IOP Conf. Series: Materials Science and Engineering 745 (2020) 012076 doi:10.1088/1757-899X/745/1/012076

Experimental study of the effect of impeller blades different shape on centrifugal pump performance

Hasan Ali Jurmut[1], Haider R. D. Al-Hamadani[1,*] and Hayder Saad Oleiwi[1]

[1] Al-Furat Al-Awsat Technical University, Al-Musaib Technical College, Department of Machines and Equipment Engineering Techniques, Babil, Iraq

[*]Email: com.hsn@atu.edu.iq, dr.haider.alhamadani@atu.edu.iq , com.hyd1@atu.edu.iq

Abstract: The influence of two different shapes impeller blades on performance of centrifugal water pump is experimentally investigated under different operational conditions. Test rig is designed and used to operate the required pump during different conditions. The centrifugal water pump is tested under different flow rate with two types of impellers each one consists different blades angle. The experimental results showed that the impeller blade different geometry could improve the water pump mechanical efficiency, the head, the power, and the volumetric efficiency by 11.7%, 15.38%, 24.2%, and 12.9% respectively. The experimental results showed better centrifugal water pump performance when impeller blade with higher outlet angle is used.

Keywords: Centrifugal pump, Impeller shape, Head and Efficiency, Pumps Performance

1. Introduction

The centrifugal pumps are the most powerful mechanical equipment and widely used for different industrial applications comprise for example irrigation, oil refineries and power-plants. Modifying the pump impeller and pump diffuser could result in improvement of centrifugal pump performance. Previous studies [1-3] have reported that various pump impeller blades outlet angle has considerable theoretical effect on centrifugal pump mechanical performance. A number of studies [4-7] have investigated the influence of various fluid viscosity on mechanical performance of centrifugal pump. The study is carried out using numerical analysis and compared with the experimental work. Numerous studies [8-10] have attempted to explain the influence of different impeller blades outlet angle for oil centrifugal pump by create a mathematical model. The results of latter model are compared later with experimental work results. The outcome of this study showed that the blades outlet angle has considerable influence on outlet-shaft power, pump mechanical efficiency, and pumping head. Several studies [11-13] tested the influence of impeller outlet angle of oil pump by using two approaches, numerically and experimentally. The outcome of these studies concluded that increase impeller outlet angle is led to pump performance improvement. Another studies [14-16] have also investigated the impeller blades inlet angle influence on pump performance. The obtained results showed that increases in impeller blades inlet angle, affect the pump efficiency. Previous studies [17-19] identified experimentally the influence of various parameters on the performance of centrifugal pump. These studies showed that, the highest efficiency of pump occurred with the discharge impeller blade angle of 25^{o} with impeller of six blades and efficiency 85% blades splitter compared with impellers without splitter. Tarodiya and Gandhi [20] reported that blades exit angle, had similar influence on pump efficiency and pump mechanical head. Their study showed that increased in impeller blades exit angle improves centrifugal pump performance and influences the pump hydraulic

IOP Conf. Series: Materials Science and Engineering 745 (2020) 012076 doi:10.1088/1757-899X/745/1/012076

efficiency, head, and pump shaft power. However, large exit impeller blade angle increased the input power consumption and the hydraulic efficiency and vis versa. Kassim et al. [21] showed that adding multi-slots to the impeller blades enhanced fluid pressure distribution comparing with that without slots at variable flow rates. Raghunathan and Cooper [22] investigated experimentally the influence of small and wide-angle diffusers with combinations of normal and inclined slots on pump performance. The results showed that the inclined slots produced better fluid output pressure and noticeable increase in fluid discharge angle. Hassan et al. [23] investigated the effect of different slots geometry on centrifugal pump performance. The study showed that increased the slot radial position reduced the head. The slot inclined angle has higher effect on the pump efficiency and pump head.

Although some studies had been carried out for impeller blades influence on centrifugal pump performance; the mechanism of this effect has not been established accurately. Moreover, there is very little scientific understanding of different impeller blades angle influence on mechanical performance of centrifugal pumps. In this study, a test-rig is designed for this purpose and to investigate experimentally the influence of different impeller blades angle on centrifugal water pump performance. The following sections illustrated the methodologies and the experimental work procedure then the key findings and the conclusions of this research.

2. Governing Equations

The polar vector diagram so called velocity triangle of impeller shown in Figure 1 is used to demonstrate vane relationship with number “1” for inlet fluid and number “2” for outlet fluid. The velocity triangle of impeller inlet is not shown in this paper.

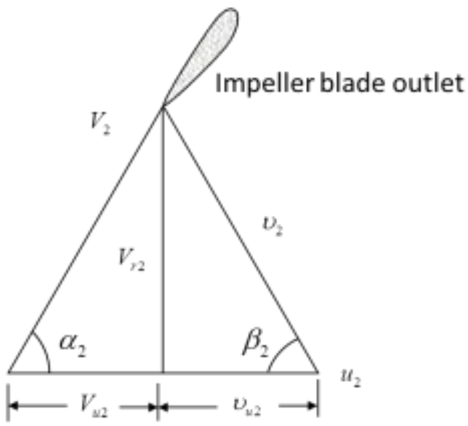

Figure 1. Velocity triangle of impeller outlet

According to Figure 1 the equations of resultant velocity V, fluid discharge Q, the inlet and outlet power P_{in}, P_{out}, the head H and pump efficiency η can be summarised as following:

$$V = \sqrt{(V_r^2 + V_u^2)} \quad (1)$$

The linear and angular velocity u, ω are calculated as following:

$$u = r\,\omega \quad (2)$$

IOP Conf. Series: Materials Science and Engineering 745 (2020) 012076 doi:10.1088/1757-899X/745/1/012076

$$\omega = \frac{2\pi N}{60} \tag{3}$$

The fluid flow rate, inlet and outlet power can be calculated as following:

$$Q = VA \tag{4}$$

$$P_{in} = T\omega \tag{5}$$

$$P_{out} = \gamma Q H_t \tag{6}$$

The pump efficiency and the total head can be calculated as following:

$$\eta = \frac{H_a}{H_t} \tag{7}$$

$$H_t = \frac{\Delta P}{\rho g} \tag{8}$$

$$\eta_T = \frac{P_{out}}{P_{in}} \tag{9}$$

3. Test Rig Design

In this study, the test rig used for experimental work includes gasoline engine connected to water centrifugal pump. The engine has maximum rotational speed of 3600 rpm and the pump work with 50mm in inlet and outlet diameter pipes as shown in Figure 2. Figure 3 illustrates the two types of impellers used in experimental tests with different blades angle these are: shape No.1 and shape No.2. The outer diameter for impeller shape No.1 is 122.5 mm and for shape No.2 is 185.6 mm respectively. The test rig is designed to be suitable for the purpose of this study with semi-open impeller. The test rig includes orifice flow meter, gate valve, constant speed electric pump, and flexible pipe suction.

The centrifugal pump outlet pipe is connected to flow meter and gage pressure. The inlet pump pipe is connected to gate valve (i.e. throttle valve), fitted on the discharge pipe to allow for accurate control of mass-flow-rate.

4. Experiments Work

The experimental test started with uncertainty analysis by doing calibration for the designed test rig. Later, the test rig is operated with centrifugal pump of impeller shape No.1 (see Figure 3) with different water flow rate. The latter can be accomplished by change the control valve gradually until the control valve is fully opened. The test rig is used to operate again after replaced the pump impeller by shape No.2. The data taken from those testes are: inlet and outlet value gage pressure and the flow rate. Controlling the water flow rate is accomplished by use control valve.

IOP Conf. Series: Materials Science and Engineering 745 (2020) 012076 doi:10.1088/1757-899X/745/1/012076

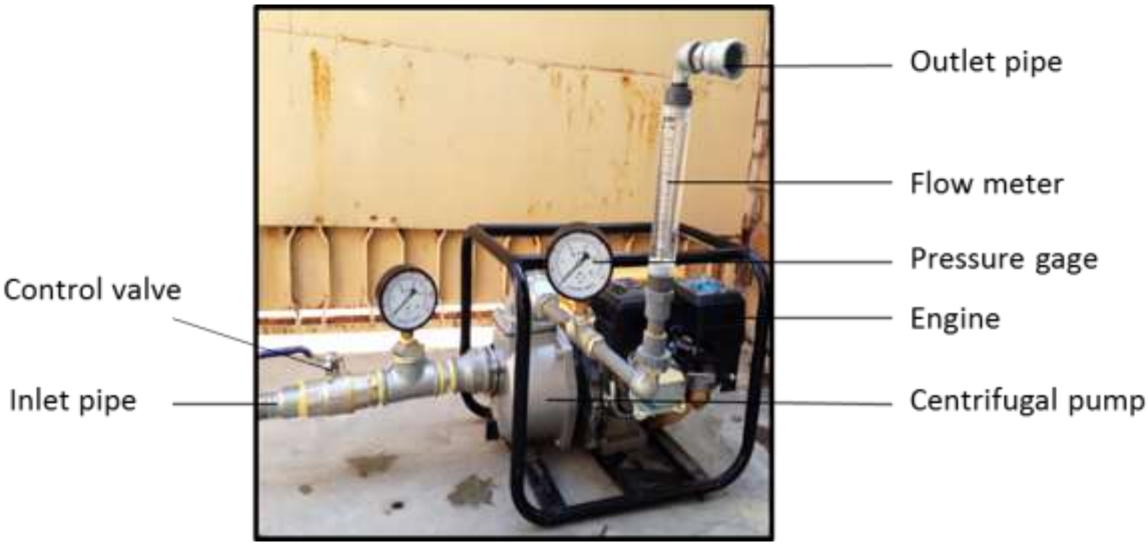

Figure 2 : Test rig layout

(a) Shape No. 1 (b) Shape No. 2

Figure 3 : Pump impellers with different blades angle configuration used in experimental work, left shape No.1 and right shape No. 2

5. Results and Discussions

The results of this study for centrifugal water pump operates with different impeller bales angel configurations namely shape No.1 and 2 (see Figure 3) on pump performance are shown in Figures 4, 5, 6 and 7. The pump rotational speed was constant through all the tests and was around the maximum speed rate of 3600 rpm. Figure 4 shows that the head for centrifugal pump with impeller shape No.1 is higher than that with shape No.2 configuration. The pump head for the pump when operates with impeller configuration of shape No.1 is recorded with maximum head of 26 meter while the head for that with shape No.2 configuration was lower by 4 meters. This means that the pump with impeller shape No.1 produced head higher than that of shape No.2 by 15.38%.

IOP Conf. Series: Materials Science and Engineering 745 (2020) 012076 doi:10.1088/1757-899X/745/1/012076

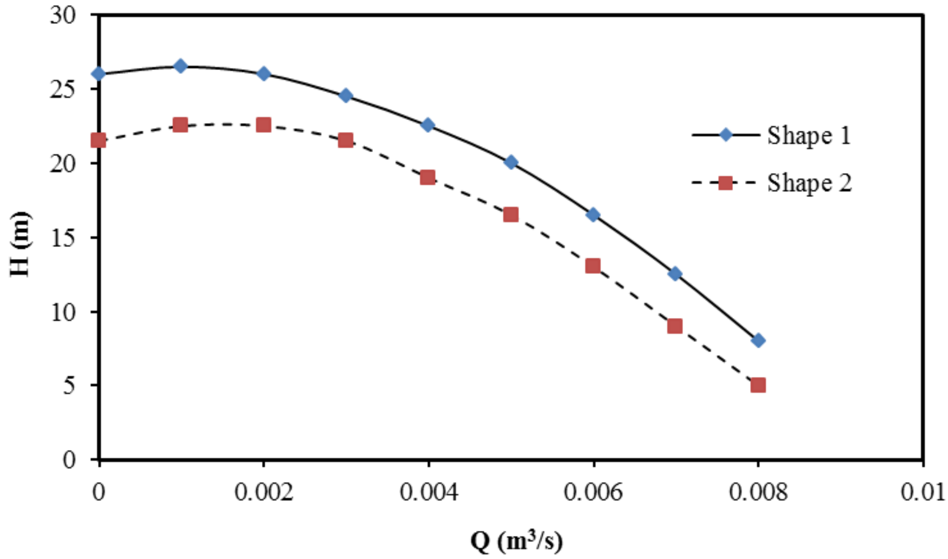

Figure 4: Pump head variation with water flow rates for different impeller blades angel

Figure 5 illustrates that the power of pump operates with impeller of shape No.1 configuration is higher than that of pump operates with impeller of shape No.2. The pump maximum power is increased by 24.2% when the pump operates with impeller blades angle of shape No.1. This noticeable increase is due to the fact of higher exist angle of impeller blades of shape No.1 than that of shape No.2.

Figure 6 shows the variation of pump efficiency operates at constant rotational speed with various flow rates for different shape of impeller blades configurations. The highest efficiency of pump with impeller shape No.1 configuration was 51% while the efficiency of pump operates with impeller of shape No.2 configuration was 45%. This difference is tend to be logical and matches the value of theoretical efficiency calculated by using equation 7.

Figure 7 shows the maximum volumetric efficiency η_v variations with water flow rate. The pump with impeller shape No.1 configuration approached 93.1% of volumetric efficiency which is higher than that with impeller shape No.2 configuration by 12%. The reason behind this rise in pump volumetric efficiency is caused by the configuration of the blades in impeller shape No.1 which allows more fluid volume to discharge. Hence, gives the better performance of centrifugal pump.

The fluid used in this study is water. However, different type of fluid could be used to study how its affect the performance of centrifugal pump operates with different impeller blades angel configurations.

IOP Conf. Series: Materials Science and Engineering 745 (2020) 012076 doi:10.1088/1757-899X/745/1/012076

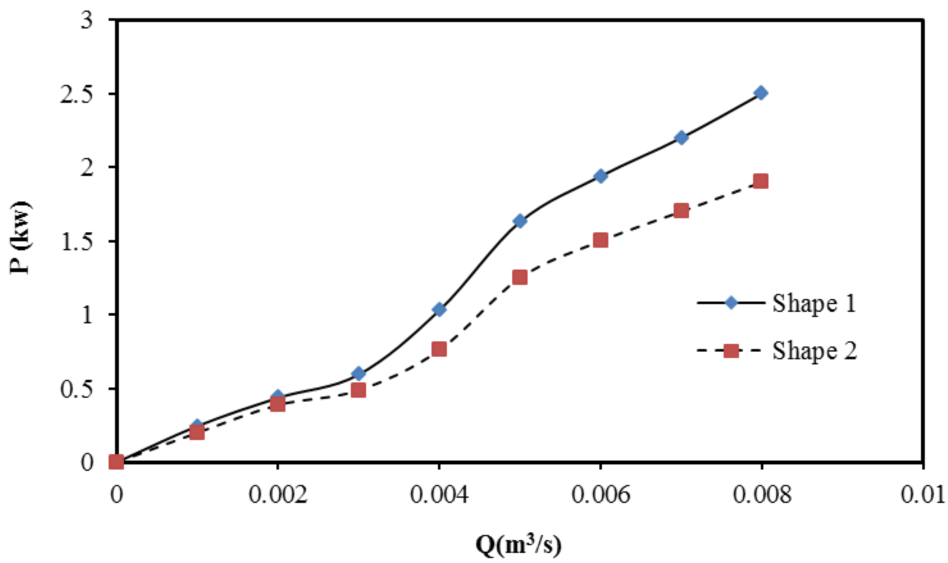

Figure 5: Variation of pump power with flow rates for different blades impeller angle

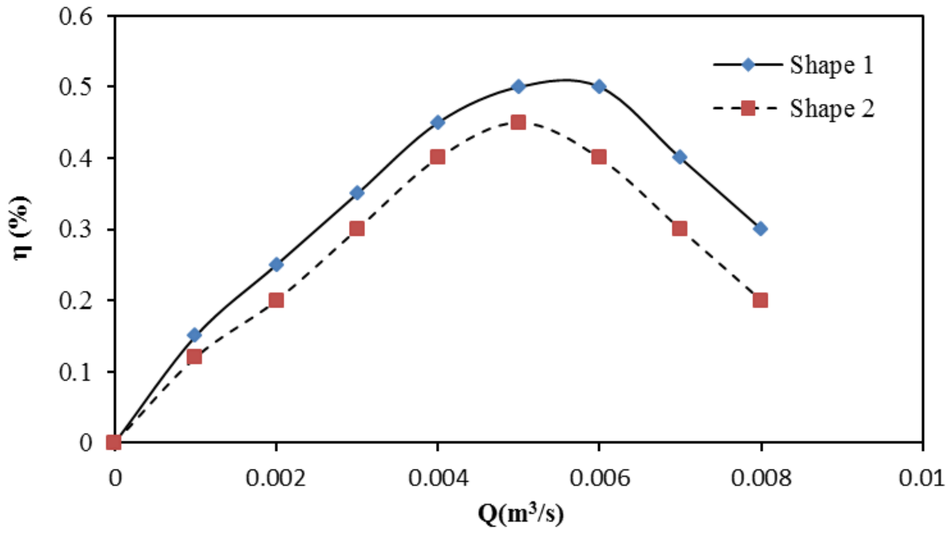

Figure 6: Pump efficiency variation with flow rates for different impeller blades

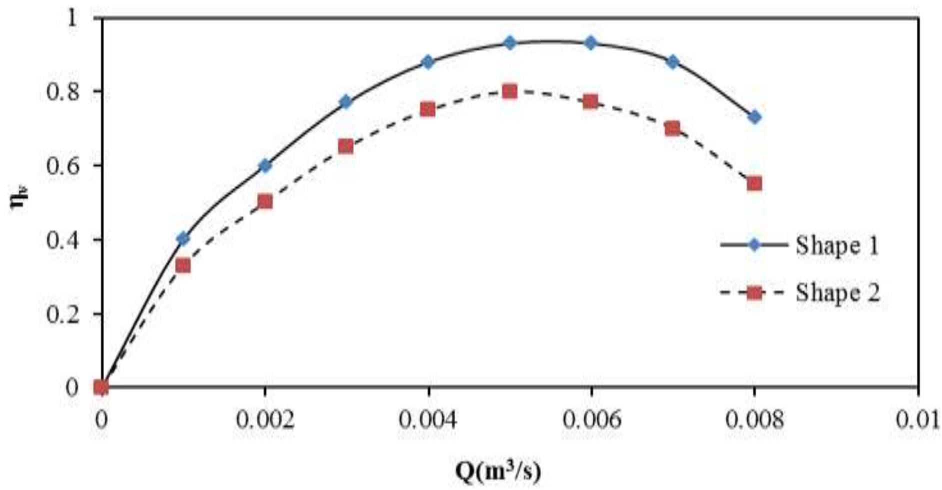

Figure 7: Pump volumetric efficiency variation with flow rates for different impeller blades

6. Conclusions

In this study the influence of different configurations impeller blades of centrifugal pump on pump performance is carried out experimentally by using a test rig. Pump efficiency, pump head, pump power, and pump volumetric efficiency are all measured experimentally by using a test rig designed and assembled for the purpose of this study. The following key findings can be summarized:

1. The configuration of pump impeller blades has significant influence on pump mechanical performance. The impeller designed with blades configuration of shape No. 1 has better influence than that of shape No. 2 and increases the pump efficiency, head, volumetric efficiency and power by 11.7%, 15.38%, 24.2%, and 12.9% respectively.
2. Increases impeller blades exit angle improves the performance of centrifugal pump.

7. References

[1] M. Patel and A. Doshi, "Effect of impeller blade exit angle on the performance of centrifugal pump," Int J. Emerging Technology and Advanced Engineering, vol. 3, pp. 91-99, 2013.

[2] L. Tan, B. Zhu, S. Cao, H. Bing, and Y. Wang, "Influence of blade wrap angle on centrifugal pump performance by numerical and experimental study," Chinese Journal of Mechanical Engineering, vol. 27, pp. 171-177, 2014.

[3] E. Bacharoudis, A. Filios, M. Mentzos, and D. Margaris, "Parametric study of a centrifugal pump impeller by varying the outlet blade angle," The Open Mechanical Engineering Journal, vol. 2, 2008.

[4] M. Shojaeefard, M. Tahani, M. Ehghaghi, M. Fallahian, and M. Beglari, "Numerical study of the effects of some geometric characteristics of a centrifugal pump impeller that pumps a viscous fluid," Computers & Fluids, vol. 60, pp. 61-70, 2012.

[5] L. Zhou, W. Shi, and S. Wu, "Performance optimization in a centrifugal pump impeller by orthogonal experiment and numerical simulation," Advances in Mechanical Engineering, vol. 5, p. 385809, 2013.

[6] J. Gülich, "Pumping highly viscous fluids with centrifugal pumps—Part 2," World Pumps, vol. 1999, pp. 39-42, 1999.

[7] J. Gülich, "Pumping highly viscous fluids with centrifugal pumps—Part 1," World pumps, vol. 1999, pp. 30-34, 1999.

IOP Conf. Series: Materials Science and Engineering 745 (2020) 012076 doi:10.1088/1757-899X/745/1/012076

[8] L. Wen-Guang, "Blade exit angle effects on performance of a standard industrial centrifugal oil pump," Journal of applied fluid mechanics, vol. 4, pp. 105-119, 2011.

[9] S. A. I. Bellary and A. Samad, "Pumping crude oil by centrifugal impeller having different blade angles and surface roughness," Journal of Petroleum Exploration and Production Technology, vol. 6, pp. 117-127, 2016.

[10] J. Gulich, "Effect of Reynolds number and surface roughness on the efficiency of centrifugal pumps," Journal of fluids engineering, vol. 125, pp. 670-679, 2003.

[11] M. S. Fard and F. Boyaghchi, "Studies on the Influence of Various Blade Outlet Angles in," American Journal of Applied Sciences, vol. 4, pp. 718-724, 2007.

[12] K. Morinushi, "The influence of geometric parameters on FC centrifugal fan noise," Journal of vibration, acoustics, stress, and reliability in design, vol. 109, pp. 227-234, 1987.

[13] S. Stevens, S. Harasgama, and P. Wray, "The influence of blade wakes on the performance of combustor shortened prediffusers," Journal of Aircraft, vol. 21, pp. 641-648, 1984.

[14] S. Yang, F. Kong, H. Chen, and X. Su, "Effects of blade inlet angle on performance of pump as turbine [J]," Journal of Central South University (Science and Technology), vol. 1, 2013.

[15] S. V. Jain, A. Swarnkar, K. H. Motwani, and R. N. Patel, "Effects of impeller diameter and rotational speed on performance of pump running in turbine mode," Energy conversion and management, vol. 89, pp. 808-824, 2015.

[16] S.-S. Yang, H.-L. Liu, F.-Y. Kong, B. Xia, and L.-W. Tan, "Effects of the radial gap between impeller tips and volute tongue influencing the performance and pressure pulsations of pump as turbine," Journal of Fluids Engineering, vol. 136, p. 054501, 2014.

[17] E. Korkmaz, M. Gölcü, and C. Kurbanoğlu, "Effects of blade discharge angle, blade number and splitter blade length on deep well pump performance," Journal of Applied Fluid Mechanics, vol. 10, pp. 529-540, 2017.

[18] M. GÃļlcÃž, N. Usta, and Y. Pancar, "Effects of splitter blades on deep well pump performance," Journal of energy resources technology, vol. 129, pp. 169-176, 2007.

[19] M. Gölcü and Y. Pancar, "Investigation of performance characteristics in a pump impeller with low blade discharge angle," World pumps, vol. 2005, pp. 32-40, 2005.

[20] R. Tarodiya and B. K. Gandhi, "Hydraulic performance and erosive wear of centrifugal slurry pumps-A review," Powder Technology, vol. 305, pp. 27-38, 2017.

[21] M. S. Kassim, F. A. Saleh, and M. A. Kadhum, "Experimental and Numerical Investigation of Blades Slots on Rotating Stall Phenomenon in Centrifugal Blower," 2015.

[22] S. Raghunathan and R. Cooper, "Passive boundary layer control with slots in short diffusers," Journal of fluids engineering, vol. 122, pp. 177-179, 2000.

[23] A. F. A. Hassan, H. M. Abdalla, and A. A. E. A. Aly, "Effect of Impeller Blade Slot on Centrifugal Pump Performance," Global Journal of Research In Engineering, 2016.