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# Re-creation of Burst Impeller for Automation - A Reverse Engineering Application

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***Abstract*----This 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 burst impeller. In this present work a burst impeller of an old 0.5 hp motor taken. 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 software's, 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.**

***Index Terms*— Reverse Engineering; Laser Scanning Technology; ANSYS; Computational Fluid Dynamics; Rapid Prototyping.**

## I. Introduction

### A. 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:

- Identify the system's components and their interrelationships
- Create representations of the system in another form or a higher level of abstraction
- 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.

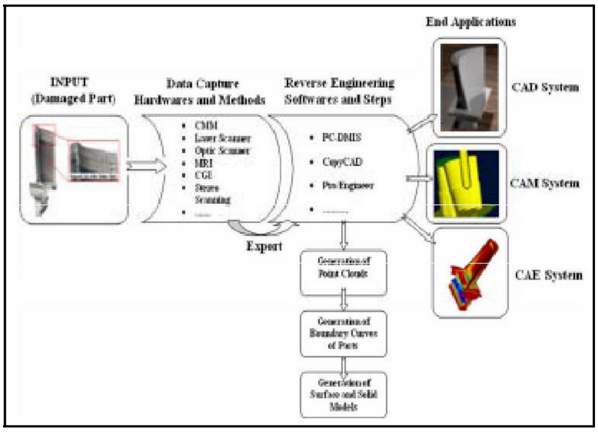


Fig. 1: Application of Reverse Engineering

 

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## II. METHODOLOGY

A case study of broken impeller of 0.5 hp pump done for the purpose of obtaining point cloud data which was exported into associate nursing .stl format of the CAD program. The best method to approximate a 3D geometrical model is by approximating it with lots of triangular aspects.

Fig. 2: The Damaged Impeller

### A. The Typical Reverse Engineering Process Can be Summarized in Following Steps

1. Physical models which needs to be redesigned or to be used as a base for new project.
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. 3.

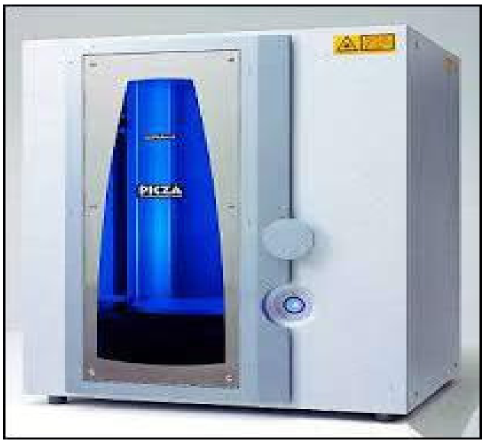


Fig. 3: Roland Model LPX-600 Laser Scanner

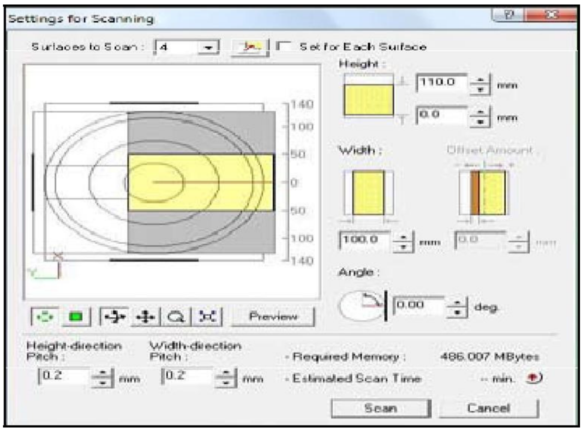


Fig. 4: Model Software Setting for Scanning

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. 4.

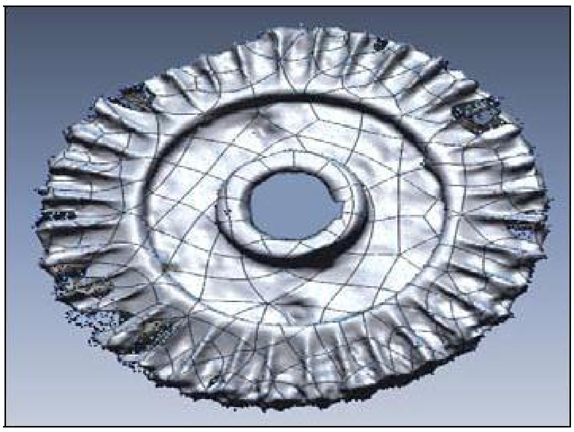

Fig. 5: Stl Image File of Scanned Component

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### B. Obtaining the Solid Geometry From the Point Cloud Data

Fig. 6 shows a Rapid form 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. Rapid form 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. 6: Rapid from Software Interface

The scanned image is imported in Rapid from software which helps to extract geometry from the .stl file or point cloud data shown in fig. 5 to Solid geometry.

### C. Data Captured Through Laser Scanned Image

By scanning the damaged component of broken impeller through Roland model LPX-600 Laser scanner following data was captured.

Those details are mentioned in below Table 1

Table 1:

| | |
|---|---|
| Diameter of impeller | 65mm |
| Outer diameter of sealing face | 44mm |
| Inner diameter of sealing face | 40mm |
| Outer diameter of shaft hole | 20mm |
| Inner diameter of shaft hole | 12mm |
| Diameter of holes (2 no's) | 4mm |
| Length of sleeve | 4mm |
| Breadth of sleeve | 2mm |
| Depth of shaft hole | 8mm |
| Thickness of web | 2mm |
| Number of vanes (Both sides) | 72 |
| Thickness of blade (72 no's) | 2mm |
| Height of blade at outer edge (72 no's) | 4mm |
| Height of blade at inner edge (72 no's) | 2mm |

## III. Design And Analysis

### A. Creating 3-D Model

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 to CATIA V5 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 poly lines and the file was transferred to .IGES file format. Finally the model is converted into solid model as shown in fig. 11.

### Material Properties for Brass

Table 2:

| 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 |

### B. Geometry

After the broken impeller was scanned in scanner and exported in .stl file format. The solid model was generated using Rapid form software which accepts imported .stl data file and exports in other editable formats. The component was rebuilt and saved in catia for further use. Catia is based on Para solid modeler who utilizes a parametric feature-based approach for creating models and assemblies. So in ANSYS workbench for geometry module the part was imported in .IGES format shown in fig. 7.

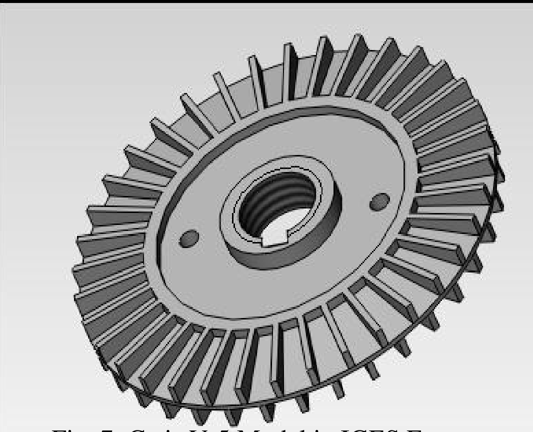

Fig. 7: Catis V-5 Model in IGES Format

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### C. 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. 12.

### D. Meshing

The geometry and the mesh of a 72 bladed pump impeller domain is generated using ANSYS Workbench. An unstructured mesh with tetrahedral cells is also used for the zones of impeller as shown in fig. 8. The mesh is refined as in the regions close to the leading and trailing edge of the blades. Around the blades, structured hexahedral cells are generated to obtain better boundary layer details. A total of 35722 elements are generated for the impeller domain. Mesh statistics are presented in Table 3.

Table 3:

| | | |
|---|---|---|
| 1 | Number of nodes | 5234 |
| 2 | Number of tetrahedral | 34152 |
| 3 | Number of elements | 35722 |

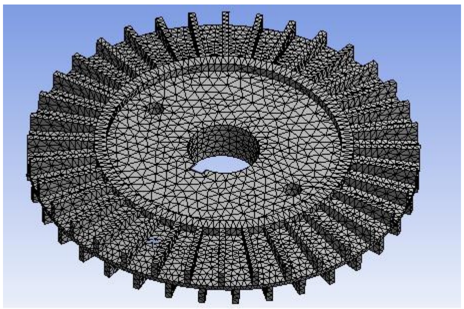

Fig. 12: Meshed Impeller

### E. Setup

Once meshing is done then impeller is ready for applying boundary conditions as shown in fig. 13. For static study on impeller parameters were considered relating to its working condition. In general working of pump a pressure of around 5-6 bar is built up inside the pump housing. So the pressure of 2 bar was applied on both sides of impeller on its blades. Then motor was run at around 1500 rpm i.e nearly equal to 150 rad/s. The impeller was held at centre using cylinder support joint.

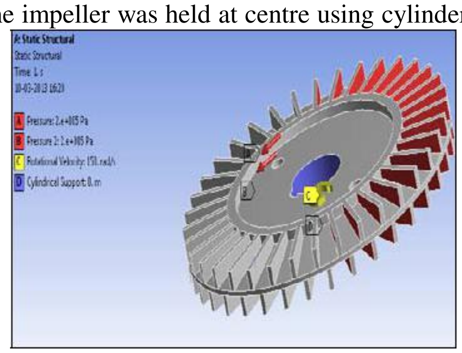


Fig. 9: Setup of Load & Boundary Conditions

### F. Solution

After applying the boundary conditions for the component. It was solved using ANSYS solver. The solving time depends on size of geometry and also on mesh structure; finer the structure more is the calculations time.

### G. Geometry

At the time of impeller was scanned in scanner and exported in .stl file format, the water model of the impeller was generated using Rapid form software which accepts imported .stl data file and exports in other editable formats. The water model was rebuilt and saved in solid works for further use. So in ANSYS workbench for geometry module the part was imported in .IGES format shown in fig. 10.

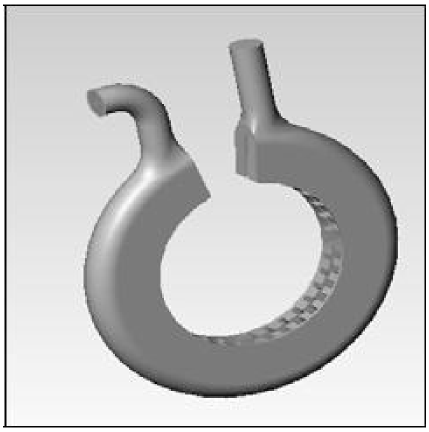

Fig. 10: Catia Model of Fluid Part of Impeller

### H. 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 fig. 11.

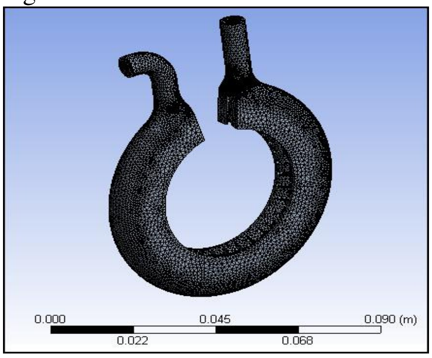


Fig. 11: Meshed Model of Solid CFD Model

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**I. Setup**

After meshing of component was completed it was exported to Setup module. Here the boundary conditions and input conditions for the model were given. The inlet was denoted with notation "IN" and opening was detonated with "OUT". Rest of the body was recognized as wall. The impeller was given RPM as per required. Water was considered as Default liquid medium. The completed boundary condition of the part is shown in fig.12.

**J. Pressure Contour without Any Modification of Geometry**

It can be observed from the fig. 12 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.

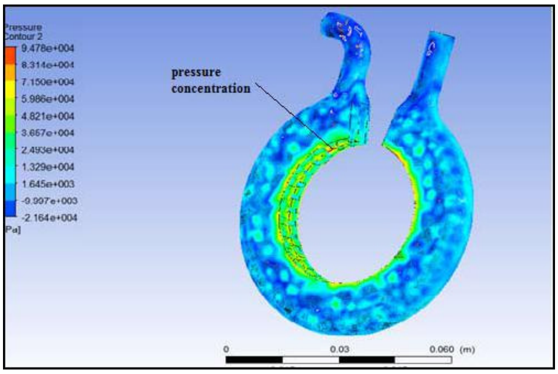


Fig. 12: Pressure Contour for Impeller without Modification

**K. Blade Loading at 50% Span**

Blade loading plot for the centrifugal impeller at 50% span is shown in fig. 13. Gradual increase of pressure is observed with stream wise increment. High pressures on pressure side of the blade and low pressures on suction side of the blade are observed. At leading edge, pressure drop on both pressure and suction side are observed due to the acceleration of the flow in to the impeller. At 10% stream wise location pressure drop is observed on pressure side of the blade. At trailing edge of the blade, pressure drop is observed due to the blade.

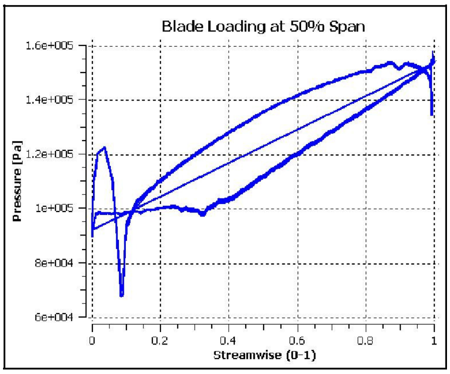


Fig. 13: At 50% Span

**L. Stream Wise Variation of Area Averaged Absolute Velocity**

Stream wise variation of area averaged absolute velocity is shown in fig. 14. From 30% stream wise location, the area averaged absolute velocity is increasing with stream wise increment due to the dynamic energy transfer from the impeller to the fluid. From 90% stream wise location, the area averaged absolute velocity is decreasing because of increase in pressure in outlet duct.

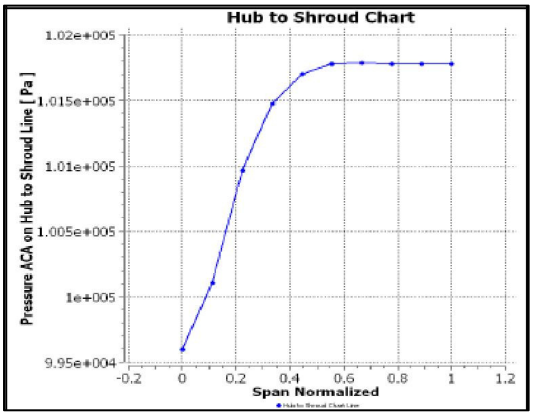


Fig. 14: Steam wise variation of Area Averaged Absolute Velocity

**M. Boundary Conditions**

Pump impeller domain is considered as rotating frame of reference with a rotational speed of 1500 rpm. The working fluid through the pump is water at 25$^{o}$C. Turbulence model with turbulence intensity of 5% is considered. Inlet static pressure 3.5kg/cm$^2$ and outlet mass flow rate of 0.0035m3/s are given as boundary conditions.

Three dimensional incompressible N-S equations are solved with ANSYS-CFX Solver.

**N. Results Obtained With Given Specifications Through ANSYS -CFX**

| S.NO | Description | parameters |
|---|---|---|
| 1 | Diameter of casing | 0.7m |
| 2 | Rotational speed | 1500rpm |
| 3 | Volume of flow rate | 0.0035m3/s |
| 4 | Head in | 3.05m |
| 5 | Head out | 4.3m |
| 6 | Flow coefficient | 0.0239 |
| 7 | Head coefficient | 0.34 |
| 8 | Shaft power | 3209.3w |
| 9 | Power coefficient | 0.031 |
| 10 | Static efficiency | 61.2% |
| 11 | Total efficiency | 89.1% |

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### O. Actual Specifications of 0.5 hp Regenerative Turbine

Below mentioned specifications are belongs to a regenerative turbine pump with thread type. But above mentioned specifications belongs to pump with sleeve, Hence some decrease in efficiency we can find because of key alignment in above table no 4.

Table 5:

| S.NO | Description | parameters |
|---|---|---|
| 1 | Diameter of casing | 0.7m |
| 2 | Rotational speed | 1500rpm |
| 3 | Volume of flow rate | 0.0041m3/s |
| 4 | Head in | 3.05m |
| 5 | Head out | 4.3m |
| 6 | Flow coefficient | 0.0241 |
| 7 | Head coefficient | 0.36 |
| 8 | Shaft power | 3209.3w |
| 9 | Power coefficient | 0.031 |
| 10 | Static efficiency | 63.2% |
| 11 | Total efficiency | 92.1% |

### P. Applications Area of Rapid Prototyping

Most of the RP parts are finished or touched up before they are used in specific areas of applications. Applications can be grouped into design, engineering analysis and planning and tooling and manufacturing. A wide range of industries can benefit from RP and these include, but are not limited to, aerospace, biomedical, consumer, electrical, and electronics products. There are many types and classes of physical prototypes as shown in fig. 16 including various fields of the process:

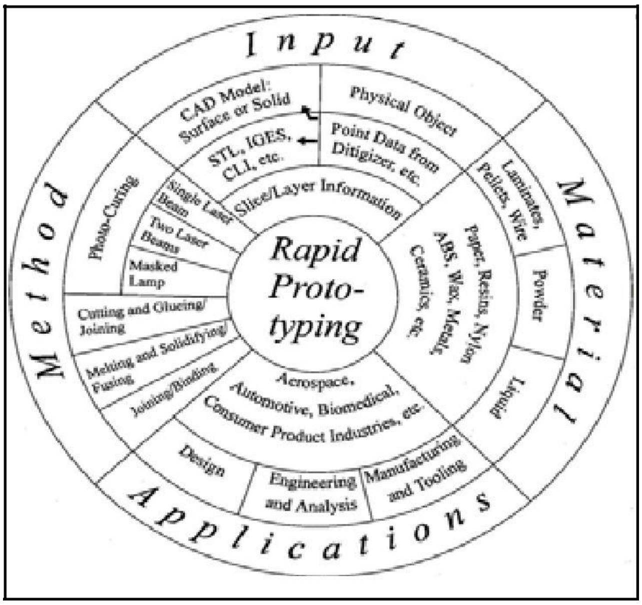


Fig. 15: Rapid Prototyping Circle

## IV. CONCLUSION

A centrifugal pump impeller is modeled and solved using ANSYS and computational fluid dynamics, the flow patterns through the pump, performance results, circumferential area averaged pressure from hub to shroud line, blade loading plot at 50 % span, stream wise variation of mass averaged total pressure and static pressure, stream wise variation of area averaged absolute velocity and variation of mass averaged total pressure contours at blade leading edge and trailing edge for designed flow rate are presented. The CFD predicted value of the head at the design flow rate is approximately H=9.4528 m.

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