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INVESTIGATION OF TOOL WEAR AND SURFACE ROUGHNESS DURING 4-AXIS FINISH MACHINING OF Ti-6Al-4V TURBINE BLADE

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Abstract*—Advanced Technology is emerging now a day to minimize time and scrap which is a major concern in industries. Most complexed models can also be fabricating by CNC machines like turbine blades, impellers, propellers, etc., The aim of this paper is focused on 4-axis milling simulation, fabrication of gas turbine blade using Titanium grade-5. The CAD model of turbine blade is prepared using Catia software. Different machining operations (parallel cut morph between two curves parallel with multiple curves root machining for one speed and Zig-Zag for another speed) are assigned with proper tools/parameters in Master CAM. After verifying the Master CAM virtual machine simulation, NC program is generated through Master CAM Sinumerik 828d postprocessor and turbine blade is fabricated through 4-axis rotary finishing. Flat end mill cutter is used for roughing at 2 varying speeds to find out the tool wear outs and ball end mill is used for finishing operations.

Keywords: 4- axis CNC machining, MasterCAM, Catia, Turbine Blade, Microscopic images, Tool wear and Surface roughness

1. INTRODUCTION

The multi-axis CNC machines are responsible for fabricating of various complexed profiles. The three most significant advantages are: reduction of process time with respective to higher material removal rates, reduced setup time for intricate prismatic parts and improved surface finish quality by minimizing the required time. The efficiency of employing 4-axis machining in manufacturing die molds has result in 10-20 times more than the efficiency of the manufacturing of 3-axis machines. The parts with irregular shapes can be machined using a single setup since, areas previously inaccessible to 3 Axis machines are made to work with added degrees of freedom. The manufacturing of turbine blade consists of automatic tool path generation for multi axis CNC machine.

While simulating machining, tool movements on workpiece decides the product according to the coding. In complex machining tasks, spindle speed, feed rate, plunge rate, retract rate, cutting time, tool changing time, constitute major part of total machining time. By concentrating on effective cutting time with respect to tool movements have to be investigated by Total Cycle Time.

There are five types of tool path – parallel cuts, morph between two curves, morph between two surface and blade root machining. The parallel tool path is used to remove the material around the surface. The direction of tool path is one-way, zigzag, spiral. The morph between two curves tool path is used to remove the material within the two curves. The blade root machining is used to remove the material from the root portion.

Five axes CNC machining refers to the ability of the CNC machine to perform movement about five different axes simultaneously.

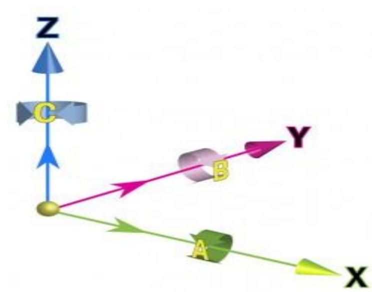


Figure 1: CNC Machine Axis Representation

Most CNC manufacturers define that the machines movement starting with 3 primary axes X, Y and Z. The Z axis is parallel to the tool spindle. The other two axes are given by the machines ability to rotate about the X and Y axis. The axis that rotates about the X-axis is called the A-axis. The axis that rotates about the Y-axis is called the B-axis. The axis that rotates about the Z-axis is called the C-axis rotation of the cutting tool installed into the machine spindle center as shown in the Figure 1. Five –axis machine tools can machine complicated shapes as well as reduce inventory costs, lead times, and setup costs.

2. Methodology of Design and Manufacturing process

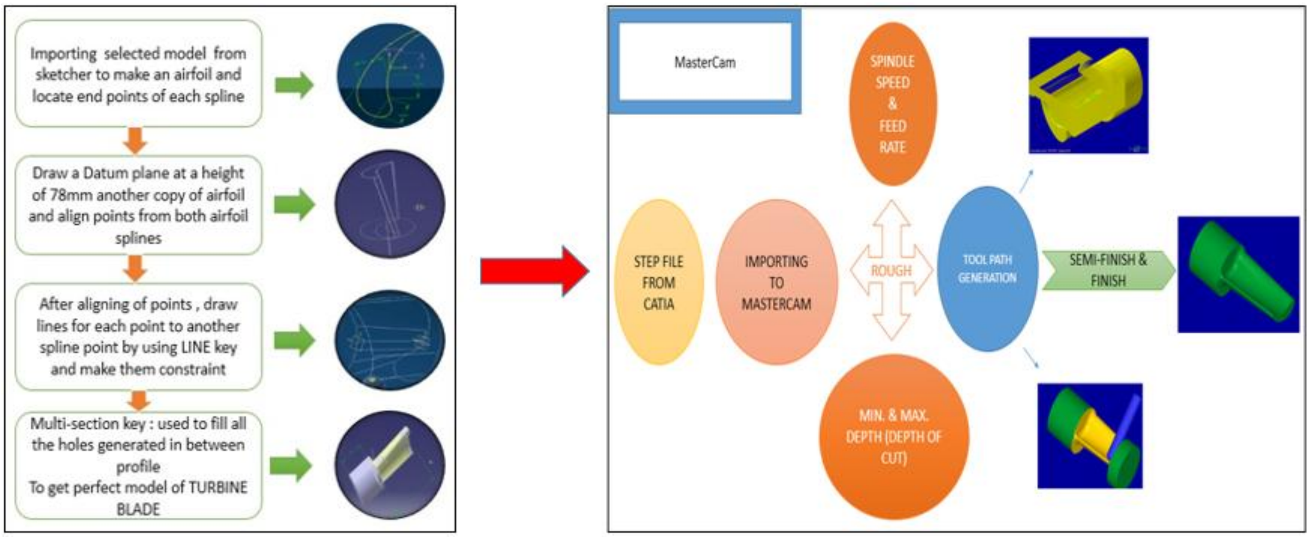


Fig.2: Methodology of Design and Manufacturing process

For, the turbine blade to be machined, the three processes, that are to be followed. They are 3-Axis Rough machining, 4-Axis Semi-finishing and 4-Axis Finishing. Before proceeding for the processes, the post processor has to be changed from default mill to selective post-processor as shown in figure.3,

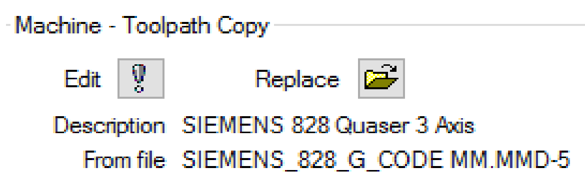


Figure.3 Selection of POST-PROCESSOR

Stock definition is to be setup, that is, the material dimensions are need to be set up, that is used to perform machining. In Stock definition, the shape of the material is defined to be cylindrical rod which is placed with respect to X-Axis. The stock origin is set as (X=0, Y=0, Z=0). The stock setup is shown in Figure 4.1.

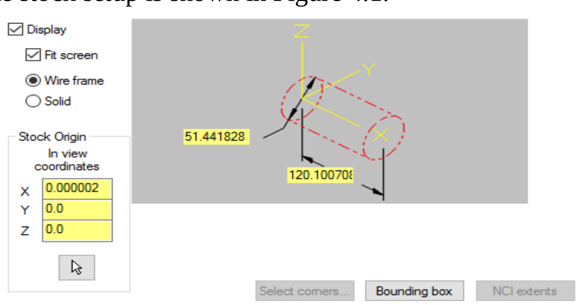


Figure.4.1 MasterCAM Stock Definition

The length of stock is set to be 150 mm and the diameter of stock is 50mm with the component to be machined is shown in Figure .4.2.

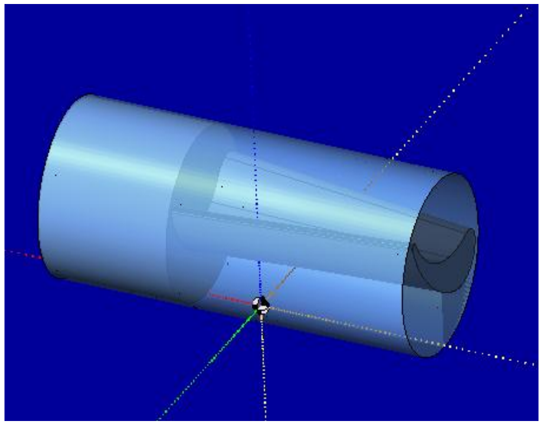
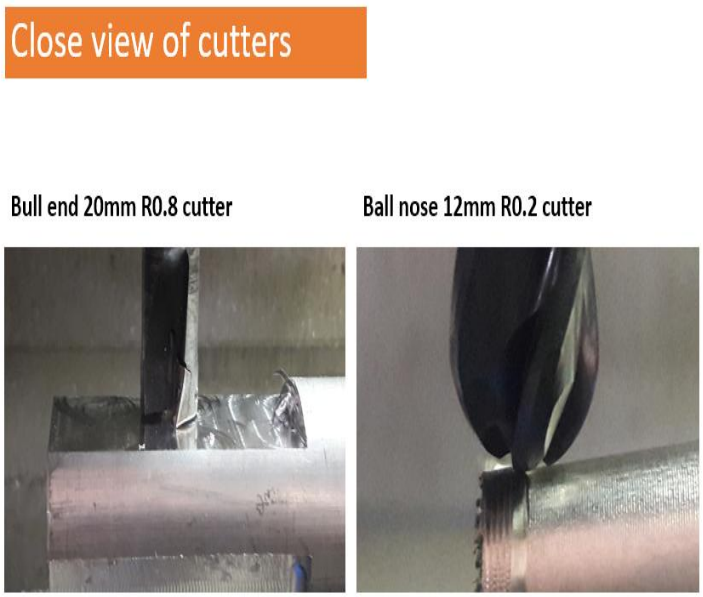


Figure.4.2 MasterCAM stock definition along with Turbine Blade

The level manager tool of Master CAM is used to organize the surfaces, model and wireframe. The splitting of the component is used to remove the material in and around the stock according to the generated program. The Semi-finish and final tool path is generated to mill residual material between blade surfaces. The 20R0.8mm Bull end mill cutter is used for its long reach and small milling area allowing for material to reach the narrow area which is to be removed without extra stock collision or interference.



- **FABRICATION OF Turbine blade model**

After generating the tool paths in Mastercam it will be get verified the machine simulation through Mastercam virtual machine simulation. [7] The parameters used in simulation are given as follows Feed rate 500mm/min Spindle speed 4000 rpm C-axis lock 90^0.Roughing and Finishing operations were carried out on Titanium grade-5 using 5-Axis CNC milling machine. For roughing operation, Surface Rough and select Pocket option and Surface Rough = Rest Mill were performed on both top portion and bottom portion of Turbine Blade, Minimum Depth is 24mm and Maximum Depth is -3.0mm are considered.

In Surface Rough through Pocket operation is selected which is considering 25mm diameter 0.8mm radius-3-inserts Flat End Mill was focused with Spindle speed of 1200RPM and Feed Rate of 1400mm/min during machining of both top and bottom [4,7] part .
Here for finishing operation, always remember that spindle speed must be higher than the feed rate to avoid tool wears and flank wears [2, 4]. A continuous contact should be maintaining between tool and flank. In between coolant have to be supplied continuously concentrated exactly at tool tip portion to avoid generation of heat during machining due to continuous contact [6]. If coolant is not supplied it may have chances of tool wears or chippings.

3. Surface Roughness :

The surface roughness were tested on turbine blade by using Surfcom 1400G tester. This test was done in order to find out, which parameter gives better finish on blade. The surface roughness tester Surfcom 1400G is as shown in Figure 5.1: Surfcom 1400G

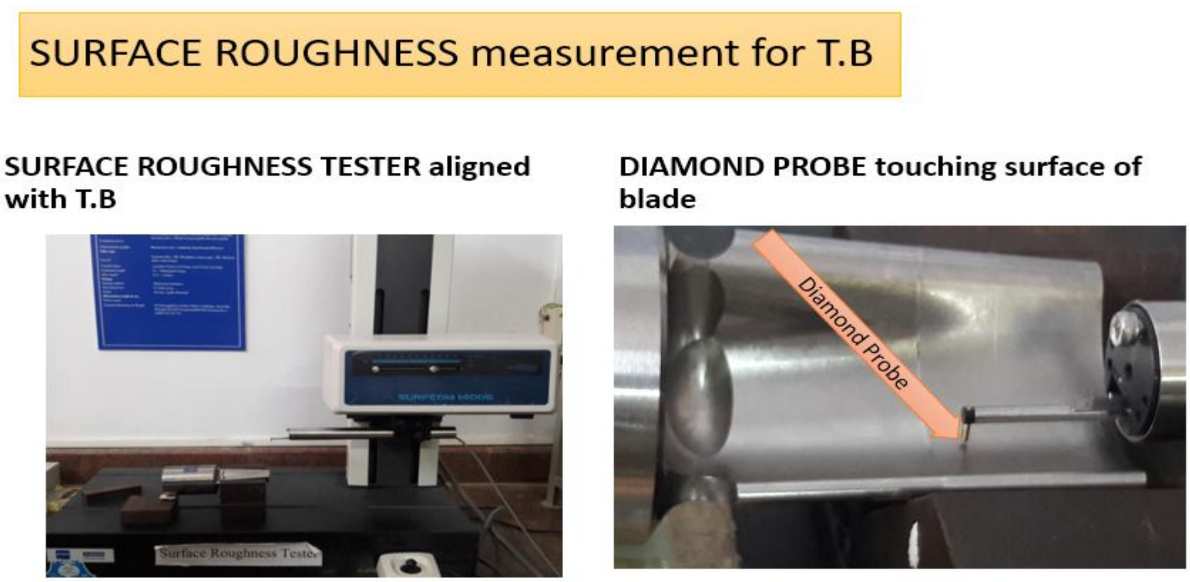


Figure 5.1: Surfcom 1400G

4. Tool Wear Measurement

Tool wear describes the gradual failure of cutting tools due to regular operation.. Due to continuous contact with the spindle and workpiece the tool gets affected.A ball nose end mill, also known as a spherical end mill or ball end mill, has a semi-sphere at the tool end. Ball nose end mills are used on workpieces with complex surfaces.

R390-11 T3 08M-PM-1030

- Insert used for ROUGHING of TITANIUM G5 material .
- Description :
- R : Right
- R390 M – PM : tool style code
- Insert length (LE) : 11
- Wiper edge : T3
- Nose radius : 0.8
- Cutting edge angle : 90 degrees
- Clearance angle : 21degrees
- Coating : PVD

As the number of cutting edges increases, your feed rate should increase to prevent burning and premature tool dulling. More flutes reduce chip load and improves surface finish if feed rate remains the same. The most common flute numbers for general milling operations are two (better space for chip ejection) and four (better surface finish).

5. RESULTS AND DISCUSSION

According to my point of view I discovered that for Titanium G5 cylinderical raw material operating the spindle speed taken around 2200rpm is having more damage to the inserts used for surface Roughing operation even though the coolant was introduced.

Comparison of tool wear microscopic images wit 10X lens :

FOR 2200 rpm :

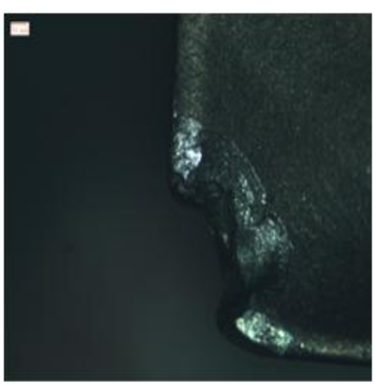


Fig 1 : Insert 1

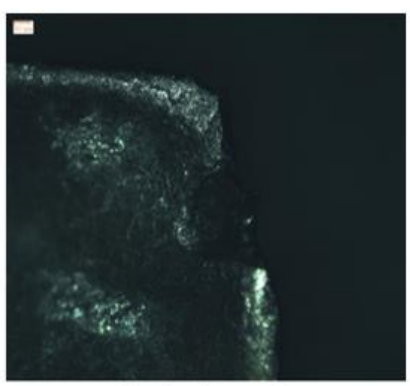


Fig 2 : Insert 2

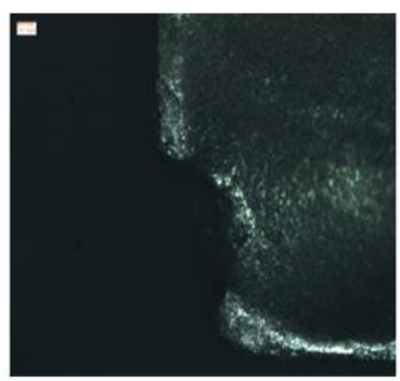


Fig 3 : Insert 3

After the experiment by veiwing the insert tip in microscope, astonishing images can be viewd in above figures.

Comparison of tool wear microscopic images wit 5X lens :

FOR 1200 rpm :

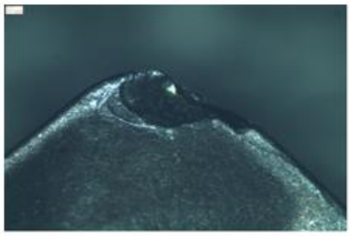


Fig 1.1 : Insert 1.1

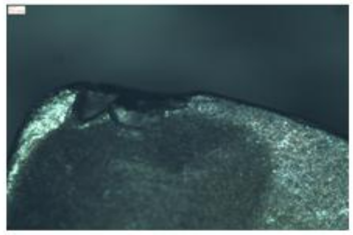


Fig 2.1 : Insert 2.1

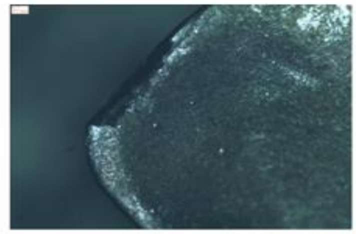


Fig 3.1 : Insert 3.1

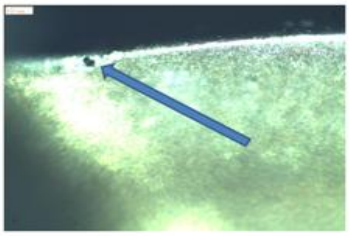


Fig 1.2 : Insert edge-line

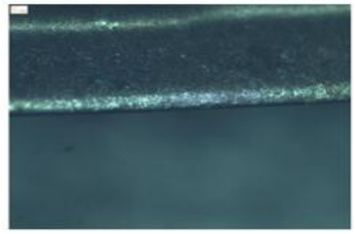
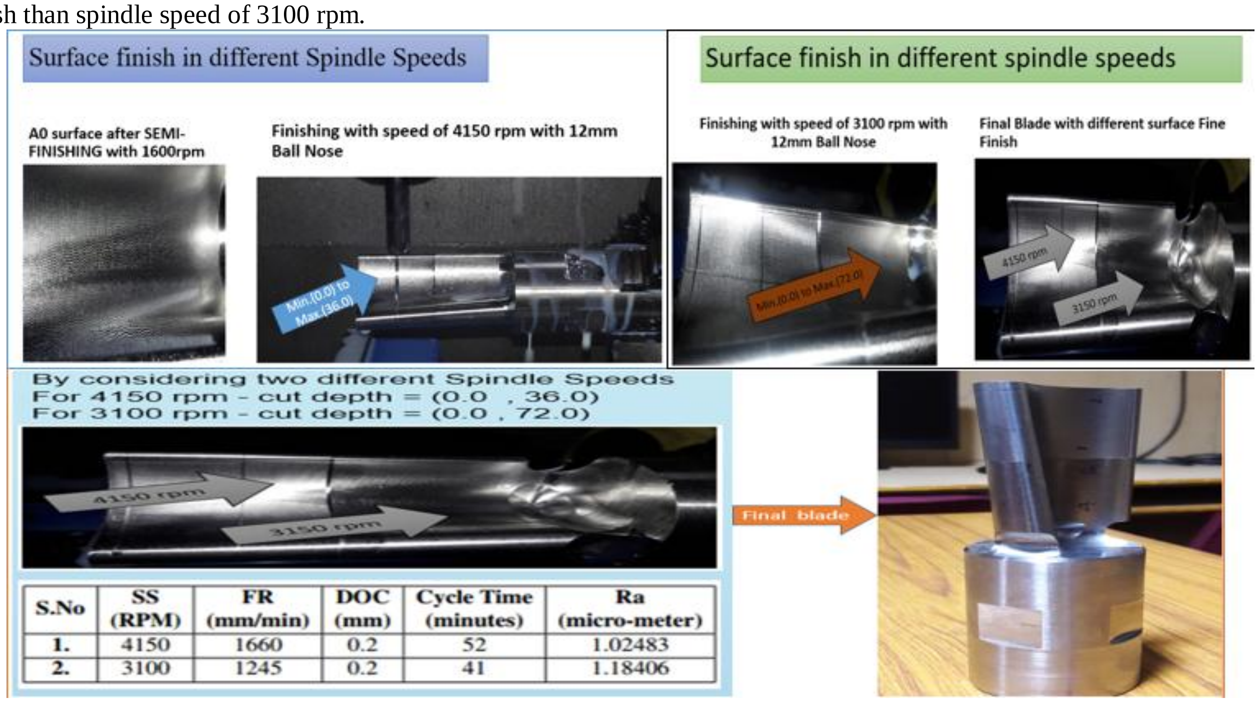


Fig 2.2 : Insert edge-line

For obtaining required shape the spindle speded was minimized to 1200 rpm and above microscopic images illustrates that the change of speed will have better results,.

After machining turbine blade, the surface roughness is measured on turbine blade. Four readings were taken and average roughness value calculated. Among them the surface finish with spindle speed of 4150 rpm is having less surface finish than spindle speed of 3100 rpm.



S.No	SS (RPM)	FR (mm/min)	DOC (mm)	Cycle Time (minutes)	Ra (micro-meter)
1.	4150	1660	0.2	52	1.02483
2.	3100	1245	0.2	41	1.18406

Two ball end mills used for finishing operation was measured for tool wear using the profile projector. According to the results obtained from profile projector, surface finish obtained with spindle speed of 4150 rpm is found to be having less tool wear i.e. .., 1.02483 micro-meter that compared to the surface finish obtained with spindle speed of 3100 rpm blade. For surface finish of 4150 rpm blade is having less tool wear, that is..,1.18406 micro-meter comparing to surface finish obtained with spindle speed of 3100 rpm.

CONCLUSION

The computer aided modeling, 4-axis milling simulation and fabrication of Titanium grade-5 turbine blade has been highlighted the advantages of having real life experiences of 4-axis machining. It eliminates the risk and collision of tool and blank in actual machining. By varying the spindle speed the life to the tool can be increases with increase with respective to the applications.

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[4] "Tool Path Optimization of Contouring Operation and Machining Strategies for Turbo Machinery Blades"Rakesh Prajapati#1, AvadhootRajurkar*2, VijaykumarChaudhary,*C M Department of Mechanical Engineering, Faculty of Technology & Engineering, Charotar University of Science andTechnology, Changa, Gujarat, India *Department of Industrial & Production Engineering, Vishwakarma Institute.*

[5] ***www. emastercam.com***