Innovative Modeling and Rapid Prototyping of Turbocharger Impeller

Mallikarjuna [1], Dr. U chandrashekar[2]

[1]*Department of Mechanical Engineering, M.S.Ramaiah Institute of Technology, Bangalore-560054, India.*

[2]*Gas Turbine Research Establishment, Bangalore-560054, India.*

ABSTRACT

A Turbocharger is a forced induction device that is used to allow more power to be produced for an engine of a given size driven by the engine's exhaust gases is used in petrol, diesel powered cars, trucks, marine applications, aircraft etc.In exhaust gas turbo charging, part of exhaust gas energy, which would normally be wasted is used to drive a turbine. The turbine shaft is connected to a compressor, which draws in combustion air, compresses it, and then supplies it to the engine. The increased air supply enables more fuel to be burnt, thus leading to lower fuel consumption and less emission; hence the engine develops higher power. Development of impeller for turbochargers through conventional manufacturing has got many challenges due to the blade geometry complexity and high competition in industries due to cost management. The normal manufacturing route involves casting and machining this would lead the cost. Time consumption and not efficient for small manufactures. The aim of the project is to make impeller for turbochargers with great design flexibility, less time consumption by integrating the reverse engineering (RE) and rapid prototyping (RP) techniques called Stereolithography apparatus (SLA). SLA technique would give the design flexibility with reduced cost and it can be used for visualization, mechanical testing etc.

Keywords: *Epoxy resin, Impeller, Reverse Engineering, Rapid prototyping, SLA.*

1. INTRODUCTION

The aim of the project is to replace the conventional manufacturing process with the rapid casting process for development of turbocharger impeller. Generally turbocharger impeller manufacturing industry used to conventional manufacturing process for development of impeller. The turbocharger impeller development through conventional manufacturing process confronts many challenges due to small thickness of blades, geometrical complexity and high competition in the turbo industry leading to severe cost-cutting measures at all stages of product development. In the normal practice development of turbocharger impeller the foundry technique of pouring metal into sand casting was the age old to today conventional practice in the manufacturing industry.

The new technique impeller to produce as following. First the design specifications are developed according to the standards and then the 3D model is created by the help of commercial software. This is followed by tooling for pattern design and creates the core and cavity made of wood or aluminium and the molten metal is poured. Later the casting is subjected to shot blasting and machined for the required dimensions and specifications. The machined and finished components are then tested for quality assurance. This entire cycle is time consuming and there is a little scope for incorporating a design modification and there is no flexibility for interventions.

For the past 100 years that approach has been acceptable. Today the emphasis is on meeting customer's unique turbocharger impeller requirements and meeting those requirements in ever shorter period of time. This reality is new challenges for impeller manufactures and caused a rethinking of the processes of design, development and implementation of the product. International practices for turbocharger impeller manufacturing have imbibed several advanced techniques in design, analysis and manufacturing domains so as to compress the time frame of production and also induct flexibility into design process. One of the recent features is the use of rapid prototyping techniques wherein the first set of impeller in design process are produced and directly used in impeller testing. For industrial enterprises a very important factor is the speed with which a new or improved product can flow to a market. In a competitive market, it is well known that products that are introduced before those of their competitors generally are more profitable and take a larger share of the market. At the same time a very important aspect for the enterprise is the production of high-quality turbocharger impellers.

2 REVERSE ENGINEERING

Reverse engineering (RE) is defined as the process of obtaining a geometric CAD model from 3-D points acquired by scanning/ digitizing existing parts/products. In RE process the physical component of turbocharger impeller is scanned and got the point cloud data using laser scanner. There are different types of 3D scanners for digitizing the surface of components but for this impeller scan laser scanner technique has been used. Then the cloud data is of impeller is taken into the Geomagic studio software for creating the model. In that software there are many tools to make perfect model of impeller. Finally developed the impeller model using CATIA V5 software

2.1 THE GEOMAGIC STUDIO APPLICATION IS MADE UP THE CAD MODEL

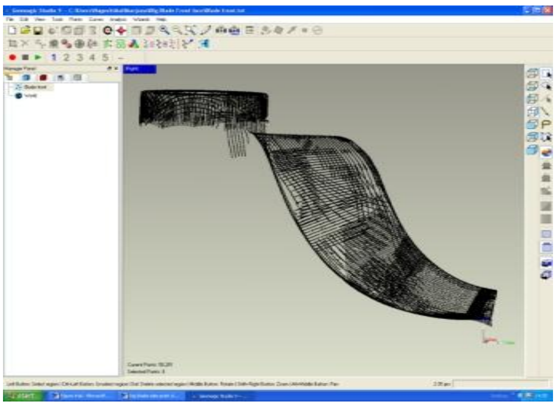
For an overall view of RE software operation, the different RE data processing phases will first be described. The required RE operations are then considered. The complete RE data processing chain, from scan data to the final NURBS

POINT AND IMAGE PHASE
Registration: Manual and automatic alignment
Data optimization: Noise and point redundancy reduction, sampling points and identifying primitives
Basic operations: Rotate and move, datum control and separating and merging point clouds
Image processing: Region growing and thresholding

POLYGON PHASE
Polygon optimization: Noise reduction and cleaning, abnormal faces cleaning, polygon mesh refinement and polygon mesh decimation.
Polygon edit and control: Filling holes, defeaturing, edge detection and sharpening control
Basic operations: Rotate and move, datum control,

CURVE PHASE
Primitive fitting: Circle, cylinder and plane
Curve construction: Cross section and curve fitting from points
Curve modification and editing: Curve reparameterization, curve degree conversion, curve smooth and clean, control point edit, transition and extension, point generation and curve redirection
Boolean, offset, shells, thicken, cut and mirror

NURBS SURFACE PHASE
Surface from curve: Loft, UV-network and extrude
Patch creation and control: Curvature detect, patch editing and patch template re use NURBS surface creation and controls: Grids, NURBS patches merging, NURBS surface smoothing and editing
Evaluation: Point to CAD, polygon to CAD, CAD to CAD



.

Fig 1 Alignment of points

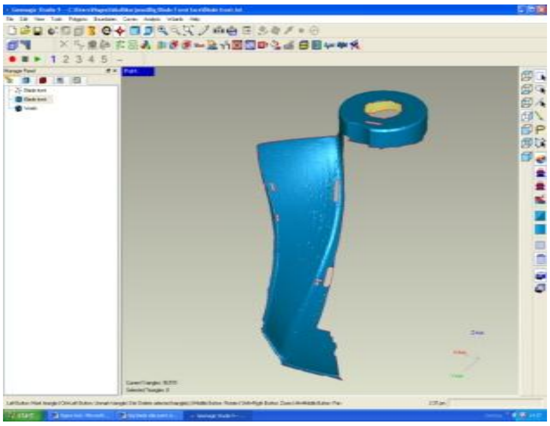


Fig 2 wrap phase

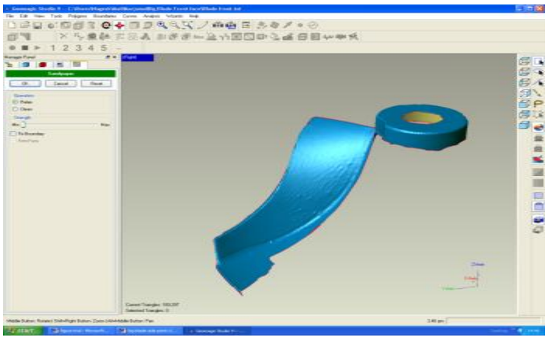


Fig 3 after cleaning the surface

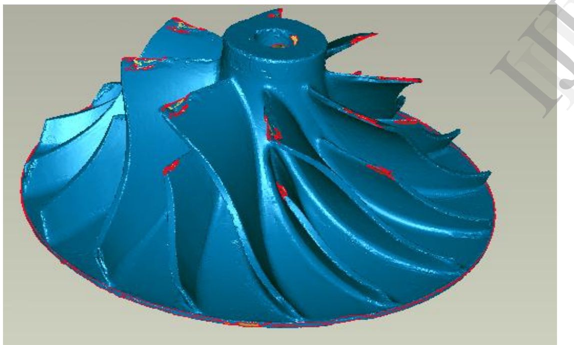


Fig 4 after merging the blades

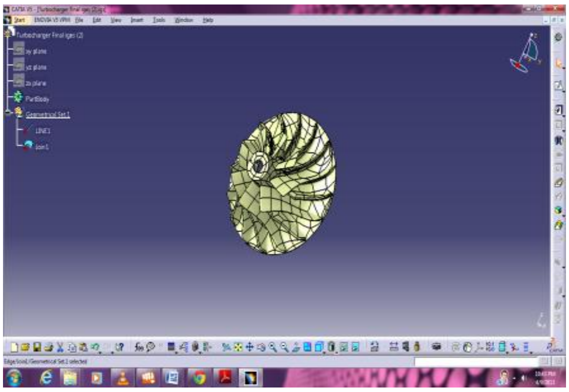


Fig 5 importing into CATIA screen

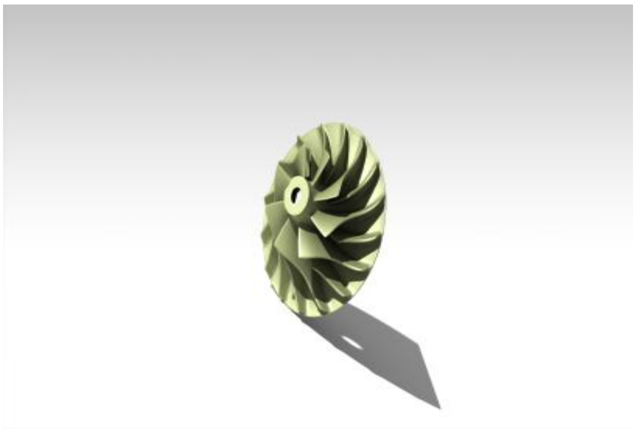


Fig 6 finished impeller model

3 LINEAR STATIC ANALYSES

3.1 Materials

The materials are used for the turbocharger impeller should have the good strength and high heat resistant properties are as follows:

- INCONEL alloy A-286
- INCONEL alloy N06230
- Wrought Aluminium alloy-2219

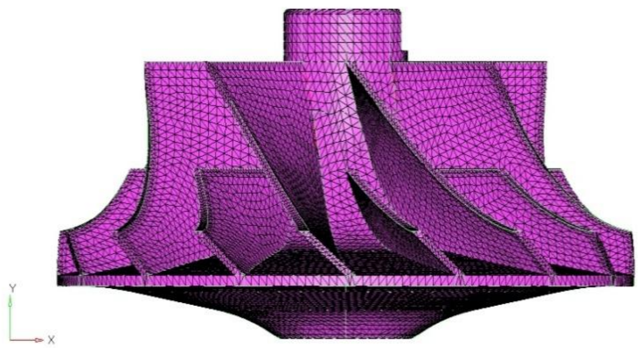


Fig 7 Meshed impeller component

3.2 STATIC ANALYSIS OF IMPELLER MODEL

Here in this analysis complete model is considered and load is a pressure 6 bar applied in y-direction to the blade faces. For three different materials stress and displacement effects on model

ISSN: 2278-0181
Vol. 2 Issue 9, September - 2013

are discussed and simulation diagrams of respective materials shown in the below figures.

3.2.1 Stress and displacement for material-INCONEL alloy A-286

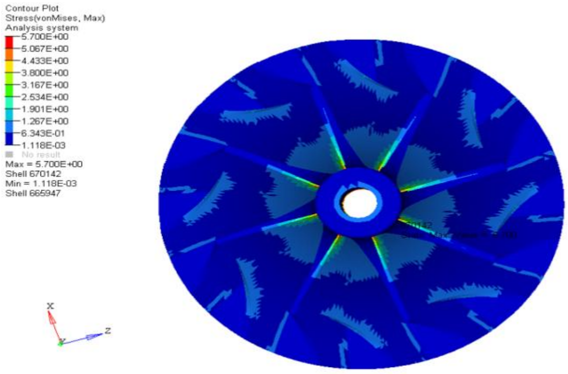


Fig 8 Impeller and simulation diagram (von mises stress)

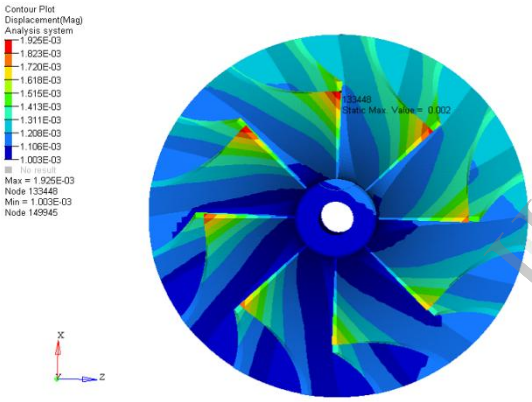


Fig 9 impeller and simulation diagram (Displacement)

3.2.2 Stress and displacement for material-INCONEL alloy N06230

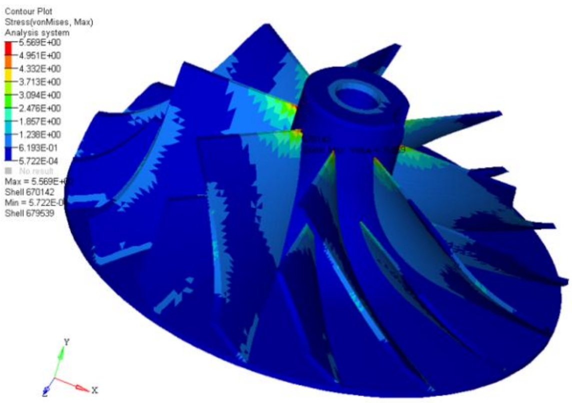


Fig 10 Impeller and simulation diagram (Von misses stress)

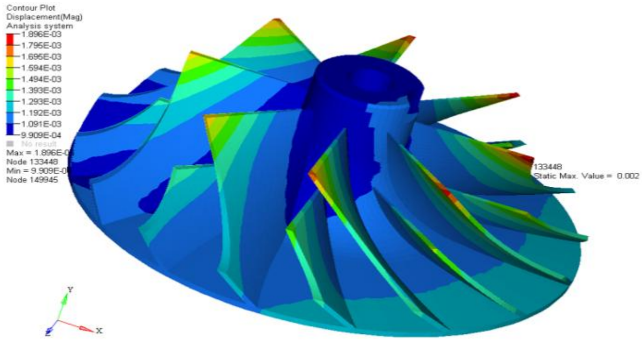


Fig 11 Impeller and simulation diagram (Displacement)

3.2.3 Stress and displacement for material-Wrought Aluminium alloy-2219

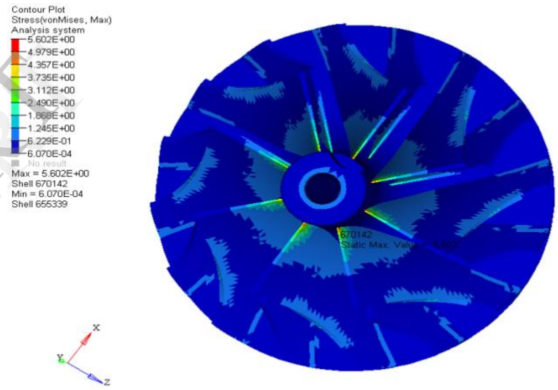


Fig 12 Impeller and simulation diagram (Von misses stress)

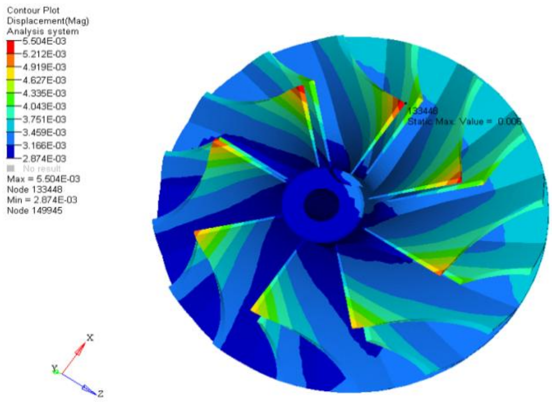


Fig13 Impeller and simulation diagram (Displacement)

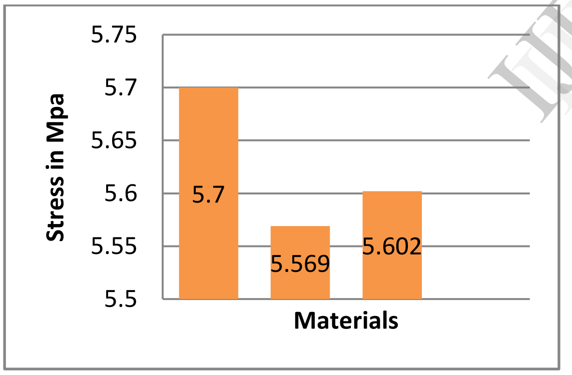
4.0 RESULTS & DISCUSSION

Table 1 Material results comparison

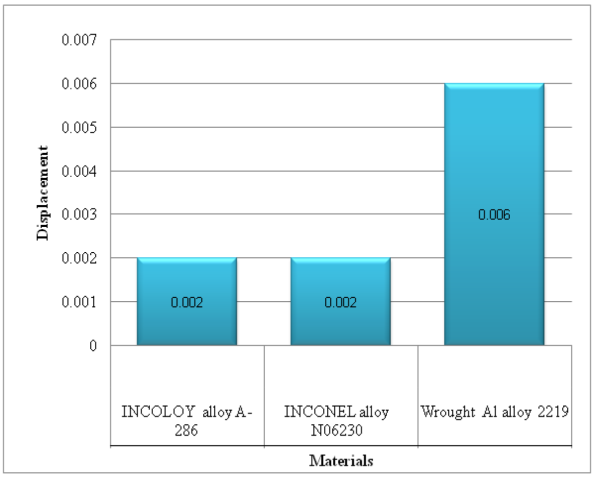
Properties	INCOLOY alloy A-286	INCONEL alloy N06230	Wrought Al alloy-2219
Max. Von mises stress in MPa	5.7	5.569	5.602
Displacement in mm	0.002	0.002	0.006

The maximum von Mises stress noticed at blade root at near the hub and shaft hole maximum stress is 5.7 N/mm^2, for material INCONEL alloy A286

The maximum displacement is about 0.006mm at load of 6 bar, for material Wrought Al alloy 2219



Graph 1 Shows stress distribution vs materials for pressure 6 bar



Graph 2 shows displacement vs materials for pressure 6 bar

It is concluded that, the maximum stress among the 3 materials is of 5.7MPa is noticed for material 1 is well within the allowable limit. Hence, the design is safe and still we can do optimization of the impeller because it is very less maximum stress when compared with the yield stress. For three materials is we can do optimization

5.0 RAPID PROTOTYPING

Rapid prototyping: The term rapid prototyping (RP) refers to a class of technologies that are used to produce physical objects layer-by-layer directly from computer-aided design (CAD) data.

These techniques allow designers to produce tangible prototypes of their designs quickly, rather than just two-dimensional pictures. A wide range of techniques and materials can be used for rapid prototyping. There are morethan ten commercial rapid prototyping processes and more than five concept modeling processes; all have unique properties. The impeller is built by using the following RP technique.

Material Sla 5510 Resin

Table 1: Properties of liquid resin

Measurement	Condition	value
Appearance		clear
Viscosity	@30°C	180cps
Part building layer thickness		0.05 mm 0.10 mm 0.15 mm

5.1 STEREOLITHOGRAPHY APPARATUS (SLA)

The Stereolithography Apparatusmethod is used most commonly in prototyping, model building or production applications. SLA prototypes have become the preferred choice among designers, engineers, researchers, students and many other areas that use rapid prototyping. SLA is the most economical method to produce plastic prototypes and models.

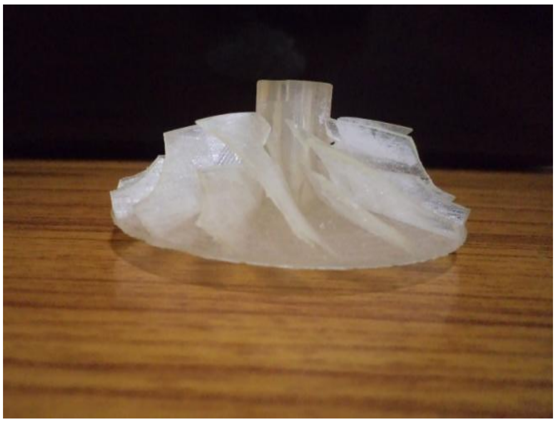


Fig 13 Impeller prototype produced using SLA process

6.0 CONCLUSION

The impeller manufacturing conventional is start with design, casting, machining and production. The impeller is most important part of the turbocharger today's market emphasizing the speed with customized components. In this scenario who will reach the market obviously sale the product and occupy the customers competitively. This reality is new challenges for impeller manufactures and caused a rethinking of the processes of design, development and implementation of the product. The project focused on how rethinking is applied in terms of the application of advanced engineering tools and methods to specify the design and development of products. Design and development of the impeller using conventional manufacturing process (Sand Casting) is very complicated, difficult and also time consuming. In this project work we are mainly concentration on the impeller design and development methods. In design RE process creating the impeller model, from physical component of impeller generating the point cloud data by laser scanner, then that data is import into the geomagic studio software and in this merged the all the scan point cloud data recreated the impeller model and finished in the Catia V5 R 19 software and finally SLA technique created the impeller prototype.

This will lead to time saving and cost of manufacturing. The development of the impeller using SLA process is used for visualization, mechanical test etc. and also Rapid tooling for mass production.In the design of the impeller we are go through checking possibility optimization process, with three different materials. And also Analysis to be carried out for optimization of component to analyze the design is safe or not using static. From the analysis part concluded that we can do optimization on impeller.

REFERENCES

[1]V.R.S.KishoreAjjarapu,K.V.P.P.Chandu,D.M.MohanthyBabu,'*'design and analysis of the impeller of a turbocharger for a diesel engine' E-ISSN2249–8974.*

[2] GrzegorzBudzik, Krzysztof KubiakJacek Bernaczek, Marek Magniszewski, '*'Hybrid Method for Rapid Prototyping of Core Models of Aircraft Engine Blades'', Vol. 19, No. 2 2012*.

[3] G. Budzik, *''Properties of made by different methods of RP impeller foundry patterns'' Volume 7 Issue 2/2007 83 – 86*

[4]Prof.R.Arravind, Dr.M.Saravanan, R.Mohamed Rijuvan. *'Modal analysis of a radial flow composite impeller' Vol. 4, Issue 1 ISSN 0976-2558.*

[5] Vinesh Raja, Kiran J. Fernandes, *Reverse Engineering an industrial prospective* by (ISBN-13: 9781846288555)

[6]Chua C.K., Leong K.F. and Lim C.S *Rapid Prototyping: Principles and Applications,* 2nd Edition (ISBN 981-238-117-1)

[7]C.Coleman. "Turbocharger History." *Renault 5 GT.* Internet:http://freespace.virgin.net/c.coleman/turbhist.htm [*Feb. 25, 2007*].

[8] Albert Kammerer *Experimental Research into Resonant Vibration of Centrifugal Compressor Blades* Diss. ETH No. 18587Swiss Federal Institute of Technology (ETH Zürich)

[9] Caitlin J. Smythe *Forced Response Predictions in Modern Centrifugal Compressor Design* Massachusetts Institute of Technology Libraries June 2005

[10] Mallilakrjuna, Souvenir and book of Abstracts Innovative modeling & rapid prototyping of the turbocharger impeller *proc. International conference on Advanced materials, Manufacturing, Management & Thermal sciences-2013*, MF53 SIT Tumkur, India.