Investigation on Under-filing of impeller vanes to improve the Performance of Centrifugal Pump

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Abstract— Now a days centrifugal pump is used in many fields like agriculture, industrial, power plant, irrigation etc. Proper head and discharge is prime requirement of customer. Sometimes modification is applied in centrifugal pump for high head and discharge. Impeller trimming is the only alternate practical solution without changing impeller design, manufacturing and modification or purchase a new impeller. Impeller trimming is the best way to increase head and discharge. Sometimes it may happen that user require more head and discharge in existing purchased pump, at that time impeller trimming is best solution to increase head and discharge. Basically impeller trimming is the procedure to decrease diameter of impeller, under-filing, over filing. Under-filing which is one of the methods of trimming is used as a concept. Under-filing means to cut or give a radius at non pressure side vane tip of impeller. Under-file the impeller vanes with 1.0 mm,2.0 mm at non pressure side of radial closed impeller of centrifugal pump , the head and discharge of pump can be improved. CFD Analysis has performed on both existing and trimmed impeller with predefined mass flow rates. After CFD analysis, compared the results of both trimmed and existing impeller. For Validation CFD results are compared with practical experiments performed on Aarohi embedded system which is used to check head and discharge of pump.

Keywords—Under-filing, impeller, trimming, Head, Discharge.

I. INTRODUCTION:

Centrifugal pump is one type of rotodynamic pump which is used to lift water by centrifugal force and rotation of impeller. Centrifugal pump converts kinetic energy of water to pressure energy by external power. Centrifugal pump is applicable for low head and high discharge. Now a days in many area like agriculture, chemical industry, power plant etc. centrifugal pump is used. Customer demands pump of different specifications. Centrifugal pump is a machine which converts kinetic energy of water into pressure energy. The flow of water when leaves the impeller is vortex. Centrifugal pump has curved vanes fitted on the circumference of a shaft through which water or fluid enters the vanes. The vanes rotate opposite to the curvature throwing water due to centrifugal force into space diffuser which keeps on expanding till it meets the delivery pipe.

II. PROBLEM OVERVIEW:

Customer purchase a centrifugal pump of standard particular head and discharge, sometimes the situation may happen that customer requires more discharge and head, at that time impeller trimming is the only practical and alternative solution to without change in design, manufacturing or purchase a new impeller. CFD analysis has performed on both existing and trimmed impeller. Under-filed with 1mm, 2.mm at non pressure side or suction side of vanes exit tips of impeller and perform CFD. Then compare the results of both impellers. Model of impeller is developed in PTC CREO Parametric 3.0 modeling software.

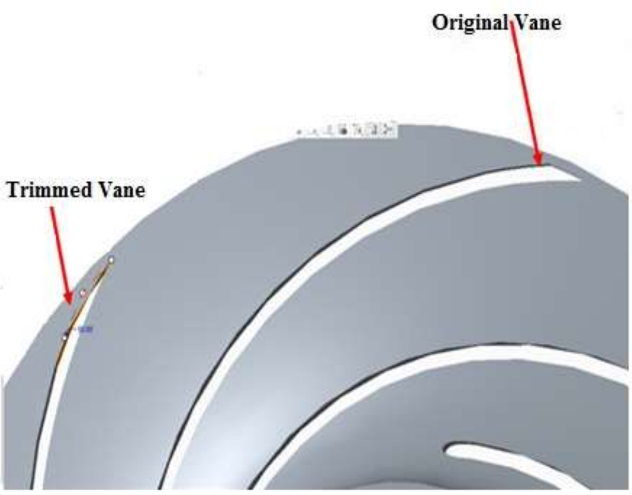


Fig.1 Comparison of Original and trimmed vane

(i) Specifications of Impeller and Pump:

Table No.1 specifications of Impeller

Type	Radial closed impeller
Rated Speed	1440 rpm
Material	SS 410
No of Vanes	6
Diameter	228 mm

Table No.2 Specifications of Pump

Pump Type	Centrifugal open well
Head in m	10
Mass flow rate (kg/S)	6.34
Shaft Diameter in mm	28
Working Fluid	Water
Power	7.5 hp
Rated frequency	50 Hz
Phase	3 phase

III. MODELING AND CFD ANALYSIS :

Three-dimensional Model of Impeller is developed in PTC CREO parametric 3.0 modeling software. CFD (Computational fluid dynamics) analysis has performed in ANSYS 16.2. Steps of CFD analysis are (i) Construction of Geometry (ii)Import to CFX fluid flow (iii) Generation of Mesh (iv) Define Various section of impeller (v) Define boundary conditions (vi)Go for solution

(i) Construction of Geometry :

The three dimensional model of impeller has developed in PTC CREO parametric 3.0. The fluid domain and vanes are separated with each other.

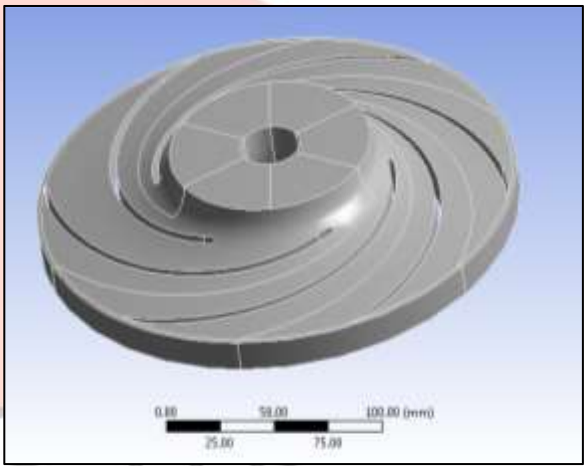


Fig.2 Model of Impeller

(ii) Import Geometry to CFX fluid Flow section :

The model of impeller is imported in CFX fluid flow section.

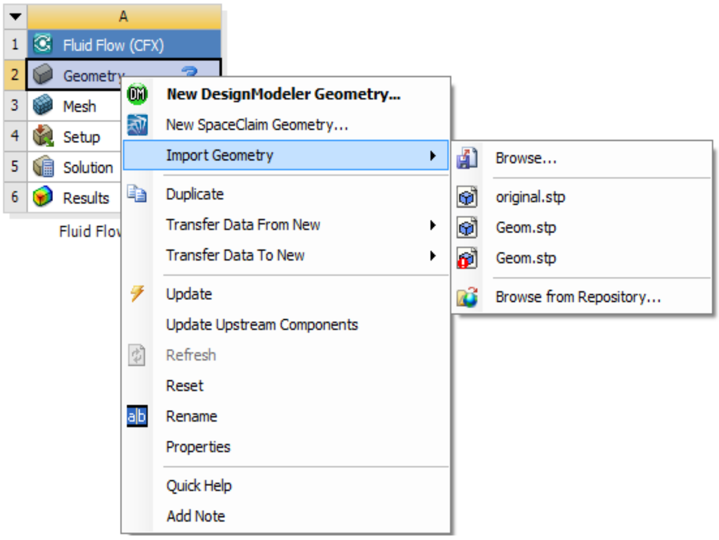


Fig.3 Import geometry to CFX section

(iii) Generation of Mesh :

After Performed grid impedance study, the type of mesh finalized. Nodes and elements are selected after grid impedance study. Tetrahedral mesh has generated in model.

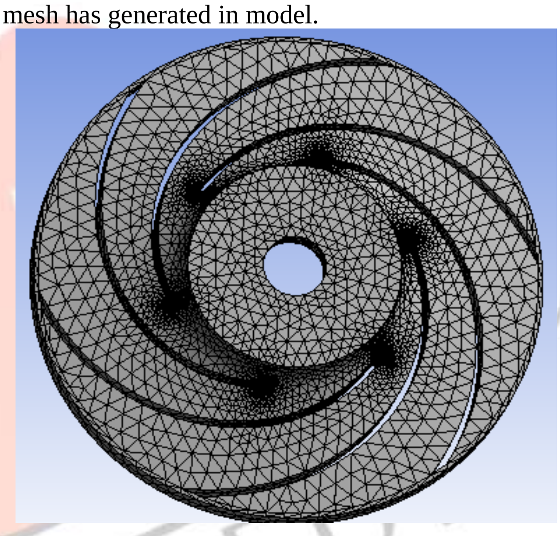
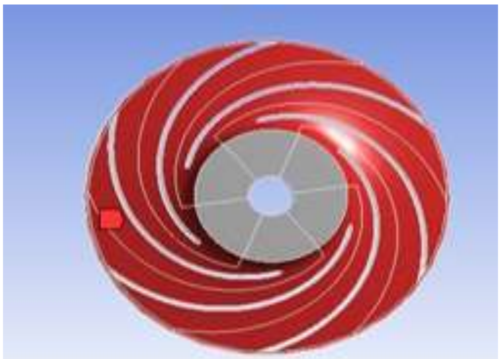
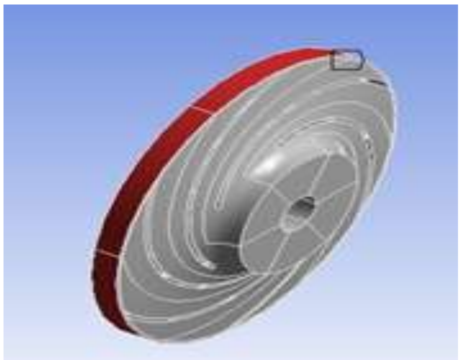


Fig.4 Generation of Mesh

(iv) Define various section of impeller :

For analysis purpose the various sections of impeller are defined and indicated separately. Here Inlet section, Outlet section, shroud, hub and vanes define separately.

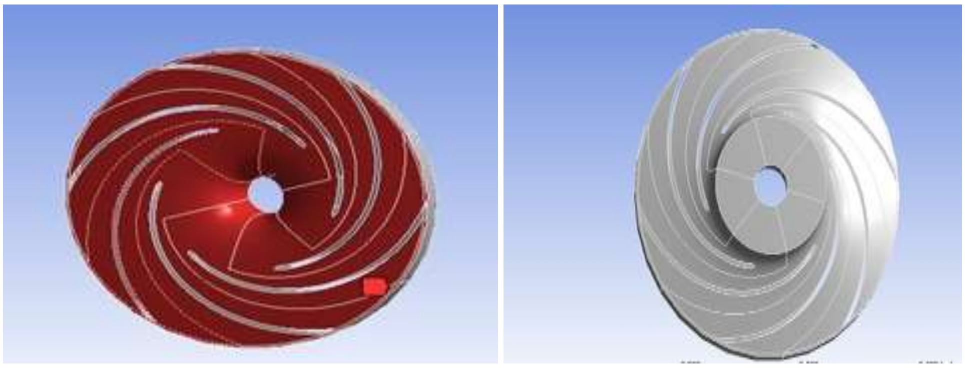


Fig.5 Define variuos section of impeller

(v) Define Boundary Conditions :

(a) Inlet boundary conditions :

Table No.2 Inlet boundary Conditions

Sr.No	Parameter	Selected Value
1	Frame type	Stationary
2	Flow type	Subsonic
3	Relative Pressure	0 atm

(b) Outlet Boundary Conditions :

Table No.3 Outlet boundary conditions

Sr.No.	Parameter	Selected Value
1	Flow type	Subsonic
2	Mass flow rate	6.34 kg/s

(c) General boundary conditions :

Table No.4 General boundary conditions

Sr.No.	Parameter	Selected value
1	Working fluid	Water
2	Morphology option	Continous fluid
3	Reference pressure	1 atm
4	Buoyancy Model	Non buoyant
5	Domain motion	Rotating
6	Angular Velocity	-1440 rpm
7	Axis definition	Coordinate axis
8	Roration axis	Global Z
9	Fluid temprature	25°C

(vi) Go for solution :

After set all boudary conditions generate the results for various pre-defined mass flow rate. CFD software will provide outlet pressure value.

IV. CFD RESULTS :

After performed CFD analysis in ANSYS following observations have found.

Table No.5 Existing impeller Results

Existing Impeller CFD Results						
Sr. No.	**Flow kg/s**	**Outlet Pressure (Pascal)**	**Inlet Pressure**	**Outlet Pressure atm**	**Pressure Difference**	**Head in m**
1	6	92181	0	0.92181	0.92181	9.5222
2	6.2	96511	0	0.97511	0.96511	9.9695
3	6.34	96597	0	0.96597	0.96597	9.9784
4	6.4	96278	0	0.96278	0.96278	9.9455
5	6.6	95543	0	0.95543	0.95543	9.8695
6	6.8	94504	0	0.94504	0.94504	9.7622
7	7	94470	0	0.94470	0.94470	9.7587

Table No. 6 Existing impeller Results

1 mm Trimmed Impeller CFD Results

Sr. No.	Flow kg/s	Outlet Pressure (Pascal)	Inlet Pressure	Outlet Pressure atm	Pressure Difference	Head in m
1	6	117460	0	1.17460	1.17460	12.1336
2	6.2	116310	0	1.16310	1.16310	12.0148
3	6.34	115690	0	1.15690	1.15690	11.9507
4	6.4	115480	0	1.15480	1.15480	11.9290
5	6.6	114720	0	1.14720	1.14720	11.8505
6	6.8	114270	0	1.14270	1.14270	11.8040
7	7	114060	0	1.14060	1.14060	11.7823

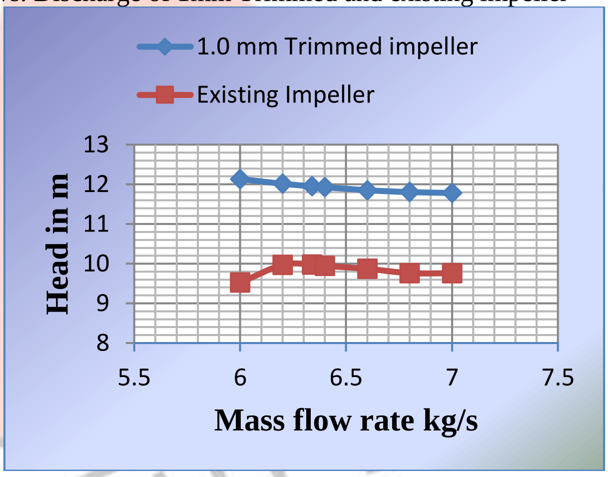
Table No.7 Existing impeller Results

2.0 mm Trimmed impeller CFD results						
Sr. No.	Flow kg/s	Outlet Pressure (Pascal)	Inlet Pressure	Outlet Pressure atm	Pressure Difference	Head in m
1	6	120620	0	1.20620	1.20620	12.4600
2	6.2	120880	0	1.20880	1.20880	12.4869
3	6.34	120620	0	1.20620	1.20620	12.4600
4	6.4	120650	0	1.20650	1.20650	12.4631
5	6.6	120680	0	1.20680	1.20680	12.4662
6	6.8	120660	0	1.20660	1.20660	12.4641
7	7	121040	0	1.21040	1.21040	12.5034

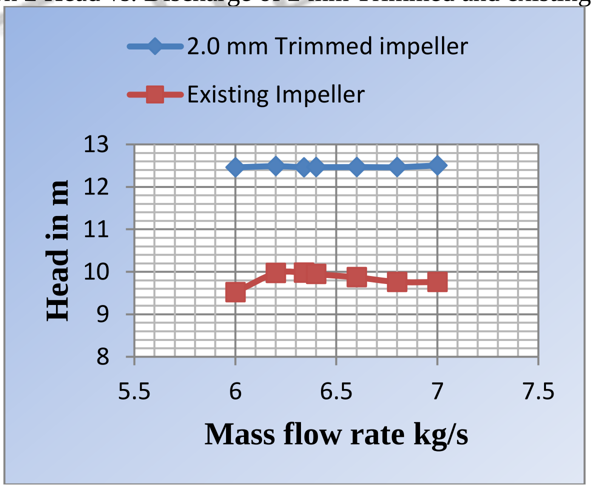
(i) Result Analysis :

(a) Head V/S Discharge

Graph 1 Head vs. Discharge of 1mm Trimmed and existing impeller



Graph 2 Head vs. Discharge of 2 mm Trimmed and existing impeller



(b) Observations :

(1) After compare the results of Existing and Trimmed impeller, it is observed that trimmed impeller gives more head and discharge.

(2) Performance of pump can be increase by under filing non pressure side of trailing edge of impeller vanes.

(3) Increase in amount of trimming will improve head and discharge of pump.
(4) Head and Discharge are inversely proposal.

V. PRACTICAL EXPERIMENTATION

Aarohi Embedded system is used to check head and discharge of pump.

Fig.6 Aarohi embedded system

(i) Experimental Sequence :

(a) Set the pump in under-ground water tank.
(b) Connect outlet of pump with Aarohi piping system.
(c) Now start pump and Aarohi system.
(d) Control mass flow rate of pump by control valve.
(e) Observe the readings on Screen.

(ii) Pump to be for test :

The centrifugal pump is set in under ground water tank and outlet section of pump is connected with Aarohi piping system.

Fig.7 Centrifugal pump for test

(iii) Trimming of impeller :

Impeller is trimmed by numetic air gun.Initially Vanes of impeller is under-filed with 1 mm and then after 2 mm.Trimmed impeller is fitted on pump.

Fig.8 Impeller to be trimmed

(iv) Connect outlet section of pump with Aarohi piping system and set mass flow rate by control valve:

Fig.9 Connect pump with Aarohi system

Connect outlet of the centrifugal pump with Aarohi piping system and set predefined mass flow rate by control valve then observe readings on Aarohi system.

(v) Results :

For 1 mm trimmed impeller

Table No.8

Sr.No.	Discharge	Head
1	6.0	11.92
2	6.2	11.89
3	6.34	11.72
4	6.4	11.64
5	6.6	11.61
6	6.8	11.42
7	7.0	11.22

For 2 mm trimmed impeller

Table No.9

Sr.No.	Discharge	Head
1	6.0	14.10
2	6.2	13.98

3	6.34	13.92
4	6.4	13.70
5	6.6	13.41
6	6.8	13.22
7	7.0	12.96

(vi) Observations :

(1) Head and discharge of impeller is incresed with under-filing.
(2) Performance of pump can be increase by under filing non pressure side of trailing edge of impeller vanes.
(3) There is minor difference between CFD results and experimental results.
(4) Experimental results are depends on quality of machining of blade trimming, surface roughness of impeller blade, temperature of water, density of fluid etc.
(5) After comparing the results of CFD analysis and Experimental results, it is observed that impeller trimming can improve head and discharge of pump.
(6) Increase in amount of trimming will improve head and discharge of pump.

VI. CONCLUSION

From results it is observed that impeller trimming can improve head and discharge of centrifugal pump. Under filing of impeller vanes trailing edge is the very convenient practical solution to improve pump performance. By trimming energy added to impeller will also decrease so power requirement of impeller will also decrease.