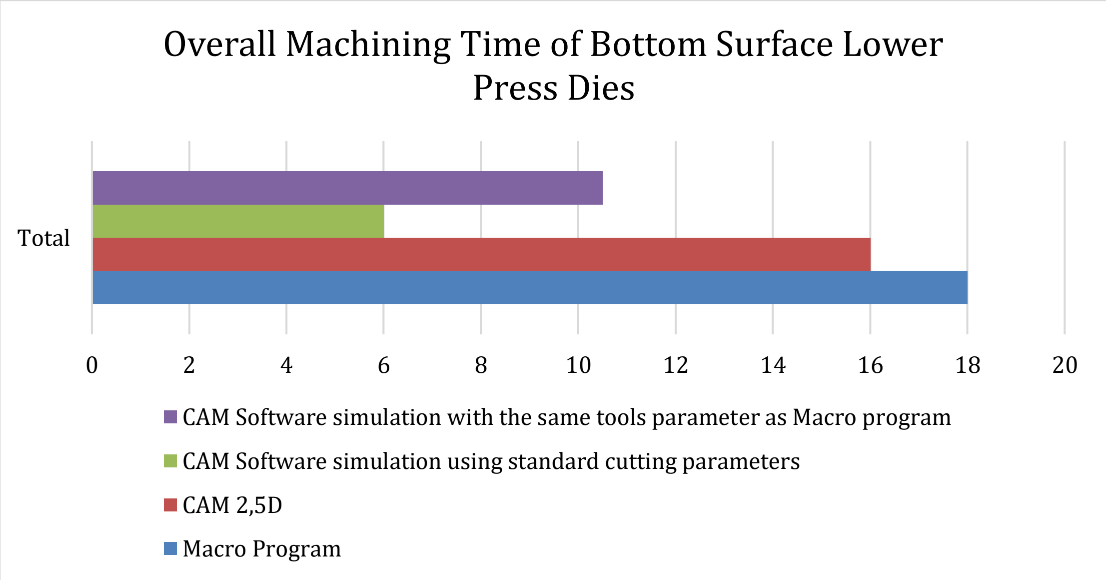


Figure 5. Overall machining time of bottom surface of lower press dies

4. CONCLUSION

The study has presented the performance evaluation of macro programming and CAM 2.5D. From the CNC machining results, it can be concluded that the bottom surface of the lower press dies is 2 hours faster using the 2.5D CAM system. However, its performance can be increased for a minimum of 2.5 times following cutting tool standards. Parameter optimization also plays important roles in resulting better results. The importance of aligning tool parameters with cutting tool standards is emphasized, particularly in CAM 2.5D. This optimization is key to realizing the full potential of the technology, resulting in substantial time savings and improved machining performance. The findings have direct implications for dies press manufacturing, suggesting that the integration of CAM 2.5D can significantly improve the efficiency of CNC machining processes. The study encourages manufacturers to consider technology-driven solutions for faster and more accurate results.

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