International Journal of Advance Research in Science and Engineering
Volume No.07, Special Issue No.01, March 2018
www.ijarse.com
IJARSE
ISSN: 2319-8354

# DESIGN OF IMPELLER FOR OPTIMIZATION

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**ABSTRACT**

*This paper presents a simplified, impeller and vane profile design procedure by using 3D model. The intent of this paper is to offer a detailed picture of impeller and vane profile design procedure based on fundamental understanding of published procedures using 3D model. There are limited number of published vane profile design procedures by Val S. Lobanoff, John S. Tuzson, A. J. Stepanoff, and others. There is also a lack of explanation and detailed step by step procedure available for designers to systematically design and develop impeller and vane profile design, so the designers are encouraged to reverse engineer the vane profiles popularly available in the market. In the case of published procedures great problem arises while following them since some of them are contradictory to each other. In this paper while designing the vane profile, the overall dimensions of an existing impeller were not changed. Commercial 3D CAD software is used to create the 3D model. Simplification in vane profile design procedure will encourage the designers to enhance the performance of existing as well as new models of pumps.*

***Keywords-3D model, vane profile design procedure, published procedures, vane profile, CAD software.***

## I.INTRODUCTION

In recent years lots of efforts are being made by pump manufacturers to simplify the impeller vane profile design procedure with improvement in pump performance. In pump industry efforts have been taken to simplify the vane profile design procedure for centrifugal pumps only, but very few efforts have been taken to simplify the vane profile design procedure for other pumps. There are limited numbers of published vane profile design procedures by Val S. Lobanoff, John S. Tuzson, A. J. Stepanoff, and others. There is lack of explanation as well as detailed step by step procedure available for the designer to systematically design and develop impeller and vane profile. A great problem arises while following these procedures, since some of the procedures are not matching with each other. So the designers have to use their own judgmental skills for designing the vane profile. The simple method of constructing vane profile is to draw a single radius circular arc using the calculated angle $\beta_1$, $\beta_2$ and radii $R_1$, $R_2$ but this may have serious implications in the performance of the pump.

Here, to begin with a line AM is drawn making an angle of $\beta_2$ to AO as shown in Fig.1.0. Then an angle of $\beta_1$+ $\beta_2$ is drawn at O with the radius OB and a line is drawn from A to the point B, the intersection point on radius $R_1$ and is extended up to D. Then a perpendicular line is drawn in the middle of AD which intersects at M. MA will be the radius of arc and arc AD will be the vane profile.

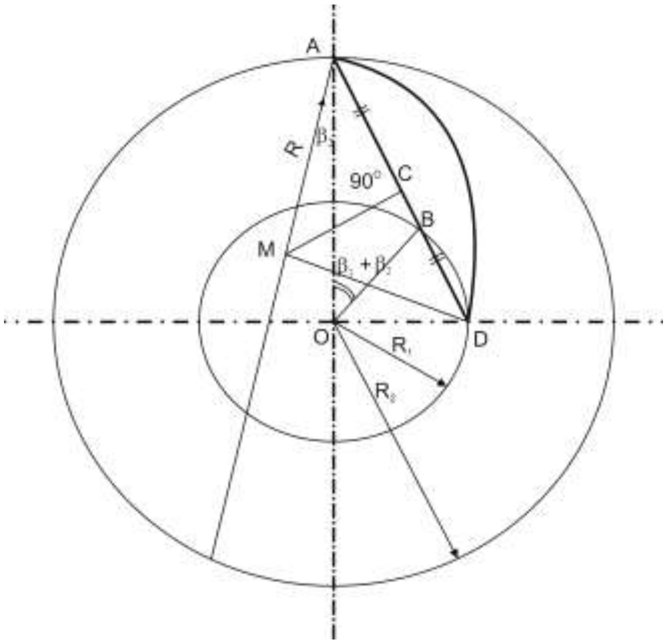


**Fig. 1.0 asimple geometric method of constructing vane profile**

## Impeller Vane Profile design using CAD/CAE:

In recent years the rapid development in both computer software and computer hardware has made it possible an trial and error design process with the help of computer aided design (CAD) and computer aided engineering (CAE). Without actually manufacturing an impeller a 3D model can be generated using commercial 3D CAD software's, SolidWorks, etc. and models can be simulated for flow visualization using CFD (Computational Fluid Dynamics), but CFD usually gets the qualitative picture correct which is useful in helping the designer understand what is happening in the flow also the accuracy of CFD being relatively poor, highly dependent on mesh quality and models used. Effective use of CFD relies heavily on experienced users. Some of the commercially available CFD software's are ANSYS FLUENT, ANSYS CFX, SolidWorks flow simulation, Flow 3D, OpenFOAM, etc. This paper does not includes the CFD approach, but focuses only on a simplified working vane profile design procedure using simple mathematics, geometry assisted by modern CAD software. Another interesting technology being used is rapid prototyping. We will not be discussing anything about this technology in this paper as it is not in our scope.

## II. PROPOSED DESIGN OF PLAIN VANE PROFILE

It is interesting to know that the available published procedures lack both in explanation as well as detailed step by step procedures, so they are difficult to implement. After studying and fundamentally understanding various published procedures as well as current industrial practices, a proposed simplified vane profile design procedure is presented in this paper.

It was decided that the overall dimensions of the existing impeller were to be maintained and only the vane was to be redesigned. The existing impeller was taken from one of the leading manufacturer of submersible pump who used this particular design for quite a number of years. Table 2.0 shows the specifications of this impeller

| S. No. | Description | Values |
|---|---|---|
| 1 | Impeller inlet diameter ($D_1$) | 41 mm |
| 2 | Impeller outlet diameter ($D_2$) | 98 mm |
| 3 | Number of blades (Z) | 6 |
| 4 | Shaft diameter (Ds) | 13 mm |
| 5 | Blade inlet height (B1) | 13.30 mm |
| 6 | Blade outlet height (B2) | 7 mm |
| 7 | Mass flow rate (Q) | 0.0022 kg/s |
| 8 | Head (H) | 9 m |
| 9 | Rotation (N) | 2900 RPM |

**Table 2.0 Specifications of the impeller used to construct the vane profile**

Let $\beta_1$ and $\beta_2$ be the inlet and outlet angles of this impeller respectively. Selection of $\beta_2$ is made generally for an optimum efficiency. An average value of $22.5^o$ is called normal for all specific speeds. The limit of $\beta_2$ followed in a good design is from $17.5^o$ (minimum) to $27.5^o$ (max). We selected the value for $\beta_1$ and $\beta_2$ as $23\,^o$ and $29\,^o$. For smooth flow, we must design the vane such that this angle increases smoothly from $23^0$ to $29^0$

The next step is to construct the vane shape. There are several methods to construct the vane shapes. The one used in practice consists of tangent circular arc. The radius of the Circular arc contained between the rings $D_1$ and $D_2$ is given by,

$$R = \frac{R_2^2 - R_1^2}{2(R_2 \cos \beta_2 - R_1 \cos \beta_1)} \qquad \ldots\ldots\ldots\ldots(1.0)$$

Where $R_1$ and $R_2$ are the radius of Inner and Outer diameters of the impeller. While using this method, the impeller is divided into a number of concentric rings, not necessarily equally spaced between $R_1$ and $R_2$. The value of R for any two consecutive concentric rings is calculated using the Equation (1.0) and vane shape is plotted which is actually an arc tangent to both the rings. An accurate vane shape can be obtained by joining the areas as shown in the proceeding part below.

International Journal of Advance Research in Science and Engineering
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www.ijarse.com
IJARSE
ISSN: 2319-8354

We know that the radius of Inner diameter is given by 41/2 = 20.5 mm and the radius of Outer diameter is given by 98/2 = 49 mm. Now, the intermediate values of radius can be found out by $(R_2-R_1)/n$. where, n = number of intermediate concentric rings required. We will select value of n =11 for better resolution. The values thus obtained are 20.5, 23.091, 25.68, 28.273, 30.864, 33.455, 36.046, 38.637, 41.228, 43.819, 46.41 and 49.00 mm. Similarly, the corresponding values for the vane angle β can be found out graphically using Fig. 2.0.


**Fig. 2.0 A graph for R vs. β**

A table is constructed as shown below showing the calculated values of $R_1$, $R_2$, $\beta_1$ and$\beta_2$ for various values of R .

| $R_1$ | $R_2$ | $\beta_1$ | $\beta_2$ | R |
|---|---|---|---|---|
| **20.5** | **25.68** | **23** | **24.1** | **26.16** |
| **25.68** | **30.864** | **24.1** | **25.2** | **32.67** |
| **30.86** | **36.046** | **25.2** | **26.1** | **39.01** |
| **36.046** | **41.228** | **26.1** | **27.4** | **47.30** |
| **41.228** | **46.41** | **27.4** | **28.4** | **53.78** |
| **46.41** | **49.001** | **28.4** | **29** | **60.80** |

**Table 2.1 Calculated values for $R_1$, $R_2$, $\beta_1$ and $\beta_2$**

Using these values the Vane profile can be generated. SolidWorks 2012 software is used to construct the Impeller geometry as follows:

The circles of radius 52 mm is to be drawn on front plane and extruded by 10 mm and name its centre as point C. This circle is to be used as a reference solid to generate the vane profile.

1. The first step is to draw the circle of radius 49 mm on above reference solid equal to outer radius of impeller by taking C as a center point. The second step is to construct all the concentric circles using radii $R_1$ calculated as shown in Table 2.1 by taking C as a center point. Line AB represents the value of R which makes an inclination of $23^o$ with AC or X- axis. The line AB of length 26.16 mm is to be drawn by taking point A of line AC as start point. The angle between X-axis or line AC and line AB must be equal to $\beta_1=23^o$ as shown in Fig. 2.1.

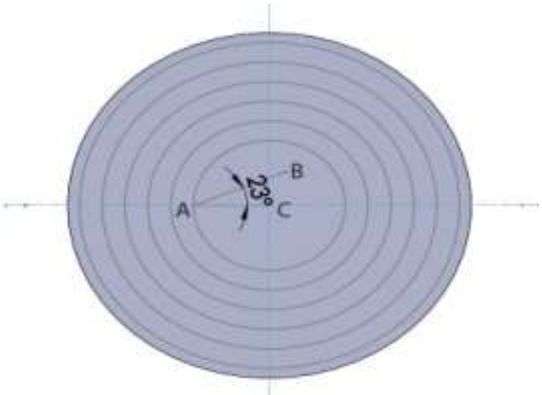


**Fig. 2.1 Concentric circles of radii $R_1$ and line AB making an angle of $23^O$ with line AC**

2. The third step is to construct the first arc AE having inlet vane angle $\beta_1=23^o$ and radius of curvature 26.16 mm. The arc AE of radius 26.16 mm is to be drawn by taking end point B of line AB as a centre point of arc and point A of line AC as a start point. The point where this arc intersects the second concentric circle is taken as end point for arc i.e., point E as shown in Fig. 2.2

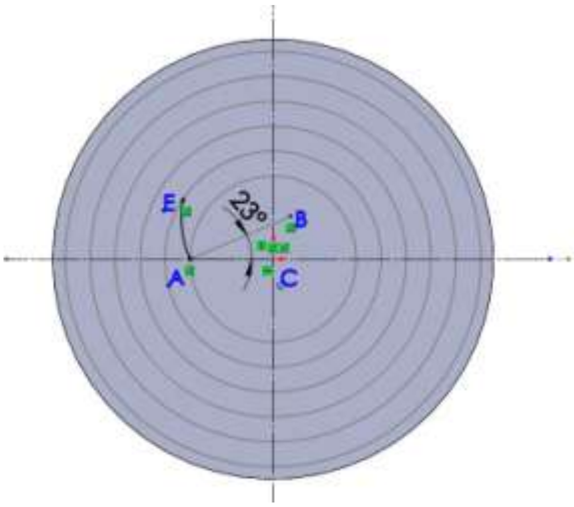


**Fig. 2.2 Arc AE is drawn by taking line AB as radius, point B as centre, A as start point and E as end point**

IJARSE
ISSN: 2319-8354

3. The fourth step is to construct the second arc EF of radius of curvature of 32.67 mm. For that the line ED of length 32.67 mm is to be drawn by taking point E of arc AE as a start point. The line should pass through the end point B of first line AB. Then the arc EF of radius 32.67 mm is to be drawn by taking end point D of second line as a centre point of arc and intersection point E as a start point. The point where this arc intersects the third concentric circle is taken as end point for arc i.e., point F as shown in Fig. 2.3.

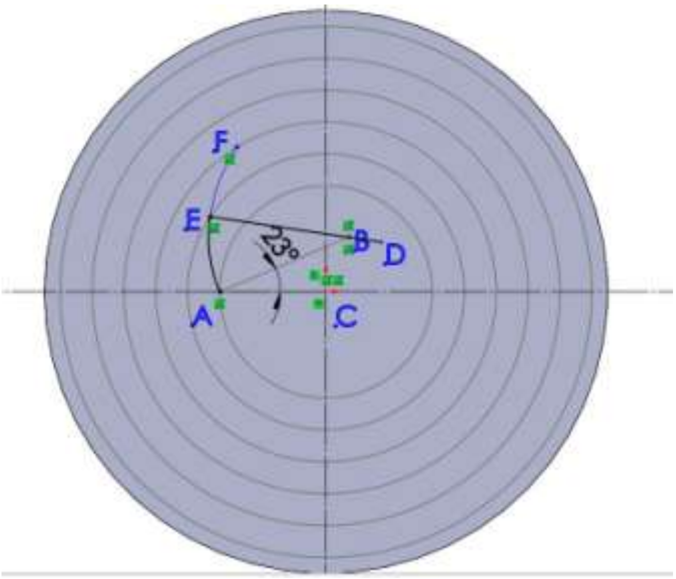


**Fig. 2.3 line ED passing through point B and arc EF drawn by taking D as centre**

4. Same procedure has to be repeated for the remaining values of R as shown in the Table 1.0 Finally, the plain vane profile is achieved in the form of a continuous arc as shown in fig. 2.4.

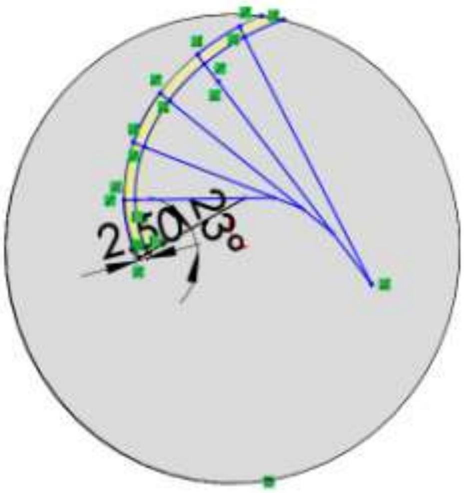


**Fig. 2.4 Completed view of plain vane profile**

Since this impeller contains 6 number of vanes, the fifth step is to use the circular array or pattern command to have a 6 vanes around a Z-axis. To achieve the gradual increase in Blade outlet height (B1) to Blade inlet height (B2) i.e. from 7 mm to 13.30 mm a revolve cut operation is used. The final 3D model of the vane is thus obtained as shown in fig. 2.5.

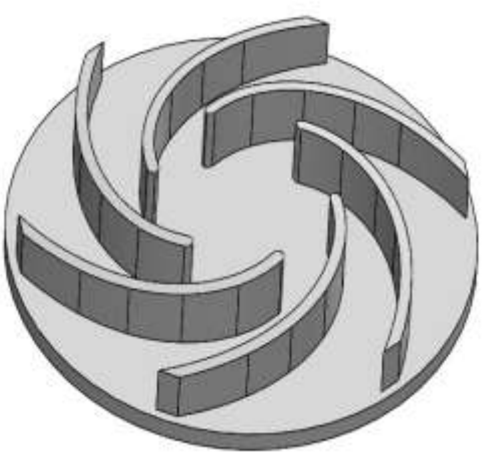

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**Fig. 2.5 3D model of 6 vanes revolved around Z-axis and gradual increase in blade height**

5. Finally the assembling of various parts is to be done to get the final 3D model of impeller as shown in Fig. 2.6.

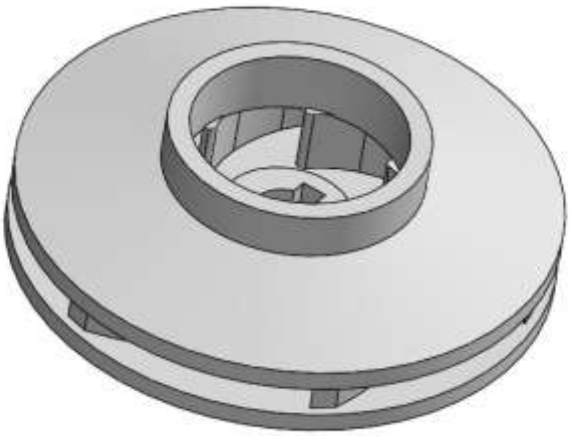

**Fig. 2.6 Finished 3D model of impeller**

## III.CONCLUSION

This paper thus presents a simplified, impeller and vane profile design procedure by using 3D model. The method presented here is quite fast and rapidly helps the designer to experiment with various values of Inlet and Outlet diameters $D_1$ and $D_2$ along with Inlet and Outlet angles $\beta_1$ and $\beta_2$. The industrial practices suggest that the values for $\beta_1$ and $\beta_2$ are to be selected as $23^o$ and $29^o$. The designer may develop a small computer program or a excel worksheet to carry out the calculation fast. Once the 3D Model of the Impeller is developed then instead of going for the manufacture one may go for the CFD Analysis. Such analysis will assist the manufacturer in making the manufacturing decision more quickly. The vane profile design method presented here is applied on an Impeller whose dimensions are known.

## IV.ACKNOWLEDGEMENTS

Our Sincere thanks to our guide Indrajit D.Burse, for providing in our research work. We express our thanks to our Institution namely Bharati Vidyapeeth's College of Engineering, Kolhapur for providing us with a good motivation, environment and facilities like Internet, books, computers and all that as our source to complete this research work. Our heart-felt thanks to our families, friends and colleagues who have helped us for the completion of this work.We are heartily thankful to Dr.Virajit A.Gundale owner of VIRA PUMPS, Kolhapur, Maharashtra, INDIA and Prof,Vinayak Pawar sir for sharing us valuable information for this paper and providing necessary resources and setup for performing necessary research and trials.

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