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Part Modeling with Reverse Engineering

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Abstract

The project is about application of reverse engineering. Reverse engineering helps in obtaining the geometry of part or product which is not available otherwise. Its application makes it possible to reconstruct the original component with its drawing and manufacturing process. It is used in various fields but here the main application is related to a broken impeller of an old 0.5 hp motor. Currently this part is not available in the market as it is out dated and drawing of the component does not exist. As the part is no longer available it has to be made in-house so it will require all activities from designing to rapid prototyping. The procedure includes various stages which will help understand the different phases of reverse engineering. The process starts with understanding the reverse engineering procedure. The part geometry is first obtained with the help of scanning technology. Then with the use of different softwares the three-dimensional image of the broken impeller is obtained. Once the image is obtained the part is optimized using ANSYS software. After the optimized geometry is obtained, the pattern of the part is obtained using Rapid prototyping machine. This can be used for casting of the original part.

***Keywords**— Reverse engineering; Laser scanning; Ansys; Computational fluid dynamics; Rapid prototyping*

1. Introduction

1.1 About Reverse engineering concept

Engineering is the profession involved in designing, manufacturing, constructing, and maintaining of products, systems, and structures. At a higher level, there are two types of engineering: forward engineering and reverse engineering. Forward engineering is the traditional process of moving from high-level abstractions and logical designs to the physical implementation of a system. In some situations, there may be a physical part without any technical details, such as drawings, bills-of-material, or without engineering data, such as thermal and electrical properties. The process of duplicating an existing component, subassembly, or product, without the aid of drawings, documentation, or computer model is known as reverse engineering.

Reverse engineering can be viewed as the process of analyzing a system to:

1. Identify the system's components and their interrelationships
2. Create representations of the system in another form or a higher level of abstraction
3. Create the physical representation of that system

Reverse engineering is very common in such diverse fields as software engineering, entertainment, automotive, consumer products, microchips, chemicals, electronics, and mechanical designs. For example, when a new machine comes to market, competing manufacturers may buy one machine and disassemble it to learn how it was built and how it works. A chemical company may use reverse engineering to find a patent of a competitor's manufacturing process. In civil engineering, bridge and building designs are copied from past successes so there will be less chance of catastrophic failure. In software engineering, a good source code is often a variation of other good source code. In some situations, designers give a shape to their ideas by using clay, plaster, wood, or foam rubber, but a CAD model is needed to enable the manufacturing of the part. There is no guarantee that the CAD model will be acceptably close to the sculpted model. Reverse engineering provides a solution to this problem because the physical model is the source of information for the CAD model. This is also referred to as the part-to-CAD process as shown in Fig.1.

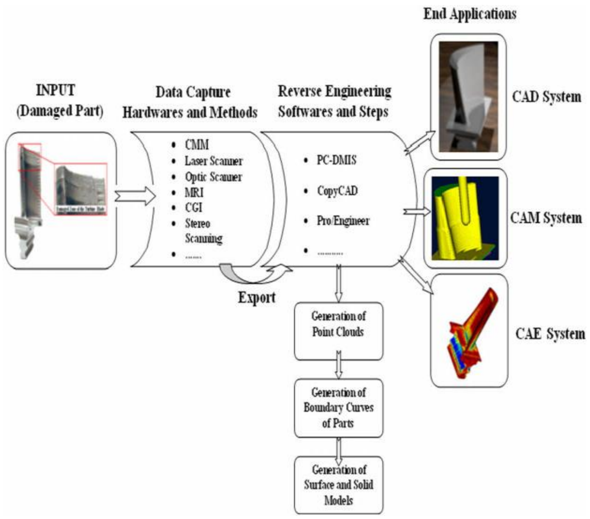


Fig.1 Application of reverse engineering

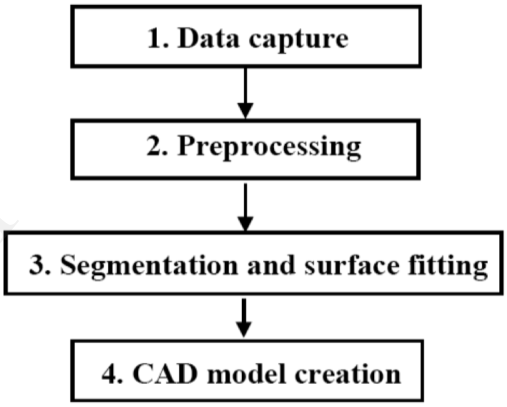
1.2 Steps involved in reverse engineering process

Since the reverse engineering process can be time-consuming and expensive, reverse engineers generally considers whether the financial risk of such an endeavor is preferable to purchasing or licensing the information from the original manufacturer, if possible.

In order to reverse engineer a product or component of a system, engineers and researchers generally follow the following four-stage process: shown in Fig.

- Identifying the product or component which will be reverse engineered
- Observing or disassembling the information documenting how the original product works
- Implementing the technical data generated by reverse engineering in a replica or modified version of the original
- Creating a new product (and, perhaps, introducing it into the market)

In the first stage in the process, sometimes called "prescreening," reverse engineers determine the candidate product for their project. Potential candidates for such a project include singular items, parts, components, units, subassemblies, some of which may contain many smaller parts sold as a single entity.
The second stage, disassembly or de-compilation of the original product, is the most time-consuming aspect of the project. In this stage, reverse engineers attempt to construct a characterization of the system by accumulating all of the technical data and instructions of how the product works.
In the third stage of reverse engineering, reverse engineers try to verify that the data generated by disassembly or de-compilation is an accurate reconstruction of the original system. Engineers verify the accuracy and validity of their designs by testing the system, creating prototypes, and experimenting with the results.
The final stage of the reverse engineering process is the introduction of a new product into the marketplace. These new products are often innovations of the original product with competitive designs, features, or capabilities. These products may also be adaptations of the original product for use with other integrated systems, such as different platforms of computer operating systems.



Flow chart.1 Reverse Engineering process

Often different groups of engineers perform each step separately, using only documents to exchange the information learned at each step. This is to prevent duplication of the original technology, which may violate copyright. By contrast, reverse engineering creates a different implementation with the same functionality.

2 The typical Reverse Engineering process can be summarized in following steps

1. Physical model which needs to be redesigned or to be used as the base for new product.
2. Scanning the physical model to get the point cloud. The scanning can be done using various scanners available in the market.
3. Processing the points cloud includes merging of points cloud if the part is scanned in several settings. The outlines and noise is eliminated. If too many points are collected then sampling of the points should be possible.
4. To create the polygon model and prepare *.stl*files for rapid prototyping.
5. To prepare the surface model to be sent to CAD/CAM packages for analysis.

6. Tool path generation with CAM package for suitable CNC machine manufacturing of final part on the CNC machine.

The Roland Model lpx-600 laser scanner is a medium sized scanner used to scan object of maximum height of around 150 mm and diameter of 120 mm. It operates with interface of computer with software Dr. Picza which helps in setting up the scanning parameters and also shows the scanning process. It stores the scanned file in .stl format. The scanner is shown in Fig.2.

Fig.2 Roland Model LPX-600 Laser scanner

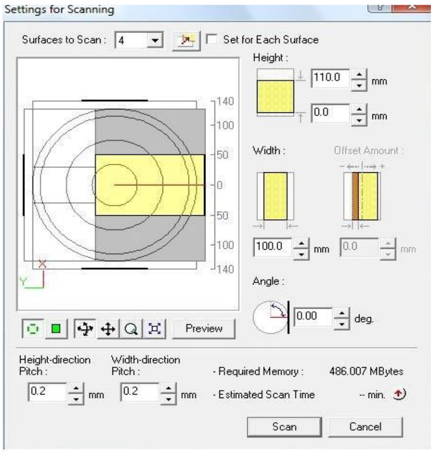


Fig.3 Model software setting for scanning

Fig.4The damaged impeller

Once the scanned image of object is obtained using scanner it is exported into .stl format shown in Fig.5. The parameter set in the above software decides the quality of scanned image. As the time for scanning increases the quality of scanned image improves. The software used for the purpose is provided by Roland Lpx scanner named Dr. Picza shown in Fig.3.

Fig.5 .stl image file of scanned component

3 Obtaining the solid geometry from the point cloud data

Fig.6 show a Rapidform software window which is used for converting the point cloud data in CAD model. The original .stl data is scattered and contains some noise around the boundary of model. The noise creates a problem while generating a solid model so it has to be cleaned from the data. Rapidform software has features which help to point out the noise from the data and with the help of noise reduction tool the noise is reduced. Then we get a clean .stl data which can be used for further processing.

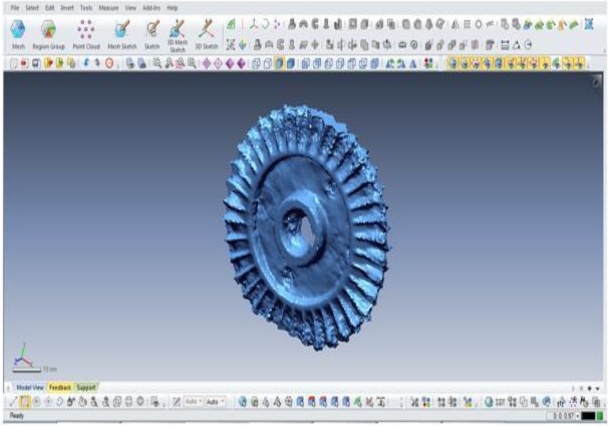


Fig.6Rapidfrom software interface

The scanned image is imported in Rapidfrom software which helps to extract geometry from the .stl file or point cloud data shown in Fig to Solid geometry. The main problem with the software is that it cannot directly save the file in .STEP or .IGES format for that we have to transfer the file toCatia software and do the necessary changes which can be saved in any format required. Once the three dimensional geometry is ready we can use it for further purpose of CAM and CAE operations. The captured point cloud data was converted into polylines and the file was transferred to .IGES file format. Finally the model is converted into solid model, the cross section of which is showed in Fig.7.

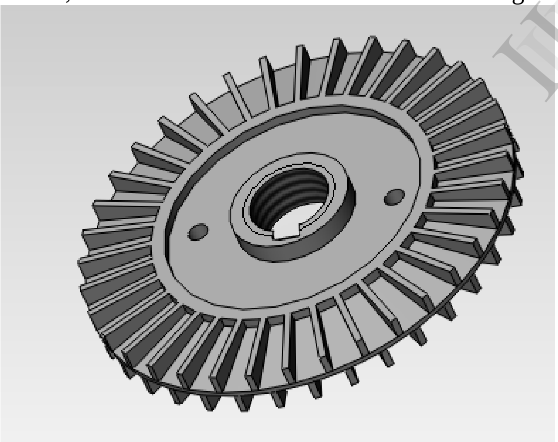


Fig.7Catia model of scanned component

4 Design analysis of impeller

The analysis of part is done in two steps first is Static analysis and then Computational fluid dynamic. Finite Element Analysis (FEA) is done in order to solve problems such as stress, heat flow, vibration and other fields for analysis. ANSYS is used for general purpose Finite Element Analysis, this enables user to perform strain and stress analysis for the given part. Thus, in this case study we have successfully completed

1. 3 D scan and reconstruction of geometry of damaged component
2. Developed CAD model and clean up the geometry of the component.
3. The analysis of component was done using ANSYS Static structural analysis. It helps to find whether the Model will work in specified conditions.
4. Manufactured the component by Rapid Prototyping

4.1 Engineering Data: The Ansys software contains basic material data inbuilt for some special material the data has to be entered manually. For the analysis purpose the material Brass was used for the component as the original impeller is of the same material. The properties of this material are shown in Table.1.

Sr No.	Property	Value	Unit
1	Density	8600	Kg.m^3
2	Young's Modulus	1.2E+11	Pa
3	Poisson's Ratio	0.33	-
4	Bulk Modulus	1.0526E+11	Pa
5	Shear Modulus	4.5801E+10	Pa

Table.1 Material properties for Brass

4.2 Model: For analysis purpose impeller has to be divided into small portions which are done with the help of mesh and at each point the calculations are carried out which show the ultimate behavior of the component for the applied conditions. The body was converted in mesh with fine structure. So once the command is given Software automatically generates the mesh on object shown in Fig.8.

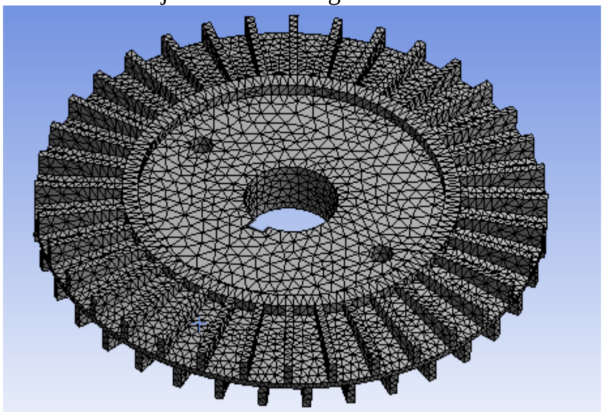


Fig.8Meshed impeller

4.3 Results: Calculations were carried and results were displayed with following parameters.

Total Deformation- so max deformation was found to be 0.0035 mm at the end of the blades as shown in Fig.9.

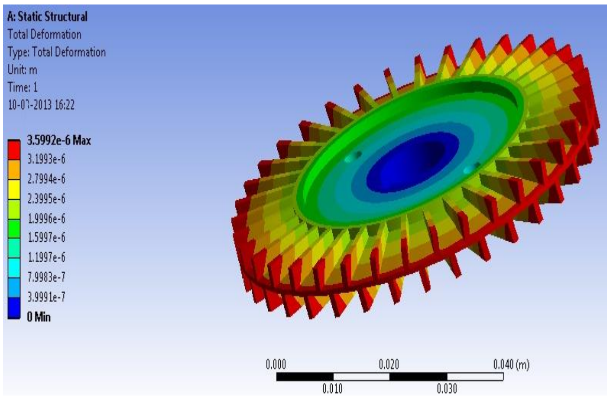


Fig.9Deformation of impeller

Equivalent (Von –Mises) stresses: the min and max value of stress was found to be 35195 Pa and 2.2009e+007 Pa as shown in Fig.10.

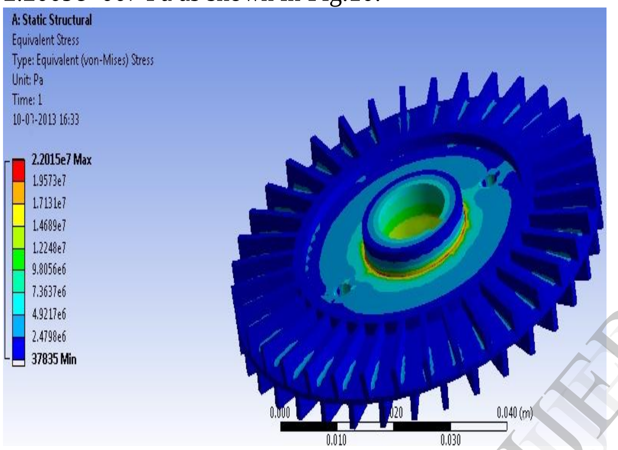


Fig.10Equivalent (Von –Mises) stresses

Shear stress: The min and max value of shear stress was found to be -8.5403e+006 Pa and 9.222e+006 Pa as shown in Fig.11.

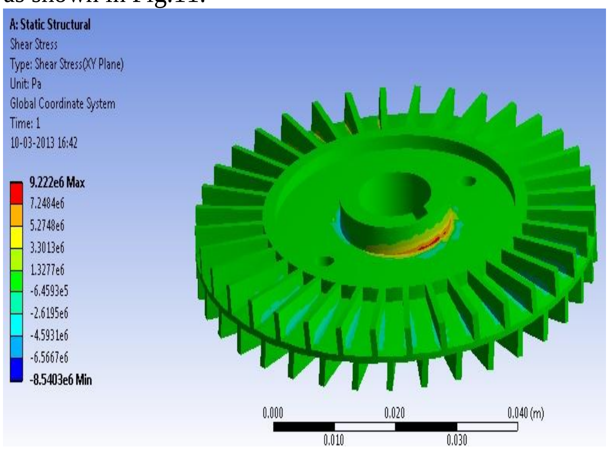


Fig.11Shear stress developed in component

5 CFD Analysis

ANSYS fluid dynamics is used for modeling and analyzing the fluid model and other model related to fluids. It includes all the necessary tools to design, optimize and modify the fluid model developed in software. ANSYS CFX has potential for solving high range and complex problems with a good amount of accuracy in comparatively less time.

5.1 Model: For analysis purpose water model of impeller has to be divided into small portions which are done with the help of mesh and at each point the calculations are carried out which shows the ultimate behavior of the water model of impeller for the applied conditions. In this step the water model was converted in mesh with fine structure. So once the command is given Software automatically generates the mesh on object. Details such as fine medium or coarse mesh have to be selected. More the mesh is fine more accurate results can be considered but at the same time the calculation time is increased. The meshing of the water model of impeller is shown in figure.12.

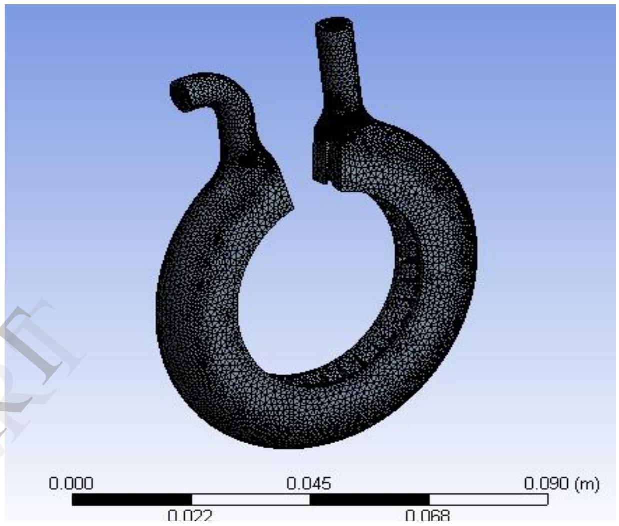


Fig.12Meshed model of solid cfd model

5.2 Results

5.2.1 A. Pressure

5.2.1.1. **without any modification of geometry:**

It can be observed from the Fig.13 that pressure was increased at the inner edges of blade pressure was increased. So it results in clogging of water at the inner edges of impeller so fillet of 15 mm was provided at inside edges of impeller and calculations were again carried out.

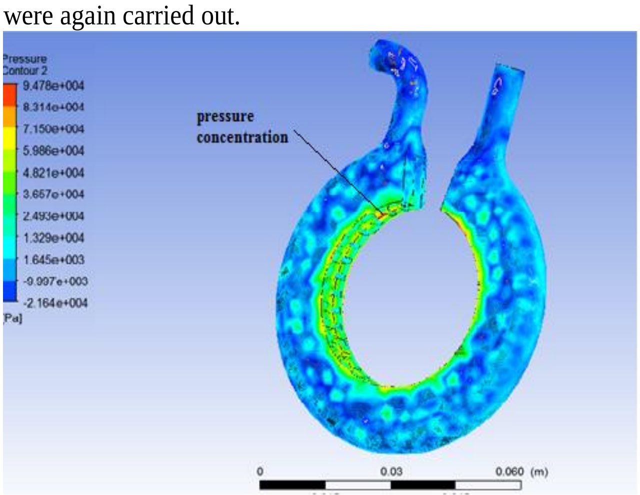


Fig.13Pressure contour for impeller without modification

5.2.1.2. with fillet at inner edge:
After providing fillet of 15 mm at inner edges it was seen that there was decrease of pressure at inner edges of impeller which can be seen in Fig.14

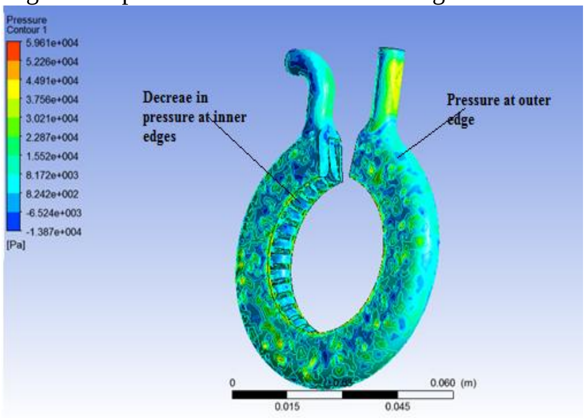


Fig.14 Pressure contour for impeller after fillet of 15 mm is provided

5.2.1.3. with side fillet and inner edge fillet
From Fig.15 it is seen that there is pressure at the outer edges of blades hence the outer edges were provided with chamfer of 2 mm. which generates the curved profile at the edges. After carrying out CFD analysis the results presented in Fig. show that the pressure at the outer edge has reduced as compared to Fig. 17

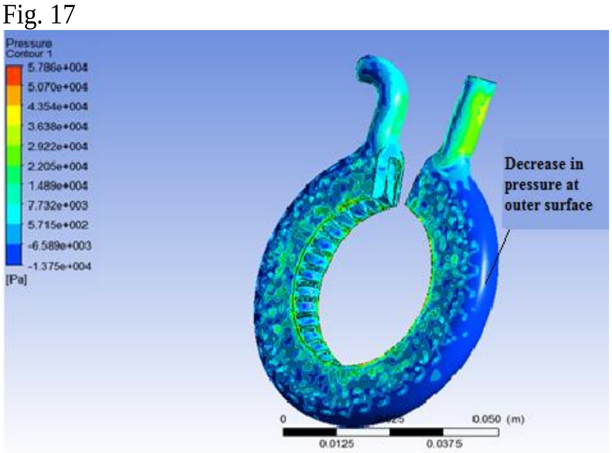


Fig.15Pressure counter for impeller with inner edge fillet and side edge fillet

5.2.2 B. Velocity

5.2.2.1. without any modification of geometry:
It is observed from Fig.16 that the velocity vector is scattered. Due to this the overall flow rate decreases.

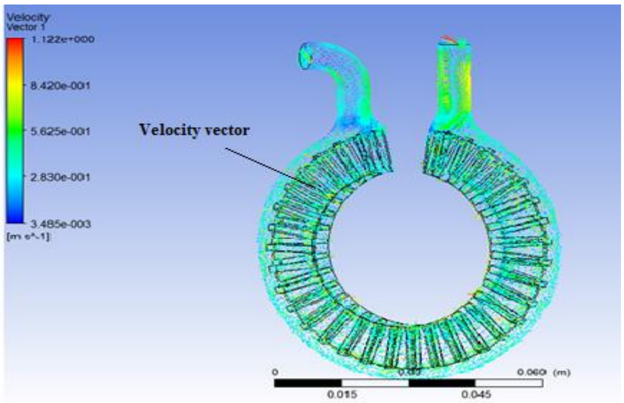


Fig.16Velocity vector for impeller without any modification

5.2.2.2. with fillet at inner edge:

Compared to Fig.16 the velocity vector is in order which ultimately results in increase of flow rate of fluid as seen in Fig.17

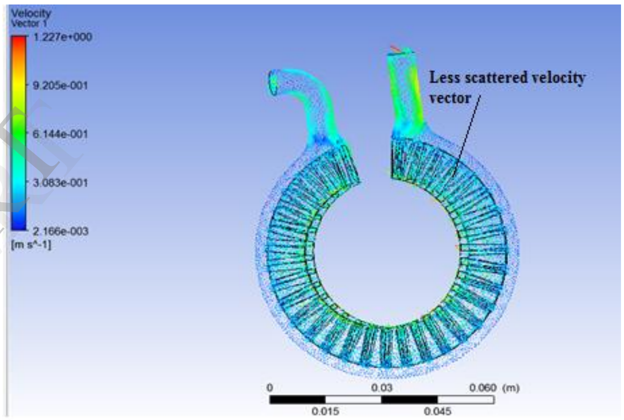


Fig.17velocity vector for impeller with fillet at inner edge

5.2.2.3. with side fillet and inner edge fillet
Comparing with Fig the velocity vector is in order which ultimately results in increase of flow rate of fluid as shown in Fig.18

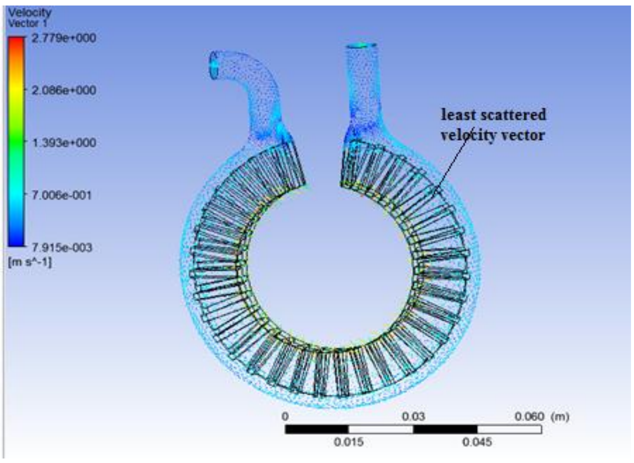
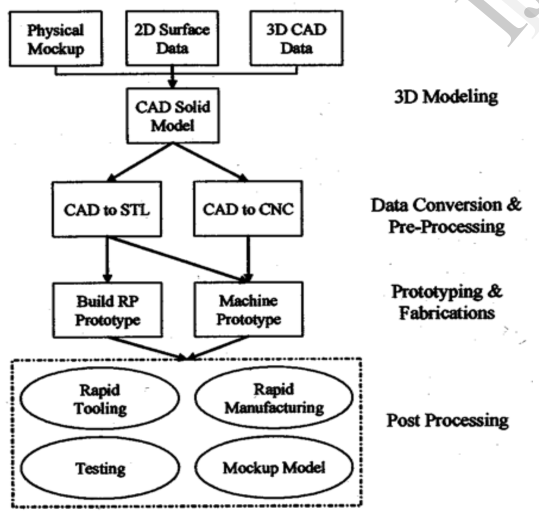


Fig18 velocity vector for impeller with side fillet and inner edge fillet

The static analysis shows us maximum deformation at the outer edges of blades which can result in wear of the edges. To avoid this chamfer of 2 mm was provided at the ends of blades. As the neck of the impeller was showing concentrated stress it can be overcome by providing a round fillet. After making the necessary changes the blade was capable of withstanding the design load. Once static analysis was done fluid analysis was done in order to increase its efficiency of water from the pump which can be observed from Fig to Fig.

6 Concept of Rapid Prototyping

Rapid Prototyping refers to the fabrication of three dimensional physical models directly from a computer-aided design. This additive manufacturing process provides designers and engineers the capability to literally print out their ideas in three dimensions. According to Wohler's Report 2000, RP is defined as: a special case of machine technology that quickly produces models and prototype parts from 3-D data using an additive approach to form the physical models The generic RP process is shown in Figure The RP process provides a fast and inexpensive alternative for producing prototypes and functional models as compared to the conventional routes for part production.



Flow chart 2Generic Rapid Prototyping process

The advantage of building a part in layers is that it allows you to build complex shapes that would be virtually impossible to machine, in addition to more simple designs. RP can build intricate internal structures, parts inside of parts, and very thin-wall features just as simple as building a cube. All the RP processes construct objects by producing very thin cross section of the part, one on top of the other, until the solid physical part is completed. This simplifies the intricate three-dimensional construction process in that essentially two-dimensional slices are being created and stacked together. For example, instead of trying to cut out a sphere with a detailed machining process, stacks of various sized "circles" are built consecutively in the RP machine to create the sphere with ease. RP also decreases the amount of operation time required to build parts. The RP machines, once started, usually run unattended until the part is complete. This comes after the operator spends a small amount of time setting up the control program. Afterwards, some form of cleanup operation is usually necessary, generally referred to as post processing. Models can usually be built within hours, and the build materials for most processes are inexpensive. Some RP machines are small and environmentally friendly so they can be placed into a designer's office.

The additive Manufacturing Technologies of Rapid Prototyping is the technique to manufacture intricate and dense features. In this technique computer software generated data in CAD model is feed directly to the machine in digital form. Companies are using this technique in order to cut down the lead time for prototyping new product and also it reduces cost and increases the competitiveness in the market.

Fig.20

Additive rapid prototyping machine objet connex 500
The Objet500 Connex offers all of the power of pioneering Connex multi-material 3D printing in a build envelope of 500 x 400 x 200mm (19.7 × 15.7 × 7.9 in.) — large enough to support large models or many parts. Using patented simultaneous multi-material PolyJet technology, the Objet500 Connex can 3D print models with up to 14 different materials in a single job the machines shown in Fig.20.

As this process uses the laser curing technique the process is much cleaner as compared to other rapid prototyping process. Special type of curing powder is used for this process which hardens when laser is focused on to it. Before starting the machine it is necessary to clean the lenses of machine. Company provides special type of cleaning chemicals which assures that there is particle incursion during the process.

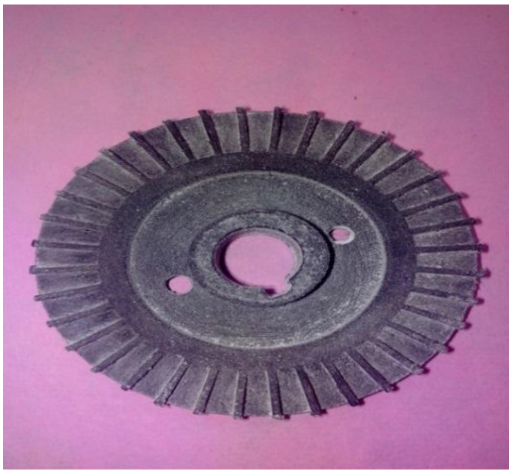


Fig.21 Rapid prototype of impeller

The component obtained from RP machine is shown in Fig.21. First the component has to be cleaned to remove the extra resin collected into its cavity. The part without any modification was manufactured in RP machine to check the feasibility of the whole process. Once that was done the part was analyzed and optimization was done with help of engineering data and software.

7 Conclusion

The work done till now shows how reverse Engineering can be used for worn out or broken parts whose availability is a problem, in such cases as there is no any documentation or drawing available prior so everything has to be done from the starting phase. Reverse engineering plays a vital role in providing a digital data for CAD CAM & CAE applications. As the basic data is recovered by Reverse Engineering process it can be used further for different procedures. In this method the main advantage is that once we get the CAD model of the component it can be used for analysis and design optimization which proves to be beneficial in developing any product from market point of view. It is shown that the ANSYS Workbench environment can be used very effectively to realize any parametric optimization. Also reverse engineering can be used in combination with Rapid Prototyping for obtaining the model which can be used for further manufacturing of original product. A Rapid prototype model helps in visualization and better understanding of final product.

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Biography

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