

A Comparison of CNC Lathe Machine Programming Simulation and CNC Lathe Machine Production Results

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ABSTRACT

This study compares the simulation results of a CNC lathe program with the actual production results of a CNC lathe. CNC lathes are used in the manufacturing of precision components for various industrial applications. Simulation of CNC lathe programs can provide an accurate estimate of the production output before the actual production process begins. In this study, we compared dimensional tolerance, geometric accuracy, and surface quality between simulated and actual results. The simulation method used is 2D modeling which involves the calculation of tool trajectories and cutting parameters inputted into the simulation panel. Actual production data was obtained from the measurement of components produced from the CNC lathe. A comparative analysis was conducted to evaluate the extent to which the simulation can predict the actual production results. The results show that, although the simulation can give a good picture, there is still a significant difference between the simulation results and actual production. The findings have practical implications in improving efficiency and accuracy in the planning and production process using CNC lathes.

INTRODUCTION

CNC (Computer Numerical Control) lathes are a vital technology in the modern manufacturing industry as they are capable of producing components with high precision and consistency. Feeding motion simulation on these machines is essential to optimize cutting tool trajectory, speed, and depth of cut to minimize cycle time and maximize tool life. However, there are frequent discrepancies between simulation results and real production finishes. This is due to various factors such as material characteristics, machine conditions, and idealized assumptions in simulations that do not always reflect real conditions. These inaccuracies can lead to increased processing time, faster tool wear, and product defects. In the context of time and production cost efficiency, simulation accuracy is critical to reduce material and time wastage.

The research was conducted with data collection methods through direct observation to the field, machining process to make workpiece samples using ST 41 metal, taking measurement data with roughness test tools on workpieces, and data analysis to reach conclusions from the research. The results

showed that cutting speed affects the surface quality of the workpiece. Variations in cutting speed produce different levels of surface roughness, where the higher the cutting speed, the better the surface quality. Conducted research using the CNC simulation learning method by utilizing software such as Mastercam. The results showed a significant increase in student learning achievement using computer-assisted learning with Mastercam software. The CNC simulation learning method is considered effective and efficient in learning complex systems such as CNC machining processes. (Ady, 2023; Prianto, 2017)

Using the motion calibration method on the X, Y, and Z axes with programming codes G01, G02, and G03. The results show that the calibration process with a distance of 1 mm as the reference value in programming codes G01, G02, and G03 produces a maximum deviation of 0.01 mm, which is considered optimal because the accuracy of the measuring instrument used is 0.01 mm. With the method of measuring workpieces, making incremental and absolute programs. The results show the average absolute and incremental programming time at certain variations of spindle rotation and feeding. The calculation of cutting time is faster in the incremental program compared to the absolute program at feedings above 80mm/min, especially at feedings of 100mm/min. (Amala, 2013; Soemardi, 2017)

Method of data analysis involves the use of G codes in the CNC program, such as G92 for the absolute method and G91 for the incremental method. Examples of numeric variable data used are X for the intended diameter, Z for longitudinal motion, F for the cutting stroke speed, and H for the cutting depth. In addition, in the simulation of making the piston master cylinder kit, the CNC program uses code M03 to start the spindle rotation, and M05 to stop the spindle rotation. The final results of the program simulation in this study show that the piston master cylinder kit product produced using the TU-2A CNC machine has a very small size and a high level of precision. The surface roughness test tools used are Digital Roughness Tester and Manual Roughness Bar involving the testing of independent variables, such as feeding thickness (0.10 mm, 0.15 mm, 0.20 mm, 0.25 mm, and 3.0 mm) and spindle rotation speed (1400 rpm and 1600 rpm). Based on the results, it is known that the feed thickness affects the surface roughness of the S45C material. A feed thickness of 0.15 mm at 1600 rpm produces the lowest surface roughness, while a feed thickness of 0.30 mm at 1400 rpm produces greater roughness. It can be concluded that the feed thickness has a significant influence on the surface roughness of the S45C material. (Sudiadi, 2018; Prianto, 2017)

The importance of using simulation studies of CNC lathe feeding results generally focus on optimizing processing parameters to achieve precise dimensional tolerances. This study aims to determine the difference between the simulated product production on the CNC lathe panel and the final production result.

METHOD

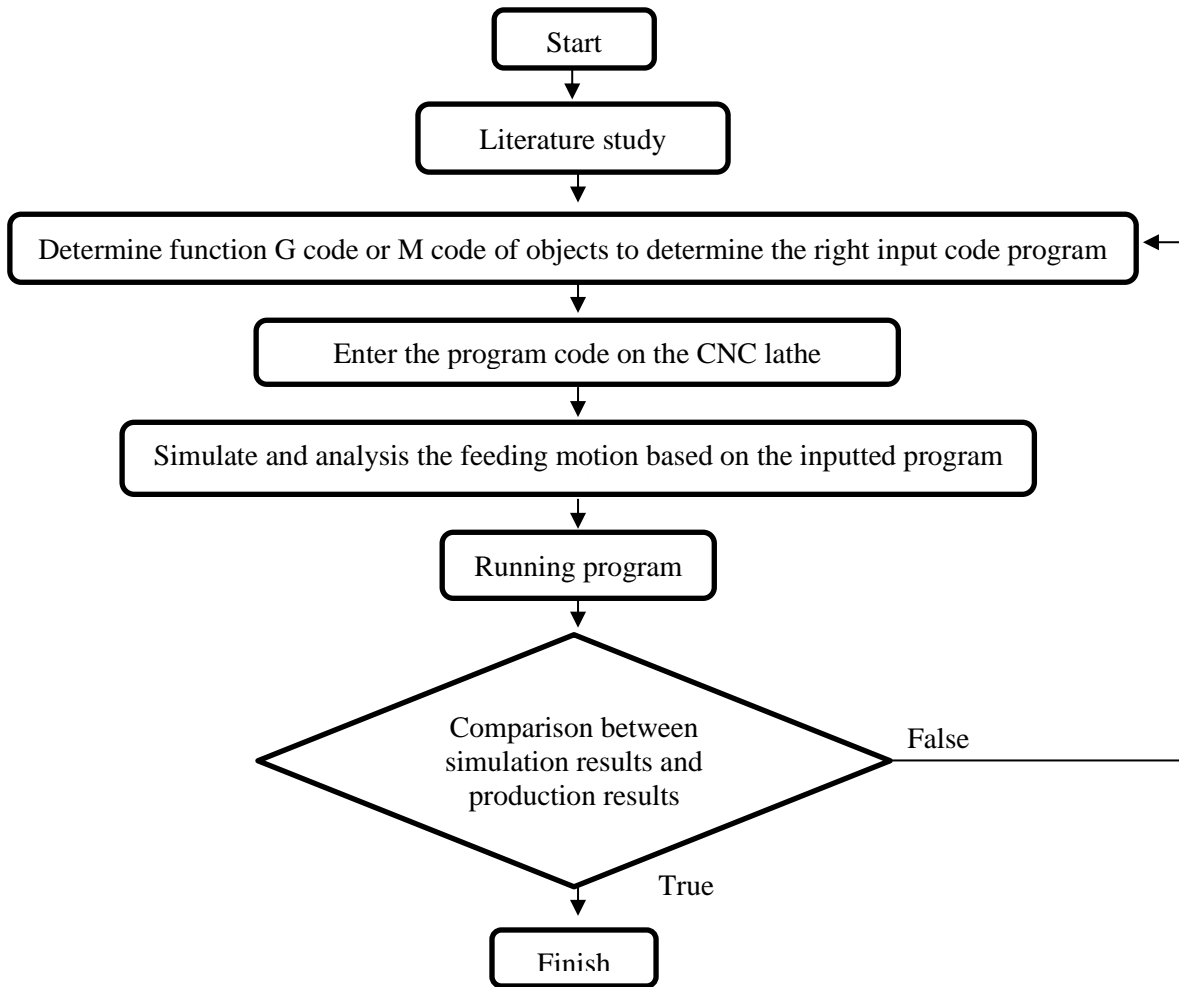


Figure.1 Research Flow Chart.

This research will produce a conclusion between the comparison of the results of the program simulation on the CNC lathe panel with the final production results in the form of tolerance of the size of the program code input to the final size, so that if there is a production using a lathe brand mitsubishi LIOUY-HSING 20L can use the tolerance reference in this study as a reference for the tolerance size of the production process to be used.

COORDINATE AXIS OF CNC LATHE MACHINE

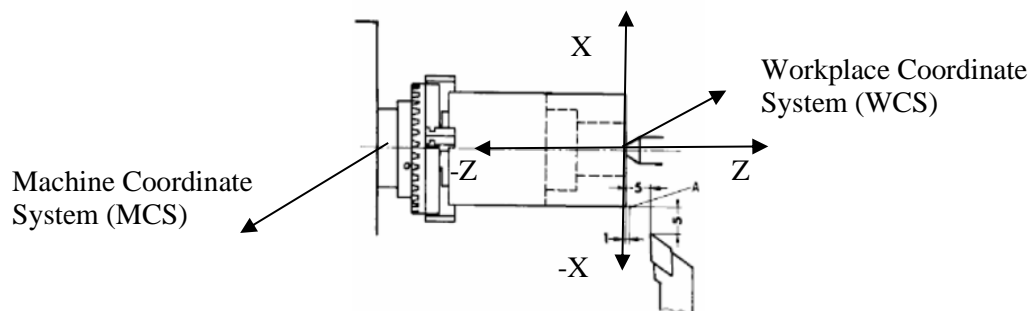


Figure. 2 Illustration of Axis Movement on a CNC Lathe Machine.

Machine Coordinate System (MCS) on a CNC lathe is a reference system used to regulate the movement of cutting tools and workpieces within the machine's workspace. This coordinate system is important for regulating the travel of the cutting tool and determining the relative position between the tool and the workpiece precisely. This machine coordinate system is usually set by the machine manufacturer at the time of initial installation, where the origin of the coordinate system is often positioned at one corner or the center of the machine worktable.

Workplace System Coordinate (WCS) on a CNC lathe is a reference system used to set the movement of cutting tools and workpieces precisely according to the needs of the production process. This coordinate system helps convert the workpiece coordinates measured in program coordinates into appropriate movements in the CNC lathe. . The machine coordinate system on a CNC lathe usually consists of three main axes, namely the X, Y, and Z axes. However, the lathe used in this research only has two axes, namely X and Z. Here is the explanation:

- The X-axis refers to the horizontal movement of the cutting tool along the long axis of the machine.
- The Z-axis refers to the vertical movement of the cutting tool along the height axis of the machine.

The workplace coordinate system can be reset or redefined according to the specific needs of the application. The origin point of the workplace coordinate system can be placed wherever required, such as at a workpiece corner, center point, or other reference point. This allows flexibility in the location and orientation of the workpiece for each processing operation. Using the workplace coordinate system, operators can program CNC lathes to manufacture complex parts more efficiently and accurately. This allows for precise adjustment between the design model and the physical manufacturing of the workpiece, as well as reducing the chances of errors during the production process.

G-Code program on a CNC lathe

Code	Function
G00	Moves in a straight line without feeding.
G01	Feeding motion in a straight line.
G02	Circular clockwise feeding motion based on a predetermined radius.
G03	Counterclockwise circular feeding motion.
G04	Stop feeding for a certain time.
G27	Reference point return check.
G28	Return to starting position.
G30	Return to the 2nd, 3rd, and 4th reference points.
G71	Roughing Cycle.
G74	Drilling Cycle.
G97	Constant spindle speed.

Table. 1 G-code CNC lathe.

The G-code on a CNC lathe is a series of commands that control the movement of cutting tools and other functions. In CNC programming, G-codes are used to give specific instructions to the machine on how to

perform cuts, rapid movements, tool changes, and other functions. In addition, the G code also organizes rapid movements between cutting points to improve the efficiency of processing time. The use of G-codes is also necessary to instruct the machine in the replacement of cutting tools, either automatically or manually. In addition, G-codes can be used to provide absolute or incremental coordinates for cutting tool movement in the machine coordinate system.

M-Code program on CNC lathe

Code	Function
M00	Opsional stop program.
M01	Opsional memberhentikan spindle.
M03	Rotating the spindle clockwise.
M04	Rotating the spindle counterclockwise.
M05	Spindle stop.
M06	Tool change.
M08	Coolant On.
M09	Coolant Off.
M30	End of program then return to the initial program.
M97	Calling the Haas subprogram.
M99	Return to subprogram.

Table. 2 M-code CNC lathe.

M codes on CNC lathes have an important role in controlling various machine functions apart from the movement of cutting tools. M codes are usually used to trigger certain actions or status changes on the machine, such as enabling or disabling certain devices, starting or stopping processes, performing machine parameter settings, and performing other actions required during the production process. The use of M codes in CNC programs provides more detailed control over machine operations and allows operators to manage the production process more effectively.

Simulation Production of Holder B64

The production process of the B64 holder with a CNC lathe using S45C stainless carbon raw materials requires special accuracy in program input settings by considering the tolerance of the workpiece in order to obtain optimal production accuracy and efficiency. Before inputting the program on the CNC lathe, first determine the size of the item to be made according to the etiquette drawing specified by the consumer. Production begins by placing the item on the chuck to set coordinate point 0 on the workpiece before inputting the program code. Here is the drilling program code on the B64 holder.

PROGRAM CODE	DESCRIPTION
N00 ;	»» is a program block reference number that can be freely specified
G0 T0202 ;	»» straight motion moving tool number 2 without feeding.
G97 M03 S500 ;	»» rotate the spindle clockwise at 500 rpm.
G00 X0. Z30. ;	»» straight motion with no feeding in the X-axis at zero point and 30mm in the Z-axis.
Z5. M8 ;	»» brought the lathe tool 5mm closer to zero and turned on the coolant.
G1 Z0. F0.03 ;	»» feeding motion to zero point with a feedrate of 0.03mm for surface leveling.
G74 R0.1 ;	»» rotating drill with 0.01mm radius.
G74 Z-24. Q1000 F0.03 ;	»» drill -24mm deep with each cutting distance Q1000 and feedrate 0.03mm.
G0 Z50. M9 ;	»» Z-axis straight motion backs the tool away from the workpiece and turns off the coolant.
G28 U0 W0 ;	»» The tool returns to its original side (incremental motion where the zero point does not stay).
M05 ;	»» spindle stop.
M30 ;	»» the end of the program before running it again manually.

Table 3 Program code at the drilling stage.

Then enter OP1 (Process Optimization 1) the production stage which contains :

N1	G01 U2.
G00 T0404	G00 Z30. M09
G97 M03 S500	G28 U0 W0
G00 X155. Z50.	M01
Z3. M08	N3
G94 X23. Z1.4 F0.15	G00 T0707
Z0.9	G97 M03 S500
Z0.2	G00 X25. Z50.
G00 X151. Z2. S400	Z2.M08
G71 U0.8 R0.5	G71 U0.8 R0.2
G71 P63 Q64 U0.25 W0.05 F0.2	G71 P55 Q99 U0.4 W0.05 F0.18
N63 G0 X145.55	N55 G00 X79.0
G01 Z0	G01 Z-12.
X147.95 W-1.2	N99 G01 X70.
Z-6.1	G00 X30. M09
N64 G01 X151.	G28 U0 W0
G00 X30. M09	M01
G28 U0 W0	N4
M01	G00 T0101
N2	G97 M03 S800
G00 T0202	G00 X80.5 Z50.
G97 M03 S300	Z2. M08
G00 X150. Z50.	G01 Z0 F0.1
Z2. M8	G02 X89.6 W-0.45 R0.45
G94 X76. Z0 F0.12	G01 Z-12
G00 X145.93 Z2. S600	U-1 F0.2
G01 Z0 F0.3	G00 X30. M09
X147.93 W-1	G28 U0 W0
Z-5.6 F0.12	M30 :

Table. 4 Program code at stage OP1.

Description progress OP1 (Front Holder):

The external rapping (N1) feeds the outside of the raw material from 155.58 mm to a size of 140 mm slowly in order to produce an outer surface of the holder that is not too rough by reducing the feedrate to facilitate the external finishing stage. Furthermore, external finishing (N2) smoothes the outside of the N1 process so that the surface of the holder is not rough so that the outer diameter size of 139.95 mm is obtained and if it accidentally scratches the skin it does not cause injury. Then enter the internal rapping stage (N3) repeatedly feeding kosntan based on the program block number specified in the raw material from the drilling section forward and forming a size of 89.5 mm specified in the CNC lathe program slowly in order to produce a holder outer surface that is not too rough to facilitate the internal finishing stage. Ended with internal finishing (N4) smoothing the inside of the N3 process at a diameter of 89.5 mm to a diameter of 89.25 mm so that the surface of the holder is not rough and if it accidentally scratches the skin does not cause injury.

Continue to OP2 (Process Optimization 2) production stage which includes:

N1	U2. F0.2
G00 T0404	G00 Z10. M09
G97 M03 S450	G28 U0 W0
G00 X155. Z50.	M01
Z6. M08	N3
G94 X74. Z3.1 F0.15	G00 T0707
G00 X151. Z5.5	G97 M03 S500
G71 U0.6 R0.5	G00 X79.5 Z50.
G71 P77 Q88 U0.2 W0.1 F0.2	Z1.5 M08
N77 G00 X77.	G71 U0.5 R0.5
G1 Z0	G71 P11 Q12 U-0.25 W0.05 F0.18
X140. Z-1.5	N11 G00 X90.7
N88 G01 X150.	G01 Z0
G00 Z10. M09	X89.3 W-0.7
G28 U0 W0	Z-2.8
M01	G3 X87.9 Z-35 R0.7
N2	N12 G1 X79.5
G00 T0202	G00 Z10. M09
G97 M03 S500	G28 U0 W0
G00 X150. Z50.	M01
Z2. M08	N4
G01 Z-1.5 F0.5	G00 T0101
X140.1 F0.1	G97 M03 S800
U2. W1.	G00 X90.6 Z50.
Z0	Z2. M08
X86. W0.5	G01 Z0. F0.1
G00 X139.15 Z2.	X89.3 W-0.65
G01 Z0 F0.1	Z-2.8
X139.95 W-0.4	G03 X87.9 Z-3.5 R0.7
G01 Z-1.5	G01 X80.53 F0.12
U0.2	G02 X79.63 W-0.45 R0.45 F0.1
U0.5 W0.2	G01 U-0.2 W-0.5
X147.03	G01 U-1. F0.2
Z-1.5	G00 Z20. M09
G03 X147.93 W-0.45 R0.45	G28 U0 W0
G01 U0.2 W-0.5	M30

Table. 5 Program code at OP2 stage.

Description progress OP2 (Rear Holder) :

External rapping (N1) feeds the outside of the raw material from 155.58 mm to a size of 142 mm slowly in order to produce a holder outer surface that is not too rough by reducing the feedrate to facilitate the external finishing stage. Furthermore, external finishing (N2) smooths the outside of the N1 process so that the surface of the holder is not rough so that the outer diameter size of 141.93 mm is obtained and if it accidentally scratches the skin it does not cause injury. Then enter the internal rapping stage (N3) repeatedly feeding kosntan based on the program block number specified in the raw material from the drilling section forward and forming the 80 mm size specified in the CNC lathe program slowly in order to produce a holder outer surface that is not too rough to facilitate the internal finishing stage. Ended with internal finishing (N4) smoothing the inside of the N3 process at a diameter of 80 mm to a diameter of 79.68 mm so that the surface of the holder is not rough and if it accidentally scratches the skin does not cause injury.

Simulation running program on CNC lathe panel

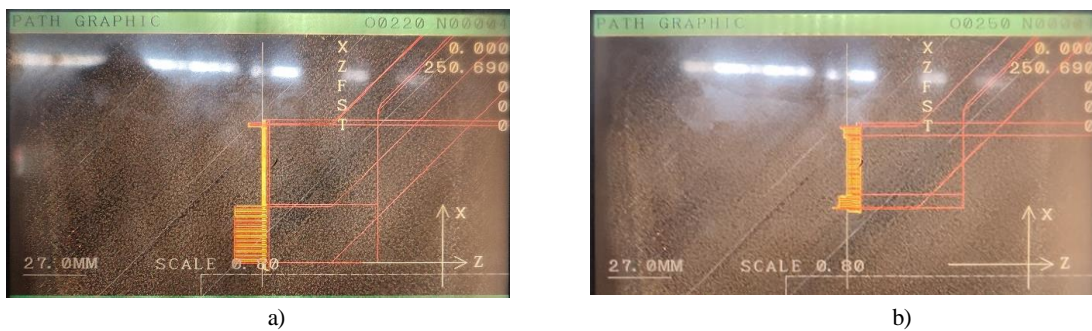


Figure. 3 Simulation results panel of a) OP1 and b) OP2 feeds on CNC lathes.

This simulation shows the feeding motion of the tool during the lathe process which gives an idea of the size of the final product. From the simulation picture obtained, it can be estimated the size of the product to be produced, so that the operator can estimate the size tolerance in the program that will be used in the future.

Result production of OP1



Figure. 4 OP1 production results front section of a) Outer diameter and b) Inner diamter on a CNC lathe.

In the OP1 production process, the results of the front outer diameter size of 139.95mm were obtained with the [G01 Z0 F0.3] [X147.93 W-1] feeding program code which resulted in a simulation size of 140 mm. Then the inner diameter of the front produces a size of 89.25 mm with a feeding program code [G02 X89.6 W-0.45 R0.45] which is an absolute and incremental program to make it easier to determine point 0 which in the incremental program W point 0 is not settled.

Result production of OP2



Figure. 5 OP2 production results rear section of a) Outer diameter and b) Inner diameter on a CNC lathe.

In the OP1 production process, the results of the rear outer diameter size of 141.93 mm were obtained with the feeding program code [G03 X147.93 W-0.45 R0.45] which resulted in a simulation size of 140mm. Then the inner diameter of the rear produces a size of 79.68 mm with a feeding program code [G02 X79.63 W-0.45 R0.45 F0.1] which is an absolute and incremental program to make it easier to determine point 0 which in the incremental program W point 0 is not settled.

Comparison results size between program simulation and final production yield

No.	Section	Program Simulation Size	Final Production Yield Size
1.	Outer Diameter (Front)	140 mm	139,95 mm
2.	Inner Diameter (Front)	89,5 mm	89,25 mm
3.	Outer Diameter (Rear)	142 mm	141,93 mm
4.	Inner Diameter (Rear)	80 mm	79,68 mm

Table. 6 Comparison of program simulation size and production results.

In the simulation drawing, the yellow line is the feeding motion and the red line is the free tool motion without feeding. In order to become a holder, the outer diameter of the rear part with a size of 142 mm and the outer diameter of the front part with a size of 140 mm are applied. Then proceed with the inner diameter of the back with a size of 80 mm and the inner diameter of the front with a size of

89.50 mm. However, in the production of objects produced measuring the outer diameter of the back with a size of 141.93 mm and the outer diameter of the front 139.95 mm. Then the inner diameter of the back with a size of 79.68 mm and the inner diameter of the front with a size of 89.25 mm.

CONCLUSION

In this study, it was emphasized that for at least two production turns of the holder, a feeding size tolerance of 0.1-0.5 mm is required to ensure more optimal results. Therefore, it is important to simulate the program before running it to compare the required size tolerance, so as to determine whether the item is feasible to produce or not. Program simulation results are not always the same as production results because they are influenced by factors such as the accuracy of program input, lathe tool conditions, and spindle rotation stability.

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