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Research Paper

TURN-MILL PROCESS OPTIMIZATION OF A COMPLEX ELECTRONIC COMPONENT

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Mill turning is a process applied in the milling of a curved surface while the work piece rotates around its center. Depending on the eccentricity of the tool, when a flat-end mill tool performs a curved trajectory perpendicular to the rotation axis of the tool, its bottom part is engaged in removing material. This paper presents the techniques of tool path planning for the simultaneous turn-mill machining. The new turn-mill machine tools allow the parallel processing of both multi-axis milling and turning operations simultaneously. Turn-mill machine tools have been identified to be able to significantly reduce the total setup time and manufacturing cost by milling and turning the complex parts with a single setup. In this paper, computational geometric analysis of a complex electronic component has been presented for turn-mill machine tool operations. The electronic component presented in this paper is a type of low resistance resistor that acts as a sacrificial device to provide over current protection, of either the load or source circuit. Its essential component is a metal wire or strip that melts when too much current flows, which interrupts the circuit in which it is connected. This component is complex because it has huge number of operations and is very difficult to manufacture in 3 and 4 axis milling machines because it requires 46 tools to load at a time for manufacturing. Dimensions are also highly critical and complex. In this paper optimized process plan has been developed for the turn mill process of the electronic component which gives high surface finish and less machining time. CAD/CAM systems have been implemented to develop the optimum turn mill process plan.

Keywords: Manufacturing process plan, Tool design, NX-CAD, NX-CAM, DMG 5-axis milling machine

INTRODUCTION

The presence of multiple spindles and live tools on a turn-mill machine allows complex parts to be machined within single setup without the time-consuming multiple set-ups and transferring among different machine tools.

It is preferred to reduce the number of setups since setup operations are costly and affect part precision. Turn-mill machine tools

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are opening new ranges of applications in manufacturing due to their capability of performing milling, turning, drilling, and boring operations within the same machine. Using the turn-mill machine tools can significantly reduce the total machining lead-time and eliminate the non-value added multiple set-ups in machining of complex parts.

Due to the lack of CAD/CAM support for turn-mill machine tools, there are still shortcomings in using the turn-mill machines in manufacturing industry. Some of these shortcomings include:

- Few CAD/CAM systems supporting simultaneous turn-mill machining processes.
- Few tool path generation methods for the special turn mill machining.
- Lack of manufacturing cost analysis for turn-mill machining.

It is very difficult to manufacture a complex electronic component in 3 and 4 axis milling machines because it requires 46 tools to load at a time for manufacturing. Special tools must be designed to manufacture such a complex part.To achieve a high surface finish, proper tool path, tooling and Fixturing has to be defined. Dimensions are highly critical and complex. Iterations/experiments cannot be done on a CNC machine, because of its high operating cost. Developing the optimum machining process plan, this gives high surface finish and less machining time.

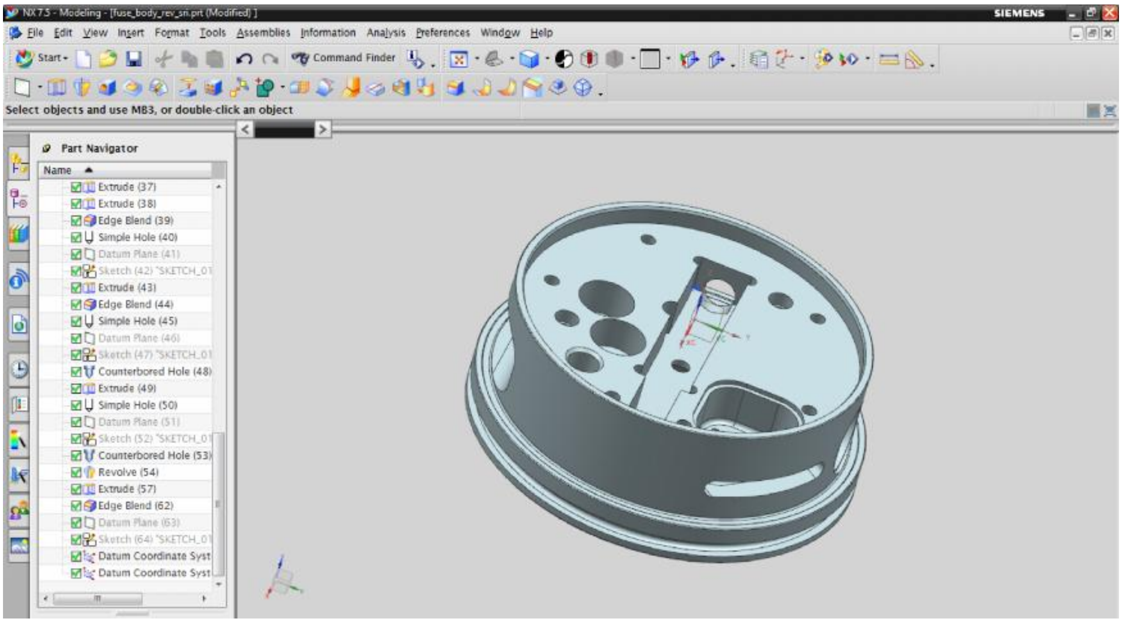
COMPUTER AIDED DESIGN

Final 3D model of electronic component using Unigraphics NX-7.5

Manufacturing process plan

- Identify suitable machine.
- Selecting suitable tools for manufacturing electronic component component.

Figure 1: Final 3D Model



- Selection of fixture.
- Listing down the Sequence of operation performed on electronic component component.
- Generating tool path using NX-CAM software.
- Designing tools for reducing machining time.

Identify Suitable Machine

DMG 5-axis milling machine is used for manufacturing electronic component component. In DMG 5-axis milling machine X, Y, Z, B, C are 5 vectors, X and Y are tool movement and Z is for table upwards movement, B for spindle movement, C for table rotation.

Figure 2: DMG 5-Axis Machine

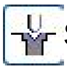
MORI SEIKI 4-AXIS CNC turning machine is used for machining electronic component. DMG MORI SEIKI offers the industry's best lineup of high-performance lathes with better precision and rigidity, greater multi-axis compatibility and smaller footprints.

Selecting Suitable Tools

OD_80_L facing, roughing

Figure 3: MORI SEIKI 4-Axis Machine

Facing in the context of turning work involves moving the cutting tool at right angles to the axis of rotation of the rotating work piece.

SPOT_DRILLING

This operation subtype allows the tool to pause at the tool tip or shoulder depth of the tool by a specified number of seconds or revolutions.

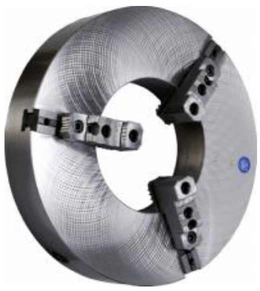
 DRILLING

This operation subtype allows you to do basic point-to-point drilling.

END MILL

A milling cutter that performs a mix of peripheral and face milling.

Figure 4: 3-Jaw Chuck



Selection of Fixture

3-jaw chucks provide the quickest and easiest way of holding work in the milling and lathe machines.

Sequence of operation

- OD_Facing operation
- OD_Rough operation
- GROOVE _OD operation
- ROUGH BORE_ID
- Planar mill operation
- Spot drilling operation
- Drilling operation
- Reamer operation

Generating Tool Path

Turning Operations on Electronic Component

Material of electronic component is aluminum alloys. Aluminium alloys are light weight and high strength material.

Below image shows ROUGH TURN_OD operation of electronic component with 1300 rpm speed and 0.24 mmpr feed

Below image shows verification of ROUGH TURN_OD operation

Milling Operations on Electronic Component

Below image shows planar mill operation of electronic component with 1400 rpm speed and 230 mmpm feed.

The Manufacturing Process of Electronic Component on CNC Machine

Raw material is placed on the machine, and degree of freedom is arrested using fixtures. 3-jaw chuck is used for arresting degree of freedom of the electronic component.

First step: Facing operation is done on the raw material.

Second step: Planar mill operation will be done on sides of the electronic component.

Figure 5: ROUGH TURN_OD Operation

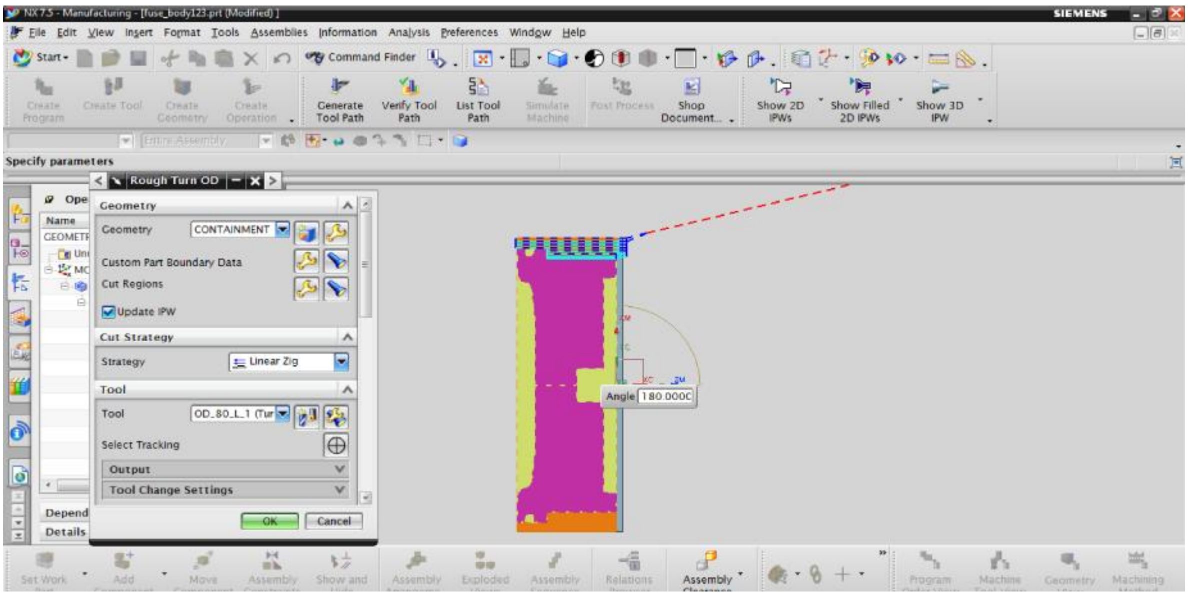


Figure 6: Verification of ROUGH TURN_OD Operation

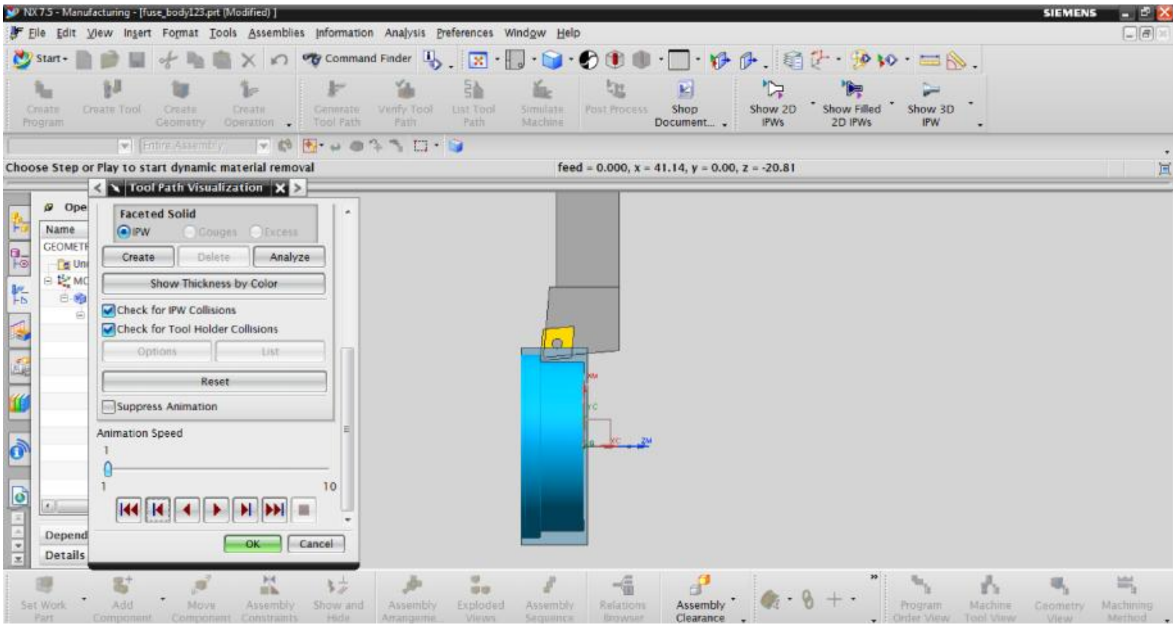
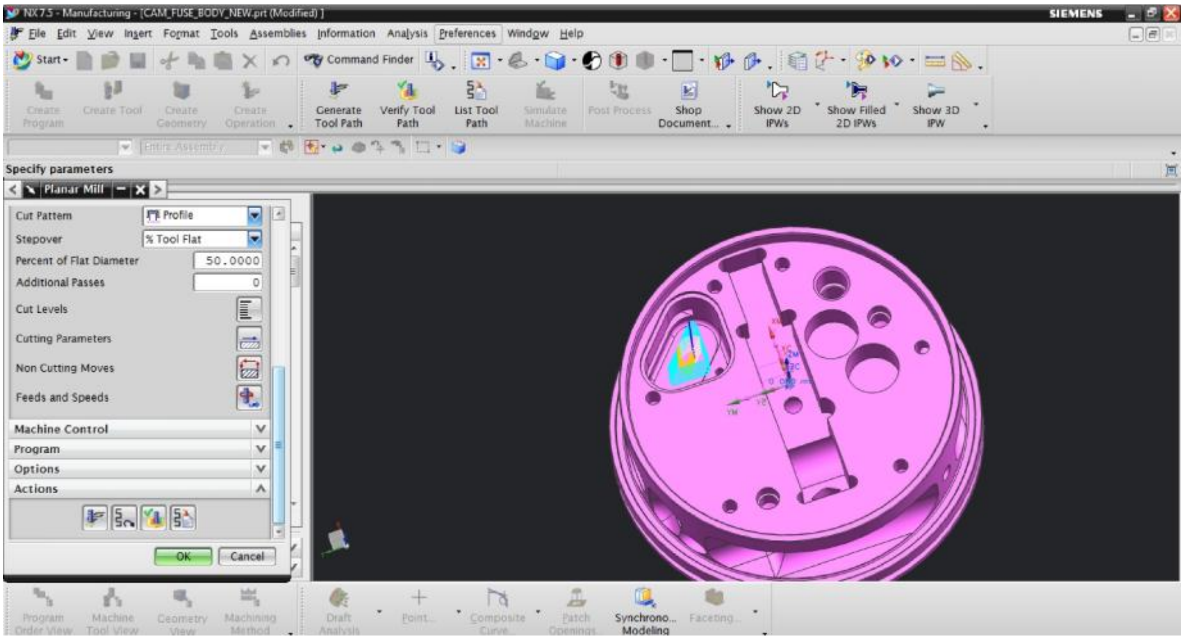


Figure 7: Planar Mill Operation

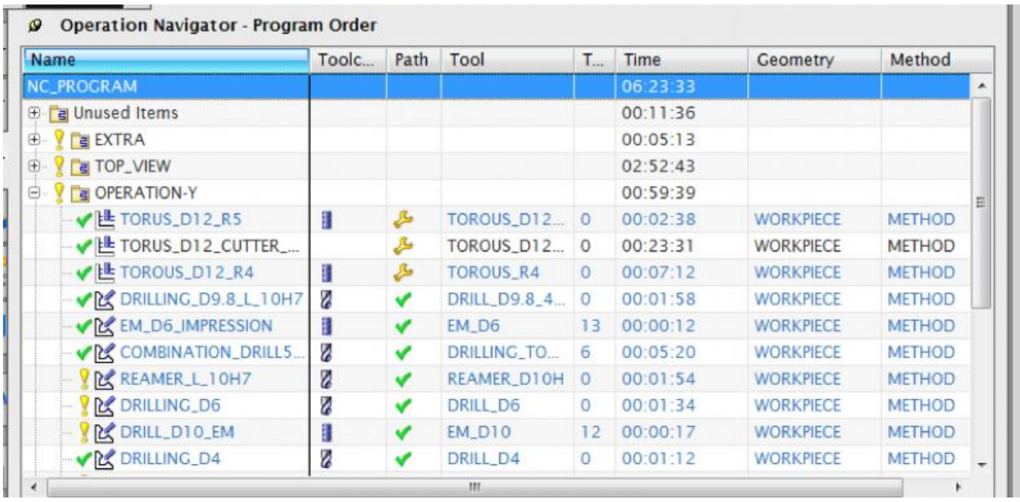


Third step: Angular planar mill operation will be done on electronic component.

Fourth step: Drilling operation will be done to create holes.

Fifth step: After completing setup_1 operation component is removed from fixture and it is reversely placed in fixture for setup_2 operations.

Figure 8: Time Taken for Manufacturing Electronic Component



Operation Navigator - Program Order

Name	Toolc...	Path	Tool	T...	Time	Geometry	Method
NC_PROGRAM					06:23:33		
Unused Items					00:11:36		
EXTRA					00:05:13		
TOP_VIEW					02:52:43		
OPERATION-Y					00:59:39		
TORUS_D12_R5			TOROUS_D12...	0	00:02:38	WORKPIECE	METHOD
TORUS_D12_CUTTER_...			TOROUS_D12...	0	00:23:31	WORKPIECE	METHOD
TOROUS_D12_R4			TOROUS_R4	0	00:07:12	WORKPIECE	METHOD
DRILLING_D9.8_L_10H7			DRILL_D9.8_4...	0	00:01:58	WORKPIECE	METHOD
EM_D6_IMPRESSION			EM_D6	13	00:00:12	WORKPIECE	METHOD
COMBINATION_DRILL5...			DRILLING_TO...	6	00:05:20	WORKPIECE	METHOD
REAMER_L_10H7			REAMER_D10H	0	00:01:54	WORKPIECE	METHOD
DRILLING_D6			DRILL_D6	0	00:01:34	WORKPIECE	METHOD
DRILL_D10_EM			EM_D10	12	00:00:17	WORKPIECE	METHOD
DRILLING_D4			DRILL_D4	0	00:01:12	WORKPIECE	METHOD

Sixth step: Again facing, planar milling and drilling operations will be done on the component. Finally finish operation will be done.

Below image shows time taken for manufacturing electronic component.

DESIGN OF TOOLS

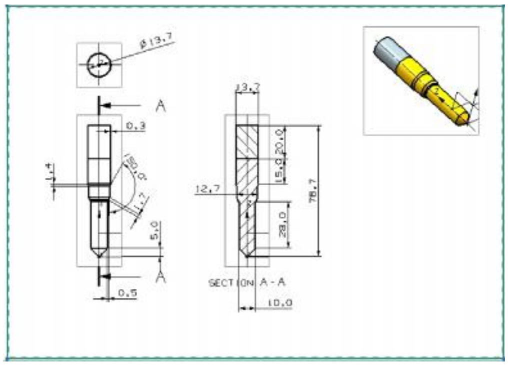
Tools are designed for typical operations to reduce manufacturing time and cost and to get high surface finish. These tools reduce number of operations. Each designed tool can do nearly four operations at a time and reduce machining time, tool change and tool setup time as well as part cost. Tools are designed as per the dimensions required for machining such operations.

Using designed tools we can go for high cutting speed and feeds. The machining time will be reduced at high speed cutting as well as component cost is reduced.

Tool 1

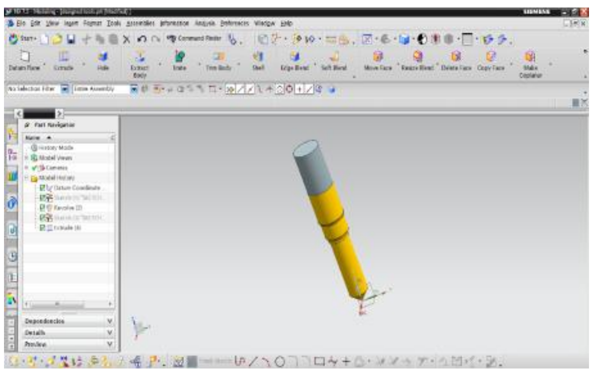
Below image shows 2D input of designed tool-1

Figure 9: 2D Input of Designed Tool-1



Below image shows final part of designed tool

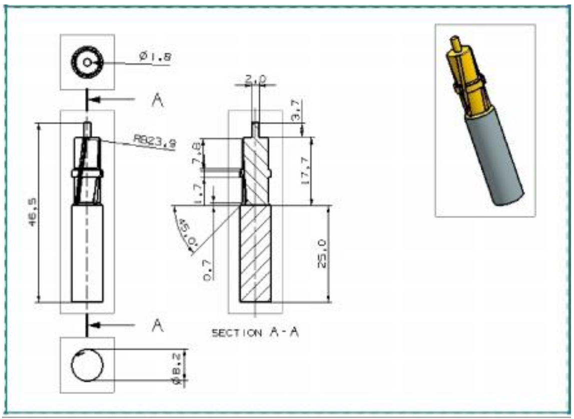
Figure 10: Final Part of Designed Tool-1



Tool 2

Below image shows 2D input of designed tool-2

Figure 11: 2D Input of Designed Tool-2



Below image shows final part of designed tool

Figure 12: Final Part of Designed Tool-2

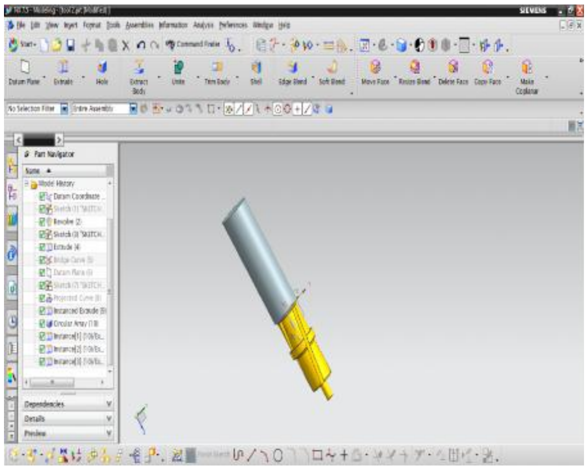
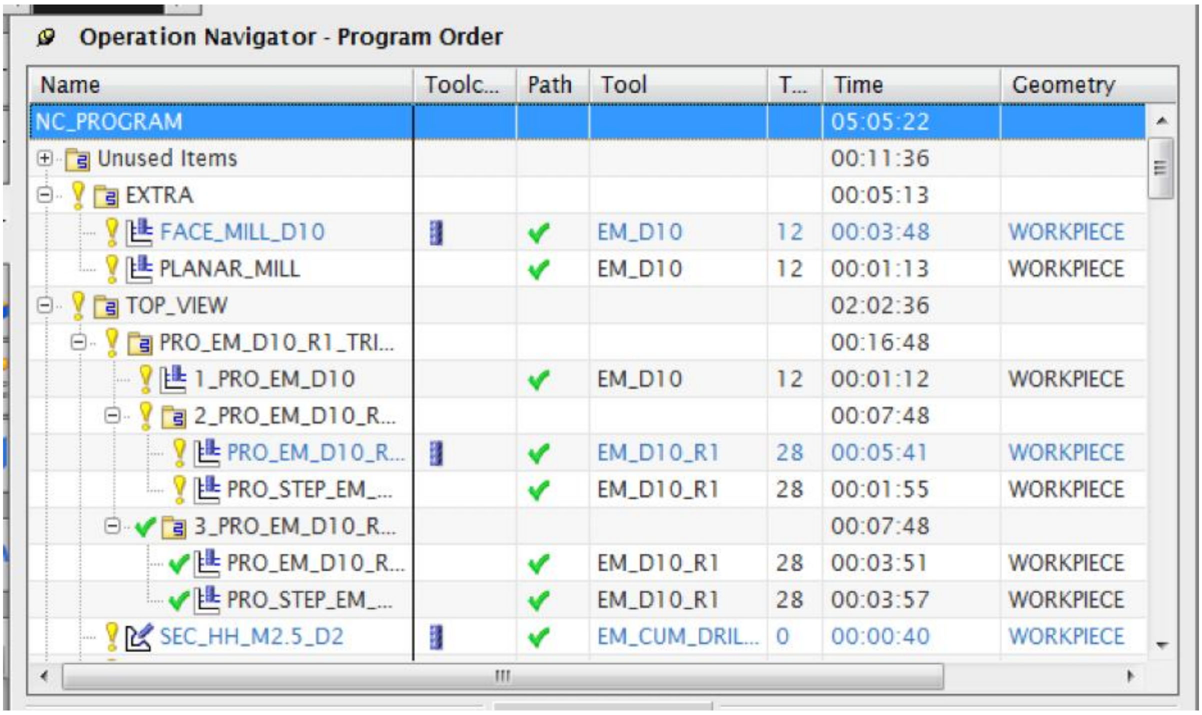


Figure 13: Time Taken for Manufacturing Electronic Component Using Designed Tools



Operation Navigator - Program Order

Name	Toolc...	Path	Tool	T...	Time	Geometry
NC_PROGRAM					05:05:22	
Unused Items					00:11:36	
EXTRA					00:05:13	
FACE_MILL_D10		✔	EM_D10	12	00:03:48	WORKPIECE
PLANAR_MILL		✔	EM_D10	12	00:01:13	WORKPIECE
TOP_VIEW					02:02:36	
PRO_EM_D10_R1_TRI...					00:16:48	
1_PRO_EM_D10		✔	EM_D10	12	00:01:12	WORKPIECE
2_PRO_EM_D10_R...					00:07:48	
PRO_EM_D10_R...		✔	EM_D10_R1	28	00:05:41	WORKPIECE
PRO_STEP_EM_...		✔	EM_D10_R1	28	00:01:55	WORKPIECE
3_PRO_EM_D10_R...					00:07:48	
PRO_EM_D10_R...		✔	EM_D10_R1	28	00:03:51	WORKPIECE
PRO_STEP_EM_...		✔	EM_D10_R1	28	00:03:57	WORKPIECE
SEC_HH_M2.5_D2		✔	EM_CUM_DRIL...	0	00:00:40	WORKPIECE

The Manufacturing Process of Electronic Component on CNC Machine with Designed Tools

Manufacturing process will be same for machining electronic component but designed tools were used to reduce machining time and cost of the part. The time taken for manufacturing electronic component is shown below

RESULTS AND DISCUSSION

Product Cost Reduction, Reduction Machining Time

Manufacturing Component on CNC Machine Using Default Tools

Manufacturing component with regular tools consumes more time and increases manufacturing cost.

Time and cost calculation for manufacturing electronic component as shown below

Manufacturing time taken by single component = 6 hrs 24 mins

Machining cost per hour for milling operations = 1200 rs

Machining cost per hour for drilling operations = 800 rs

Machining cost per piece for turn-mill operations (machining cost per min x machining time in min) = 1200/60*198 min = 3960 rs

Machining cost per piece for drilling operations (machining cost per min x machining time in min) = 800/60*186 min = 2480 rs

Total machining cost per piece = turn-mill + drilling = 3960 + 2480 = 6440 rs

Table 1: Table of Machining Time and Cost Using Default Tools for Manufacturing

SET UP Operations	Time Required in Mins.	Machining Cost per Hour	Machining Cost/Piece
Turn-Mill	198	RS. 1200/HR	RS. 3960
Drilling	186	RS. 800/HR	RS. 2480
Total	**384**		**RS. 6440**

Manufacturing Component on CNC Machine Using Designed Tools

Using designed tools number of operations can be reduced and manufacturing time will be reduced as well as part cost is reduced

Manufacturing time taken by single component= 5 hrs 6 min

Machining cost per hour for turn-mill operations = 1200 rs

Machining cost per hour for drilling operations = 800 rs

Machining cost per piece for turn-mill operations (machining cost per min x machining time in min) = 1200/60*198 min = 3960 rs

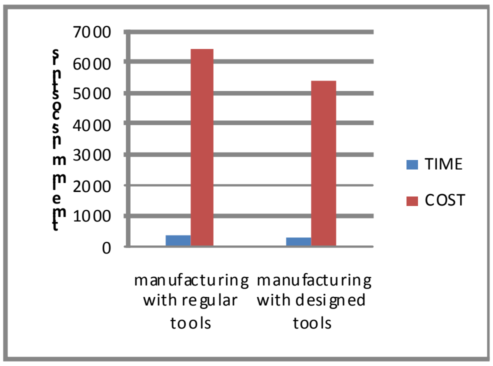
Machining cost per piece for drilling operations (machining cost per min x machining time in min) = 800/60*108 min = 1440 rs

Total machining cost per piece = turn-mill + drilling = 3960 + 1440 = 5400 rs

Table 2: Table of Machining Time and Cost Using Designed Tools for Manufacturing

SET UP Operations	Time Required in Mins.	Machining Cost	Machining Cost/Piece
Turn-Mill	198	RS. 1200/HR	RS. 3960
Drilling	108	RS. 800/HR	RS. 1440
Total	**306**		**RS. 5400**

Figure 14: Graph of Machining Time and Cost



Graphical representation of manufacturing time and cost of the component.

CONCLUSION

Modeling of electronic component is done using unigraphics software. Proper tools are specified which will support for machining typical components like electronic component. Manufacturing process sequence of electronic component is shown in the document. Manufacturing time is noted when part is manufactured with regular tools, to reduce time and cost tools are designed as per the operations. New tools are designed to do 4 operations at a time and reduce manufacturing cost and time. Graphical representation of Product cost reduction, Reduction of manufacturing times is shown in results. Graphical representation of Product cost reduction rate of electronic component shows reduction of time as well as cost of component when manufactured by using designed tools which will reduce manufacturing time and cost of the component. Optimization of manufacturing process by using designed tools to reduce manufacturing cost and time.

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