International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 05 Issue: 12 | Dec 2018 www.irjet.net p-ISSN: 2395-0072

Analysis of Centrifugal Pump Impellers with Modified Micro Grooves.

V. VIGNESH

PG Student, Department of mechanical engineering (Engineering Design), Government college of technology Coimbatore, Tamilnadu, India

---***---

Abstract - Centrifugal pumps with low specific speed efficiency are not attained to high. The microgrooves are introduced on the impeller to reduce the hydraulic losses. The article focusses on the impact of optimized microgrooves on the efficiency of centrifugal pumps with extremely low specific speed (n_q<8). The characteristic of the smooth impeller, existing rectangular and optimized semi-circular microgroove impeller was compared. The design of the impeller developed by using solidworks software. Flow phenomena and distribution of the pressure and velocity of the impeller obtained by using ANSYS CFX software.

Key Words: **Centrifugal Pump, Low specific speed, Microgroove Impeller, CFD**

1. INTRODUCTION

The hydraulic machines which convert the mechanical energy into hydraulic energy are called Pumps. If the mechanical energy is converted into pressure energy by means of centrifugal forces acting on the fluid, then the hydraulic machine is called as centrifugal Pump. Research and development have resulted in both improved performance and new materials of construction that have greatly expanded its field of applicability.

Casing receives liquid at a higher velocity from the impeller and converts it into pressure energy. The impeller often discharges directly into the volute, which is a spiral-shaped flow passage usually of circular or trapezoidal cross section. Its cross section increases gradually around the impeller periphery, starting from the tongue and then ending in the volute throat.

Computational Fluid Dynamics (CFD) is a computer-based tool for simulating the behaviour of systems involving fluid flow, heat transfer and other related physical processes. It works by solving the equations of fluid flow over a region of interest, with specified (known) conditions on the boundary of the region. CFD has grown from a mathematical curiosity to become an essential tool in almost every branch of fluid dynamics, from aerospace propulsion to weather prediction. This CFD is commonly accepted as referring to the broad topic encompassing the numerical solution, by computational methods, of the governing equations which describe the fluid flow, the set of Navier-Strokes equations, continuity and any additional conservation equations, for example energy (for heat transfer).

CFD is being used as an effective tool by many researchers to carry out different studies and investigations on the centrifugal pumps. CFD analysis can prove to be a worthy tool when compared to trial and error methods, various blade design methods are being used to analyse and compare the efficiency and head of radial flow pumps at various discharge conditions. Steady-state 3-D Navier-Stokes equations coupled with the k-epsilon turbulence model have also been used.

2. LITERATURE REVIEW

The microgrooves are new concept that was developed and patented by Janusz Skrzypacz[1].The performance of low specific speed centrifugal pump is reduced due to hydraulic losses. So introducing the microgrooves on the shroud section of closed impeller could increase the overall performance of the pump. Microgrooves are replica of vane profile of the impeller and its size is less than 1 mm both in length and width. The author [1] developed rectangular shaped microgroove impeller and he analysed the impeller in CFD. The fabricated rectangular microgroove impeller fabricated by using RPT method and respective pump test conducted.

To optimize vane profile of the impeller should make difference on the performance of the pump. There are three types method normally followed to create the vane profile of the impeller such as double arc, point to point and circle arc method. Among them circle arc method [7] could yield the best result of the pump. The vane profile ought to follow either forward or backward curve method. The backward curve method to enhance performance of the pump. These methods were analysed by M. Nataraj[2].

The number of blades could increase the performance of the impeller that concept theoretically explained[4].The blades could yield low stress if it is in the backward direction. Mentzos et al [15] analysed the flow over the impeller of centrifugal pump using finite-volume technique along with a structured system for the plot results of the discretized equations. The CFD technique was used to predict pressure distribution, the flow patterns, and head-capacity curve. The results shows that the grid size was not sufficient to determine the local boundary layer variables, global ones were well captured.

It is proposed, the existing microgroove in a rectangular shape[1] that is difficult to fabricate. So optimize the shape of the existing microgrooves could enhance performance and ease the fabrication of the impeller of the pump.

3. PUMP SPECIFICATION

3.1. BASIC PARAMETERS OF PUMP

The following parameters are the characteristics of any pump. The given values are taken for the pump.

1. Total head (H) - 21.3 m

2. Discharge (Q) -5.3 m^3/hr - 0.00147 lit/s

3. Speed (n) - 2950 rpm

3.2. SPECIFIC SPEED

In order to classify pumps into different categories, the specific speed was first introduced by Camerer in 1914 and further developed by Stepanoff in 1948.

When calculating the specific speed with Equation H_{opt} is the head. The sub-script opt indicates that they are evaluated at the best efficiency point of the pump, also called as BEP. By calculating the specific speed it is possible to classify which kind of pump would be suitable for different applications, and it is also possible to compare pumps in different operating conditions. n_{sq} is a number used for classifications of the pump in the same way as the Reynolds' number find the flow of the fluid. The specific speed equation as follows,

$$n_{sq} = n\sqrt{Q} / H^{3/4}$$

$$= (2950\sqrt{0.00147}) / (21.3)^{3/4}$$

$$= 11.4$$

From the above calculation, the pump is under low discharge radial centrifugal pump category envisaged from the table 1

Type of impeller	Positive displacement pumps	Centrifugal		
		Radial		Mixed
		Low discharge	Normal discharge	Higher discharge
$n_s = \frac{3.65\, n\sqrt{Q}}{H^{3/4}}$	8–35	40–80	80–150	150–300
$\frac{D_2}{D_1}$	–	≈ 2.5	≈ 2	1.8–1.4
$n_{sq} = \frac{n\sqrt{Q}}{H^{3/4}}$	2–10	10–22	22–41	41–82

Table 1. Classification of the pump based on the specific speed value

4. IMPELLER DESIGN

The design of the impeller developed in the solidworks software. This CAD software is much useful to develop 3D design of the component. The geometrical dimensions of the impeller are shown in the table 2

S.No	Parameter	Annotation	Smooth Impeller	Impeller with Semicircular MG
1	Inlet Diameter	D_1	40 mm	40 mm
2	Outlet Diameter	D_2	150 mm	150 mm
3	Hub Diameter	d_h	20 mm	20 mm
4	Inlet Angle	β_1	43°	43°
5	Outlet Angle	β_2	39°	39°
6	MG Radius	r	-	0.5 mm
7	Total No of MG	N	60 Nos	60 Nos
8	Blade Width	b	4mm	4mm

Table 2. Geometrical Dimensions of the Impeller

The impeller with existing rectangular microgrooves have a same dimensions of the semi-circular microgrooves.

4.1. DESIGN PROCEDURE FOR THE SMOOTH IMPELLER

From various methods of impeller profile generation, the circular arc method to be chosen due to its simple construction steps. The following step by step procedure are followed to create the smooth impeller.

- ✓ In circular arc method the diameter of the impeller is divided into a number of concentric circular rings (n) not necessarily equally spaced.
- ✓ The radius of impeller eye and outer are named as R1 and R2 respectively. The radius of intermediate rings can be obtained by calculating the term (R2-R1)/n. The calculated value is added

to the eye radius. This radius value is used to create the next ring of the eye impeller. The same procedure followed up to it should reach the outer diameter of impeller.

- ✓ The blade mean line drawn using concentric circular arc method
- ✓ The inlet and the outlet circles are drawn.
- ✓ Two axes of reference, one vertical and one horizontal, are drawn.
- ✓ In order to trace the profile with four radii of curvature, four more circles, that is, point 1 to 6, are drawn at equal intervals on the axis.
- ✓ The curve is drawn through A, B, C, D and E based on the positions G, H, I, J and K.
- ✓ From the point where inlet circle meets the horizontal axis, a line at an angle of inlet vane angle (43°) is drawn to the length of the radius of curvature of the first arc (31 mm).
- ✓ An arc is drawn with the end point of this line as the center and with the corresponding radius, till the arc meets the next circle.
- ✓ From the point where the arc meets the next circle, a line is drawn to the length equal to the next radius of curvature and passing through the previous centre.
- ✓ An arc is drawn with the end point of this line as the centre and with the corresponding radius till the arc meets the next circle.
- ✓ This procedure is followed till the four arcs are drawn.

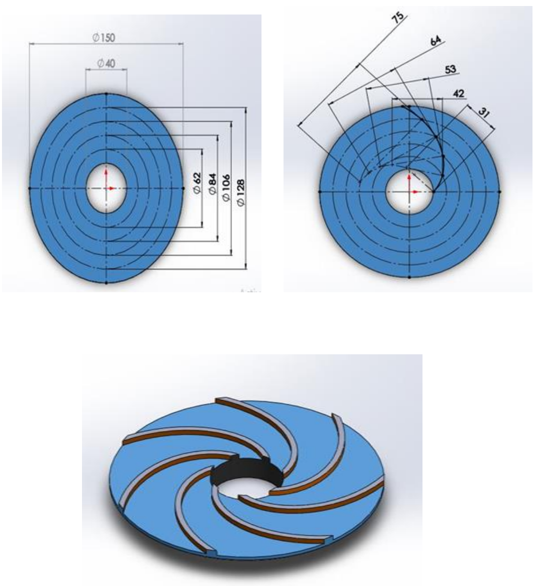

Fig 1. Smooth Impeller Design

4.2. MICROGROOVE

The names itself explain the concept of groove. The groove is designed alike the pattern of vane profile of the impeller. The main difference between the groove and vane profile are the size and profile. The groove is designed in the two different profile, the first one is rectangular which concept the author proposed his article[1] and the second one is semicircular which profile was chosen by me to ease the fabrication of the impeller and enhance the performance of the low specific speed impeller pump.

4.3. DESIGN PROCEDURE FOR THE MICROGROOVE IMPELLER

The design of the microgroove on the impeller shroud section is developed by using Solidworks CAD software. The important design steps of the microgrooves are as follows

- ✓ The smooth impeller was opened in solidworks. Its blade surface is selected by sketch tool. The sketch tool is used to create pattern of the vane profile which was created by using circular arc method. The number of curves in between the two blade is five.
- ✓ The plane is created at the tip of the curve. The plane is used to create the profile of the microgroove in the curve.
- ✓ The rectangular profile which size are 0.5mm width and 0.1mm depth are developed.
- ✓ By using the sweep tool, the micro groove is formed on the impeller.
- ✓ The same step followed to each curve. Then the five developed microgrooves are patterned by using circular pattern tool.
- ✓ The whole microgrooves are mirrored on the opposite side of the closed impeller.
- ✓ The same procedure followed to develop the semicircular microgrooves. The dimension of the Semicircular is 0.5mm radius.

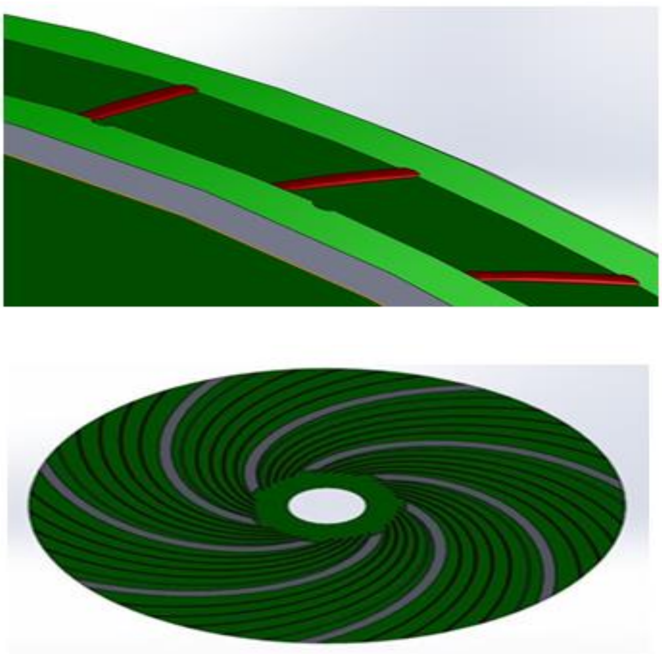

Fig 2. Semi-circular microgroove Impeller Design

5. ANALYSIS OF THE IMPELLER

The impeller was analyzed by using ANSYS CFX software. The following procedure followed to analyze the impeller.

5.1. GEOMETRY

In this section the appropriate design is imported and the design is opened by design modular window. Then the design is generated by using the generate tool. If the design is correctly imported means, it will shows a right tick mark otherwise indicate the warning messages. The following figures 3 shows the imported design of the impeller without and with microgrooves (Rectangular and semicircular profile)

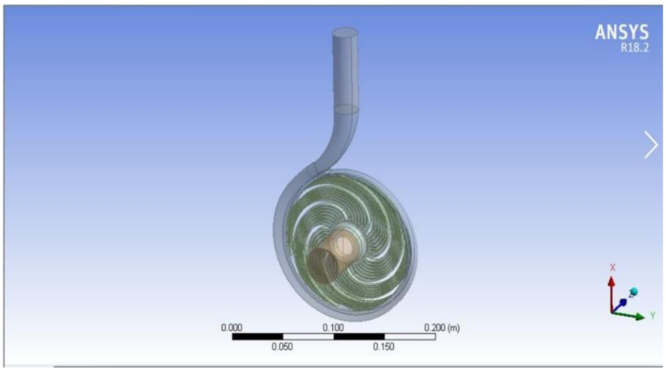

Fig 3. Geometry of the semi-circular microgroove Impeller

5.2. MESH

The calculation of the complex component is a tedious and complicated one due to its infinite number of degrees of freedom. The mesh tool is a discretization tool which is used to make the finite number of element and nodes in the complex model.so that the calculation of the model is easy and precise. In this mode the boundary layer of the impeller is named by using create named section tool. So that it can be easily identified in the setup section. The below figure show the meshing on the impeller. The mesh was created separately in the boundary layer of the impeller and other section of the impeller.

5.3. ASSUMPTIONS

The simulation of flow inside the centrifugal pump is done on basis of following basic assumptions:

•Steady state condition.

• Constant fluid properties.

• Incompressible fluid flow.

• The walls were assumed to be smooth hence any disturbances in flow due to roughness of the surface were neglected.

5.4. BOUNDARYCONDITIONS

Boundary conditions are the set of conditions specified for the behaviour of the solution to a set of differential equations at the boundary of its domain. Mathematical solutions are determined with the help of boundary conditions to many physical problems. These conditions specify the flow and thermal variables on the boundaries of a physical method.

The pump has various components like inlet, outlet, blades, hub and shroud. The pump inlet was defined as total pressure boundary condition and mass flow rate outlet was given at the pump outlet. The other surfaces were given as wall boundary conditions. Rotating faces of impeller considered as wall and no slip wall condition is applied. At fluid, wall interface, there must be no slip. Operating temperature is specified at the inlet.

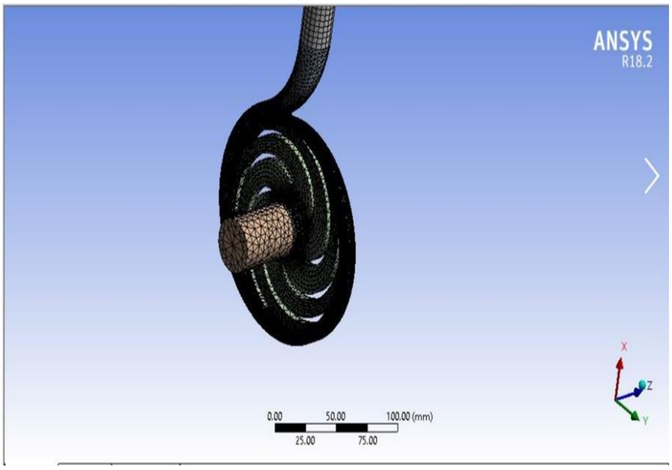

Fig 4. Mesh of the Semi-circular Microgroove Impeller

5.5. SETUP

The Necessary input value is filled in the appropriate section. The setup section is very important area which will calculate the results based on the input data. The basic parameters of the pump value entered in the appropriate field.

5.6. SOLUTION

In this section, the setup file is ready to run if we select the run option. In this section the iteration level and backup setup could be established by the user.

5.7.RESULT

The results section is used to get the appropriate results from the problem solution. There is a plenty of result option available in the ANSYS CFX, user could select the appropriate results among the available option. The Impeller smooth and with microgrooves plot results are shown in the below figures.

5.7.1 VELOCITY DISTRIBUTION OF THE IMPELLER

Fig 5. Smooth Impeller

Fig 6. Semi-circular micro grooved Impeller

5.7.2 PRESSURE DISTRIBUTION OF THE IMPELLER

Fig 7. Smooth Impeller

Fig 8. Semi-circular micro grooved Impeller

5.7.3 TURBULENT KINETIC ENERGY OF THE IMPELLER

Fig 9. Smooth Impeller

Fig 10. Semi-circular micro grooved Impeller

Table 3. Performance of the pump

Performance of the pump Characteristics		Smooth Impeller	With Rectangular Micro groove	With Semicircular Micro groove	Units
Flow	Q	5.3	5.3	5.3	m^3/hr
Rotational Head	N	2950	2950	2950	rpm
Total Head	H_{total}	22.43	23.02	23.53	m
Static Head	H_{static}	21.52	22.01	22.63	m
Power	P	0.43	0.439	0.445	kW
Volute Loss		16.75	16.70	16.61	%
Total Efficiency	$\eta_{efficiency}$	75.81	76.36	76.92	%
Static Efficiency	$\eta_{efficiency}$	72.75	73.12	73.53	%
Impeller Head	H impeller	26.94	27.35	27.96	m
Impeller Efficiency	$\eta_{efficiency}$	91.07	91.53	92.12	%
Surface Roughness	H_r	5	5	5	microns

The results of the existing rectangular microgroove is slightly vary with the semicircular microgroove impeller. So the plot results of rectangular microgroove could not distinguish itself from other microgrooves. Hence the plot results of the existing microgroove restrained.

The ANSYS CFX results based on computational validation of the impeller, the impeller with rectangular microgrooves and semicircular microgrooves is discussed in the table 3.

5.8. GRAPHICAL EVALUATION

To using the ANSYS governing equation, the flow rate of the pump varied in lps unit. The results of the Power, total efficiency and total head of the smooth impeller, existing rectangular and proposed semi-circular microgrooves impeller of the pump graphed by using Microsoft excel software.

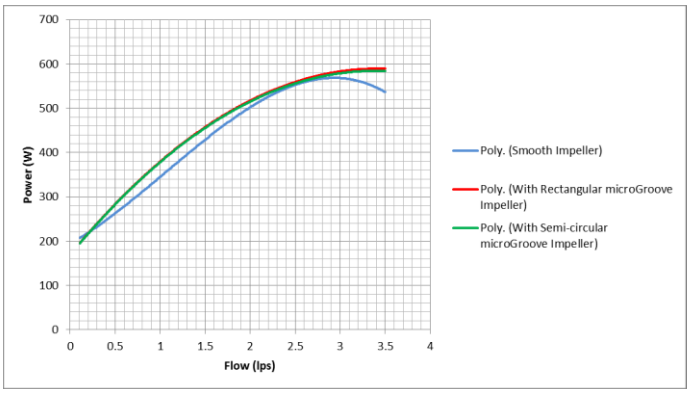

Chart 1. Performance graph of flow vs Power

From the above graph, its clear that the power consumption of the smooth impeller and microgroove impeller varied after the BEP.

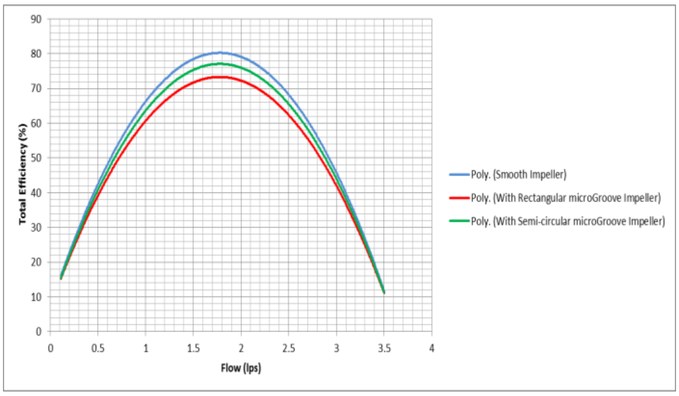

Chart-2. Performance graph of Flow vs Total Efficiency

From the graph, the efficiency of the semi-circular micro groove impeller slightly varied from smooth impeller and enhanced from the existing rectangular microgroove impeller.

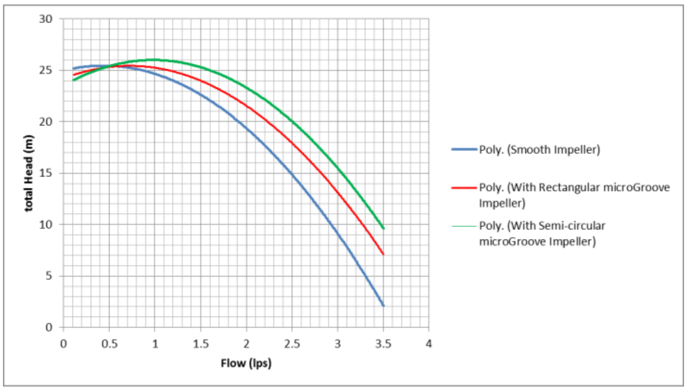

Chart-3. Performance graph of Flow vs Total Head

The Total head of the semi-circular microgroove is comparatively high from the smooth impeller and its yield better performance than existing rectangular microgroove impeller.

6. CONCLUSION

In this work, the impeller designed with semi-circular and existing rectangular microgrooves were analysed. The performance of conventional impeller and impeller designed with semi-circular and existing rectangular microgrooves results were compared and tabulated. According to the result, the impeller with semi-circular microgrooves have better overall performance than others. The fabrication of the semi-circular grooves is comparatively easy from existing rectangular type microgroove impeller. Hence the semi-circular microgroove impeller is useful to improve the performance of the low specific speed radial flow centrifugal pump.

REFERENCES

[1] Janusz Skrzypacz, Marcin Bieganowski, "The Influence of Micro Grooves on The Centrifugal Pump Impeller", International Journal of Mechanical Sciences, Feb 2017.

[2] R. Ragoth Singh, M. Nataraj, "Design and Analysis of Pump Impeller using SWFS". World Journal of Modelling and Simulation Vol.10, No.2, pp. 152-160, Jan 2014.

[3] Krishna Kumar Yadav, Karun Mendiratta, V K Gahlot, "Optimization of The Design Of Radial Flow Pump Impeller Though CFD Analysis", International Journal of Research in Engineering and Technology, Vol. 11, No. 5, pp. 157-161, Nov 2016.

[4] Mr. C.V.S.Rajesh, Mr.SK.Hidayatulla Sharief, "Design of Impeller Blade by Varying Blades and Type of Blades Using Analytical", International Journal of Magazine of Engineering, Technology, Management and Research. Vol. 4, No. 4, pp. 107-117, April 2017.

[5] P.ArunKumar, P.Dhachinamoorthi, K.Saravanakumar, S.Venkatesh, "Analysis and Investigation Of Centrifugal Pump Impellers Using CFD", An International Journal of Engineering Science and Technology, Vol.4, No.4, pp 112-117, August 2014.

[6] Dr. Mohammed Ali Mahmood Hussein, Dr. Wajeeh Kamal Hasan, "The Effect of Rotational Speed Variation on the Velocity Vectors in the Single Blade Passage Centrifugal Pump (part 2)", Journal of Mechanical and Civil Engineering, Volume 9, Issue 2, pp 43-52, Sep 2013.

[7] Ashish Bowade, Charu Parashar, "A Review of Different Blade Design Methods for Radial Flow Centrifugal Pump", International Journal of Scientific Engineering and Research, Volume 3, Issue 7, pp 24-27, July 2015.

[8] Mr. Chetan Kallappa Tambake, Prof. P. V. Salunke, "Design of Monoblock Centrifugal Pump Impeller", International. Journal of Mechanical Engineering and Information Technology, Vol. 3 Issue 3, March, pp 1074-1079

[9] Johann Friedrich Gülich, Centrifugal Pumps-Second edition Springer Heidelberg Dordrecht London, New York.

[10] Dr. R. K.Bansal, "A Text Book of Fluid Mechanics and Hydraulic Machines", Laxmi Publications, New Delhi.

AUTHOR

V.Vignesh, Author
Department of Mechanical Engineering (Engineering Design)
Government college of Technology.