

Cad/Cam solutions for 5axis cnc programming and machining 3D shrouded Impellor of a Centrifugal Compressor with inspection on 3D cmm

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Abstract- The most critical component in any centrifugal compressors is impeller. Impellers are the rotating devices designed to alter the flow and/or pressure of liquids, gases, and vapors. In industries, design and manufacturing of Impeller is very difficult because of their complex geometry of vanes or blades. In this project, scoop milling technology is introduced for manufacturing of 3D shrouded impeller to avoid the manufacturing difficulties. NX CAD is used for modeling the impeller. ANSYS workbench is used for static and modal analysis. MAX-PAC CAM software is used for planning of tool path and generation of the NC post-processor for manufacturing an impeller or blade. 5 axis proof machining of the 320mm diameter shrouded 3D impeller on Chiron 5axis CNC machine and finally inspection of impeller by using 3D coordinate measuring machine (CMM).

Keywords—NX cads, NX cam, Max pack software, 5axis cnc machine, 3D CMM.

I INTRODUCTION

In a centrifugal compressor, energy is transferred from a set of rotating impeller blades to the gas. The designation “centrifugal” implies that the gas flow is radial, and the energy transfer is caused from a change in the centrifugal forces acting on the gas. Centrifugal compressors deliver high flow capacity per unit of installed space and weight, have good reliability, and require significantly less maintenance than reciprocating compressors. However, the performance characteristic of centrifugal compressors is more easily affected by changes in gas conditions than is the performance of reciprocating compressors.

The physical size (diameter) of a centrifugal compressor is determined by the volumetric flow rate at the inlet. The compression ratio (or head) determines the number of stages (length). The rotating speed of a centrifugal compressor is an inverse function of diameter to maintain a desired peripheral speed at the outer diameters of the impellers regardless of the physical size of the compressor. Very large (i.e., high-volume) flow compressors may operate at speeds as low as 3,000 rpm. Conversely, low-volume flow compressors may operate at speeds up to 30,000 rpm. Power requirement is related to mass flow, head, and efficiency. Depending on the particular Application, centrifugal compressor powers can range from as low as 500 hp (400 kW) to more than 50,000 hp (40 MW).

II Components of centrifugal compressor

Centrifugal compressor essentially consists of three components.

1. A stationary casing
2. A rotating impeller:-As shown in Fig (a) which imparts a high velocity to the air. The impeller may be single or double sided as show in Fig (b) and (c), but the fundamental theory is same for both.
3. A diffuser:- Consisting of a number of fixed diverging passages in which the air is decelerated with a consequent rise in static pressure.

III SCOOP MILLING TECHNOLOGY

Bhel Hyderabad designs manufactures and supplies the Centrifugal Compressors of different ratings for various processing industries. In these Compressors most critical and complex component is the 3D impeller, which is comprised of twisted integral vanes attached to hub and shroud. Presently, the shroud of the 3D Impellers is welded together with the vaned hub through arc welding process. Because of the narrow gaps of approach, between vanes and hub & shroud, manual welding is very difficult and cumbersome. Because of which the welding defects are becoming common, with which the quality of the 3D Impeller is being affected. All the above problems are leading to loss of efficiencies and mechanical strength of the Impeller. The above process is human dependent, laborious and time consuming. To avoid the above said problems, now-a-days the total 3D Impellers, including the shroud, are being machined from a single solid blank through 5-Axis scoop milling methods. For the first time in BHEL, the state-of-the-art 5-Axis CNC Part Programming and 5-Axis Scoop Milling Technologies have been established to manufacture the Shrouded 3D Impellers of Centrifugal Compressors from a single solid forged blank.

Suitable 5-Axis Cutter paths developed for scoop milling methods of Shrouded 3D Impellers such as Pocket roughing, Plunge milling, Box passes and flow-direction finish milling to cover the entire cavity areas of the Shrouded Impeller, special type of form cutting tools have been used such as ball nose cutter, flat end cutter, lollipop, bull nose, barrel etc ...for machining of 3D shrouded impellor in 5 axis CNC machine.

IV NX CAD MODEL CREATION OF A CENTRIFUGAL COMPRESSOR 3D SHROUDED IMPELLOR

UG/CAD model creation for a impellor

1. Import the control data point from the measured results from the CMM machine to create the control points A-E and M-Q. use the hub camber line and the shroud camber line with [curve degree]:4.
2. Create the camber surface (ruled surface) based on the hub camber surface (ruled surface) based on the hub camber line .the camber surface is a kind of free -form surface.
3. Create the hub surface by rotating the hub camber line about the +Z-axis for 360°
4. Define the hub solid model using the hub surface.
5. Create the hub solid model using the hub surface.
6. Create the impellor solid model by using the camber surface and the designed thickness.
7. Duplicate 12 impellers by rotating the created impellers by rotating
The created impellor by 30° along the +ZC-axis
8. Create the base plane and modify the top plane of the hub. An example of the created impellor is shown in Fig3.

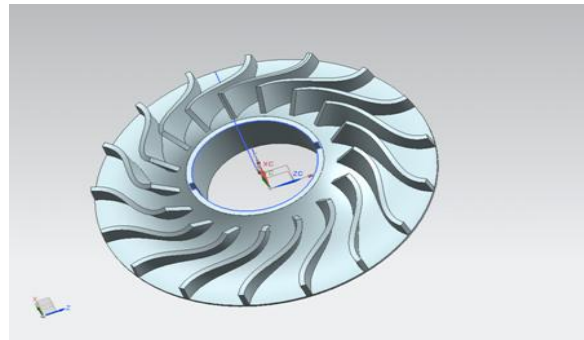


Fig3:UG/CAD model of hub camber line, hub surface and camber surface for impellor

V UG CAM TOOL PATH GENERATION AND SIMULATION

Following the UG cad model, the UG/CAM module was adopted to directly generate the required NC code for multi axis machining. The related functions for manufacturing found from the [manufacturing] module of UG CAM the milling process was selected for configuring the tool path .the cutter location file (CLSF) file of the tool path can be obtained before generating the correct NC code, the NC output format and the configuration parameters of the machining system must be defined and edited by the machine data file generator. A machine data file with the format will be obtained after the editing of the generator. The post-processor module can then transfer obtained CLSF by using the definition of (mdfa) to obtain the required NC code. The machine data file generation for impellor manufacturing is further discussed in the following sections.

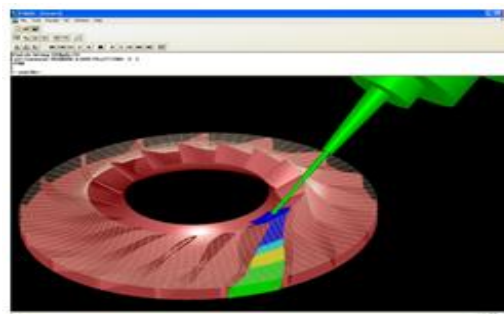


Fig 4: CAD model of impeller and the tool path for finish milling.

a) Tool path generation

The impellers inside one centrifugal compressor are normally of the same dimensions. Therefore, the tool path configuration normally involves the consideration of only one impellor CAD model the obtained tool path is duplicated for generating the NC code for the other impellers. There are three kinds of tool paths normally include in manufacturing

an impellor of blade. They are rough milling semi finish milling, and finish milling. The rough milling to adopt roughly cut out the shape of the impellor or blade from the initial dimensions of the stock material. at this stage, the efficiency of the removal rate is the main factor to be considered. in this research, a three axis milling module [cavity mill] with [fixed contour] type of machining was adopted as the rough milling configuration. The machining result from the rough milling is obviously different CAD model. A VERICUT simulation example for turbine blade machining use [cavity mill] with fixed counter configuration shown in figures it is clearly found that large amount of residual material remains un cut around the root of the impellor .the reason is very simple. in that the spindle shaft of the three axis milling machine does not have any swirling capacity. Therefore cutter cannot reach the root of a impellor model with its cross section curves twisted along the Z-axis. TO precisely cut out the design dimensions of a impellor four or five axis machining system is obviously required .in this research, a five axis machining system with UG CAM module [Variable contour] function is configured to generate the tool path. The flow chart of the parameter definition by using [Variable contour] function to configure the five axis machining tool path is shown fig.4

b)UG CAM setting for five-axis machining

The tool path simulation is generated by UG CAM module based on the configuration [variable contour].the general and essential steps of UG CAM setting to generate the tool path are briefly given as follows:

1. Select [application]> [manufacturing] to enter UG CAM manufacturing module. The window of the [operation manager] will be displayed
2. Select [variable contour] function from the [sub type] function in [operation manager] window.
3. Select the solid model of turbine or impeller to define [part geometry] for the surface to be cut.
4. Setting of the tool parameters. The tool parameters Include tool type, tool diameter, tool length, flute length, and number of flutes. The setting steps are [variable contour]> [Tool select]> [New]> [tool parameter setting]
5. Select the [drive method] of the tool path. in this research, [surface area] drive method was selected. The drive method was selection. For example: for example:[surface area]>[surface area drive method window will be displayed after the drive method selection. For example:[surface area]>[surface area drive method window]>[drive geometry]>select the part part[faces]to be cut (surface of blade or impellor).setting [cut type]>setting [step over]distance.
7. Setting the orientation of the tool axis. Here the [normal to part] is selected means that the tool axis is always normal to the part surface.
8. Setting machining parameters the feed rates of engaging and retracting rapid movement are set here. In the [cutting parameters] window, the depth of each cut and multiple cut level arrangement can be configured here. The [clearance] plane is also defined here. The clearance plane is used to prevent collision.
9. Select the [generate] function to generate the tool path.
10. Export cutter location source file (CLSF).
- 11.The final part of this step is post processing .select [tool box] function >[CLSF] function start [post process]>select [GPM.exe] as the post processor >import the generated [CLSF] data >set the mdfa file >set the mdfa format of NC code>NC program is generated

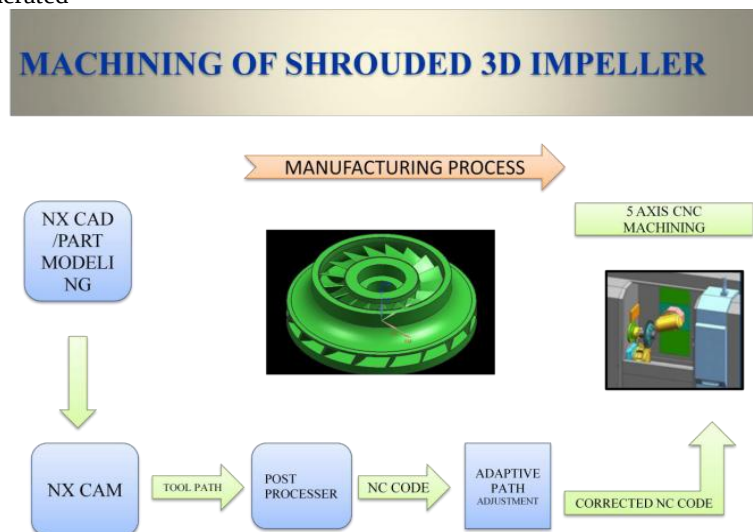


Fig 5: General procedure for the five axis machining by using UG/CAM.

UG CAM tool path generation and simulation

In the present fixture the inspection of the product is carried out manually, which leads to problems of misalignment and inaccuracy. This inaccuracy will increase the rejection of components. In order to minimize this error and reduce the rejection, it becomes essential to design a special purpose auxiliary attachment to the existing fixture. This improves the capability of the inspection fixture. The manufacturing of inspection fixture more expensive after complete of manufacturing parts some problems like miss alignments, dimensional tolerance, inaccuracy so avoiding this problem

first take prototype model by seeing this prototype manufacturer easily understand how to proceed in mft process and also avoid the miss alignment problems .

VI MEACHINING PROCESS OF 3D SHROUDED IMPELLOR IN 5 AXIS MEACHINE FDM 3D PRINTED PARTS HAVE VERY DIFFERENT

In this method a model of shrouded impeller is designed in unigraphics that part model is then transferred to NXmanufacturing process tool path is generated. Through a post processor where NC code is converted to Chiron M800 5-axis CNC machine where machining is done as show in Fig 5.

VII TOOL PATH PLANNING FOR IMPELLOR MACHINING

There are several steps with a fixed sequence that must be followed in the tool path planning for machining a complete impeller. First is the preparation of the stock material. The characteristic of the stock material is a cylindrical bar with the shroud surface as the profile. The stock material is normally cut by a lathe machine and then fixture on the table of a five axis machine tool. Both the machining accuracy must be considered for practical machining process. Therefore, the rough mill is considered for cutting out the material between the pressure surface and suction surface .the same tool path was repeated for the other impellers inside the compressors. The rough mill may also be cut on a three axis milling machine tool to decrees cutting cost the function is called [cavity mill]in UG CAM the pressure surface and suction surface are ruled surfaces. Therefore, the side of the tool is configured to be coincident with ruling of the ruled surfaces. Therefore, the side of the tool is configured to be coincident with the ruling of the ruled surfaces. Therefore, the side of the tool is configured to be coincident with the ruling of the ruled surface in the finish machining. The essential steps for manufacturing the centrifugal compressor impellers are summarized in fig.6

a) Tool path planning for precision machining of impeller

The tool path planning for the precision machining of an impeller and a turbine blade are similar. The [variable contour] machining functions of UG CAM module is adopted again. The differences of tool path planning between the impeller and machining are given as follows.

1. The [Drive Geometry] selections for impellor are: [choose] hub surface.

2. The [surface drive] method for machining impellor is the following.(1)The drive surface :[ruled surface].(2)The tool axis:[swarf drive].(3)The projection vector:[swarf ruling].swarf drive enables the defining of a tool axis that follows the swarf ruling of the drive surfaces. This tool axis allows the side of the tool to cut the drive surfaces sand the tip of the tool to cut the drive surfaces. This tool axis allows the side of the tool to cut the part surfaces. If the tool is none tapered, then the tool axis is at an angle to the swarf rulings.

3. Tool parameters:

1. Rough milling: flat end mill cutter with 10 mm dia 150 mm long.
2. Semi finish milling: tapered ball nose cutter 6mm dia 200 mm length.
3. Finish milling: Lolly pop cutter 6 mm dia 200 mm length.

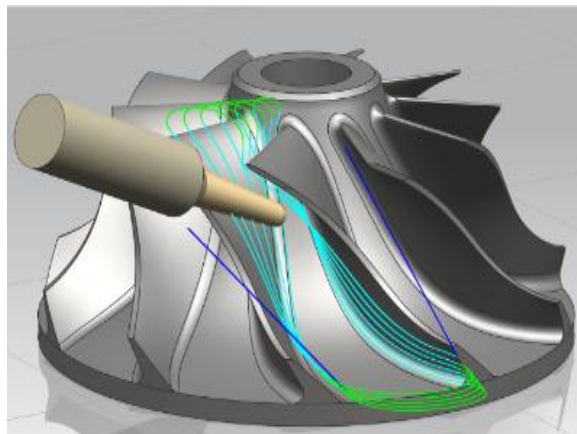


Fig 6:CAD model of impellor and the tool path for finish milling.

VII. POST PROCESSING OF CLSF FILE.

Five-axis machining requires machine-control (NC) post process to convert the cutter location (CL) data (that define the tool path data with a CAM system) in to the NC data that the machine can read. NC post process is that the method of translating machining instructions of a CAM system in to NC program code for a unique machine.

Tool path should be modified to suit the unique parameters of each different Machine/controller combination. This modification methodology is called post processing. The result of post processed tool path is NC code as show in table 1.

Table1. Two essential elements for post processing

Tool Path Data	This is an NX tool path in the form of CLS file.
A Postprocessor	This is a program that reads the tool path data and reformats it for use with a particular machine and its accompanying controller.

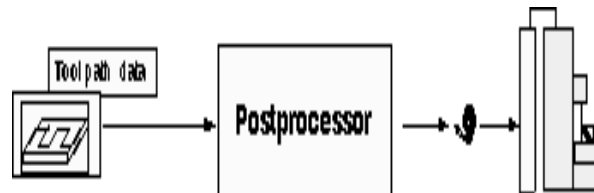


Fig 7: Details of post processor.

The tool path details reformatted by the post process or for the machine. NX provides a generalized post process or program, Post process or that uses NX tool path data input, and outputs machine readable NC code. Post-process or is highly customizable and might be used for both simple and complex machine tool/controller combinations. Post Builder is the NX product that is used to customize the post process or for each machine tool/controller combination. As shown in Fig 7

VIII.INSPECTION FOR 3D CLOSED IMPELLOR

When LK CAMIO Studio-Inspect is started, it opens in a non-program mode with the system set off-line. In this mode, the menus are used to define and calibrate sensors, define, measure and tolerance features and performs general CMM operations. A new program is created; a template of DMIS commands is inserted into the program

a)Procedure for inspection

Procedure for inspection of 31Click on the Inspection on the tool bar. Click on the Wizard icon on the tool bar. The Feature Wizard's function is to interrogate the points taken by the sensor and automatically decide the type of feature that is being inspected.

1. Check that the operation mode is set to CNC. Click on the Repeat icon. This will allow moving from feature to feature without restarting the Feature Wizard.
2. The CMM is now ready for you to teach a CNC part program.
3. The Teach method of inspection described here uses the CMM hand box to record the CMM's current position by pressing the blue Manual Print button. Automatic points are recorded by taking a manual point with the Slow Speed button depressed.

b).Measurement of points on 3D shrouded impellor

1. Select the inspection command.
2. Select curve or edge runner to inspect.
3. The spacing or no of divisions are given for noting different x and y values at each division.
4. Add nominal values as per the CAD model.

5. Tolerances are given in by selecting output ☐ ☐ feature ☐ ☐ select tolerance ☐ ☐ high and low level tolerance is given.



Fig 8. inspecting the shrouded impeller internally by using probe

IX RESULTS AND CONCLUSION

1. This scoop milling technology reduces overall manufacturing cycle time of the shrouded 3D impellers by avoiding laborious welding process involved in the present practice. the material wastage is also reduced by avoiding multiple no. of individual parts of the impeller assembly. This development reduces overall manufacturing cycle time by 30%to 40%.thus improving the product delivery schedules.
2. This technology also improves efficiency of the shrouded impellers by 2%to 3% resulting in better performance. This improved performance enhances the business potential of centrifugal compressors.
3. This is the only method: here Manual internal welding is not possible due to highly intricate passages of complex 3D twisted design of vanes of shrouded 3D impellers of centrifugal compressors.
4. Integrally shrouded 3D impellers avoid heat distortion and have stronger shroud joints then welded impellers. This improves the product life cycle. This technology dependency on the collaborates.

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