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OPTIMISING THE TOTAL COST AND QUALITY OF MANUFACTURING OF HPT NOZZLE IN AL31FP ENGINE OF SU-30 AIRCRAFT

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Abstract—*In view of the development of sophisticated technological equipment and machinery, there has been an increasing demand to manufacture complicated components with high accuracy in large quantities. Production of these components calls for machine tools which can be set up fairly and rapidly without much attention. The present work deals with High Pressure Turbine Nozzle. High pressure turbine is a critical component in the AL31FP* Engine assembly. This is mounted over the High Pressure Turbine Shaft (HPTS). Its main functions are to support the HPTS and to prevent the leakage through air seals and oil seals.*
The project work focuses to optimize the total cost and quality of the product as well as study in detail the cause of frequent breakage of brazed tools, idle times, unnecessary movement of men and material in the existing process. A critical analysis is being made based upon root cause analysis, data defining all causes related to higher cycle time and use of large no of cutting tools which causes various mismatches in critical contour areas of the part. By optimizing the cycle time and service level of the part which will help to overcome the problem of higher cycle time and large amount of rework, in the manufacture of High Pressure Turbine Nozzle (HPT Nose).This effort will help in eliminating all types of wastes so that the total work content will become equal to the basic work content in the whole process.

Keywords: *UG program, Part Technology.*

1. INTRODUCTION

HPT Nose will be connected with the high pressure turbine disc and houses ring of oil sealing (graphite assembly) which arrest the leakage of air and oil, and it also houses the low pressure turbine with help of labyrinth, and placed adjacent to the combustion chamber where the temperature is in the range of 740ºC -765ºC. Again the HPT Nose holds and balances the high pressure turbine with 24 numbers of bolts. So when the hot gas expands in the high pressure turbine, it will damage the HPT Nose. To avoid this and to retain its original shape and size against creep HPT Nose are made of Nickel base alloy (73 % Nickel). As the HPT Nose is subjected to very high temperature, there should be no miss matching on the machined surface of the part, because the miss match on the machined surface gives rise to stress concentration and variations.

Since many components are mounted on the HPT Nose its configuration becomes complicated and again mating of the components requires close dimensional tolerances, which is difficult to achieve during present practice of machining.

HPT Nose as Nickel base alloys are tougher in nature and difficult to machine .There is frequent breakage of inserts during machining which consequently creates problem in taking tool geometry offsets. While doing backside machining the tool gets fouled with the provided technological jaw and uniformity in dimension is not produced.

1.1 THE PROBLEM DEFINITION

To find and establish a process which will help to overcome the problem of higher cycle time and large amount of rework, in the manufacture of High Pressure Turbine Nozzle (HPT Nose).This effort will help us in eliminating all types of wastes so that the total work content will become equal to the basic work content in the whole process.

2. METHODOLOGY

The Russian technology has being used perform more operations for every part of engine

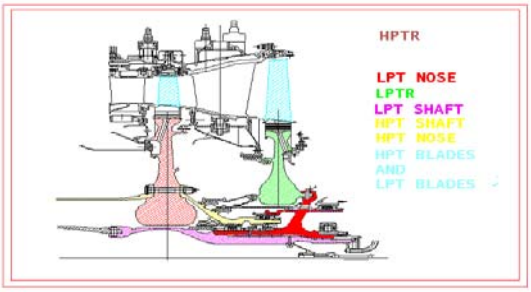


Fig. 2.1

ASSEMBLY OF HPT NOSE WITH THE OTHER COMPONENTS

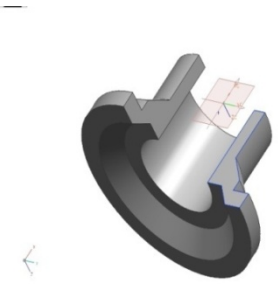


Fig. 2.2

3D VIEW OF THE BLANK

(LEADINIG EDGE OF HPTR)

The figure 2.1 shows schematic representation of HPT nose connected with various components in AL31FP ENGINE. Figure 2.2 shows billet of HPT nose in 3D view which has drawn on NX software to analyse the part.

2.1 CNC SHOP

The CNC shop is equipped with state of the art CNC machine to meet the manufacturing requirement of all critical components of AL31 FP engine. The shop is centrally air conditioned having covered area of 5000 Sq meters.

All the machines are connected to a centrally located modular UPS system. The qualities of electrical power supplied to the machines are free from all type of electrical disturbances. All the machines are provided with isolation foundation as per the guidance of machine maker. The shop is well lighted by powerful fluoresce light from the ceiling. In day time the building is so designed that sun light is available. The movement of jobs from machine to machine and other work area are done by over head crane. The CNC machines are provided with Siemens 840 D control System. All the machines are connected to the DNC system in the network. NC Program can be uploaded and downloaded for any location in the network. Machines like Mill Turn and Vertical Machining Centres are equipped with remote programming and diagnostic features, through analogue telephone line.

NC program is generated through Unigraphics NX-3 CAD/CAM software. This multi user package seats on high performance HP workstations. All the CAD/CAM workstations are connected to each other in the net. Virtual manufacturing is done with the help of UG verify before the program is transferred to the CNC machine. The sophisticated machines and software are backed by a team of highly dedicated, skilled work force, who are willing to take up the challenge of tomorrow.

2.2 DESCRIPTION OF THE PROBLEM

The following operations (43050, 43065, 43120, 43125, 43135, 43185, 43190 and 43195)* has to be performed on high pressure turbine nozzle (HPT NOSE) using Turning Centre and machining centre as per the supplied technology the cycle time is very high and these operations are consuming more number of cutting tools which leads in higher total cost and time. The operations NO 41030, 41035 and 43195 which are performing on conventional machines are consuming large amounts of setting time as well as more number of cutting tools. As per the supplied technological drawing of High Pressure Turbine Nozzle for operation No 43140, 43145, 43190 and 43195 are given in the following pages. 43140, 43145 operations are taking much longer time. As per technology they are two separate operations, so these operations are being done in two different fixtures because of their individual setup time .They are taking much longer time .As per technology 43190 is getting done in CNC shop and sending back to the turbine shop for the next operation (43195), So it is consuming a lots of time in the form of material movement and individual setup times of both the operations.

Now the current problem is resolve with the help of nx3 and nx6 software. With the help of this modelling program nx3 software we could able to process the part on the CNC machines like EMCO-T500-I AND VTC- TOSHULIN

*The details of operation code numbers are given the appendix

3. CRITICALLITY OF THE PROBLEM

The specific application of product is meeting the defence requirement of the nation. As explained earlier High Pressure Turbine Nozzle (HPT) plays a very vital role in the proper functioning of the Main shaft for the transfer of power in the engine. A slight deviation in its geometrical and dimensional specifications may cause severe problem in the engine. So utmost care should be taken to meet the technological requirements. Mismatching in the critical contour area of the HPT Nozzle is a major problem faced by the department. Again the use of more number of cutting tools consumes a lot of setting time. Programs generated on Unigraphics consumes a lot of time for the machining. All these problems finally lead to the higher cycle time for the said part.

4. CURRENT PROCEDURE ADOPTED FOR HPT NOSE

Currently the HPT Nose is being manufactured in a sequence of 57 operations. In that major operations are turning, milling, drilling, slotting and grinding. Rest of the operations are heat treatment operations and polishing, lapping, bench work, washing, marking etc. among these major operations are CNC milling, CNC turning and remaining all are conventional operations .For this operations the total cycle time i.e. standard

machine hour rate is 222.68124hrs. The total time to manufacture the part is very high and also the operations are getting deviated if we use technological tools.

There are 57 manufacturing operations and all of these operations being done with the specific fixtures, fixture cost for all these operations are very high, in some operations brazed tools are being used, if brazed tools are failed during the operations, the regrinding or replacing cost as well as the time is also too high. So as to avoid this we can use inserted tools which will give a long life, many times higher than the brazed tools and more over it would not take much time to change the insert as there is no need of changing total tool .

Major Operations are:

Operation	No of times
Turning	6
Drilling	6
Milling	2
Slotting	1
CNC Milling	2
CNC Turning	5

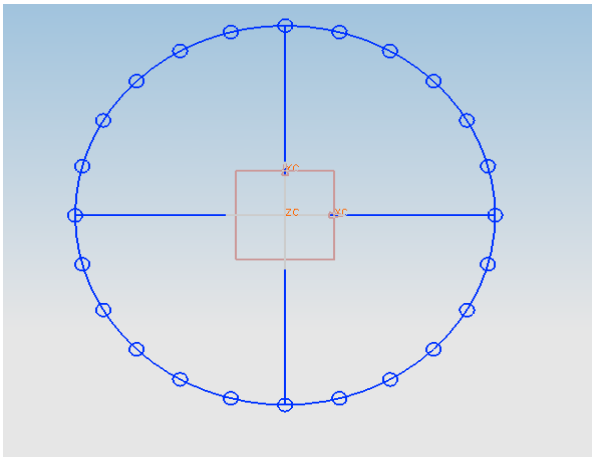
TOTAL SETUP TIME/part=52.255HRS

TOTAL UNIT TIME/part=170.42624

5.1 RESULTS & DISCUSSIONS

SOLUTION 1

Instead of doing the operation NO: 43140 and operation NO: 43145 separately and using two separate fixtures, it suggested to merge both of the operations and use a single fixture as shown in FIG 5.1. With this setup time of operation NO: 43145 can be eliminated and also the fixture for the operation NO: 43145 can be eliminated which leads in smoothness in operation and further total cost and cycle time also can be reduced



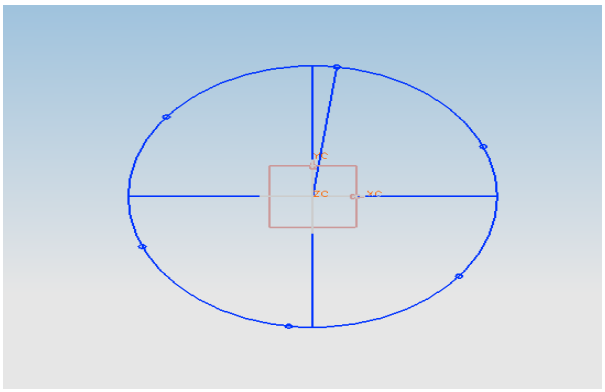


Fig. 5.1 A: Operation NO: 43140 (above) and 43145 (below) before clubbing

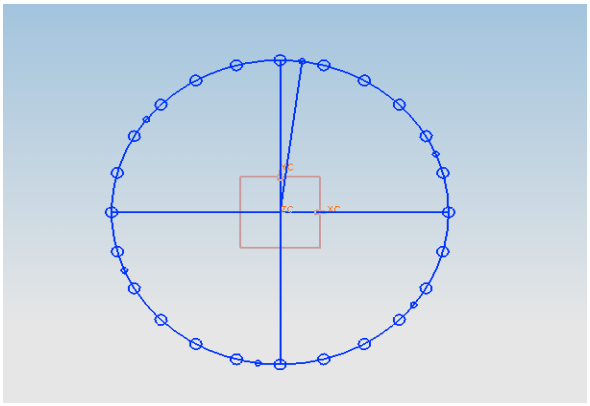
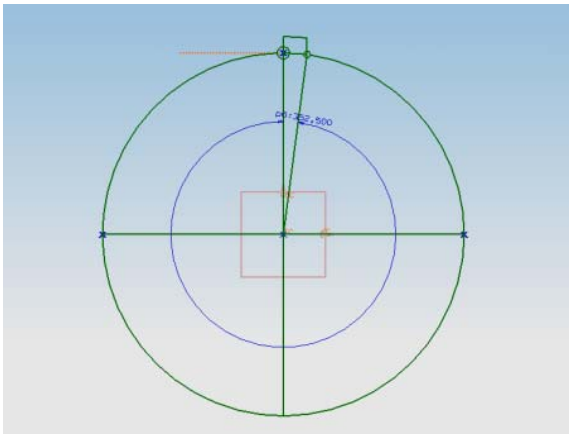


Fig. 5.1 B: Operation NO: 43140 and 43145 after clubbing



Calculations for modification jig as for the requirement

Pitch circle diameter = 275
Perimeter = ΠD
= 3.14*275=863.5 mm (for 360 degrees)
For 1 degree = 863.5/360=2.39861 mm
Required dia of the A type hole = 9.6 mm
Required dia of the B type hole = 5.8 mm

B type holes are 7 degrees 30 minutes apart from the A type holes. So literally on circumference it is about 17.998 mm so a existing jig can be modified as a required new jig without any deviations and loss to its originality.

SOLUTION 2

It is found Operation No. 43195 can be converting from conventional method to CNC and it can club with the Operation No. 43190. So Instead of doing the operation NO: 43190 and operation NO: 43195 separately and using two separate fixtures, it suggested to merge both of the operations and use a single fixture .With this setup time of operation NO: 43195 can be eliminated and also the fixture for the operation NO: 43195 can be eliminated which leads in smoothness in operation and further total cost and cycle time also can be reduced. The figure 5.2 showed below which are clubbed together.

43190(milling) 43195(drilling)

Fig. 5.2: After clubbing operation no 43190 and 43195

SOLUTION 3

It is found Operation No. 41025, Operation No. 41030, Operation No. 41035 and Operation No. 43195 can be converted from conventional turning to CNC turning to avoid un necessary inter shop material moment for operations and inspections which leads in smoothness in operation and further total cycle time can be reduced drastically by replacing the brazed tools with inserts.

SOLUTION 4

Instead of using technological tools we have asked the tooling department to supply TAILOR made tools which will prevent us from doing rework to avoid fouling of tools in the part during operation. Setting time for the technological tools will be more because after the wear out or breakage of tool tip we have to take the tool out of the holder and a new tool against the worn one has to be loaded. So fresh offsets has to be taken. So this practice consumes a lot time. But the use of Tailor made tools can save this time as instead of changing the tool we just have to change the insert and then the operation can be continue.

SOLUTION 5

By using Unigraphics programme post processor we can calculate machining time for operations these are done based on sandvik catalogue recommended feed, speed and depth of cut.

There are so many operations and for this operations used individual fixtures, the fixtures cost is very high, for some operations are using brazed tools, if brazed tools are break are failed then for regrinding are replacing too much time then operations also may taken delay instead of that we can use inserted tools if any brakeage will come simply we replace one not total tool.

SOLUTION 6

Instead of using different set of jaws for turning operations 41030 and 41035 a special set of jaws has been designed. This will not only reduce the setting time but also it will help in producing the part with better geometrical parameters

Suggested operations are shown in the table no 5.1.The table shows the existed and proposed time for suggested operations of HPT nose.

Table 5.1

OP:NO	DEP	OPERATION	Existing Setup time (HRS)	Existing Unit time (HRS)	PROPOSED SET UP TIME (HRS)	PROPOSED UNIT TIME (HRS)	REMARKS
41025	610	TURNING	0.73	2.342550	0.73	2.2	Brazed tools replaced with inserts.
41030	610	TURNING	0.73	7.0449	0.73	4.26667	Brazed tools replaced with inserts.
41035	610	TURNING	0.73	18.19	0.73	10.5	Brazed tools replaced with inserts
43050	616	CNC TURN	6.50	20.6076	6.50	8.58333	Brazed tools replaced with inserts.
43065	616	CNC TURN	6.50	12.4050	6.50	5.56667	Brazed tools replaced with inserts.
43120	616	CNC TURN	5.25	6.5620	5.25	1.43	Brazed tools replaced with inserts.
43125	616	CNC TURN	5.25	4.1013	5.25	2.45	Brazed tools replaced with inserts.

43135	616	CNC TURN	6.500	12.3038	6.500	3.99343	Brazed tools replaced with inserts.
43140	610	DRILLING	1.8250	9.698640	1.8250	4.41782	HSS drill is replaced by carbide drill
43145	610	DRILLING	1.0950	2.078280	0	2.03541	Clubbing the operation with 43140.
43185	616	CNC MILL	1.0850	4.5114	1.0850	1.1667	Used inserted carbide tip.
43190	616	CNC MILL	0	6.1519	0	2.47833	Used inserted carbide tip.
43195	610	DRILLNG	2.19	9.704850	0	1.921	Clubbing the operation with 43190.
45270	610	DRILLING	2.19	5.5741	2.19	2.86714	HSS drill is replaced by carbide drill

Machining times for existed and proposed methods

Existed total setup time = 52.255 Hrs
Existed total unit time = 170.42624 Hrs
Proposed total setup time = 48.97 Hrs
Proposed total unit time = 103.0264 Hrs
Net Saving in Setup time = 3.58 Hrs
Net Saving in unit time = 67.4 Hrs

5. 1 RESULT OF THE PROJECT

Final inspection is carried out by inspector with the help of required gauges, measuring instruments and CMM and concluded that the machined HPT Nose is free from any deviation as per drawing.

Cutting parameters are established for machining of Nickel base alloys including cutting tools and insert grade.

Fixture and cutting tool holders are modified to use them for further similar parts without any loss of time. Jaws are modified and drawings prepared so that it can be used for further similar part in same machine.

5.2 BENEFITS

By taking all care as narrated earlier, it would be helpful for the management at arriving target in time. Some tangible and intangible benefits may be derived from the project work as furnished below:-

- Reduction in cycle time and lead time.
- Reduction in lead time, throughput time.
- Elimination of unnecessary movement of man and materials.
- Reduction in setting time of tools.
- Improve quality and productivity.
- Reduction in repeat inspection.
- Additional work centre has been avoided.
- Better customer satisfaction.
- Reduction in supervisory work.
- Improvement in customer good will.
- Gains confidence due to customer satisfaction.
- Increase in organization efficiency.
- Development of creativity.

5. SCOPE FOR FURTHER STUDY

- It can be implemented with little or no modification to meet the specific requirements in other components of the aero-engine.

6. ACKNOWLEDGMENT

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APPENDIX

41025=TURNING
41030=TURNING
41035=TURNING
43050=CNC TURNING
43065=CNC TURNING
43120=CNC TURNING
43125=CNC TURNING
43135=CNC TURNING
43140=DRILLING
43145=DRILLING
43185=CNC MILLING
43190=CNC MILLING
43195=DRILLING
45270=DRILLING
SED=SUKHOI ENGINE DIVISION
CMM=COORDINATE MESURING MACHINE