Numerical Optimization and Analysis of an Axial Pump

Mahdi Tayebi[1], Ali Esmaeili[1*] and Kamyab Karbasishargh[1]
[1] *Department of Mechanical Engineering, Faculty of Engineering, Ferdowsi University of Mashhad, Mashhad, Iran*
* aliesmaeili@um.ac.ir

Abstract— One of the main components of various industries are axial pumps, which are often used in the field of marine propellants with nozzles, waterjet systems, agricultural applications, sewage treatment, etc. These pumps are used for low head and high-volume flow. This issue has led to the use of numerical solution methods and the development of these methods to predict and optimize the hydraulic performance of these pumps. In this study, by analysing and simulating the three-dimensional and turbulent flow of the water agent fluid in compressible and unstable conditions and activating the two-phase flow due to the possibility of cavitation phenomenon, the effective factors in increasing or decreasing the hydraulic efficiency and axial pump head such as tip lagging are investigated. Blade, wrap angle, number of blades and the height of the cylindrical area of the blade are investigated and subjected to optimization and sensitivity analysis. The results show that the reduction of the wrap angle causes the reduction of the overall efficiency which can be compensated by reducing the wrap angle and also increasing the number of blades.

Keyword: Axial pump, Pump Head, Hydraulic Efficiency, Wrap Angle, Optimization

1. INTRODUCTION

The flow field inside the axial pump has special complications due to the presence of leakage flow in the opposite direction of the fluid movement and the presence of vortices around the opening of the blades and the unstable boundary layer on the blade surfaces. In order to optimize pump efficiency, researchers in this field studied various factors, such as pressure fluctuations, cavitation phenomenon, and hydraulic losses, which reduce efficiency and destroy equipment [1,2]. Due to the high speed of the fluid flow in the pump, any sudden pressure changes will impose additional forces on the equipment and cause noise and vibration. In addition to this parameter, the presence of air bubbles in water (which is known as cavitation phenomenon) causes damage to the pump parts and reduces its useful life.

2. METHODOLOGY

1. NUMERICAL METHOD

The turbulence model considered for this simulation was k-ω sst. The two-phase model is also considered.

The head and hydraulic power equations of the pump are calculated from relations (1) and (2), respectively, and the efficiency is calculated from relation (3).

$$H[m] = \frac{\Delta P_{tot}}{\rho g} = \frac{(P_{tot_2} - P_{tot_1})}{\rho g} \quad (1)$$

$$P_{hyd}[kw] = \rho g Q H = Q.\Delta P_{tot} \quad (2)$$

$$\eta = P_{hyd}/P_w \quad (3)$$

2. GEOMETRY MODELLING

The geometry designed is shown in figure 1.

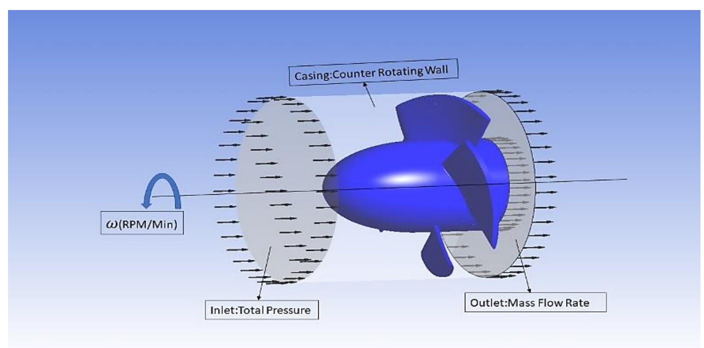

Fig. 1 Geometry of the axial pump

3. RESULTS & DISCUSSION

In order to validate the simulation, a validation of the head pump per flow rate was performed [4].

Here, the effects of 9 different angles in the range of 60 to 90 degrees were investigated, the results of which can be seen in the figure 4. The problem has been simulated by changing the wrap angle and keeping other geometrical variables and boundary conditions constant.

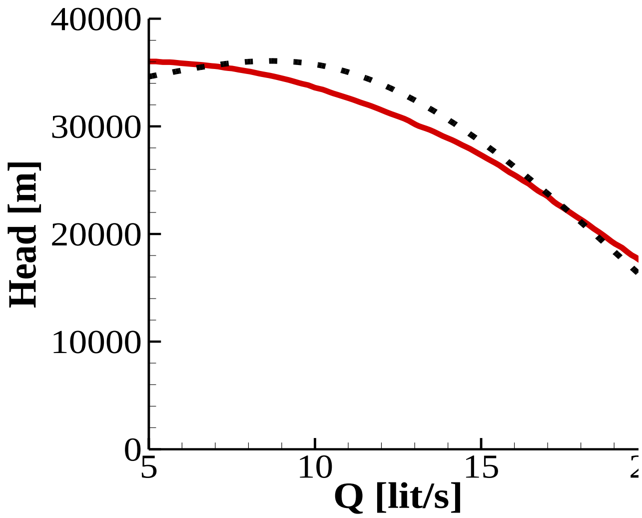

Fig. 3 Numerical simulation validation [9]

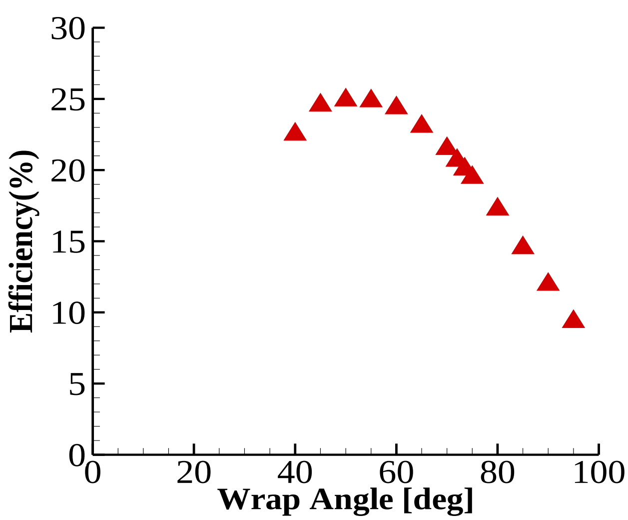

Fig. 4 The effects of wrap angle changes on the percentage of pump hydraulic efficiency

Figure 3 indicate that the highest efficiency occurs at a twisting angle of 60-degrees and the lowest head occurs at an angle of 90-degrees.

According to this analysis, the reduction of the wrap angle involves the reduction of the overall efficiency of the pump (due to the large volume of space where there is no blade, the fluid without it will be removed from the Impeller section) which can be compensated by reducing the wrap angle and increasing the number of blades, which is correct, but this situation also has disadvantages, such as increasing the number of blades in pumps, increasing the level of pressure fluctuations in the pump which is not desirable.

CONCLUSION

The purpose of this research was to investigate the effects of wrap angle parameter changes on head and output hydraulic efficiency as two output parameters of an axial pump. The results of the simulation are as follows:

2. Among the reasons for this phenomenon, we can mention the increase in the effective length of the blade, which leads to the separation of the flow. Therefore, the fluid flow regime in the end areas of the blade is practically in a disturbed state, and this causes a lot of waste and the head is reduced.

3. increasing in head is not under the effect of reducing the constant wrap angle, and after reaching a certain angle, the head decreases again, which is under the effect of reducing the effective surface of the blades, which no longer does anything on the fluid that passes through the impeller section.

5. Increasing the number of blades leads to increased pressure fluctuations and creating noise and vibrations of the pump, which is one of the disadvantages of increasing the number of pumps.

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