Design And Process Optimization of A Support Component of A Dynamic Air Frame In A Missile

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Abstract- *A missile is a self-propelled precision -guided weapon vehicle system. Missiles have five system components: targeting and missile guidance, flight system, engine, air frame and warhead. Missiles are classified into following types based on purpose of use they are1. Surface To Surface 2. Air To Surface 3. Surface To Air.*

Support bulk head is a thinly walled component used to hold the bulk head of a missile. The support bulk head component requires inside as well as outside machining so it needs such a fixture which holds the component stiffly and tightly. For this reason, the component is clamped at top. Thus it requires CNC machine. This component is manufactured on a 4-axis turning machine to get the exact dimensions as shown in design and also to reduce unit cost and labor work.

The aim of this project is to obtain a stable speed range for machining of a thin-ribbed bulk head support structure with minimum deflection and high surface finish. This project is also aimed to optimize the manufacturing process of the support bulk head used in missiles. In this project we develop two different process plans along with NC part program to decrease the 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 and it is imported into ANSYS software to perform finite element analysis (FEA) to determine the optimum cutting speed. NX-CAM software shall be used to generate the NC program of Support bulk head.

Keywords- Uni Graphics, Dynamic Air frame, Optimized process plan, Milling Operation

I. INTRODUCTION

Support bulk head is a thinly walled component used to hold the bulk head of a missile. The support bulk head component requires inside as well as outside machining so it needs such a fixture which holds the component stiffly and tightly. For this reason, the component is clamped at top. Thus it requires CNC machine. This component is manufactured on a 4-axis turning machine to get the exact dimensions as shown in design and also to reduce unit cost and labor work.

High-speed machining is one of the very fast developing cutting processes having a fantastic advantages compared to conventional machining processes. It is an economically viable alternative to other forms of manufacturing such as casting, forming, and sheet metal with build-up. The high-speed milling processes can produce more accurate and repeatable results, as well as reduce the costs which are associated with assembly and fixture storage, by accepting several components to be combined into a monolithic machined part.

Manufacturing is the backbone of any industrialized nation. Its importance is emphasized by the fact that, as an economic activity, it comprises approximate 20–30% of the value of all goods and services produced. The condition of the modern Manufacturing procedures is one of the extreme complexity and technological sophistication.

II. UNIGRAPHICS

NX is one of the world’s most advanced and tightly integrated CAD/CAM/CAE product Development solution developed by Siemens PLM Software. The NX software integrates knowledge-based principles, geometric modelling, and industrial design, advanced analysis, concurrent engineering and graphic simulation. This software has powerful hybrid modelling tools by integrating constraint-based features like modeling and explicit geometric modeling. This software used to design solid components and make assemblies and also to perform engineering analyses such as stress analysis and mechanism simulation. It is also designed to create tool paths for computer-based manufacturing processes and to perform other engineering design activities in a single software environment.

III. LITERATURE SURVEY

The main objective of my project is to optimize the parameters which influencing the stiffness of the high-frequency milling spindle running at 12000 rpm with a power rating of 10 KW. The theoretical analysis has been carried out to find the spindle stiffness and minimize deflection by varying the bellow parameters: (1) Spindle diameter between the bearings, (2) Bearing arrangement, (3) Overhang of spindle nose from the front bearing. The static analysis was also carried out by using ANSYS software, and there is a good correlation between the results obtained from theoretical approach and the result obtained from ANSYS.

The static analysis, the thermal analysis and the model analysis harmonic response were done by using ANSYS software. The method to establish the finite element model of the bearing support by spring-damper element COMBIN 14 was investigated and tested. Results of the static analysis show that the stiffness of spindle is 207.66N/μm, which is strong for a motorized spindle. The results of the modal analysis show that the first-order natural frequency of the spindle is 1054.6Hz, the first-order critical rotating speed is 63,276rpm which is away from the maximum rotating speed of the motorized spindle, 12,000rpm. The result of the thermal analysis shows that the thermal deformation of spindle is 6.56μm, which is too small to affect the precision of the spindle. The requirements of high-speed processing are met by analysing static and dynamic characteristics of the motorized spindle. The rationality of the given spindle structural design is verified by FEM analysis. The result shows that the method to establish the finite element model of the bearing support by spring-damper element applied to the spindle component analysis and optimization

To examine the performance of the high- speed electric spindle, the dynamic and static characteristics of the spindle are analysed by using the finite element analysis (FEA). To get the static stiffness and deformation of given spindle, static analysis of the spindle which is used in this project is carried out based on a simplified static analysis model by using ANSYS. By using ANSYS software we can also find the natural frequencies and mode shapes of the electric spindle. This project also studies the influences of the natural frequencies based on spindle span. To improve the quality of design of high-speed spindle, this project developed a mathematical models and software to simulate a rotation accuracy of the spindle which running on ball bearings.

IV. COMPUTER AIDED DESIGN (CAD)

4.1 3D MODELLING:

Bulk Head Support 2d Drawing:-

A 2D drawing is used to develop a 3D model for the component which is used in this project using Unigraphics NX 7.5 CAD software. Below images shows that the 2D drawings of the support with complete dimensions suits the best for manufacturing the required component without any possible errors.

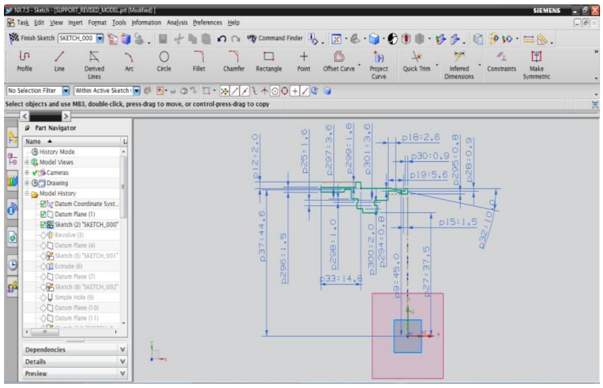


Figure : 2D drawings of the support with complete dimensions

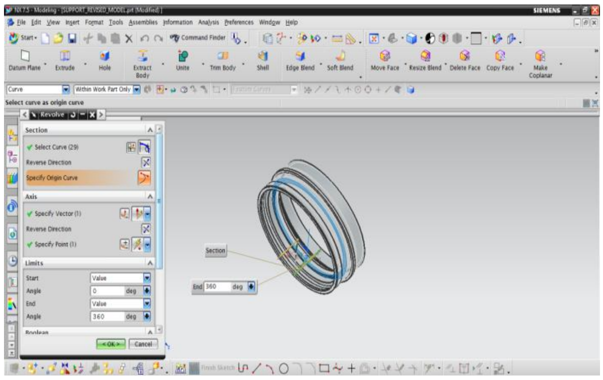


Figure : Revolve of 2D sketch of support

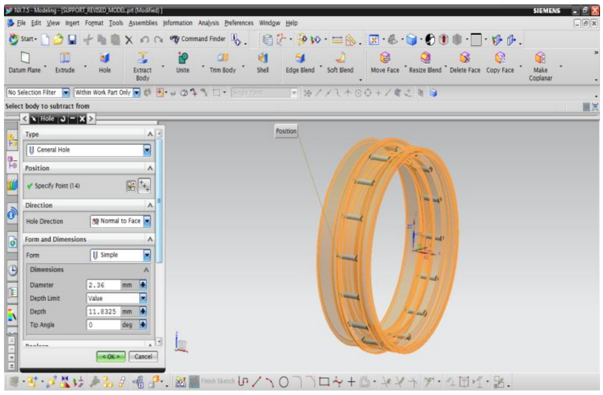


Figure : The holes on support part

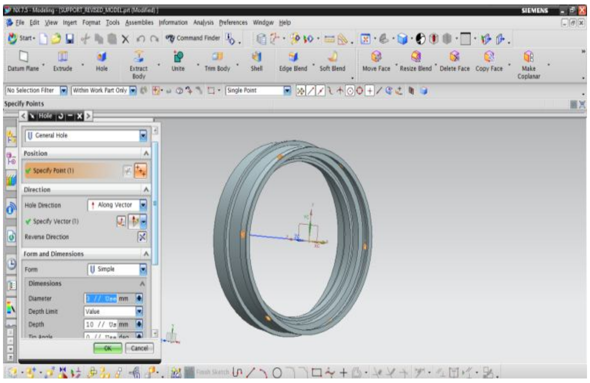


Figure : The holes one of the side of support

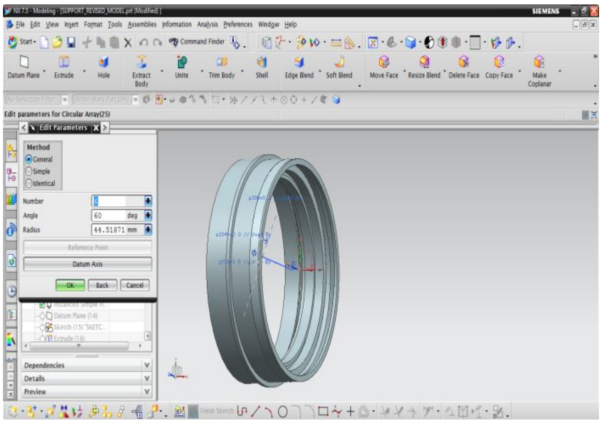


Figure: The circular array of side hole

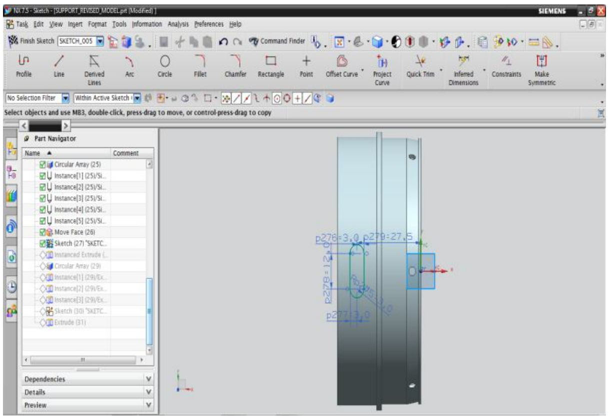


Figure: The sketch of slot on support part

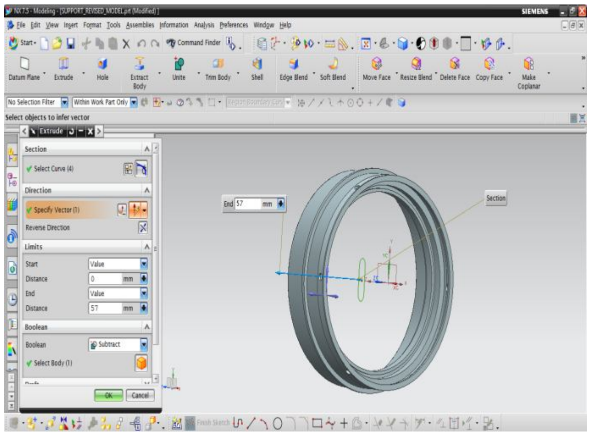


Figure: The Extrude of slot

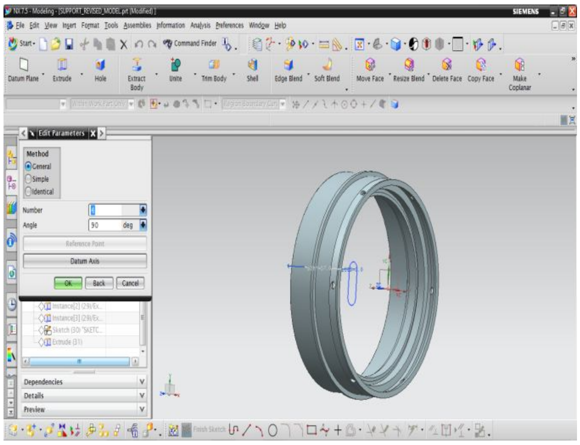


Figure: The circular array of slot

V. COMPUTER AIDED MANUFACTURING

CNC MACHINE USED IN THIS PROJECT:

In this project we used MORI SEIKI 4-AXIS CNC turning machine 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.

It has high rigidity with Integrated Turning Spindle. The spindle is directly coupled to the motor. The Rigid Turret with BIM (Built In Motor) Technology. Directly coupled Integrated driven tools. 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.

Figure : - 4-Axis CNC MORI SEIKI turning machine

TURNING OPERATIONS

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

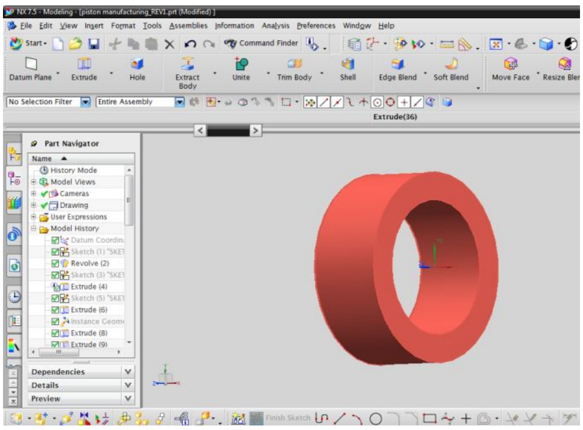
MILLING OPERATIONS:

- Drilling
- Planar_Mill

5.2 MANUFACTURING PROCESS PLANNING USING TURNING, VERTICAL MILL.

TURNING OPERATIONS:

Below image shows the blank and part of support



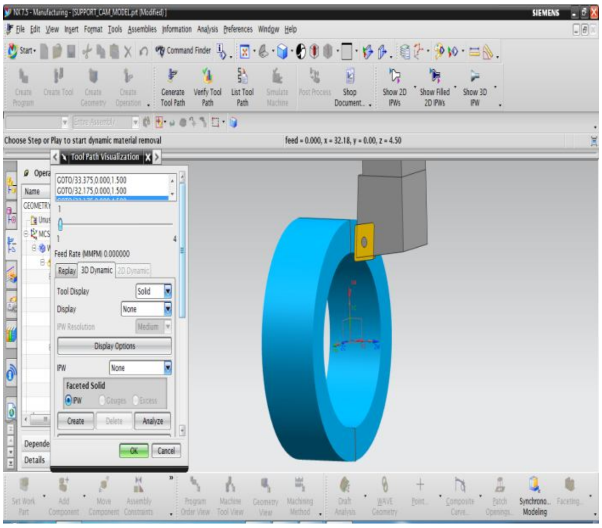


Figure The facing operation verification

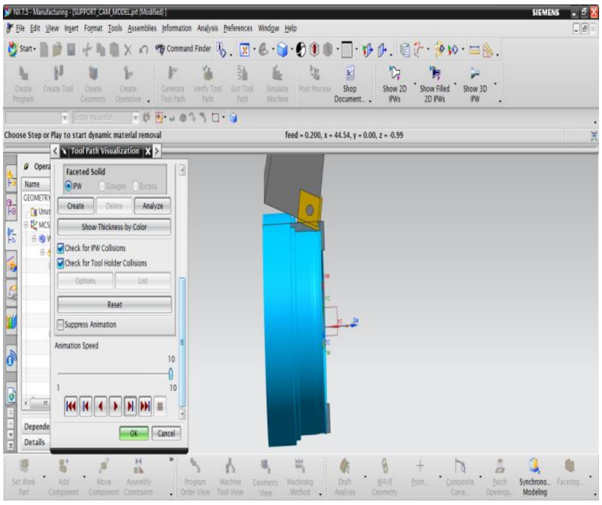
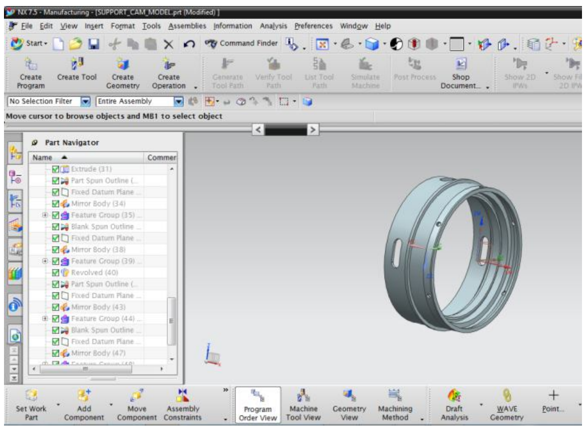


Figure The Rough Turn OD Tool Path Verification



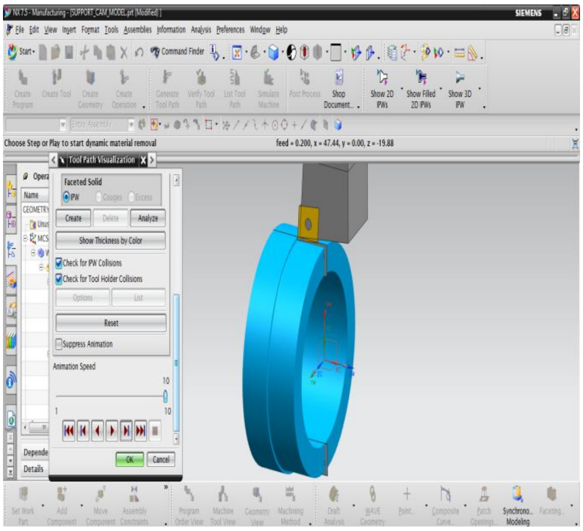


Figure: The Rough Back Turn OD Tool Path

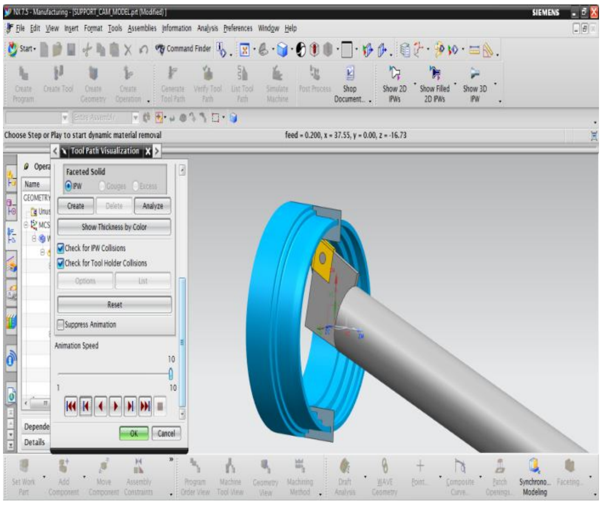


Figure: That Rough Bore ID Tool Path Verification

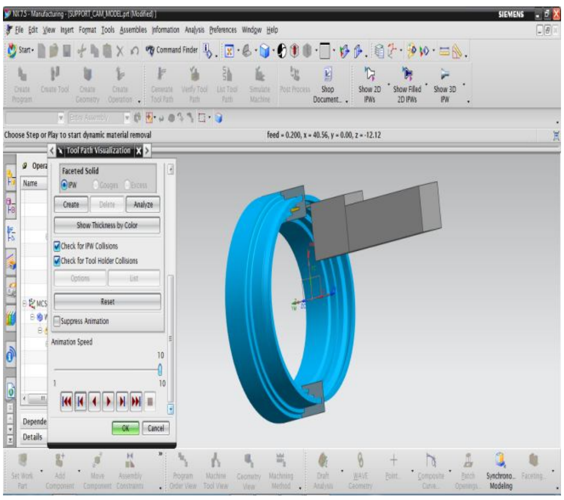


Figure The Groove Face Tool Path Verification

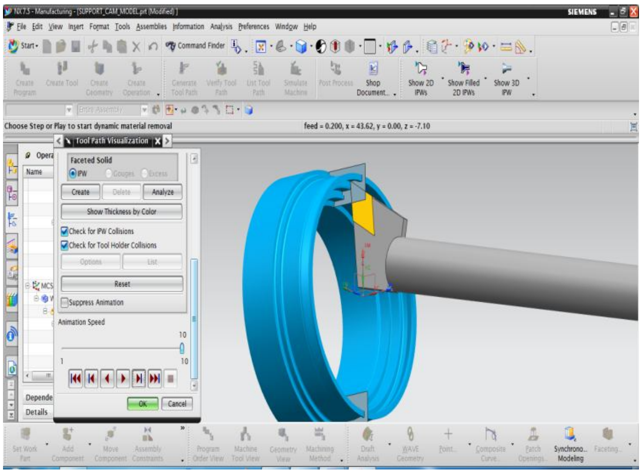


Figure: Finish bore ID tool path verification

5.3 MILLING OPERATION

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

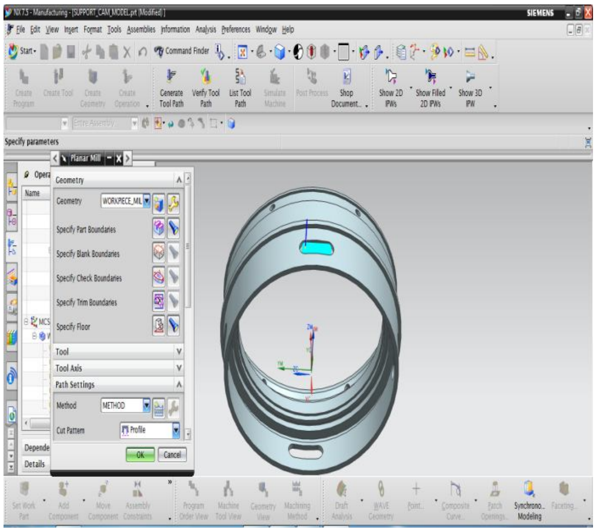


Figure: Shows the Planar mill operation on bulk head support maintaining speed at 1600rpm
and feed 250 mm/rev.

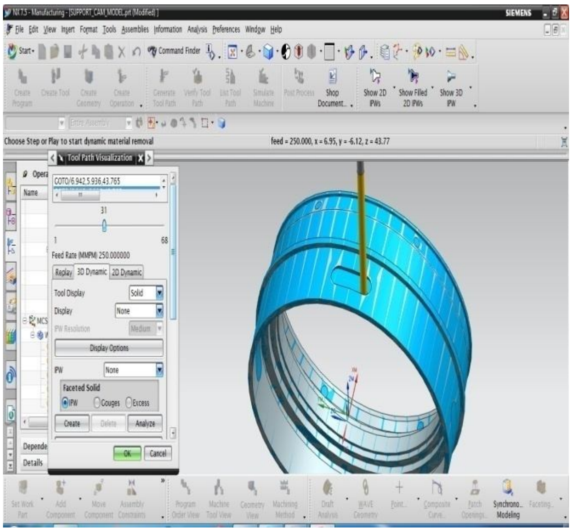


Figure: The planar mill tool path verification

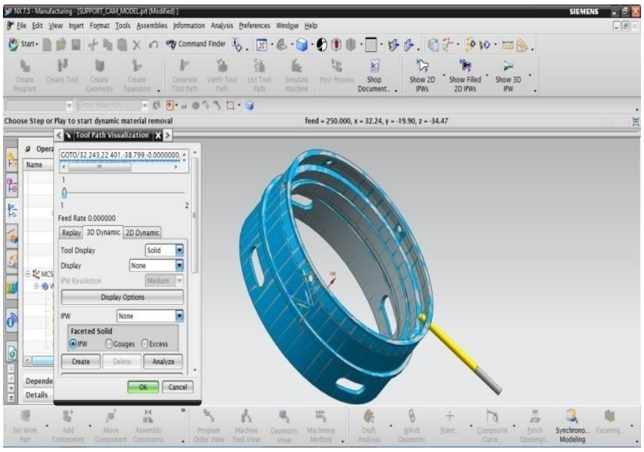


Figure: Drilling tool path verification

OPERATION LIST BY PROGRAM

PROGRAM NAME: TURNING

PROGRAM NAME: OD_OPERATIONS

OPERATION NAME	OPERATION DESCRIPTION	TOOL NAME
ROUGH_TURN_OD	turning/ROUGH_TURN_OD	OD_80_L
GROOVE_OD	turning/GROOVE_OD	OD_GROOVE_L
GROOVE_OD_1	turning/GROOVE_OD	OD_GROOVE_L

PROGRAM NAME: INTERNAL_OPERATIONS

OPERATION NAME	OPERATION DESCRIPTION	TOOL NAME
ROUGH_BORE_ID	turning/ROUGH_BORE_ID	ID_80_L
GROOVE_ID	turning/GROOVE_ID	ID_GROOVE_L
GROOVE_ID_1	turning/GROOVE_ID	ID_GROOVE_L

PROGRAM NAME: MILLING

OPERATION NAME	OPERATION DESCRIPTION	TOOL NAME
DRILLING_D2	drill/DRILLING	DRILLING_DIA2
DRILLING_D19	drill/DRILLING	DRILLING_DIA19
PLANAR_MILL_1	mill_planar/PLANAR_MILL	ENDMILL_D10
PLANAR_MILL_1_INSTANCE	mill_planar/PLANAR_MILL	ENDMILL_D10
PLANAR_MILL_1_INSTANCE_1	mill_planar/PLANAR_MILL	ENDMILL_D10
PLANAR_MILL_1_INSTANCE_2	mill_planar/PLANAR_MILL	ENDMILL_D10
PLANAR_MILL_1_INSTANCE_3	mill_planar/PLANAR_MILL	ENDMILL_D10
PLANAR_MILL_1_INSTANCE_4	mill_planar/PLANAR_MILL	ENDMILL_D10

TOOLING LIST

TURNING TOOLS

TOOL NAME	DESCRIPTION	NOSE RAD	TOOL ORIENT	ADJ REG
OD_80_L	Turning Tool-Standard	0.3000	5.0025	0
OD_GROOVE_L	Grooving Tool-Standard	0.3000	90.0456	0
OD_55_L	Turning Tool-Standard	0.3000	17.5089	0
ID_80_L	Turning Tool-Standard	0.3000	275.1395	0
ID_GROOVE_L	Grooving Tool-Standard	0.3000	270.1369	0

DRILLING TOOLS

TOOL NAME	DESCRIPTION	DIAMETER	TIP ANG	FLUTE LEN	ADJ REG
DRILLING_DIA2	Drilling Tool	2.0000	118.0000	35.0000	0
DRILLING_DIA19	Drilling Tool	25.0000	118.0000	35.0000	0

MILLING TOOLS

TOOL NAME	DESCRIPTION	DIAMETER	COR RAD	FLUTE LEN	ADJ REG
ENDMILL_D10	Milling Tool-5 Parameters	10.0000	0.0000	50.0000	0

VI. MANUFACTURING PROCESS OF BULK HEAD SUPPORT ON CNC MACHINE

The bellow process shows the details of manufacturing process of bulk head support

- The turning machine is placed by raw material. Internal operations are done first because bulk head support component is thinly walled component with fine dimensions 0.8 to 7mm thickness.
- After performing internal operations external operations are performed.

- After completing turning operation the semi finished component is loaded on the milling machine for drilling operations.

VII. DESIGN OF MANDREL

A mandrel is a one type of device which is used to hold the hollow work piece. The mandrel rotates with work piece at different varying speeds so proper care should be taken while designing a mandrel. In this project the mandrel is used to support the component internally and it allowing a high cutting speed. Without any support like mandrel in hollow side of thinly walled component gets damage, or scratches may form due to its thin wall when external operations are performing. To overcome this drawback the mandrel is designed to reduce rejection rate and to increase the production rate.

7.1 TOOL PATH GENERATION OF MANDREL

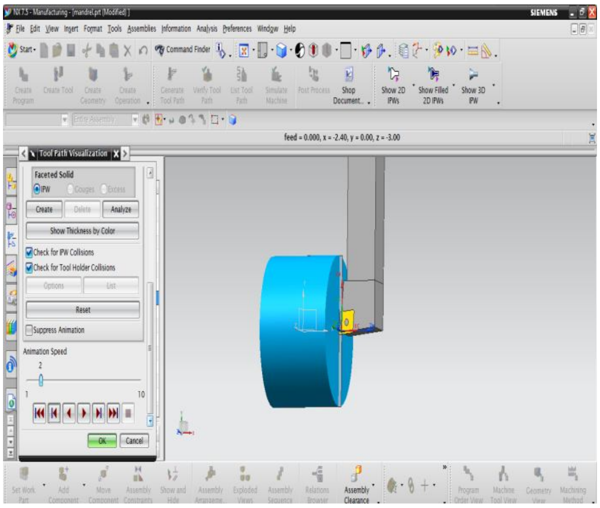


Figure Verification of facing operation of mandrel

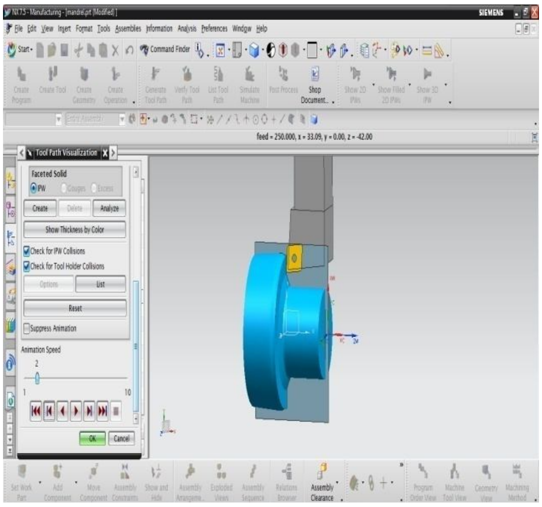


Figure: Verification of Rough Turn-OD operation on mandrel

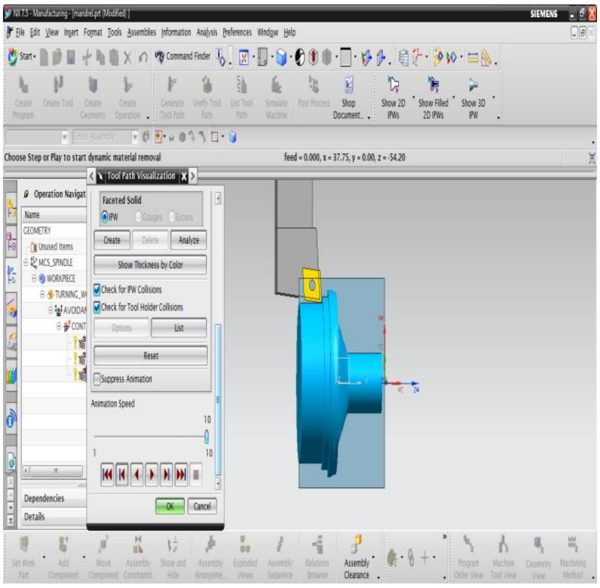


Figure: Verification of Rough Back Turn Operation of mandrel

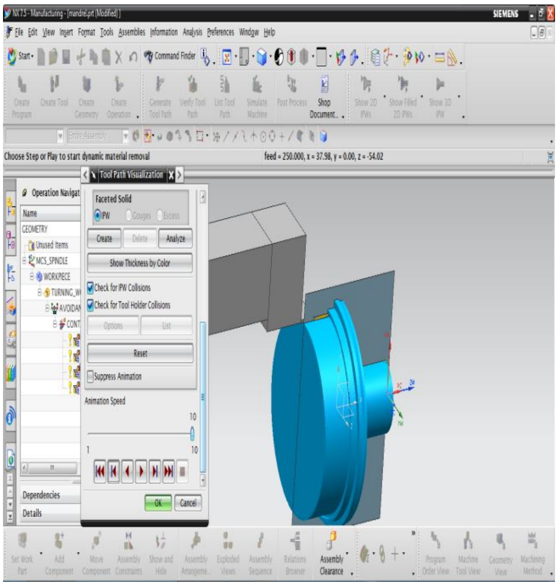


Figure: verification of Groove face operation of mandrel

Bulk head support is again internally machined to exact fit with mandrel. After completing internal operation component fit with mandrel. The mandrel acts jig itself. Mandrel makes contact with Bulk head component at inside and this contact supports the component at high cutting speeds and gives high surface finish. The cutting speed preferred to get high surface finish in this project is between 600-3300 rpm obtained from analysis report.

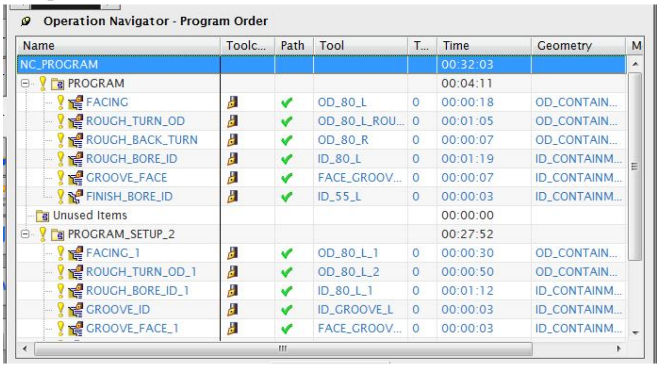
VIII. MANUFACTURING PROCESS OF SUPPORT USING CNC MACHINE

The bellow process shows the details of manufacturing process of support using CNC machine

- The raw material is located on the machine table, and degree of freedom (DOF) is seized by using fixtures.
- The turning machine is loaded by raw material. ID & OD operations and grooving operations are performed to raw material.
- After finishing of all turning operations, the semi finished component is loaded on the milling machine for drilling operations.

The time taken by Turning and milling machine to perform its operations on support is 32min.

Below image shows that manufacturing time of support component


Operation Navigator - Program Order

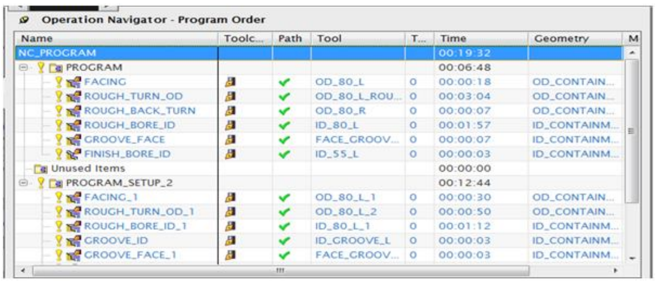
Name	Toolc...	Path	Tool	T...	Time	Geometry	M
NC_PROGRAM					00:32:03		
PROGRAM					00:04:11		
FACING		✔	OD_80_L	0	00:00:18	OD_CONTAIN...	
ROUGH_TURN_OD		✔	OD_80_L_ROU...	0	00:01:05	OD_CONTAIN...	
ROUGH_BACK_TURN		✔	OD_80_R	0	00:00:07	OD_CONTAIN...	
ROUGH_BORE_ID		✔	ID_80_L	0	00:01:19	ID_CONTAINM...	
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

- The raw material is located on the machine table, and degree of freedom (DOF) is rigidly fixed by fixtures.
- The turn-mill machine is loaded by raw material. ID & OD operations, milling operations, grooving operations are performed on the raw material because it is 4-axis turn-mill machine and it has a capable of doing milling operations and drilling operations.

The total time taken by 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...	

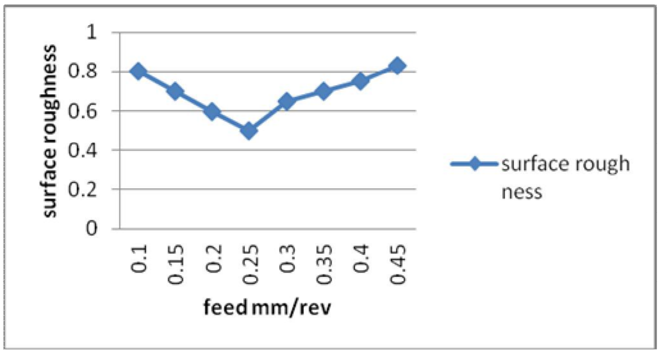
Graphical representations of surface roughness and feed at different speeds

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

ITERATION 1

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

SURFACE ROUGHNESS VS FEED

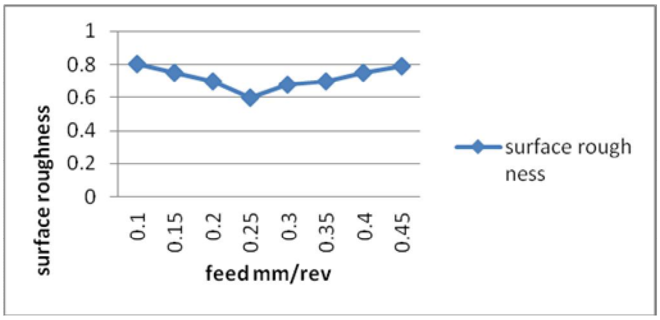


- Under ideal conditions of machining at constant speed 700rpm, as the feed increased from 0.1 to 0.45mm/rev surface roughness decreased slowly from 0.65 to 0.5(at f=0.25mm/rev), and then it increased.

ITERATION 2

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

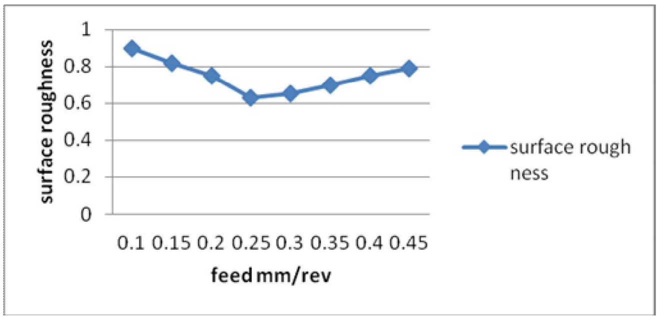
SURFACE ROUGHNESS VS FEED



- 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 plotted graphically **SURFACE ROUGHNESS VS FEED**



- Under ideal conditions of machining at constant speed 1300rpm, as the feed 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 plotted graphically **SURFACE ROUGHNESS VS FEED**

Graphical representation of surface roughness Vs feed

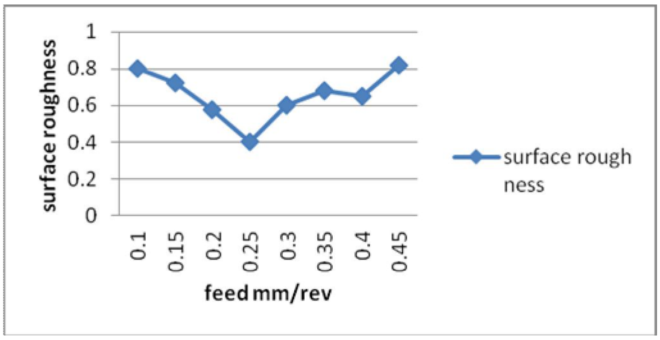
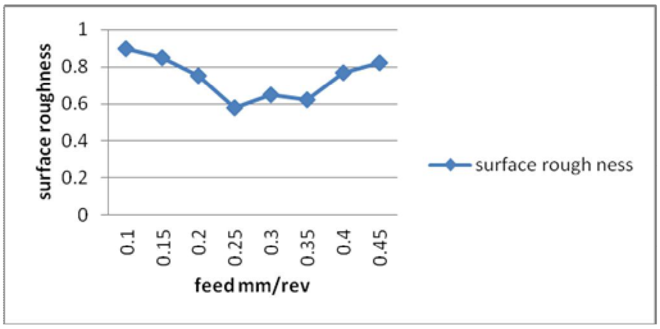


Figure: Graph of feed and surface roughness

- Under ideal conditions of machining at constant speed 1500rpm, as the feed 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 plotted graphically **SURFACE ROUGHNESS VS FEED**



- Under ideal conditions of machining at constant speed 1700rpm, as the feed 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 concluded that at feed 0.25mmpr and speed 1500 rpm we get a high surface finish.

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

Raw material:

Figure 48: - Raw material for the support component

AFTER TURING & DRILLING OPERATIONS:

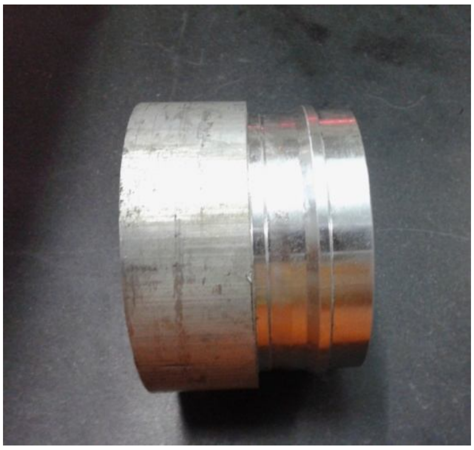
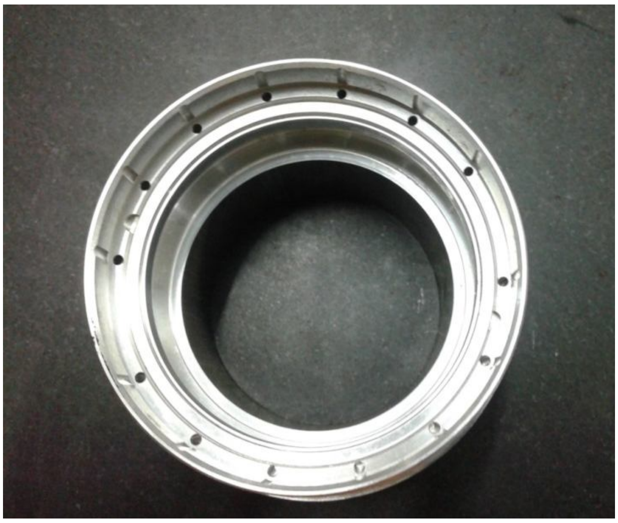


Figure 49: - Component after turning & drilling operations

Final component



IX. RESULTS AND DISCUSSION

Rejection and Reworks of bulk head support: -

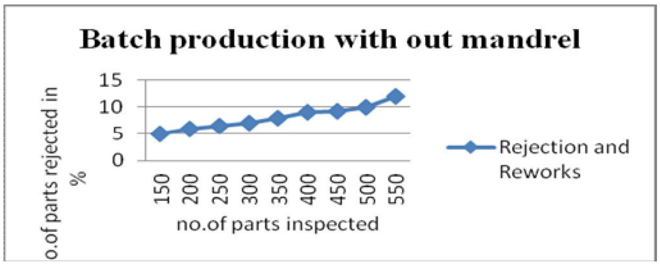


Figure: - Graph of rejection and reworks rate without mandrel

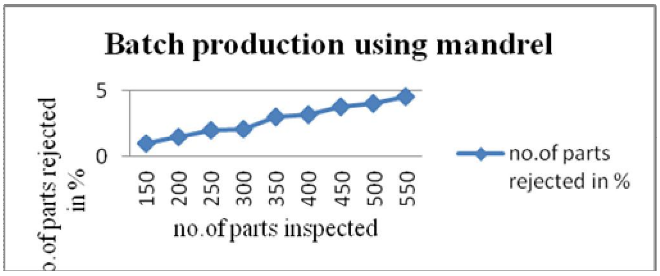


Figure: - Graph of rejection and reworks rate using mandrel

The above figure shows the 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(DOF), supports from internal side , allows high cutting speed , increases production rate, reduces machining time and labour cost.

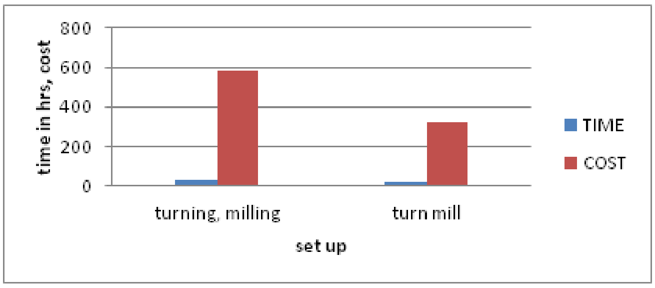
Values are taken when components manufactured on different machines

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



X. CONCLUSION

1) Unigraphics software NX_CAD is used to modelled the bulk head support
2) The Mandrel is designed to support the component from internal and to reduce the rejection rate.
3) NC program is generated by NX_CAM
4) Optimized process plan for manufacturing of a support component is turned by milling machine, and it is graphically represented in results.
5) Graphical representation of feed and surface roughness plotted with varying inputs.
6) The feed 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 a high surface finish.
7) Graphical representation of time and cost is shown in results along rejection and reworks rate.
8) The total time required for producing of the component reduced.
9) The production cost also reduced.

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