Amirkabir Journal of Mechanical Engineering

Amirkabir J. Mech. Eng., 54(1) (2022) 11-14
DOI: 10.22060/mej.2021.19794.7115

Numerical Investigation of Flow Structure and Performance of Centrifugal Pump with Cavitation

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ABSTRACT: In the present paper, the numerical simulation of the flow to identify the cavitation and its effects inside the centrifugal pump of 100-250 type of Pumpiran Company, including the impeller and volute of the pump, has been done. The Rayleigh–Plesset equation was employed to study the growth and collapse of the vapor bubble. In order to validate the numerical results, the pump curves were extracted from the present study and compared with similar experimental. The deviation of the present numerical results with the experimental ones in the pump design flow rate is 6.5%. It is found that cavitation occurs at inlet pressures of less than 45 kPa. By reducing the inlet pressure from 40 kPa to 20 kPa, the flow separation rate also increases and its position is transferred from the beginning of the blade to the inner areas of the blade. The position of cavitation occurs at 0.14 to 0.24 of the passage as well as at the beginning of the blades. The volume fraction of steam in these parts has increased from 0.04 to 0.96, respectively. With cavitation in the net positive suction head equal to 1.52, a 3% drop of the head is observed in the diagrams.

Review History:

Received: Mar. 26, 2021
Revised: Sep. 15, 2021
Accepted: Oct. 09, 2021
Available Online: Nov. 01, 2021

Keywords:

Numerical simulation
Cavitation phenomenon
Centrifugal pump
Performance curve

1- Introduction

Centrifugal pumps have found a wide role in all industries, including oil, petrochemical, and power plants, so ensuring their correct operation is very important. Vibration in centrifugal pumps may be due to various factors including hydraulic and mechanical forces. Various studies by researchers have shown that one of the main causes of vibration and damage in centrifugal pumps is cavitation [1, 2].

In general, the method of measurement and occurrence of cavitation in the industry is done using the net positive suction head parameter. In order to detect the occurrence of cavitation in the pump, Zhang et al. [3] Defined two parameters under the headings of available net positive suction head and required net positive suction head. Cavitation occurs if the available net positive suction head is less than the net positive suction head required by the pump.

Investigation of cavitation process and its effects on details of flow structure and pump performance parameters, the exact position of cavitation bubbles, and vapor volume fraction formed are among the most important issues in pump performance and especially provide solutions to improve the flow behavior and control pump performance Which has received less attention in the research of others and is addressed in this research.

2- Numerical Simulation of The Pump

2- 1- Impeller geometry

The pump simulated in this research is the model pump 100-250 of Pumpiran Company, the design specifications of the impeller are shown in Table 1.

2- 2- Meshing

The geometry of the pump is meshed by Ansys TurboGrid software. The computational area is divided into two separate areas including the impeller and the fixed volute. The impeller

Table 1. Pump impeller specifications

Parameter	Value
Thickness	7.8 mm
Input angle	22.13°
Output angle	12.54°
Inlet diameter	129.1 mm
Outer diameter	258.5 mm
Number of blades	6
Blade width	25.9 mm

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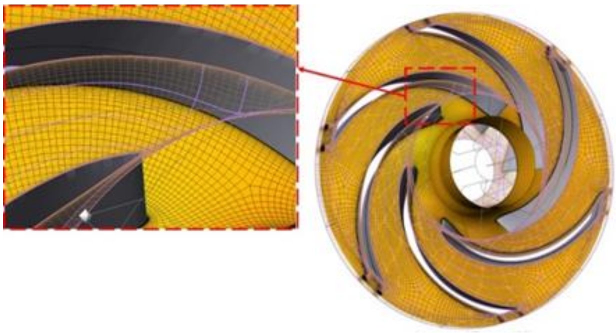

Fig. 1. Pump impeller meshing

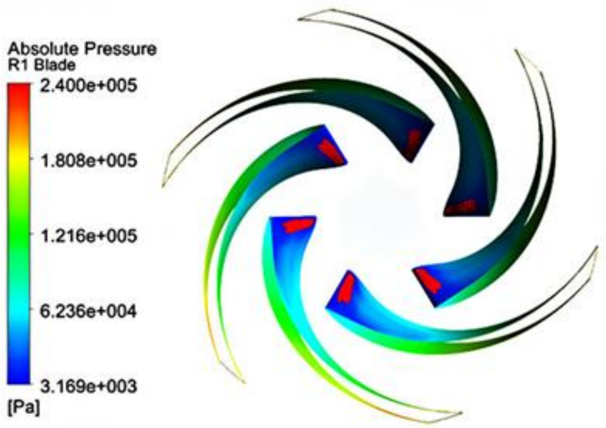

Fig. 3. Formation of cavitation bubbles (red areas) at 120 m^3/h, inlet pressure of 40 kPa and NPSH = 3.75

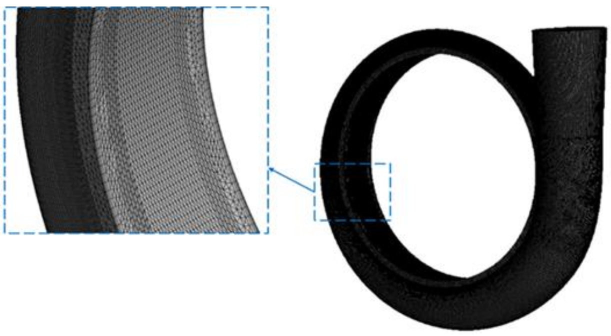

Fig. 2. Pump volute meshing

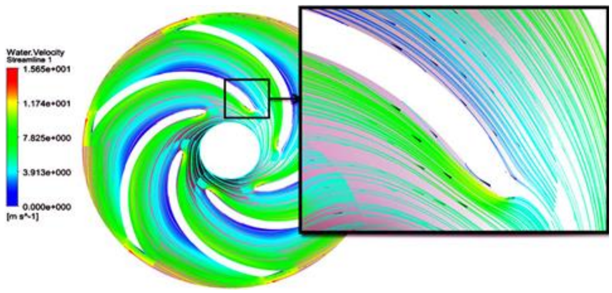

Fig. 4. Flow separation at an inlet pressure of 40 kPa

area, which includes the impeller and the fluid inside it, is rotating at an angular velocity of 1450 rpm. The impeller and volute meshes of the pump are shown in Figs. 1 and 2.

3- Results and Discussion

In the present study, in order to investigate the cavitation phenomenon and its onset, the inlet pressure of the pump is gradually reduced and the results are evaluated. For this purpose, the flow inlet pressure is changed from 100 to 15 kPa. As shown in Figure 3, the cavitation phenomenon occurs mostly at the leading edge of the pump blades.

With the occurrence and formation of the cavitation phenomenon, in addition to its effects such as a 3% drop in the head, it causes flow separation and changes in the flow behavior in the pump. This shows the effect of cavitation on the deformation and separation of fluid flow. As shown in Figs. 4 and 5, as the inlet pressure decreases and the cavitation bubbles increase, resulting in the partial space occupied by the bubbles at the beginning of the blade, the flow separation gradually increases and the flow behavior inside the pump becomes irregular. Examination of the behavior of flow lines in different states shows that at the pressure of 40 kPa, flow separation occurs at the beginning of the blade, but with the further reduction of the inlet pressure, this separation is transferred to the downstream and middle parts of the passage.

To observe the effect of cavitation on other pump performance parameters, the efficiency and power diagrams of the pump in terms of the net positive suction head have been investigated. According to the results, with a gradual decrease in the net positive suction head at a flow rate of 120 m^3, the amount of pump power is constant and equal to 2.38 kW, but this value in the net positive suction head is less than 3.784 with increasing cavitation bubbles. Gradually increased and reached 2.451 kW in the net positive suction head corresponding to a 3% drop of the head equal to 1.205. Also, the efficiency of the pump, like the power, until the beginning of cavitation (net positive suction head more than 3.784) is constant and equal to 89.9%, which with a decrease of the net positive suction head by 1.205, a 1% drop in efficiency (89.002 %) is obtained.

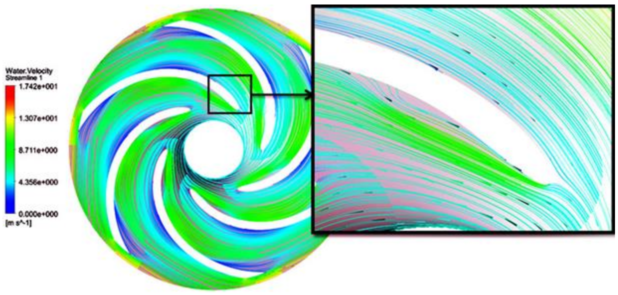

Fig. 5. Flow separation at an inlet pressure of 20 kPa

4- Conclusion

By reducing the inlet pressure from 45 kPa to 15 kPa, the vapor volume fraction increased from 0.04 to 0.96 and then remained almost constant.

According to the obtained results, the minimum required inlet pressure and the minimum net positive suction head required for non-occurrence and formation of cavitation in the flow of 120 m3/h predicted to be 50 kPa and the net positive positive suction head more than 4.3, respectively.

By reducing the flow inlet pressure, the formation of cavitation bubbles caused a pressure drop in the areas of 0.14 and 0.24 blade lengths at pressures of 30 and 20 kPa. Therefore, it is concluded that the reduction of the inlet pressure leads to the forward position of the cavitation occurrence downstream and in the middle of the passage.

The cavitation phenomenon, in addition to a 3% drop in the head at the pump outlet, causes separation and turbulence of the flow at the beginning of the blade, which is due to the formation of steam bubbles at the pump inlet and the beginning of the blade. The position of this separation is at the inlet pressure of 40 kPa in the areas of the leading edge and the beginning of the blade. However, with the gradual decrease of the inlet pressure to a pressure of 20 kPa, the amount of separation and turbulence of the flow increases more and its location is transferred to the inner areas of the blade.

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HOW TO CITE THIS ARTICLE

S. Abbasi , H. Gholizadeh Zavieh, Numerical Investigation of Flow Structure and Performance of Centrifugal Pump with Cavitation, Amirkabir J. Mech Eng., 54(1) (2022) 11-14.

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