Numerical Analysis On The Performance Characteristics Of The Centrifugal Pump

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ABSTRACT

The research is based on the performance of the centrifugal pump having the backward, radial and forward bladed type of impeller. The impeller is modeled using Creo Parametric 1.0 having 70 and 80 degree outlet blade angle for the backward type and outlet blade angle 90 for radial and 100 degree for forward type impeller respectively. Numerical simulation is carried out using ANSYS CFX and standard k-ε turbulence model is adopted for the analysis purpose. Cavitation is clearly predicted in the form of water vapor formation inside the centrifugal pump. The performance of the pump is affected by the cavitation and hence cavitation number (σ_c) is a measure of the cavitation phenomenon for the centrifugal pump, it is determined by analytical calculations. From the numerical results it has been found that the pump working on low head gives the best performance when it is operated with the backward bladed type impeller.

KEY WORDS: ANSYS CFX, Cavitation, Cavitation number, Centrifugal pump, numerical simulation, Turbulence Model k- Є.

I. INTRODUCTION

A centrifugal pump is a rotodynamic machine that uses a rotating impeller and casing, to increase the pressure energy of a fluid in order to transfer the fluid from one place to another as shown in the figure 1. They are widely used for chemical industries, sectors of liquid transportation, petrochemical industries. The performance of the centrifugal pump is affected mainly due to the lower pressure developed inside the casing which will lead to the cavitations. Cavitation is the phenomenon of formation of bubbles in the low pressure regions inside the centrifugal pump and as this bubbles travels from low pressure regions to high pressure regions, they collapse and it creates very high noise. Due to the cavitation pitting action is generated on the blade of the impeller as shown n the figure 2 Cavitation depends upon the factors like NPSH, temperature of the fluid, discharge of the pump so it must be avoided. S R Shah[1] observed that as discharge increases, the efficiency increases, reaches maximum at rated conditions and then decreases when discharge increases beyond rated conditions.

SHI Weidong[2] found that the oversize impeller outlet width leads to poor pump performances and increasing shaft power. W.G.Li [3] stated that the blade discharge angle has a strong but equal influence on the head, shaft power and efficiency of the centrifugal oil pump for various viscosities of liquids pumped , The rapid reduction in the hydraulic and mechanical efficiencies is responsible for the pump performance degradation with increasing viscosity of liquids. E.C.Bacharoudis *et al* [4] found that the outlet blade angle increases the performance curve becomes smoother and flatter. But pump performance goes down when the pump handles high viscosity working fluids is that high viscosity results in disc friction losses over outside of the impeller and that was found by M.H.S.Fard *et al* [5].

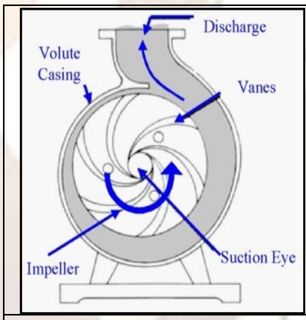


Figure 1 Centrifugal pump

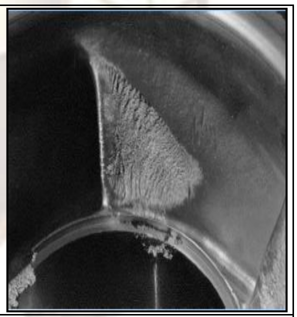


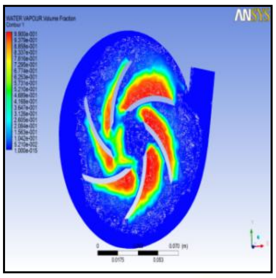
Figure 2 Impeller effected by cavitation

S.Rajendran[6] found a continuous pressure rise from leading edge to trailing edge of the impeller in a centrifugal pump due to the dynamic head developed by the rotating pump impeller. Near leading edge of the blade low pressure and high velocities are observed due to the thickness of the blade. Near trailing edge of the blade total pressure loss is observed due to the presence of trailing edge wake.

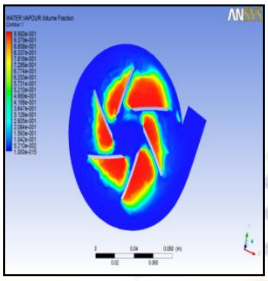
Mr. Ashok Thummar[7] found that as the total head increases the overall efficiency increases but it also follow the same nature as that of power consumption. And finally it is also investigated that as the discharge and the rotational speed of the pump increase simultaneously all the losses hydraulic as well as mechanical increase during the operating range.

II. GEOMETRIC AND NUMERICAL MODELING

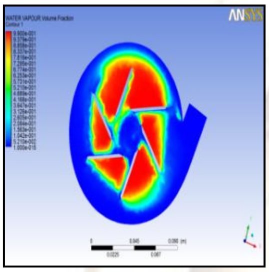
Geometric modeling of the impeller having different blade angles and the casing are modeled in the modeling tool Creo Parametric. The figure 3 and 4 shows the Creo model of the Impeller and the casing



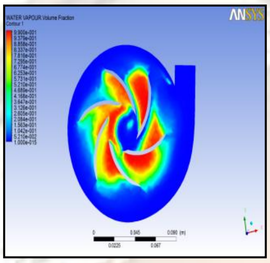
(a) 70 degree bladed impeller



(b) 80 degree bladed impeller



(c) 90 degree bladed impeller



(d) 100 degree bladed impeller

Figure 6 Water vapor contour at 20 lps

of the centrifugal pump.

For reliable and long time efficient operation of the centrifugal pump, its behavior should be studied before putting it to the actual operation. ANSYS CFX is the simulation tool that is widely used to investigate the complex flows inside the centrifugal pump. The user can give the boundary condition close to real. For the simulation of the centrifugal pump the k- ε turbulence model is implemented in the CFX.

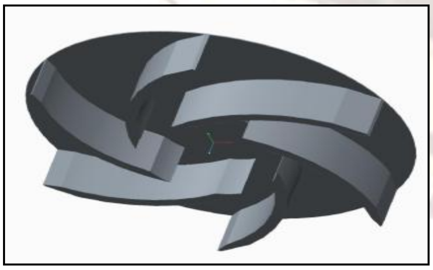


Figure 3 Creo model of Impeller

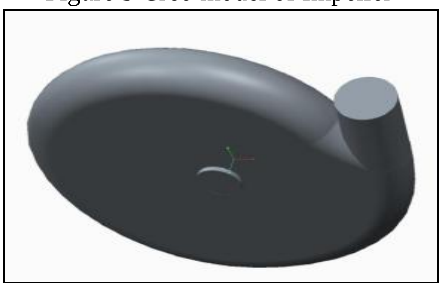


Figure 4 Creo model of casing

Auto mesh is used to mesh the model of the centrifugal pump. Figure 5 shows the meshed model of the centrifugal pump, it indicates that the tetrahedrons are used as

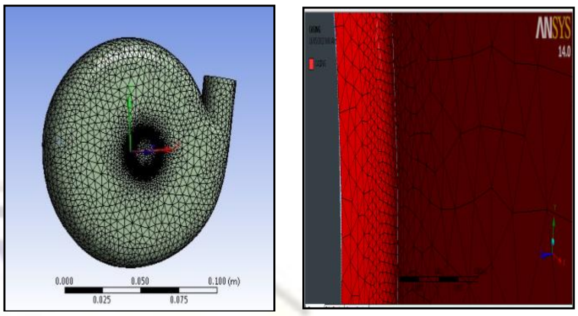


Figure 5 Meshed models of centrifugal pump

the elements. The number of nodes and the elements generated are 77542 and 419333 respectively.

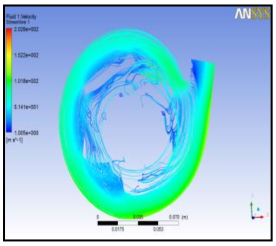
A steady state analysis is carried out taking 1 atmospheric as the reference pressure. The whole domain is given the rotation of 2900 rpm along the Z direction. Two fluids are selected in order to determine the formation of vapors inside the pump. At inlet and outlet pressure conditions are provided and the discharge of the pump is determined from the simulation. The K-epsilon model is selected because it is one of the most common turbulence models and in the standard k-epsilon model the eddy viscosity is determined from a single turbulence length scale

III. NUMERICAL RESULTS AND DISCUSSIONS

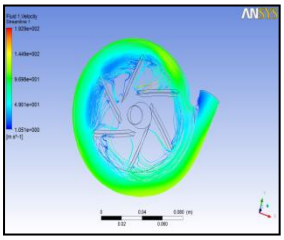
After the completion of the solver part of the simulation, results like pressure contours and the water vapor formation contours are generated for the 20 lps discharge, for all the configurations of the impellers. Figure 6 shows the formation of water vapor inside the centrifugal pump for 70, 80, 90, and 120 degree blade impeller. It is clear from the comparison that as the blade angle increase from the 70 degree to the 120 degree the formation of water vapor increases. So the impeller having 70 degree will be more preferable than the 80, 90 and 120 degree regarding the cavitation

Figure 7 shows the comparison of the stream line contours for the different blade configuration of the impeller. It indicates the turbulence generated inside the casing of the pump. As the angle is changed from 70 to 120 degree more turbulence is observed inside the pump casing. And high value of turbulence will lead to the low pressure zones and that will lead to the cavitations generation.

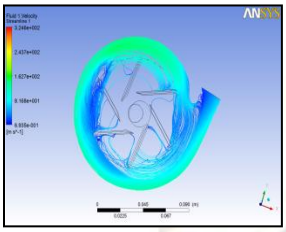
Figure 8 shows the pressure contour at 20 lps across the pump. Gradual increase from the inlet section to the outlet section were found in all the different configurations. But more low pressure zones were identified in the forward bladed pump compare to the 70 degree bladed impeller. And as the blade angle increases the area occupied by the low pressure zone increases.



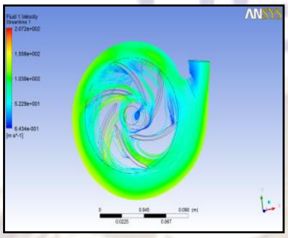
(a)) 70 degree bladed impeller



(b) 80 degree bladed impeller



(c) 90 degree bladed impeller

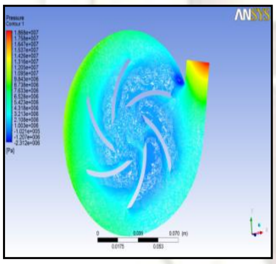


(d) 100 degree bladed impeller

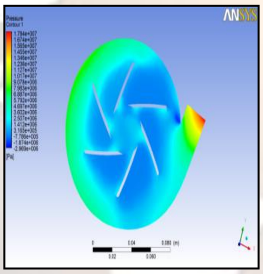
Figure 7 Streamline contours at 20 lps

Figure 8 Pressure contours at 20 lps

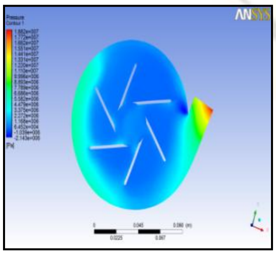
Centrifugal pump performance depends upon the blade configurations of the impeller. Head-Discharge characteristics of the centrifugal pump is



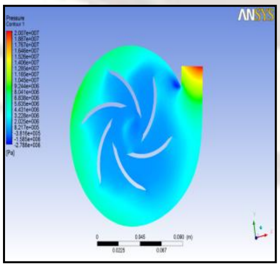
(a)) 70 degree bladed impeller



(b) 80 degree bladed impeller

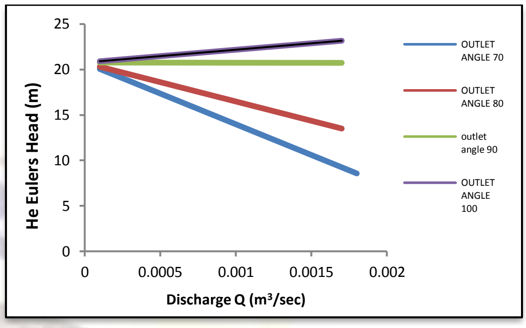


(c) 90 degree bladed impeller

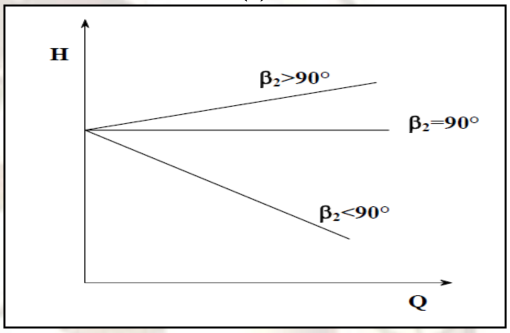


(d) 100 degree bladed impeller

predicted from the analysis as shown in the figure 9 (a) and figure (b), it shows the ideal results for the same. It shows the good agreement of the ideal results and the simulation results It indicates that as the exit blade angle increases the head and the discharge produced by the pump increases. Development of power inside the pump varies as the exit blade angle changes. Figure 10 (a) and (b) shows the power and discharge produced by the pump for different blade configuration. A fairly good matching is found between simulation results and ideal results. For higher exit blade angle, the power and discharge developed by the pump increases.



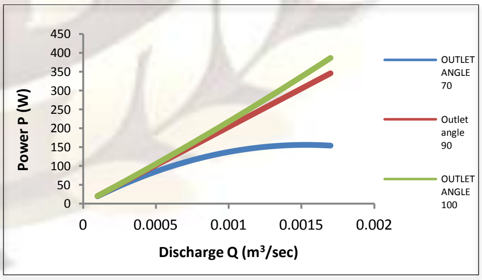
(a)



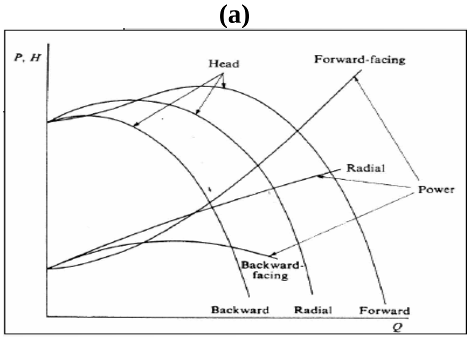
(b)

Figure 9 Head-Discharge characteristics of different blades

Cavitation Number shows indication of the cavitation for the centrifugal pump. Figure 11 shows the effect of discharge on Cavitation Number for the different blade configuration and it clearly indicates that as the exit blade angle increases the value of the Cavitation Number increases and that will lead to the cavitation.



(a)



(b)

Figure 10 Power-Discharge characteristics of different blades

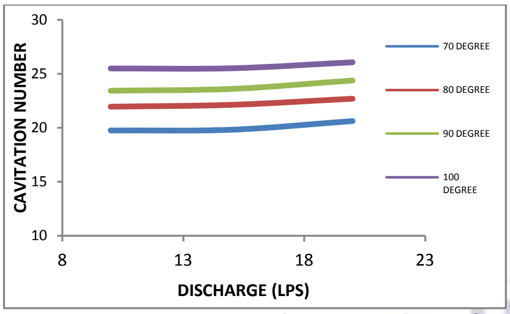


Figure 11Cavitation Number vs Discharge for different blade configurations

So regarding the cavitation backward blade impeller having exit blade angle 70 degree will be more preferable.

IV. CONCLUSIONS

The results obtained from the analysis shows that the characteristic curve for different outlet blade angles are completely matched with the numerical results and it can be concluded from the results that for low head operating conditions, the impeller with backward bladed works efficiently and the problem of the cavitations, which reduces the performance of the pump is less.

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