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Optimisation of Process Plan for Support Component of a Dynamic Air Frame in a Missile by Designing a Fixture

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ABSTRACT

A missile is a self-propelled guided weapon system. There are five system components in missiles. They are:

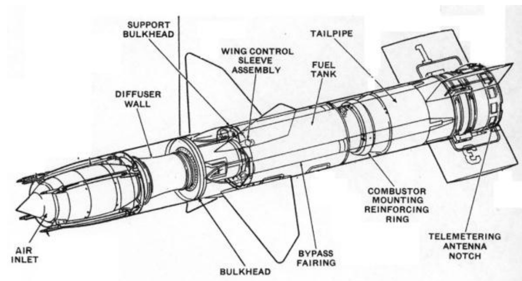
1. *Targeting and/or guidance*
2. *flight system*
3. *engine*
4. *air frame*
5. *Warhead.*

Bulk Head of missile was holded by a thin walled component called support head bulk. Machining is to be done inside and outside of the component. To machine the component a fixture is required. The fixture should be special to hold the component rigidly during machining. The component is clamped at top for CNC machining. The component should have dimensional accuracy. To get dimensional accuracy, 4-axis turning machine is used to develop the component. By using 4-axis turning machine, the cost and work of the labour is reduced.

This project is aimed to predict the stable speed range for machining thin-ribbed bulk head support structure with minimum deflection and high surface finish. This project is aimed at optimizing the manufacturing process of the support bulk head. Two different process plans along with NC programs shall be developed to decrease number of setups, which reduces machining time and the unit cost of the component. The 3D model of Support bulk head shall be modeled in NX-CAD. NX-CAM software shall be used to generate the NC program of Support bulk head.

INTRODUCTION

Bulk Head of missile was holded by a thin walled component called support head bulk. Machining is to be done inside and outside of the component. To machine the component a fixture is required. The fixture should be special to hold the component rigidly during machining. The component is clamped at top for CNC machining. The component should have dimensional accuracy. To get dimensional accuracy, 4-axis turning machine is used to develop the component. By using 4-axis turning machine, the cost and work of the labour is reduced.



High speed machining is one of the emerging cutting processes having tremendous potential compared to conventional machining processes. It is an economically viable alternative to other forms of manufacturing such as forming, casting, and sheet metal build-up. Additionally, high-speed milling processes can produce more accurate and repeatable results, as well as reduce the costs associated with assembly and fixture storage, by allowing several components to be combined into a monolithic machined part. Important applications of high-speed milling include the manufacture of dies and molds, numerous steel and aluminum parts for automobiles, and thin-walled, aluminum components for aircraft.

3D MODELING OF SUPPORT COMPONENT

Bulk head support 2D Drawing

A 2D drawing is used to design a 3D model for our component using Unigraphics NX 7.5 CAD software.

Below shows the 2D drawings of the support with all the required dimensions

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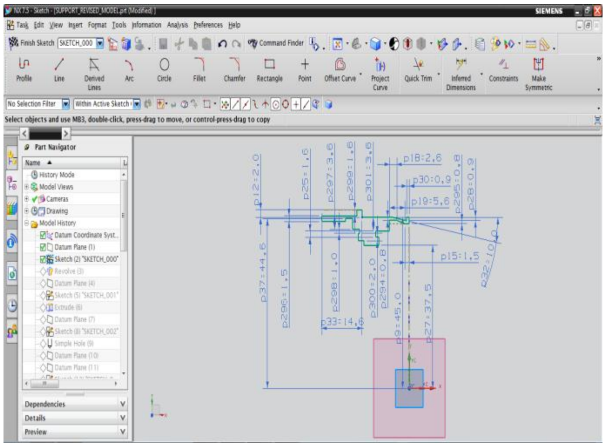
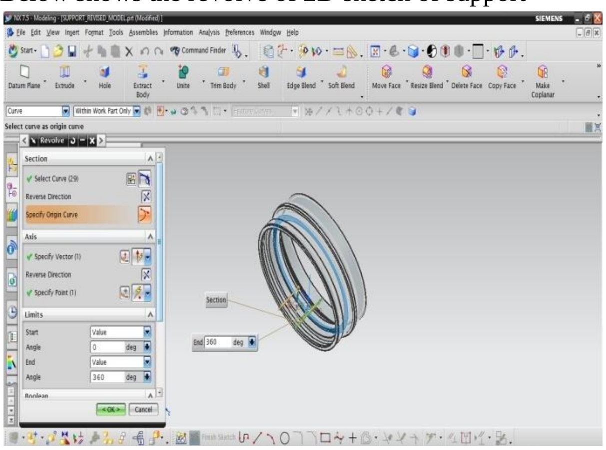
representations the suits the best for manufacturing the component without any errors.

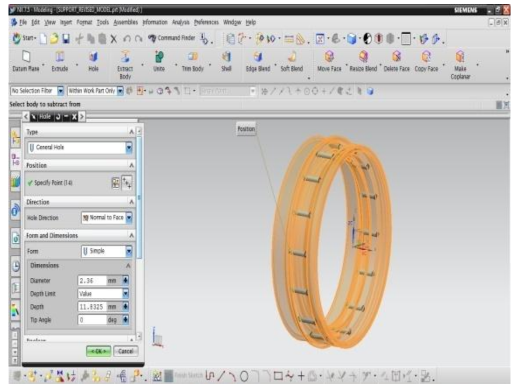
Below fig shows sketching of support



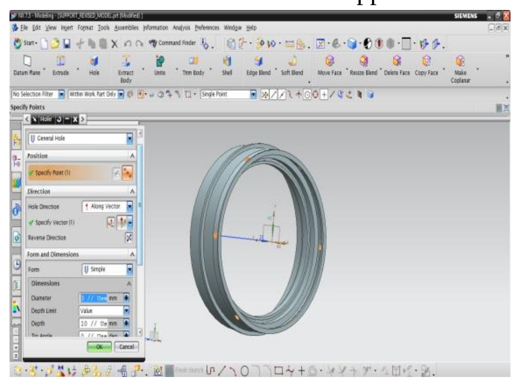
Below shows the revolve of 2D sketch of support



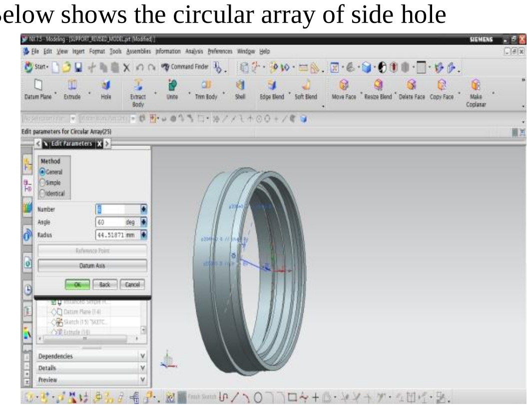
Below shows the holes on support part



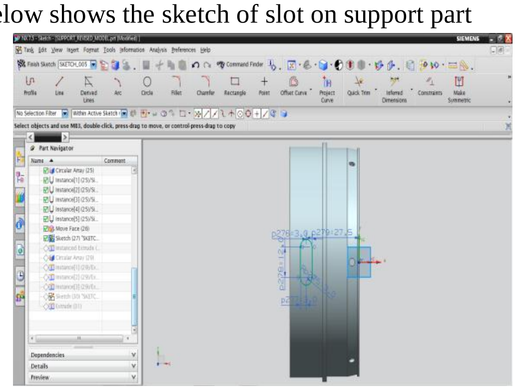
Below shows the holes on side of support



Below shows the circular array of side hole



Below shows the sketch of slot on support part



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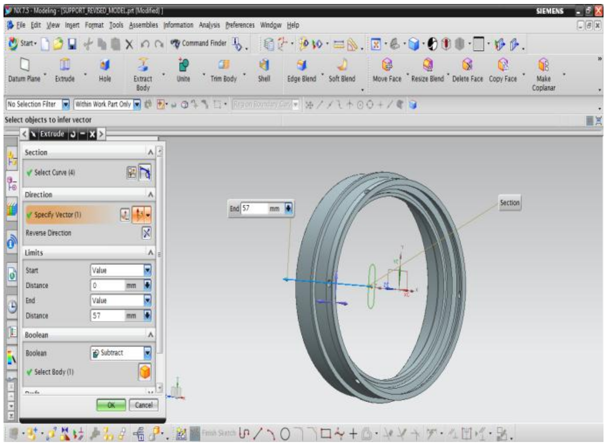
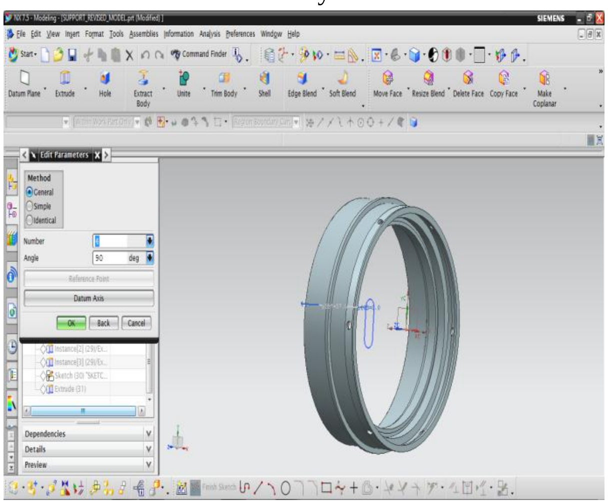
Below shows the extrude of slot



Below shows the circular array of slot



COMPUTER AIDED MANUFACTURING

Maintaining this stable speed bulk head support component is manufactured on CNC machine.

Methodology used in manufacturing of support is mentioned below:

- Identifying suitable machine.
- Selecting suitable tools for manufacturing thin walled component.
- Listing down the Sequence of operations performed on missile piston.
- Generating tool path at specified cutting speed.
- Generating NC program using NX-CAM software.

Identify suitable machine: CNC MACHINE USED IN THIS PROJECT

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

High rigidity with Integrated Turning Spindle. Spindle is directly coupled with motor. Rigid Turret with BIM (Built In Motor) Technology. Directly coupled Integrated driven tools. Is a patent technology. Y-axis machining, Up to 100mm (+/- 50). 4-axes simultaneous machining, C-axis with 360 deg and Y-axis, Machine accuracies, Positional Accuracy +/- 0.005mm, Repeatability +/- 0.003mm. In 4-axis turning machine, Axis represents as work piece rotation and spindle movement in x, y, z directions.

Fig shows 4-axis CNC MORI SIEKI turning machine

Selection of tools:

Selection of tools plays an important role in manufacturing any component. Proper tools must be selected otherwise in manufacturing process improper tools results in damage of work piece or damage to the tools, tool holders. Suitable tools for manufacturing support are listed below

OD_80_L facing

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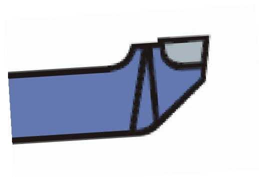
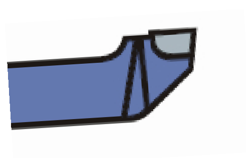
OD_80_L rough

OD_55_L finish



ID_80_L rough



ID_55_L finish

Sequence of operations performed on support component:

Sequence of operations performed on support in NX-CAM software are listed below

TURNING OPERATIONS

- Facing
- Rough_Turn_OD
- Rough_Back_Turn
- Finish_Turn_OD
- Groove_OD
- Rough_Bore_ID
- Groove_Face

MILLING OPERATIONS

- Drilling
- Planar Mill

Manufacturing process planning using Turning, Vertical Mill.

<u>Turning operations:</u>

Below image shows the blank and part of support

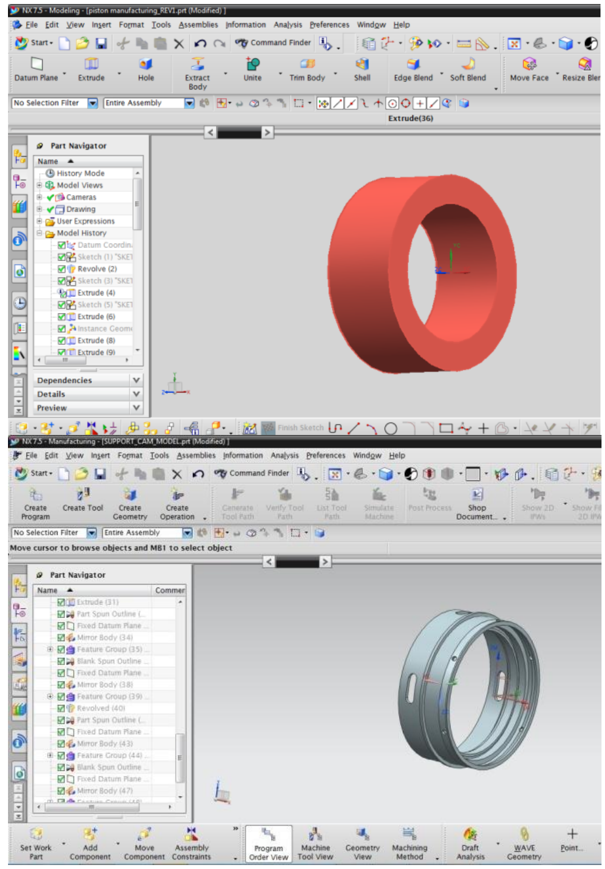


Fig shows blank and Part

Below image shows the spun generated for turning operation

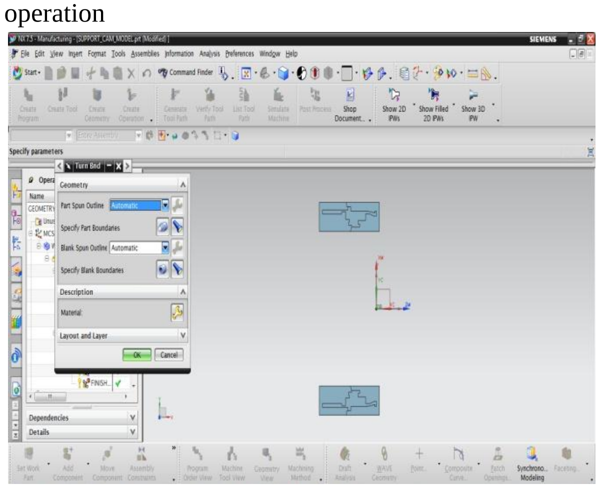


Fig shows spun of support

In turning operations tool path will be generated on spun and tool verification also done on spun.

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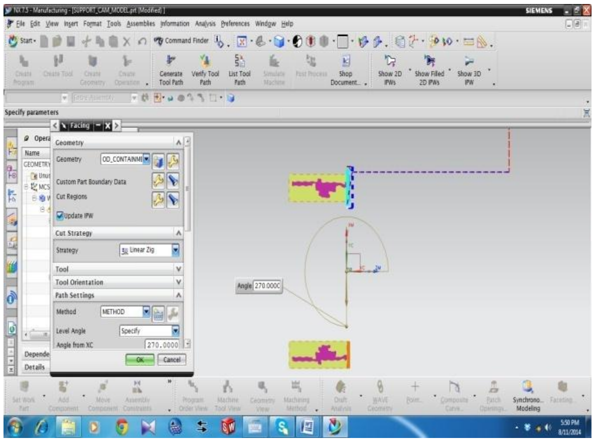
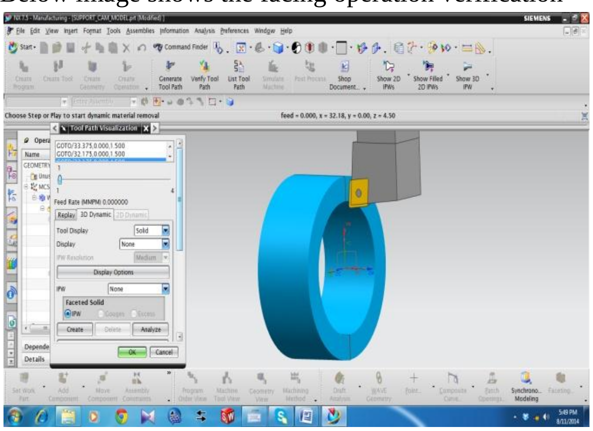
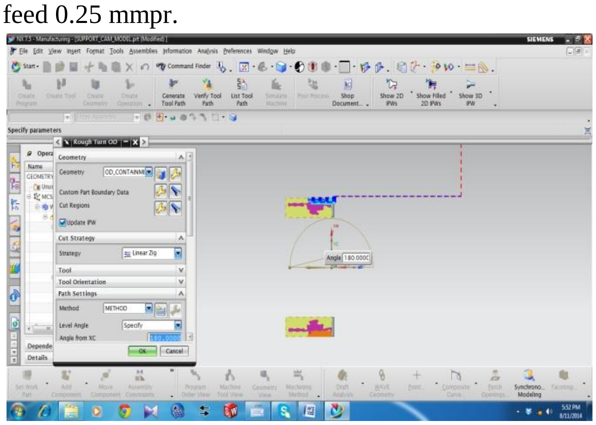
Below image shows the facing operation on bulk head support maintaining speed at 1500rpm and feed 0.25 mmpr.



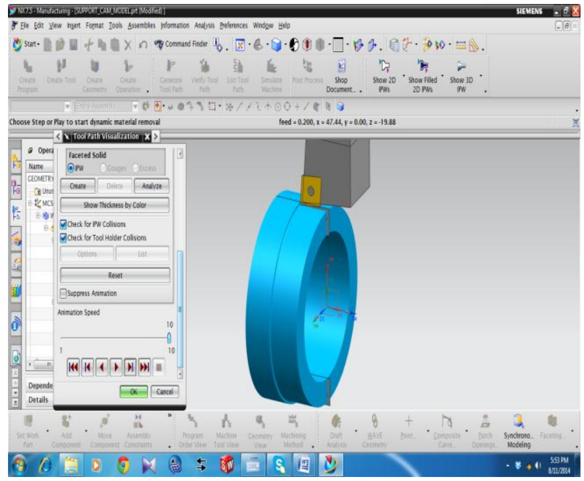
Below image shows the facing operation verification



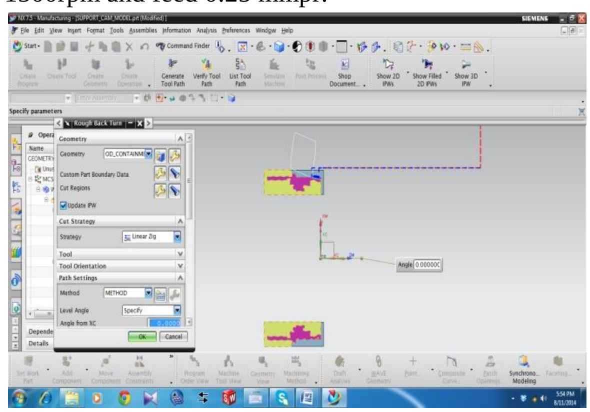
Below image shows the Rough turn OD operation on bulk head support maintaining speed at 1500rpm and feed 0.25 mmpr.



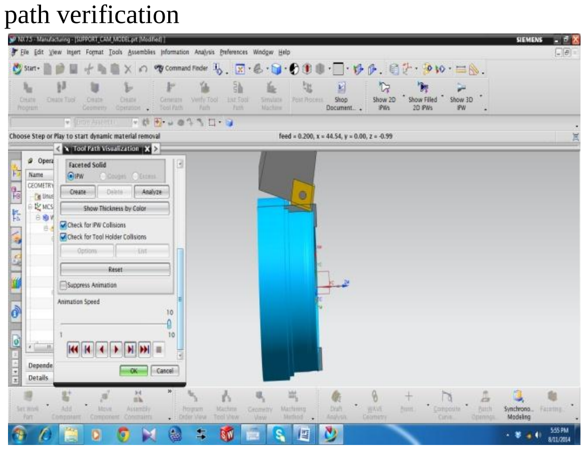
Below image shows the Rough turn OD tool path verification



Below image shows the Rough back turn OD operation on bulk head support maintaining speed at 1500rpm and feed 0.25 mmpr.



Below image shows the Rough back turn OD tool path verification



Below image shows the Rough Bore ID operation on bulk head support maintaining speed at 1500rpm and feed 0.25 mmpr.

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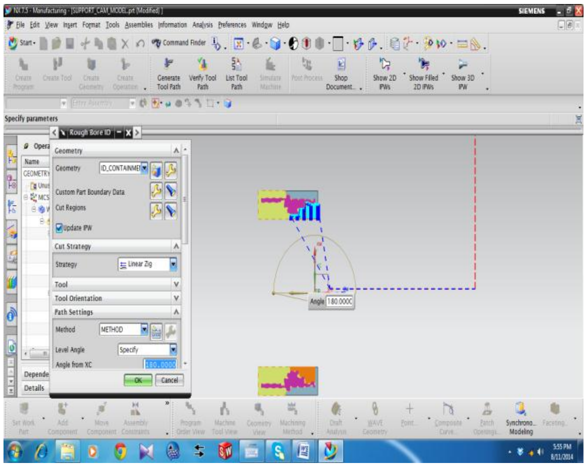
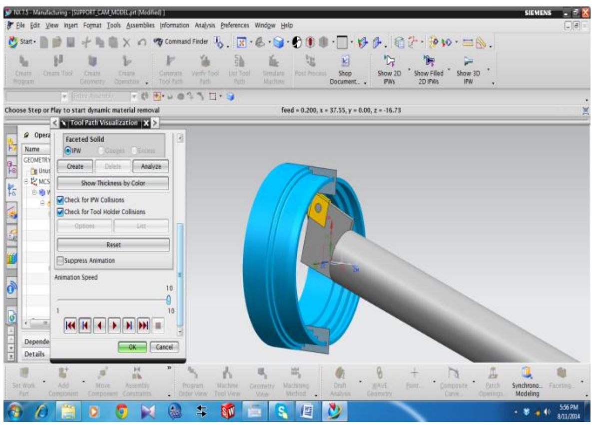
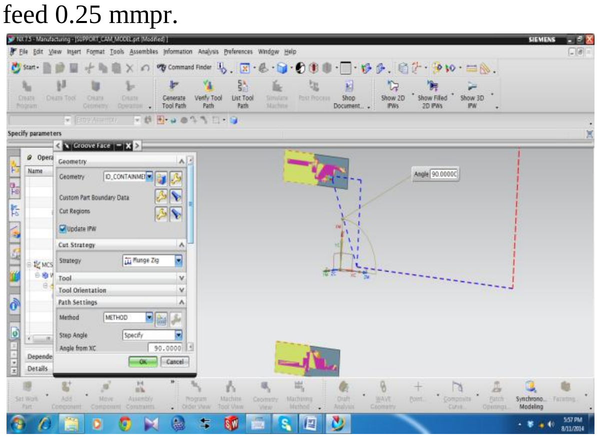


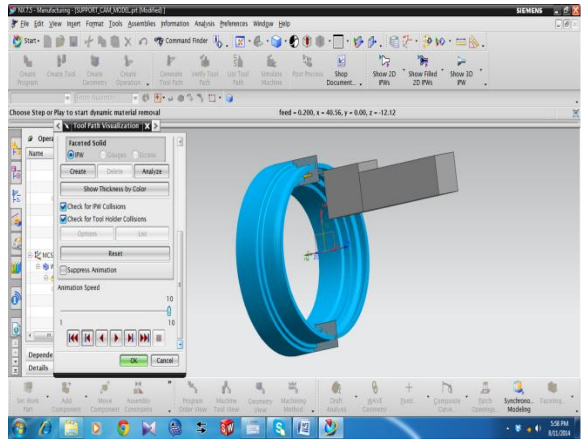
Below image shows the Rough Bore ID tool path verification



Below image shows the Groove face operation on bulk head support maintaining speed at 1500rpm and feed 0.25 mmpr.

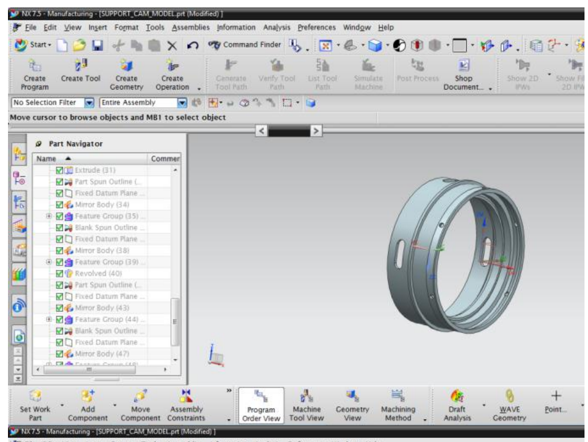


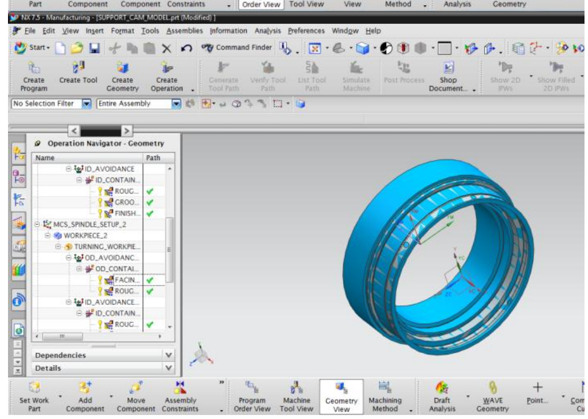
Below image shows the Groove face tool path verification



Set up_2 in turning operation:

Part & blank:





This IPW will be the blank for setup_2. After setup_1 operations this component is loaded reversely on the turning machine operations.

Below image shows the facing operation on bulk head support maintaining speed at 1500rpm and feed 0.25 mmpr.

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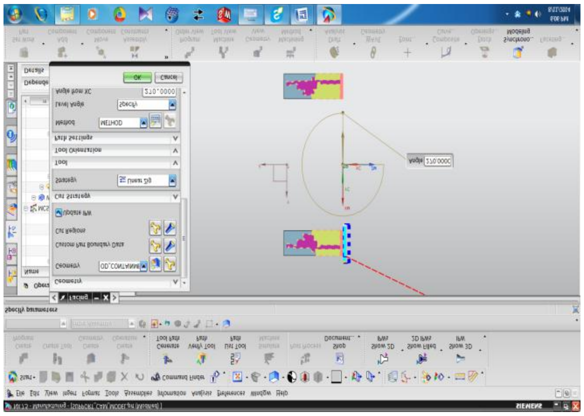
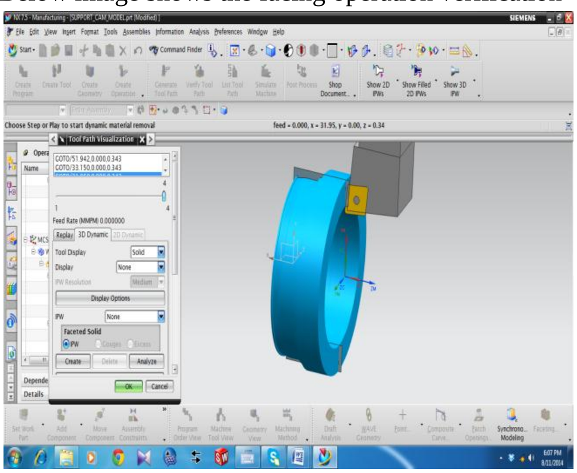
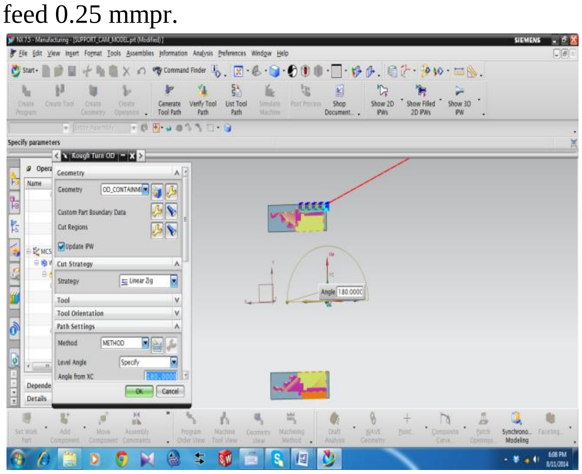


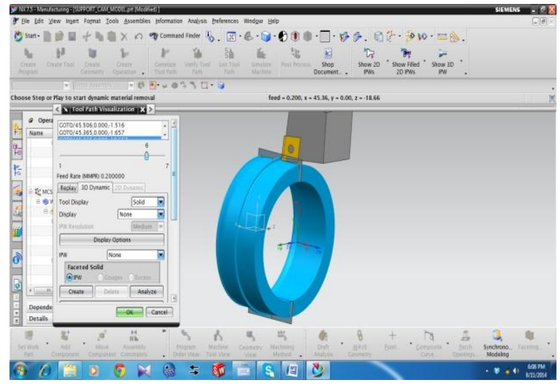
Below image shows the facing operation verification



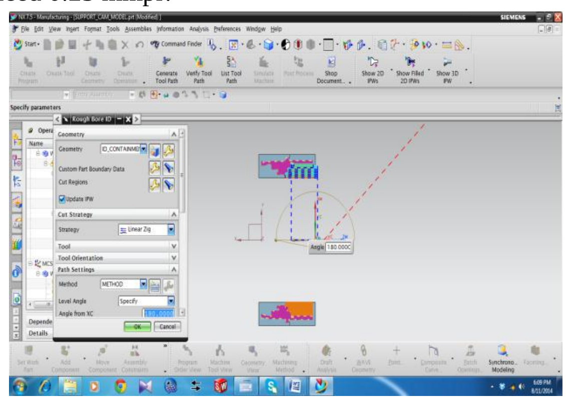
Below image shows the Rough turn OD operation on bulk head support maintaining speed at 1500rpm and feed 0.25 mmpr.



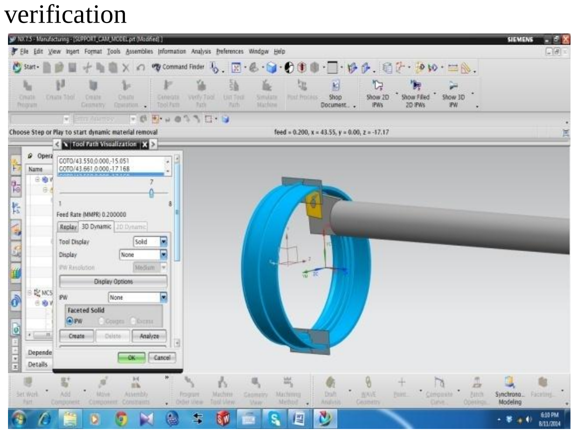
Below image shows the Rough turn OD tool path verification



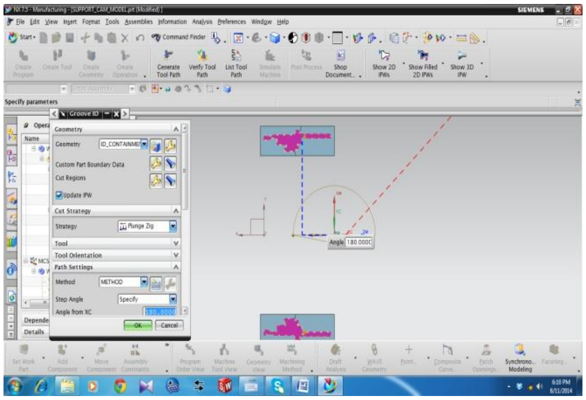
Below image shows the Rough Bore ID operation on bulk head support maintaining speed at 1500rpm and feed 0.25 mmpr.



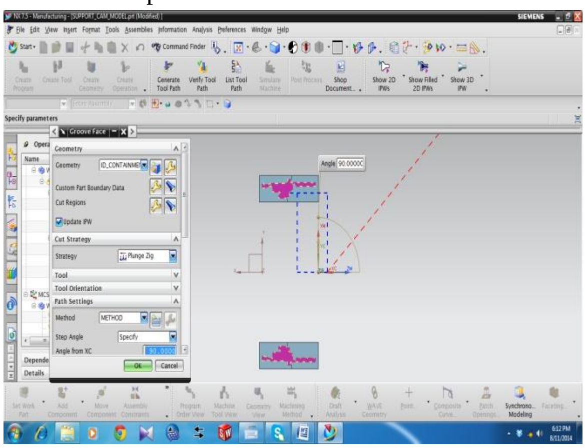
Below image shows the Rough Bore ID tool path verification



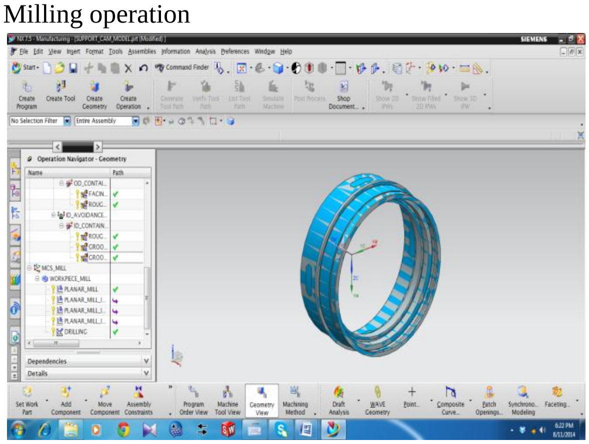
Below image shows the Groove ID operation on bulk head support maintaining speed at 1500rpm and feed 0.25 mmpr.



Below image shows the Groove face operation on bulk head support maintaining speed at 1500rpm and feed 0.25 mmpr.

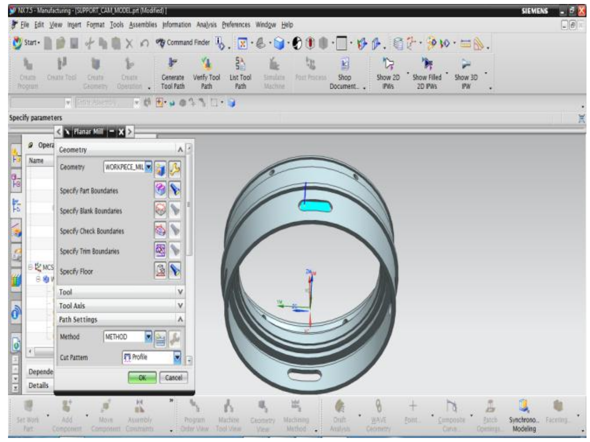


Milling operation

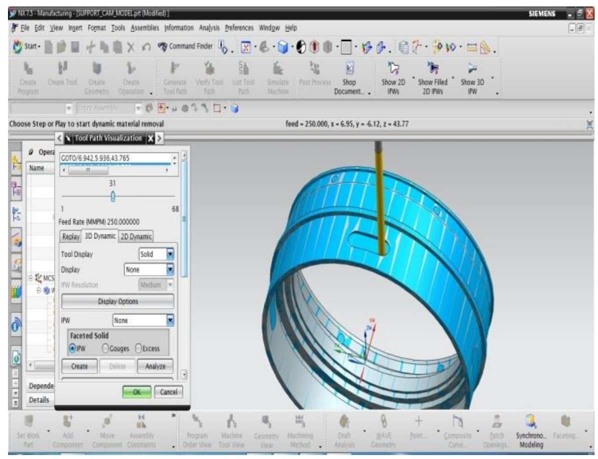


This IPW will be the blank for milling operation. After setup_2 operations this component is loaded on the milling machine.

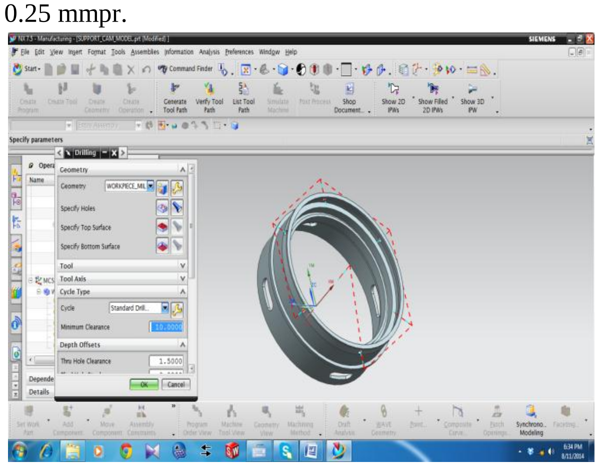
Below image shows the Planar mill operation on bulk head support maintaining speed at 1600rpm and feed 250 mmpm.



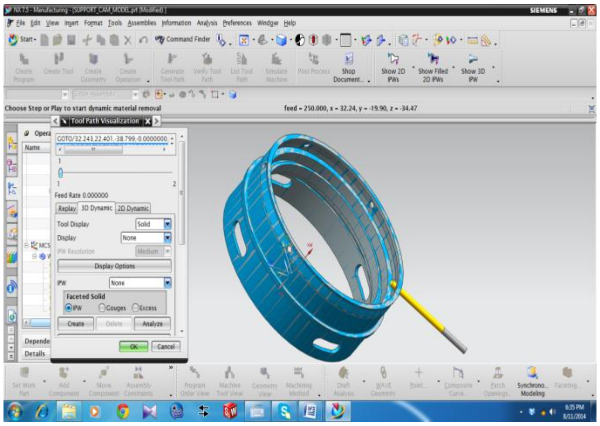
Below image shows the planar mill tool path verification



Below image shows the Drilling operation on bulk head support maintaining speed at 1500rpm and feed 0.25 mmpr.



Below image shows the Drilling tool path verification



Manufacturing process of bulk head support on CNC machine:

- Raw material is placed on the machine, and degree of freedom is arrested using fixtures.
- The raw material is loaded on the turning machine. Internal operations are done first because bulk head support component is thin walled with dimensions 0.8 to 7mm thickness.
- After completing internal operations external operations are done
- After completing turning operations the semi finished component is loaded on the milling machine for drilling operations.

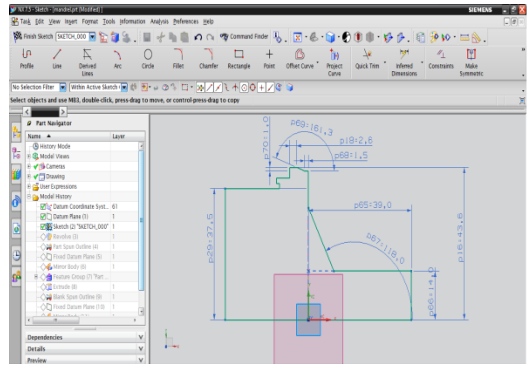
The component is damaged when external operations are performed on machine because the component became hallow after completing internal operations. To avoid damage there should be support from internal when external operations are performed. Irregularities in the surface may form nucleation sites for cracks or corrosion. In order to avoid this rejection problem mandrel is designed.

DESIGN OF MANDREL

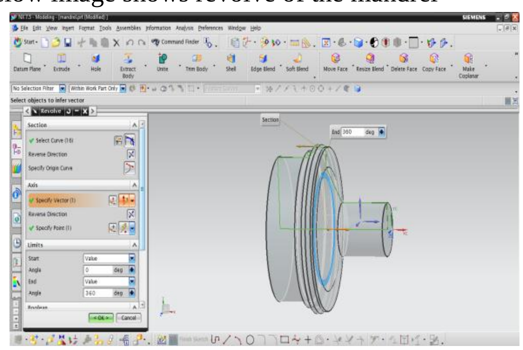
Mandrel is modeled by considering inner dimensions of Bulk head support. Inner dimensions of Bulk head support will be outer dimensions of mandrel.

2D Drawing for Mandrel

Below image shows sketch of mandrel

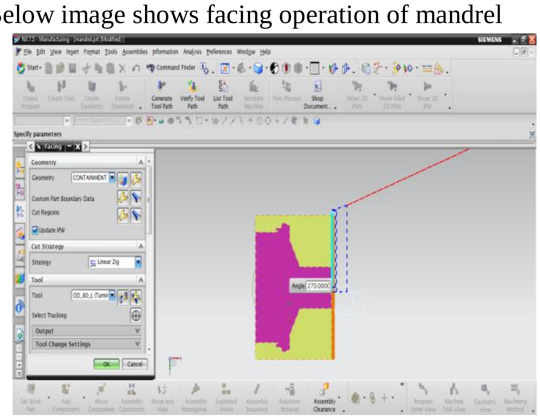


Below image shows revolve of the mandrel

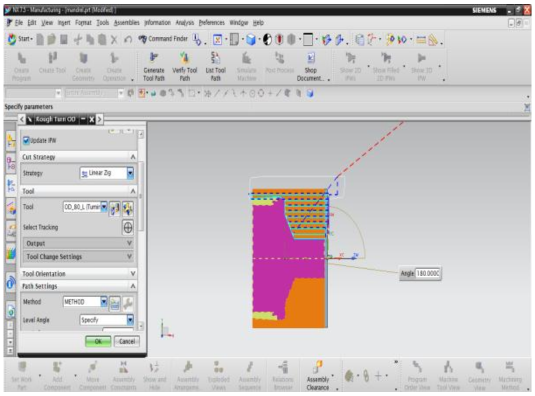


Tool path generation of mandrel:

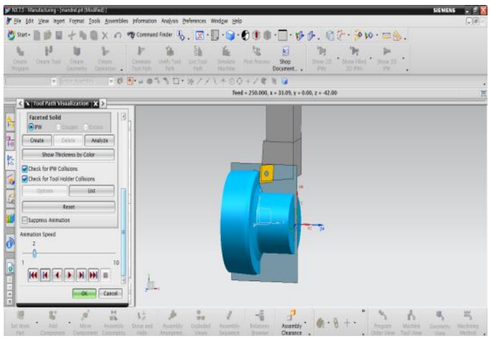
Below image shows facing operation of mandrel



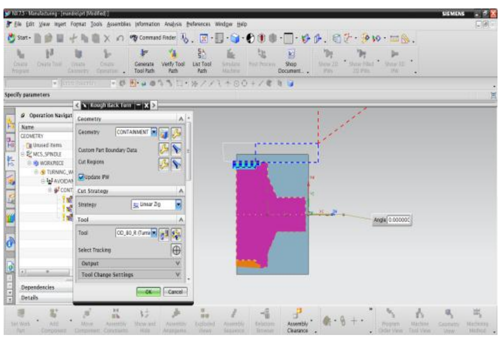
Below image shows Rough Turn_OD operation of mandrel



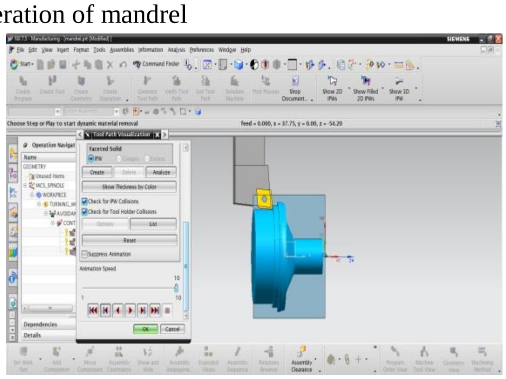
Below image shows verification of Rough Turn_OD operation of mandrel



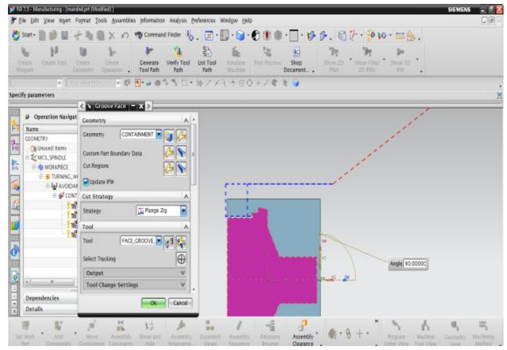
Below image shows Rough Back Turn operation of mandrel



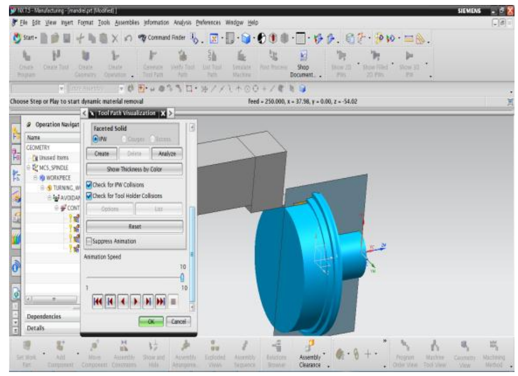
Below image shows verification of Rough Back Turn operation of mandrel



Below image shows Groove face operation of mandrel



Below image shows verification of Groove face operation of mandrel

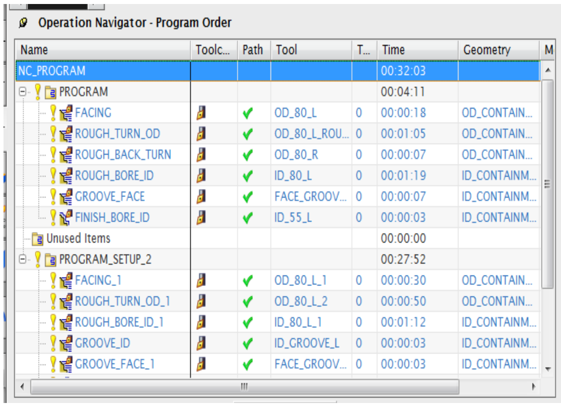


Bulk head support is again machined by using mandrel. After completing internal operation mandrel is used as jig. Mandrel makes contact inside the Bulk head component and this contact supports the component at high cutting speeds and gives high surface finish. The cutting speed preferred to get high surface finish is between 600-3300 rpm which is obtained from analysis report.

MANUFACTURING PROCESS OF SUPPORT ON CNC MACHINE.

The time taken by support component for manufacture on tuning and milling machines is 32m.

Below image shows manufacturing time of support component



Operation Navigator - Program Order

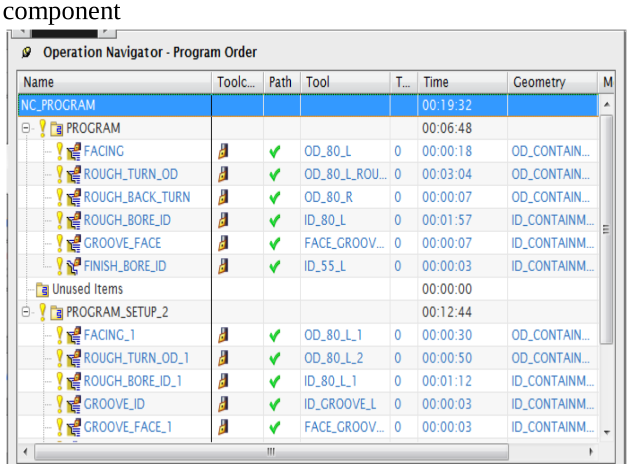
Name	Toolc...	Path	Tool	T...	Time	Geometry	M
NC_PROGRAM					00:32:03		
PROGRAM					00:04:11		
FACING		✔	OD_80_L	0	00:00:18	OD_CONTAIN...	
ROUGH_TURN_OD		✔	OD_80_L_ROU...	0	00:01:05	OD_CONTAIN...	
ROUGH_BACK_TURN		✔	OD_80_R	0	00:00:07	OD_CONTAIN...	
ROUGH_BORE_ID		✔	ID_80_L	0	00:01:19	ID_CONTAINM...	
GROOVE_FACE		✔	FACE_GROOV...	0	00:00:07	ID_CONTAINM...	
FINISH_BORE_ID		✔	ID_55_L	0	00:00:03	ID_CONTAINM...	
Unused Items					00:00:00		
PROGRAM_SETUP_2					00:27:52		
FACING_1		✔	OD_80_L_1	0	00:00:30	OD_CONTAIN...	
ROUGH_TURN_OD_1		✔	OD_80_L_2	0	00:00:50	OD_CONTAIN...	
ROUGH_BORE_ID_1		✔	ID_80_L_1	0	00:01:12	ID_CONTAINM...	
GROOVE_ID		✔	ID_GROOVE_L	0	00:00:03	ID_CONTAINM...	
GROOVE_FACE_1		✔	FACE_GROOV...	0	00:00:03	ID_CONTAINM...	

Manufacturing process planning using Turning-mill machine

- Raw material is placed on the machine, and degree of freedom is arrested using fixtures.
- The raw material is loaded on the turn-mill machine. ID & OD operations and grooving operations are done as well as milling operations also done on the raw material because it is 4-axis turn-mill machine and it is capable to do milling operations and drilling operations.

The time taken by piston component for manufacture on tuning-mill machines is 19m 32sec.

Below image shows manufacturing time of support component



Operation Navigator - Program Order

Name	Toolc...	Path	Tool	T...	Time	Geometry	M
NC_PROGRAM					00:19:32		
PROGRAM					00:06:48		
FACING		✔	OD_80_L	0	00:00:18	OD_CONTAIN...	
ROUGH_TURN_OD		✔	OD_80_L_ROU...	0	00:03:04	OD_CONTAIN...	
ROUGH_BACK_TURN		✔	OD_80_R	0	00:00:07	OD_CONTAIN...	
ROUGH_BORE_ID		✔	ID_80_L	0	00:01:57	ID_CONTAINM...	
GROOVE_FACE		✔	FACE_GROOV...	0	00:00:07	ID_CONTAINM...	
FINISH_BORE_ID		✔	ID_55_L	0	00:00:03	ID_CONTAINM...	
Unused Items					00:00:00		
PROGRAM_SETUP_2					00:12:44		
FACING_1		✔	OD_80_L_1	0	00:00:30	OD_CONTAIN...	
ROUGH_TURN_OD_1		✔	OD_80_L_2	0	00:00:50	OD_CONTAIN...	
ROUGH_BORE_ID_1		✔	ID_80_L_1	0	00:01:12	ID_CONTAINM...	
GROOVE_ID		✔	ID_GROOVE_L	0	00:00:03	ID_CONTAINM...	
GROOVE_FACE_1		✔	FACE_GROOV...	0	00:00:03	ID_CONTAINM...	

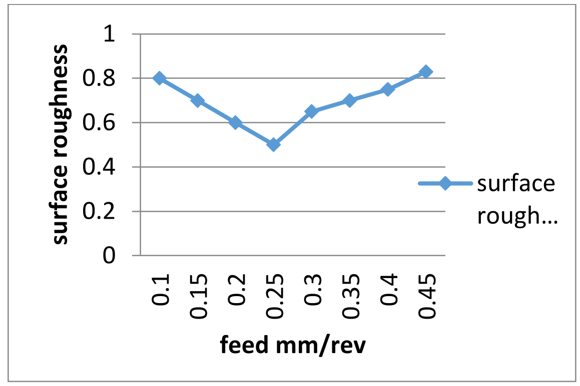
Graphical representations of surface roughness and feed at different speeds

Iterations are made to obtain high surface finish at varying speeds.

ITERATION 1

Surface roughness obtained at constant speed 700rpm. The values are plotted graphically.

SURFACE ROUGHNESS VS FEED

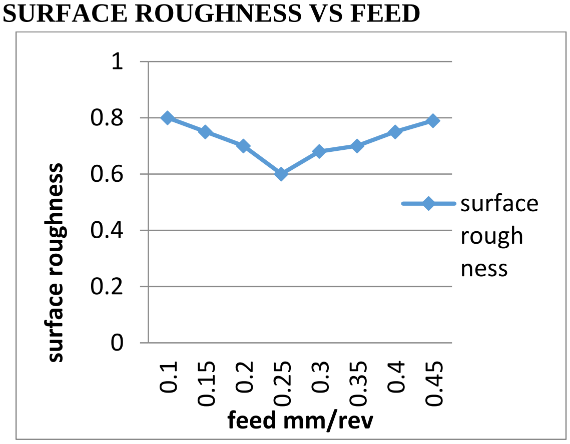


Under ideal conditions of machining at constant speed 700rpm, as the feed is increased from 0.1 to 0.45mm/rev surface roughness decreased slowly from 0.65 to 0.5(at f=0.25mm/rev) and then it increased.

ITERATION 2

Surface roughness obtained at constant speed 800rpm. The values are plotted graphically

SURFACE ROUGHNESS VS FEED



Under ideal conditions of machining at constant speed 800rpm, as the feed is increased from 0.1 to 0.45mm/rev surface roughness decreased slowly from 0.8 to 0.6(at f=0.3mm/rev) and then it increased.

ITERATION 3

Surface roughness obtained at constant speed 1300rpm. The values are plotted graphically

SURFACE ROUGHNESS VS FEED

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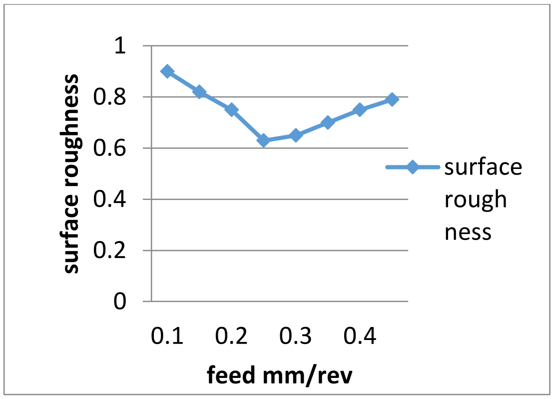


Under ideal conditions of machining at constant speed 1300rpm, as the feed is increased from 0.1 to 0.45mm/rev surface roughness decreased slowly from 0.9 to 0.63(at f=0.25mm/rev) and then it increased.

ITERATION 4

Surface roughness obtained at constant speed 1500rpm. The values are plotted graphically

SURFACE ROUGHNESS VS FEED

Graphical representation of surface roughness Vs feed

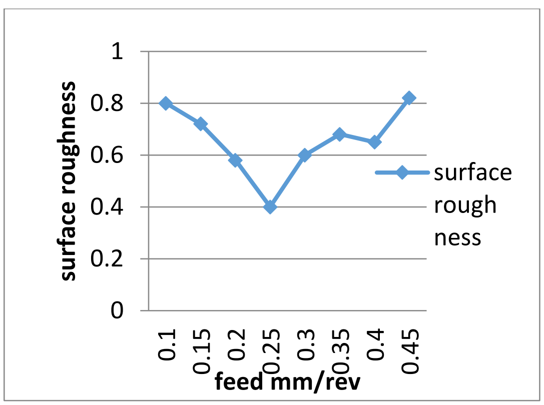


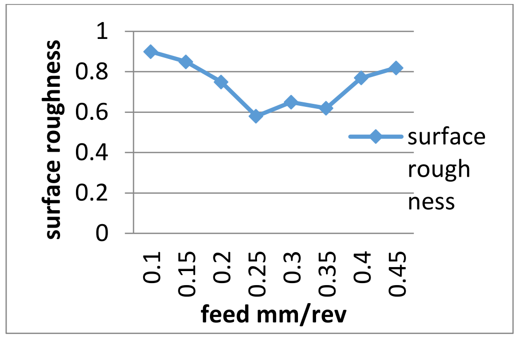
Fig shows Graph of feed and surface roughness

Under ideal conditions of machining at constant speed 1500rpm, as the feed is increased from 0.1 to 0.45mm/rev surface roughness decreased slowly from 0.8 to 0.4(at f=0.25mm/rev) and then it increased.

ITERATION 5

Surface roughness obtained at constant speed 1700rpm. The values are plotted graphically

SURFACE ROUGHNESS VS FEED



Under ideal conditions of machining at constant speed 1700rpm, as the feed is increased from 0.1 to 0.45mm/rev surface roughness decreased slowly from 0.9 to 0.57(at f=0.25mm/rev) and then it increased.

Hence the feed is optimized at 0.25mm/rev with minimum surface roughness no. 4. It is concluded that at feed 0.25mmpr and speed 1500 rpm we get high surface finish.

MANUFACTURING OF THE COMPONENT (support) ON MORISEIKI TURN MILL:

Raw material:

Fig shows raw material for support component

After Turing & drilling operations:

Final component

Fig. final component

RESULTS AND DISCUSSION

Rejection and Reworks of bulk head support

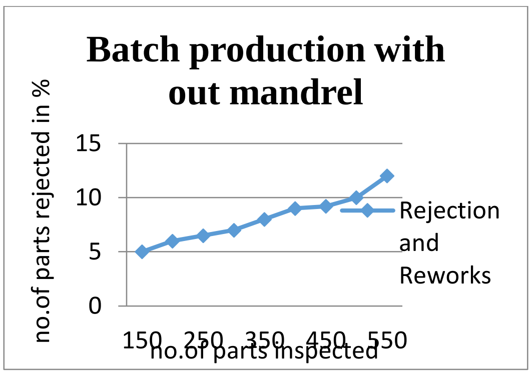


Fig shows Graph of rejection and reworks rate without mandrel

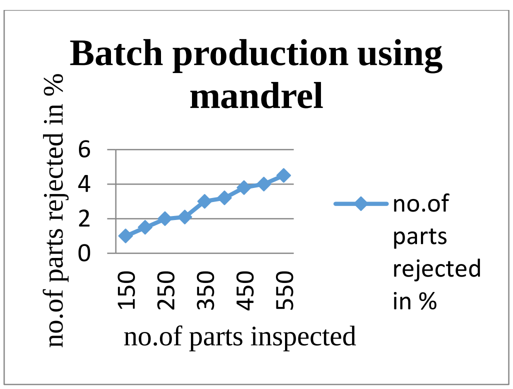


Fig shows Graph of rejection and reworks rate using mandrel

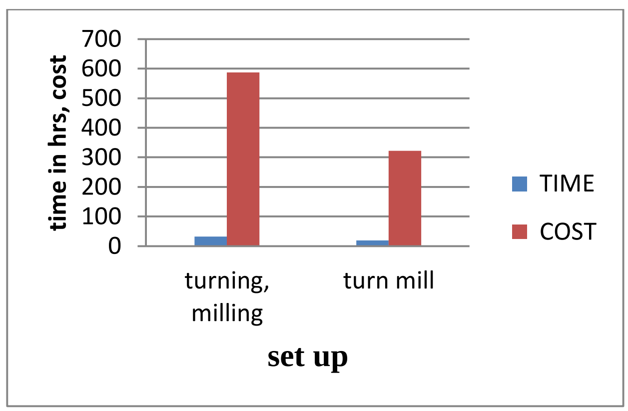
Graphical representation of rejection and reworks rate of bulk head support shows less rejection and reworks rate when manufactured by using mandrel which will arrest total degree of freedom and supports from internal and allows high cutting speed and increases production rate and reduces machining time, labour cost.

SET UP	TIME REQUIRED IN MINS.	MACHINING COST PER HOUR	MACHINING COST/PIECE
TURNING	08	RS.800/HR	RS.107
MILLING	24	RS.1200/HR	RS.480
TOTAL	32		RS.587

Turning & milling SETUP

SET UP	TIME REQUIRED IN MINS.	MACHINING COST	MACHINING COST/PIECE
TURN MILL	19:32	RS.1000/HR	322
TOTAL	19:32		322

NEW SETUP ON TURN MILL



GRAPH

CONCLUSION:

1) bulk head support is modeled using Unigraphics software NX_CAD
2) Mandrel is designed to support the component from internal and to reduce the rejection rate.
3) NC program is generated using Unigraphics software NX_CAM

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4) Optimized process plan for manufacturing support component is turn mill machine and it is graphically represented in results.
5) Graphical representation of feed and surface roughness is plotted with varying inputs. The feed is optimized at 0.25mm/rev with minimum surface roughness 0.4. It is concluded that at feed 0.25mmpr and speed 1500 rpm we get high surface finish.
6) Graphical representation of time and cost is shown in results along rejection and reworks rate.
7) The total time required for the manufacturing of the component is reduced.
8) The production cost of the product is also reduced.

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[3] C. Li, Y. Ding, and B. Lu, "Development and Key Technology inHigh Speed Cutting", J. Qingdao Technol. Univ., vol. 30, pp. 7-16,Feb. 2009.
[4] Z.-C. Lin, and J.-S. Chang, "The building of spindle thermal displacement model of high speed machine center", Int. J. Adv. Manuf. Technol., vol. 34, pp. 556-566, Sept. 2007.
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