Post-Processor Development For 5 Axis DMG 50U Milling Machine Using Siemens NX 12 Software

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Abstract. Moriseiki DMG 50U 5 Axis CNC machine that has a table-table configuration with 3L-2R machine type. Different configurations result in different machine movements, hence the need for a post-processor. The post-processor is an interface that connects the CAM software system and the numerical control machine. The post-processor has a work function to convert CL data or Toolpath from CAM software into numerical language in accordance with the machine control used. This research aims to create a post-processor with a safe procedure for use on the Moriseiki DMG 50U 5 Axis CNC machine. The post-processor that has been made will be tested to make a product with indexing and simultaneous cutting methods then analyze the geometry of the product. The resultshow the post-processor can be used properly and can meet the demands to make products and can use in the Moriseiki DMG 50U 5 Axis CNC machine.

Keywords: component; formatting; style; styling; insert (key wordPost-processor, Siemens NX 12, 5-axis machine, Numerical control.

1 Introduction

In general, all CAM software can output general data called Cutter Location (CL file). This data is in the form of a TXT file containing movement coordinate data, cutting tools and so on. So that CAM data can be executed on a CNC machine, the resulting CL data must be converted into a language that can be understood by the CNC machine. The language commonly used on a CNC machine is called G language (G-code). Post-processor is needed to change the CL datainto G language which must be adapted to the machine configuration and controls used on CNC machines. CNC machines have been widely used in the manufacturing industry because of their advantages, especiallyfrom in terms of precision, accuracy, cutting productivity and complexity of work that can be handled [1], especially on 5 Axis CNC machines. 5 axis CNC machining provides excellent machining capabilities to machine parts from any direction in one operation and machining setup, to eliminate the need for manual repositioning of the workpiece between operations as is done in 3 axis CNC machining and therefore, productivity and accuracy is improved, while reducing production time [2]. 5 axis machines have various configurations according to the kinematic chain of axes, namely translation and rotation [3]. It could be said that a 5 Axis CNC machine is a CNC machine that has 3 linear axes (X, Y, and Z) and 2 additional rotary axes. The rotary axis of a 5axis machine can be designed in a variety of configurations and kinematic structures [4].

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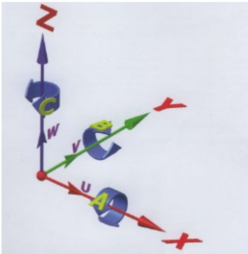

Fig 1:5 Axis CNC Machine Axis System [5].

Several studies have been carried out in post-processor development, including Haris Setiawan and Arif Budiman who developed post-processor manufacturing procedures using SolidCAM 2015 software used on the DMG 50U 5 axis CNC machine [6]. Yogi Muldani H. who made the post-processor using SolidCAM 2010 software used on the Moriseiki Nmv5000dcg 5 axis CNC machine [7]. Meanwhile Yun, et al. (2013) developed a post-processor on a combination of machines with types 2R-3L (two rotary axes) and 3R-2L (three rotary axes) with the method used being Locations of Joint Points. The advantage of this method is that it does not require inverse kinematic and forward kinematic equation methods [3]. Sharifa Magambo and Liu Ying created a post-processor based on UG for the Fanuc system [8]. The post-processor in the SIEMENS NX 12 software consists of 4 files which function to produce machining programs in numerical language (G-code) according to machine specifications, controls and features. These files are CDL, PUI, DEF, and TCL. CDL files function to create UDE (User Defined Events), PUI files function to define pre-postprocessor parameters, DEF files function to define machine configurations so that the resulting program output complies with certain machine specifications, and TCL files function to define commands. how the toolpath is built into a g-code for a particular machine. The focus of this research is how to develop a post-processor using SIEMENS NX 12 software and a 5 axis DMG 50U CNC machine of type 3L-2R (3 linear axes and 2 rotary axes) with Heidenhain iTNC 530 series control.

2 Method

This research was carried out through several stages,including, (i) Machine identification. (ii) Create a simulation engine. (iii) Create a post-processor.

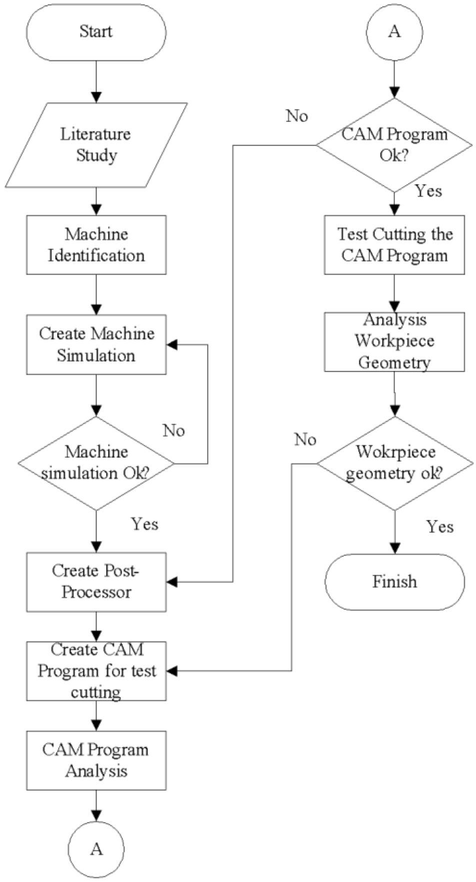

Fig 2. Flowchart for this research.

3 Machine Identification

The DMG 50U machine is a 5 axis CNC machine equipped with Heidenhain iTNC 530 control, this machine can carry out milling and drilling machining processesand can carry out indexing and simultaneous cutting methods so that this machine is able to work on workpieces with complex profiles and contours (freeform surfaces). complex parts).

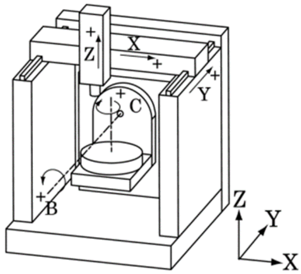

Fig 3. CNC 5 axis CNC Machine DMG 50U Axis System [6].

This machine has type 3L-2R, which means this machine consists of 3 linear axes and 2 rotary axes. The 3 linear axes on this machine are found on the machine spindle so that the spindle can move on the X, Y and Z axes. 2 rotary axes are found on the machine table where the first rotary axis is the B axis its axis rotates about the Y axis. The second is the C axis it axis rotates about the Z axis. These five axes can move simultaneously. The following are the specifications of the 5 axis DMG 50U CNC machine which are listed in table 1.

Table 1:DMG 50U CNC 5 axis Machine Spesification [9]

No	Item	Value	Unit
1	X *axis travel*	500	Mm
2	Y *axis travel*	450	Mm
3	Z *axis travel*	400	Mm
4	B *axis travel*	115 (-5/+110)	°
5	C *axis travel*	360	°
6	*Max rotational speed*	20	rpm
7	X, Y, Z *Axis infinitely programmable feed rate*	Up to 24000	Mm/min
8	X, Y, Z *Axis rapid speed*	Up to 24000	Mm/min
9	RPM *Spindle*	Up to 18000	
10	*Table Working Surface*	500	Mm
11	*Max. Workpiece Height*	400	Mm
12	*Max. load table*	300	Kg
13	M.R.Z (jarak antara meja dengan sumbu putar)	50	Mm
14	TCPM	Aktif	

3.1 Create an Simulation Engine

Creating a simulation engine on the SIEMENS NX 12 involves three main segments[10]. The first step is to create detailed geometric modeling of each part and assembly model with appropriate constraints.The second step is to identify the CAD model. Determine the junction of workpiece holding and tool holding.The third step involves a post-processor designed for the machine tool which will later be stored in the machine database file.The final stage of creating a simulation machine is creating a virtual control and post processor. The general procedure that can be established for any machine tool having 'n' number of axes can be explained with the flow diagrams shown in Figures 4 and 5. These figures show creating a kinematic model in SIEMENS NX 12 and creating a machine tool entry in NX native each in the native NX library [10].

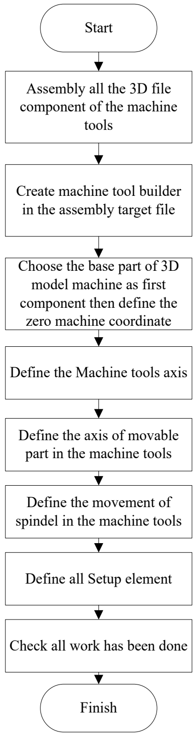

Fig 4.Flowchart for create kinematics models in Siemens NX12.

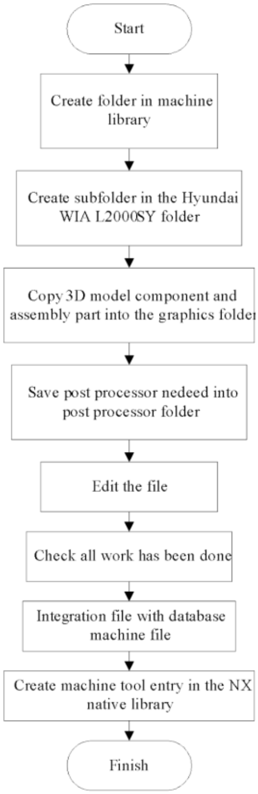

Fig 5. Flowchart for create machine tool entry in Siemens NX12.

3.2 Post-Processor Creation

The post-processor created consists of 4 files, namely: CDL File, PUI File, DEF File, and TCL File. The creation of the post-processor was carried out using special software provided by SIEMENS, namely Post Builder. The process consists of defining the machine configuration and creating a program to convert the CL file into a numeric language (G-code). The program definition step is carried out in the Machine Tool menu by adjusting the machine configuration in the software with the DMG 50U machine configuration which has a -table-table configuration (both rotating axes are on the machine table) with a 3L-2R machine type or 3 linear axes (X, Y, and Z) and 2 rotary axes (B and C). Definitions in the Machine Tool menu as shown in Figure 6.

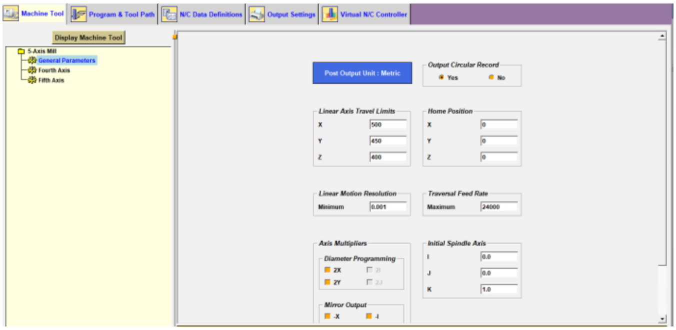

Fig 6. Machine congfiguration definition in Machine Tool Menu.

In the step of creating a program to convert a CL file into G-code, this is done in the Program & Toolpath menu by creating a program that requires the resulting G-code output to be the same as the G-code structure that can be read and executed by a machine. Creation in the Program & Toolpath menu is divided into 5 parts, namely: Program Start Sequence, Operation Start Sequence, Toolpath, Operation End Sequence, and Program End Sequence. Program creation in the Toolpath menu as shown in Figure 7.

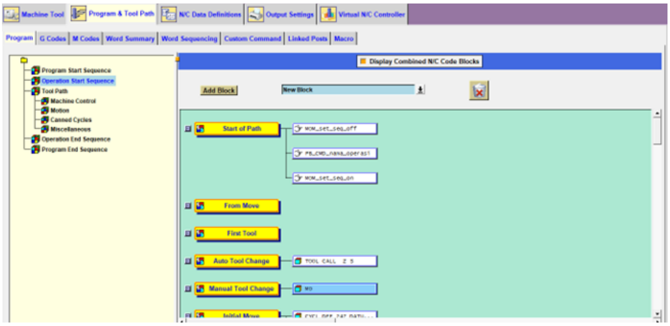

Fig 7. Program Creation in Program & Toolpath.

4 Result

The result of this research is a new post-processor for the DMG 50U 5 axis CNC machine which can be used in SIEMENS NX12 software. Validation of the post-processor was carried out by G-code analysis and experimental studies with geometric results from direct cutting methods for indexing and simultaneous cutting methods which were executed with reference to the simulation machine that had been created. The following are the results of the analysis of the G-code produced by the post-processor.

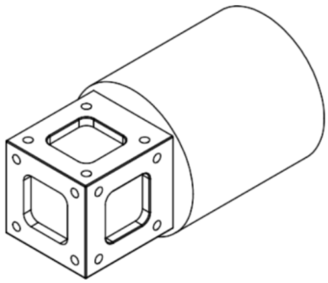

Fig 8. Workpiece for direct cutting methods.

4.1 G-Code Indexing Analysis

This method uses coordinate system rotation, so to move the tool plane in position 1 to position 2 you must create a new MCS (machine coordinate system) which has been defined as a rotating CSYS (coordinate system) that references the first MCS (machine coordinate system).The following is the g-code that has been generated from the post-processor, the g-code has successfully translated the movement of the MCS or tool plane of the workpiece as shown in Figure 9.

```
0 BEGIN PGM UJI INDEXING GABUNGAN MM
; Bismillah:)
1 BLK FORM 0.1 Z X-100. Y-100. Z-20.
2 BLK FORM 0.2 X100. Y100. Z+0.0
3 M127 ; SHORTEST PATH TRAVERSE OFF
4 M129 ; TCPM OFF
; ( FACE_MILLING_P2 )
; ( Tool:FLATE20 Diameter:20.00 )
5 TOOL CALL 8 Z S1592
6 CYCL DEF 32.0 TOLERANCE
7 CYCL DEF 32.1 T0.01
8 CYCL DEF 32.2 HSC-MODE:0 TA0.5
9 CALL LBL 250 ; RESET
10 CYCL DEF 7.0
11 CYCL DEF 7.1 X+0.0
12 CYCL DEF 7.2 Y+41.25
13 CYCL DEF 7.3 Z-30.
14 M126 ; SHORTEST PATH TRAVERSE ON
15 PLANE SPATIAL SPA+0.0 SPB+90. SPC+90. TURN FMAX SEQ+ TABLE ROT
16 M3 ; SPINDLE ON
17 M8 ; COOLANT ON
```

Fig 9. G-code that has been generated from the post-processor.

After the g-code has been successfully generated, we must validate the data from the g-code generated by the post-processor that was created. Therefore, a transformation matrix is used to calculate the linear axis displacement (shifting) so that the g-code data produced by the post-processor can be validated, namely as follows:

The calculation will be carried out on the Y axis, because the workpiece rotates about the B rotation axis and the C rotation axis, the rotation matrix formula on the Y axis is used:

$$\begin{bmatrix} \cos\theta & 0 & \sin\theta \\ 0 & 1 & 0 \\ -\sin\theta & 0 & \cos\theta \end{bmatrix}$$

So,

$$\begin{bmatrix} \cos\theta & 0 & \sin\theta \\ 0 & 1 & 0 \\ -\sin\theta & 0 & \cos\theta \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} X\cos\theta & 0 & Z\sin\theta \\ 0 & Y & 0 \\ -X\sin\theta & 0 & Z\cos\theta \end{bmatrix} =$$

$$\begin{bmatrix} (0)\cos(90) & 0 & (-32.5)\sin(90) \\ 0 & 41.25 & 0 \\ -(0)\sin(90) & 0 & (-32.5)\cos(90) \end{bmatrix} = \begin{bmatrix} 0 & 0 & -32.5 \\ 0 & 41.25 & 0 \\ 0 & 0 & 0 \end{bmatrix}$$

In other words, the shifting value of the rotary axis C which is rotated from the reference axis corresponds to the angle given in the transformation data and is both at coordinates X0 Y41.25 Z-32.5.

4.2 G-Code Simultan Analysis

APT post-processor is a postprocessor for generating neutral cutter location programs or neutral files on NX CAM, neutral files define coordinates x, y, and z to define linear movement and vectors i, j, and k to define the angle of movement of the rotary axis. The following is an analysis comparing the neutral file with the g-code generated by the post-processor. Calculating the angular displacement of vectors I, j, and k:
GOTO/-3.5715, 27.1594, -23.9602, 0.0478327, 0.7054871, 0.7071068
G-code results:
L X-3.571 Y27.159 Z-23.96 **B45 C86.121**
The following is the position of the analyzed coordinates, as seen in Figure 10:

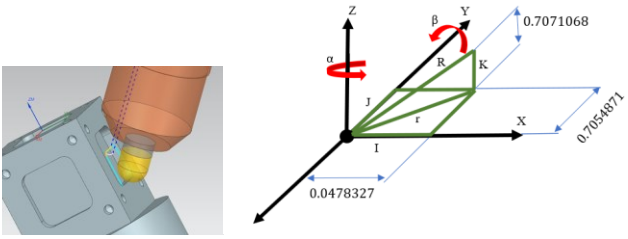

Fig 10. The coordinate position that analyzed.

4.3 Machine Simulation Result

The following is a DMG 50U virtual machine that has been created in SIEMENS NX software, as can be seen in Figure 11.

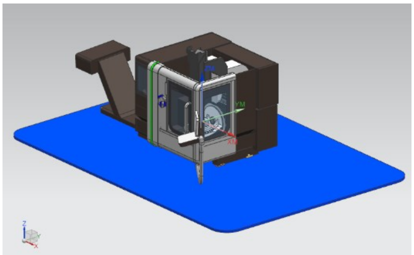

Fig 11. Virtual machine DMG 50U.

After the DMG 50U virtual machine is created, the simulation must be able to detect collisions that may occur. Collisions can be checked at two nodes either in programming or during workpiece simulation [10]. Can be seen in Figures 12 and 13.

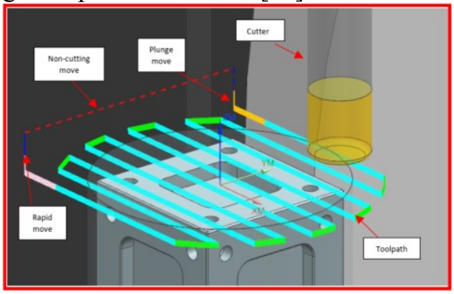

Fig 12.Checking the collosion in CAM Operation.

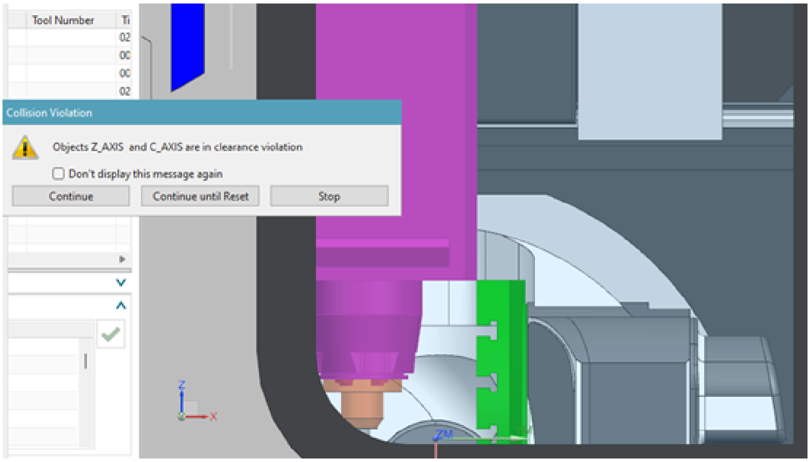

Fig 13. Checking collision in the machine virtual simulation.

Validation of the simulation machine is carried out by feeding the facing using the indexing cutting method in a position where there is a risk of collision during the process. As shown in Figure 14.

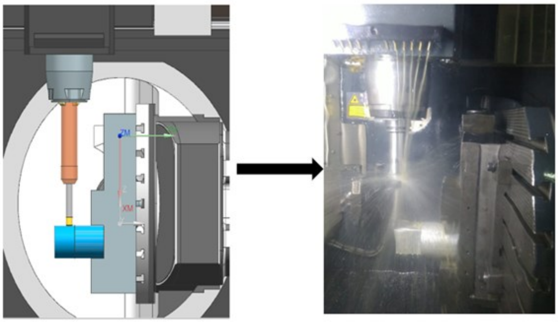

Fig 14. Test Cutting and implementation.

4.4 Analysis the Workpiece Geometry in Indexing Machining

After executing the program on the machine, the geometric analysis process is then carried out on the workpiece, the workpiece is measured to ensure whether the geometry of the measuringworkpiece resulting from the machining is the same as the geometry of the workpiece design that has been created in SIEMENS NX 12 CAD software, the measuring and auxiliary tools used for measuring the workpiece. Table 2 shows the measurement data.

Table 2:Data Result of the Dimensio for Workpiece Geometry in Indexing Machining

No	Dimension	Device	Result (mm)	Error (mm)
1	55 ± 0,3	Vernier Caliper 0,02	54,94	-0,06
2	55 ± 0,3	Vernier Caliper 0,02	55,02	0,02
3	30 ± 0,3	Vernier Caliper 0,02	29,82	-0,18
4	30 ± 0,2	Vernier Caliper 0,02	29,90	-0,10
5	30 ± 0,2	Vernier Caliper 0,02	29,96	-0,04
6	30 ± 0,2	Vernier Caliper 0,02	29,92	-0,08
7	5 ± 0,1	Vernier Caliper 0,02	5,06	0,06
8	5 ± 0,1	Vernier Caliper 0,02	5,08	0,08
9	5 ± 0,1	Vernier Caliper 0,02	5,08	0,08
10	5 ± 0,1	Vernier Caliper 0,02	5,04	0,04
11	60 ± 0,3	Vernier Caliper 0,02	59,90	-0,10
12	60 ± 0,3	Vernier Caliper 0,02	60,20	0,20
13	60 ± 0,3	Vernier Caliper 0,02	60,04	0,04
14	60 ± 0,3	Vernier Caliper 0,02	60,10	0,10

From Table 2 it can be seen that each size of the workpiece experiences deviations. However, the test workpiece has the same characteristics as the 3D model created. So it can be said that the ¬g-code produced by the post-processor is correct.

4.5 Analysis the Workpiece Geometry in Simultan Machining

After executing the program on the machine, the geometric analysis process is then carried out on the workpiece, the workpiece is measured to ensure whether the geometry of the workpiece resulting from the machining is the same as the geometry of the workpiece design that has been created in SIEMENS NX 12 CAD software, the measuring and auxiliary tools used for measurig the workpiece. Table 3 shows the measurement data.

Table3: Data Result of the Dimensio for Workpiece Geometry in Simultan Machining

No	Dimension	Device	Result (mm)	Error (mm)
1	0,5	Vernier Caliper 0,02	0,60	0,10
2	0,5	Vernier Caliper 0,02	0,40	-0,10
3	0,5	Vernier Caliper 0,02	0,60	0,10
4	0,5	Vernier Caliper 0,02	0,40	-0,10
5	0,5	Vernier Caliper 0,02	0,70	0,20
6	0,5	Vernier Caliper 0,02	0,40	-0,10
7	0,5	Vernier Caliper 0,02	0,58	0,08
8	0,5	Vernier Caliper 0,02	0,40	-0,10

From table3 it can be seen that each size of the workpiece experiences deviations. However, the test workpiece has the same characteristics as the 3D model created. So it can be said that the g-code produced by the post-processor is correct.

4.6 Workpiece Geometry Analysis Using VXelements Software

Measurements for analysis of geometric results are also carried out using VXelements 11 software. This measurement process is carried out to determine how large the size deviation value is from the machining results. Measurements were carried out by comparing the 5-axis simultaneous deburring design model with the 5-axis simultaneous deburring model that had been produced from the machining process, where the machining model was taken from the 3D scanning process.

The maximum nominal tolerance selected is 0.1mm while the minimum nominal tolerance selected is -0.1mm.

After determining the tolerance limits, the next step is to compare the 5-axis simultaneous deburring design model with the 3D scanning model. The results of the comparison show differences in deviation which are marked by differences in color. Given these differences, different points are taken from each color to display the deviation value. Based on these results, 8 points were taken as a reference for size comparison. The following are the results of the size comparison that has been carried out.

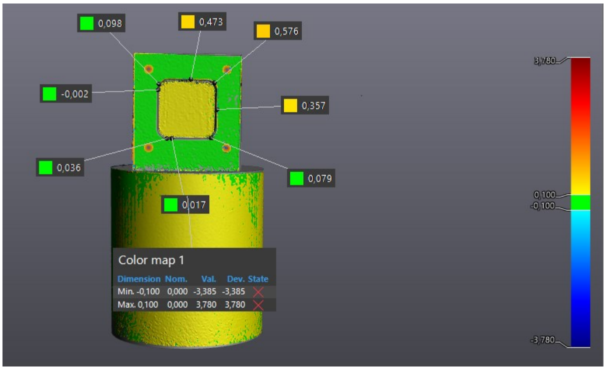

Fig 15. Workpiece Geometry Analysis Comparison Result.

Table 4:Deviation Data Form Comparison Result

Point	Deviation	Status	Tolerance
1	0,098	*Pass*	±0,1
2	-0,002	*Pass*	±0,1
3	0,036	*Pass*	±0,1
4	0,017	*Pass*	±0,1
5	0,079	*Pass*	±0,1
6	0,357	*Fail*	±0,1
7	0,576	*Fail*	±0,1
8	0,473	*Fail*	±0,1

Based on the status data, there are 5 points that fall within the nominal tolerance and there are 3 points that do not match the nominal tolerance because the results of 3D scanning with a resolution of 0.2 are less than optimal for objects that have a profile measuring 0.5 with a shiny surface.

5 Conclusion

Here are several conclusions that can be drawn from this research they are,

1. A post-processor has been created and can generate toolpath data contained in the SIEMENS NX software into a numerical language (G-code) that can be executed on a 5 axis DMG 50U CNC machine.
2. After analysis, the G-code produced by the post-processor is in accordance with the toolpath data that has been created in the SIEMENS NX software.

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