

DEVELOPMENT AND MANUFACTURE OF 3D SHROUDED IMPELLER USING 5-AXIS CNC MACHINE AND ITS INSPECTION USING CMM

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ABSTRACT-The most basic segment in any centrifugal compressors is IMPELLER. Impellers are the rotating devices intended to change the stream or potentially weight of fluids, gases, and vapors. In machining industries, design and manufacture of Impeller is extremely troublesome due to their intricate and convoluted geometry of vanes or edges.

In this project, A 450mm dia3D Shrouded Impeller is modelled using UNIGRAPHICS NX software. The software is then used for planning of tool path and generation of the NC post-processor for manufacturing an impeller or blade. ANSYS Workbench is used to conduct static and modal analysis on the impeller to determine the best possible material to be used for its manufacture. The Impeller is manufactured from a single blank from a 5 Axis CNC Machine using the scoop milling technology. Scoop milling technology is used to avoid the existing manufacturing difficulties and to minimize the manufacturing defects and errors. Finally, the manufactured impeller is inspected using a coordinate measuring machine and is checked for its dimensional accuracy.

KEYWORDS-UNIGRAPHICS NX, 5-Axis CNC Machine, CMM, NX CAD

INTRODUCTION

Impellers (also spelled impellors or impellors) are rotating devices designed to alter the flow and/or pressure of liquids, gases, and vapors. An Impeller consists of a number of twisted integral vanes which are attached to a hub and this entire part is attached to a shroud or casing. Fluids or gases are sucked in from one end and impelled from the other.

An Impeller is the most critical and important component in a Centrifugal Compressor. An impeller is the main component which makes the compressor centrifugal. 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. And it is the Impeller which gradually raises the energy of the working gas.

TRADITIONAL METHOD OF MANUFACTURE: ITS DRAWBACKS

The traditional way of manufacturing an impeller is to weld the twisted integral vanes to the hub of the impeller and then to weld together the hub and the shroud. This method involves manual welding. The Impeller thus manufactured is prone to a lot of welding defects such as cracks and solid inclusions. Also, since high pressure rise is observed in the impeller due to the flow of fluids and a lot of heat is generated there is a high chance that the shroud might get detached from the hub even after welding both the parts.

SCOPE OF THE PROJECT:

Since the main problem is with welding the two parts, if the entire impeller is made without using welding i.e. such as from a single blank itself then, the welding defects would minimize. One such way would be to develop the impeller using UNIGRAPHICS NX and manufacture the impeller from a single blank using a 5 Axis Chiron CNC machine. Scoop milling technology would suit best for the manufacture of an impeller. the most important aspect in an impeller is its vanes. These vanes are best manufactured with the help of scoop milling i.e by scooping the unnecessary metal and forming the integral vanes. 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, bullnose, barrel etc. for machining of 3D shrouded impellor in 5 axis CNC machine.

MODELLING OF 3D SHROUDED IMPELLER USING UNIGRAPHICS NX

Shrouded impellor comprises of hub or crown, to which shaft is fixed, shroud ring or band, and a series of blades, which later is fixed one end at the hub and another is fixed to shroud ring. The blades are mounted on the hub. Shroud ring has attached another side of the blade

- At first step the hub section was modeled by rotating its curved section sketch using rotate option
- Later an outward curved blade section has been drawn on the hub section and is used as a representative element to create a circular pattern with required number of blades as per design requirement (17 in this case).

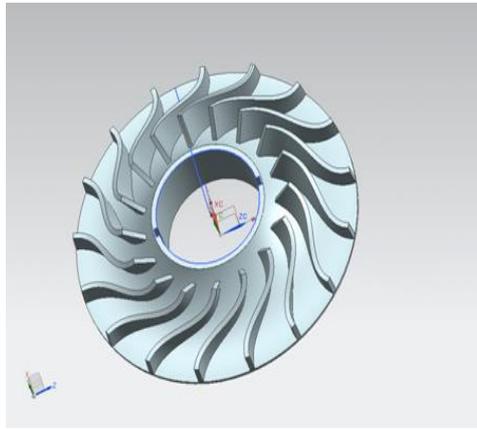


Fig.1: Hub with integral vanes

- Shroud has been modeled using rotate option by rotating the base sketch of the shroud, so creating the shroud element.

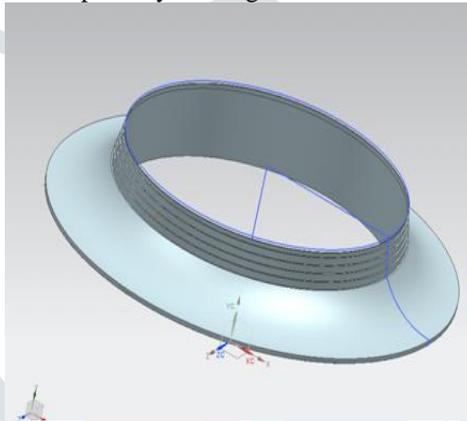


Fig.2: Shroud

- By using assembly module of NX CAD we assemble both hub-blade element and shroud element.



Fig.3: Complete Assembly of 3D Shrouded Impeller

STATIC AND MODAL ANALYSIS USING ANSYS WORKBENCH

A static analysis calculates the effects of steady loading conditions on a structure, while ignoring inertia and damping effects, such as those caused by time varying loads. A static analysis can however, include steady inertia loads (such as gravity and rotational velocity), and time varying loads that can be approximately as static equivalent loads (such as the static equivalent wind and seismic loads commonly defined in many building codes).

Using of modal analysis we can determine the natural frequencies, the damping at natural frequencies and the mode shapes at natural frequencies

Table 1: Engineering Data

For ASTM A182 F22 Young's modulus= 2E 11 Pa Density = 7850 kg/m ³ Poisson's ratio = 0.3 Yield strength = 310 Mpa	For Stainless Steel Young's modulus = 1.9E 11 Pa Density = 7750 kg/m ³ Poisson's ratio = 0.21 Yield strength = 207 Mpa	For Aluminum All Young's modulus = 7.1E 10 Pa Density = 2770 kg/m ³ Poisson's ratio = 0.33 Yield strength = 280 Mpa
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Results:-

The following results are obtained,

- a. Maximum Deformation
- b. Von Misses Stress
- c. Frequencies and its deformation

STATIC ANALYSIS RESULT:-

At load =10000N

Table 2: Static analysis result for different materials at 10000N

S.No.	Material	Maximum Deformation (mm)	Equivalent Stress (Mpa)
1	A182 f22 (Forged steel)	2.395e-12	7.3079
2	Stainless steel	2.5971e-12	7.3112
3	Aluminum	7.0081e-12	7.2783

At load =5000N

Table 3: Static analysis result for different materials at 5000N

S.No.	Material	Maximum Deformation(mm)	Equivalent Stress (Mpa)
1	A182 f22 (Forged steel)	1.1975e-12	3.664
2	Stainless steel	1.298e-12	3.655
3	Aluminum	3.5404e-12	3.639

From above tables it is clear that A182 F22 material having less maximum deformation and also Von misses stress and hoop stresses are less than the yield strength value.

Modal analysis result:

ASTM A182 F22

Table 3: Modal analysis result for ASTM A182 F22

Frequency (Hz)	1	2	3	4	5	6
	2934.0	2944.7	3229.5	3235.7	3529.2	4102.0
Displacement (mm)	0.83289	0.83027	0.839	0.84521	0.55794	0.6782

STAINLESS STEEL

Table 4: Modal analysis result for Stainless steel

Frequency (Hz)	1	2	3	4	5	6
	2862.6	2873.1	3147.6	3153.1	3439.4	3996.8
Displacement (mm)	0.84407	0.84646	0.85252	0.85959	0.56522	0.68844

ALUMINUM

Table 5: Modal analysis result for Aluminum

Frequency (Hz)	1	2	3	4	5	6
Displacement (mm)	2915.2	2925.7	3197.7	3203.3	3494.5	4058.5
	1.4133	1.4171	1.4285	1.4391	0.9427	1.148

From above tables it is clear that ASTM A182 F22 has less displacement compared to other two materials. Therefore, there is less chance of material failure.

Hence from the static and modal analysis, A182 F22 steel has less chance of failure comparatively and is the best material among the other two, for fabrication of 3D shrouded impeller.

TOOL PATH GENERATION

The tool path generation for an impeller in a centrifugal compressor involves the consideration of the impeller CAD model, modelled using UNIGRAPHICS NX.

- Click on FILE→OPEN→select IMPELLER click ok→change it from modeling
- Defining the Machine Coordinate System (MCS)
- Geometry Definition
- Specify the Part Mode specify the blank geometry
- Defining a Cut Area
- Specifying a Tool Axis
- Specifying Cutting Parameters
- Specifying Non Cutting Parameters
- Generation of Tool Path
- Verifying the Material Removal in 3D Dynamic
- Verifying the Material Removal in 2D Dynamics:
- Left out Material Will Be Seen in Thickness by Color
- Finally click on LIST button in order that generated program are given as a output during a notepad. The same operation ought to do layout in SEMI FINSHING AND FINSHING OF IMPELLER .By this thematerial removal is clearly absorbed and sensible surface finishing is obtained.

POST PROCESSING

After generating a tool path, the next and final step is to export the cutter location source file. This process is known as post processing. The two essential elements for post processing are:

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

Steps Involved in 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

MACHINING OF 450MM DIA 3D SHROUDED IMPELLER

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 5-axis CNC machine where machining is done

Steps involved in machining process

1. A cylindrical blank of size is equal to the maximum diameter of shrouded 3D impellor. Small holes are drilled at the un-machining side of blank support for the fixture as the job rotates during machining.
2. The coordinate position where to start machining is defined in the controller by giving x, y, z-values which are measured before by optical edge measures.
3. Axis CNC part programs were developed for rough and finish turning of Stainless Steel forged blank. The3-axis CNC part programs were also developed for rough milling of the turned blank. The cutting methods used for the rough milling operations are the cavity milling method of the UG NX10 software. The depth of cut and cross feeds was selected suitable to the blank material and the milling machine.
4. 5-axis CNC part programs were developed for roughing, semi-finishing and finishing operations by considering the different configurations of tooling such as deep shoulder end mills, flat end mills, fast feed end mills, bull nose cutters, ball nose cutters etc.

Tool parameters used:

1. Rough milling: flat end mill cutter with 16 mm dia 225 mm long.
2. Semi finish milling: tapered ball nose cutter 12mm dia 250 mm length.
3. Finish milling: Straight ball nose cutter 12 mm dia 250 mm length.

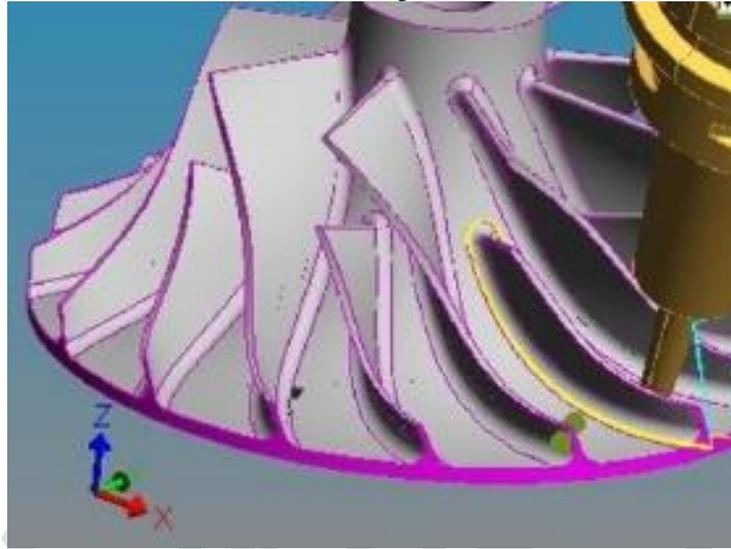


Fig.4: CAD model of the impeller and tool path semi finish milling

INSPECTION OF 3D SHROUDED IMPELLER

Metris Camio is a combined inspection and programming environment for CMMs. It is available as a suite of metrology software solutions. Camio allows creating inspection programs off-line from 3D CAD model design, or by manually programming on-line, or by a combination of these methods. It provides full 3D geometric modeling capabilities and supports SAT, IGES, VDA, CATIA and other file formats. Program scan be executed in manual or CNC (program or automatic) mode, and the results reported in text or graphical format against the 3D CAD model.

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.

Procedure for inspection

1. Click 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.
2. 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.
3. The CMM is now ready for you to teach a CNC part program.
4. 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.

Measurement of points on 3D shrouded impellor

- I. Select the inspection command.
- II. Select curve or edge runner to inspect.
- III. The spacing or no of divisions are given for noting different x and y values at each division.
- IV. Add nominal values as per the CAD model.
- V. Tolerances are given in by selecting output feature, select tolerance high and low level tolerance given.

RESULTS AND CONCLUSION

- Manufacturing the entire impeller from a single blank from a 5-Axis CNC Machine, using 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 impellor assembly.
- This innovation additionally enhances efficiency of the shrouded impellers resulting in better performance.
- Integrally shrouded 3D impellers avoid heat distortion and have stronger shroud joints than welded impellers. This improves the product life cycle.

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