ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

THE PERFORMANCE OF HYBRID CENTRIFUGAL–JET PUMP

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DOI: 10.5281/zenodo.168433

ABSTRACT

Pumps are considered the heart of any project includes fluid transportation or increasing of its pressure. For a long run, the piping pressure losses increases and the pump efficiency decreases which effect the system requirements of either discharge pressure of flow rate. A hybrid centrifugal-jet pump system is proposed in order to enhance the centrifugal pump performance to achieve the system requirements. The performance of the centrifugal and the proposed hybrid pumps are performed at a speed 2900 rpm for different ratios of centrifugal and jet pumps flow rates. The effect of the throat ratio (D/L) variation of the jet pump is also investigated at different ratios of D/L=0.33, 0.4, 0.5, 0.66. The obtained results show that the propose system increases the discharge head depending on the ratio of the jet and the centrifugal pumps flow rates. It found that the maximum increasing of the discharge head is about 43%. At the maximum flow rate ratio for all jet pump throat ratios. This means the variation of the jet pump throat ratio D/L has no observed effect on the hybrid system performance. Also the hybrid system map performance is also obtained at different throat ratio.

KEYWORDS: centrifugal pump, Jet pump, hybrid centrifugal-jet pump, characteristics curve, performance map

INTRODUCTION

The centrifugal pumps are probably among the most often used machinery in industrial facilities as well as in common life. After being invented, they passed long evolutionary way until they became accessible for various applications. Many technical applications of centrifugal pumps cannot be fulfilled without proper analysis, especially regarding pumps output parameters, its head, flow rate and efficiency [1]. Winoto et al [2]. Investigated theoretically and experimentally the performance of water jet pumps. Their experimental rig was designed and constructed to conduct the experimental study in which a commercial water jet pump was used. The theoretical efficiency equations for such jet pumps were first derived based on one-dimensional formulation. The effects of different area ratios of nozzle to mixing throat as well as different nozzle cross sections, which include circular, square and triangular nozzles, on the jet pump performance were investigated. The best nozzle cross section for the jet pump was found to be the circular nozzle. Sinisa et al [3] investigated theoretically and experimentally the possibilities of highly compressible steam in supersonic steam-water jet pump's mixing chamber. Luo, et al [4] analyzed numerically and experimentally water pumps with accumulators which absorbing pressure pulsation in high-velocity water-jet propulsion system. Hammoud [5] performed experimental observations for the performance of a jet pump with two different suction configurations and designs. Sarshar et al [6] studied the design parameters of a system for pumping liquids using a jet pump and a phase separator. Their analysis were performed at mixing fluids from separate sources comprises a jet pump having high and low pressure fluid inlets, and a main outlet for discharging a mixture of the two fluids. In this paper an experimental investigation of a hybrid centrifugal-jet pump system performance is performed. This hybrid system could be viewed as a method to enhance

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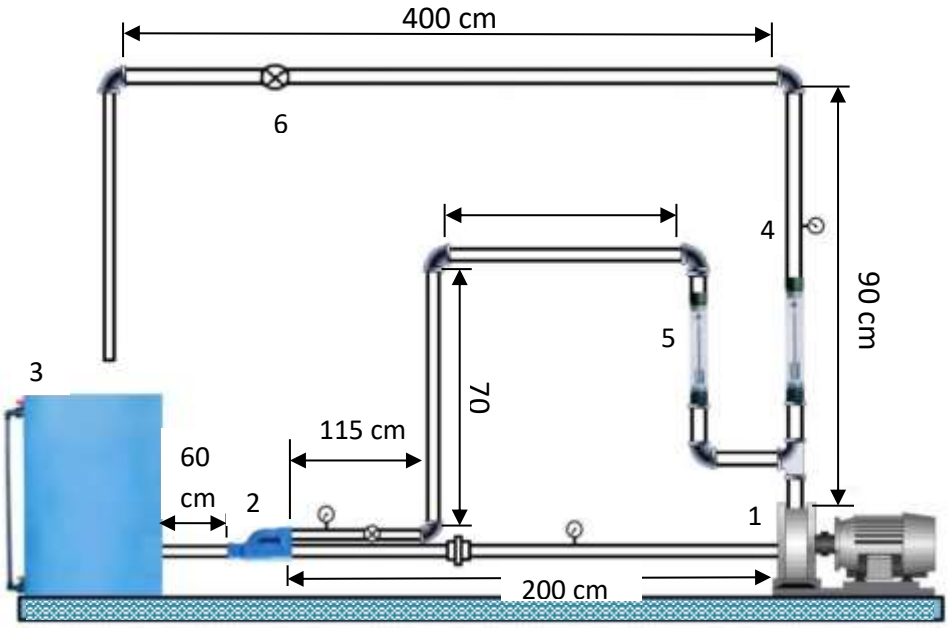
the centrifugal pump performance. In other words the versatile performance which enables the pump operation to accommodate pipe system requirements which single centrifugal pump cannot provide due to either the increasing pressure losses with time or the degradation of the pump performance for long time. In this investigation the performance of the centrifugal, pump and the hybrid centrifugal – jet pump system are tested .It is proposed to obtain a performance map for the hybrid pump system which could expand the area of operation with respect to a single centrifugal pump.

EXPERIMENTAL PROGRAM

The hybrid centrifugal–jet pump evaluation may be achieved by conducting an experimental investigation to determine the characteristics and performance of the system. In this study, different operating conditions are considered as flow rates of the jet and centrifugal pumps. and, the jet pump clearness ratio (D/L) which varied from 0.33 to 0.66 while the centrifugal pump rotating speed is kept at 2900 rpm.

Figure (1) depicts the schematic diagram of the experimental test-rig. The main component of this system is the centrifugal pump (1) model (NGM 32) 1.5 Hp, with a closed impeller which gives a maximum flow rate of 165 LPM at a discharge head of 24 m. A jet pump(3) is installed before the suction of the centrifugal pump and the distance between the jet and centrifugal pump is 2 m, the jet pump dimensions are illustrated in Fig (2). This cycle is a closed cycle where the centrifugal pump



1	Centrifugal pump	4	Pressure gage
2	Jet pump	5	Rotameter
3	Storage tank	6	Valve ball

Fig. (1) Experimental Set-up Components

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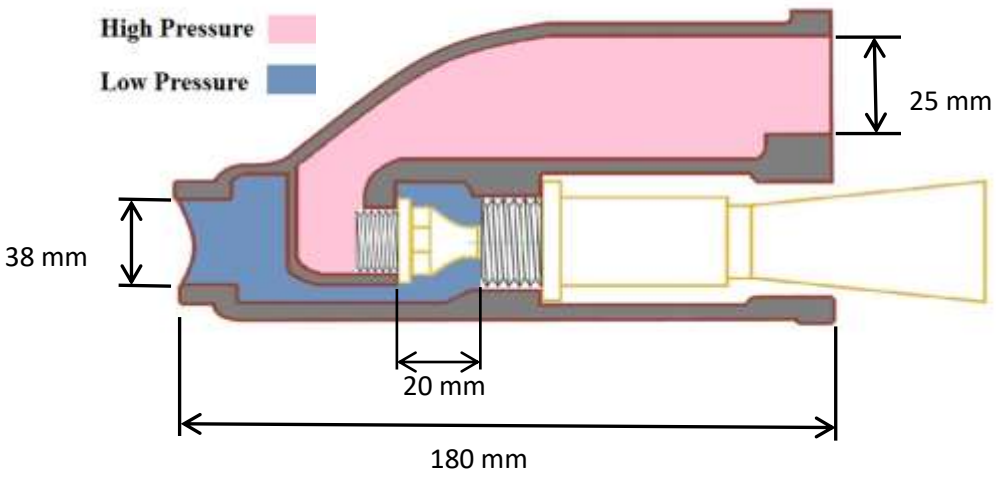

Figure (2) Cross Section and Dimensions of Jet

suction is from a 230 liter tank (3). Three pressure gages (4) type (aterma) which have an accuracy of (±0.04) bar, are used to measure the water pressure at different locations, the first pressure gage is located at the centrifugal pump suction line and the second is located at the discharge line of the centrifugal pump where the third is located at the high velocity stream pipe line of the jet pump. Two rotameter (5) type (DFG-40) which have an accuracy of ±0.04 LPM are used to measure the flow rates of centrifugal pump discharge and the high velocity flow rate of the jet pump. . Two ball valves (6) are used to control the flow rate of the centrifugal and jet pumps. For performing the system analysis the consumed electrical power by the centrifugal pump motor is measured using a wattmeter model (wc15-3F1) which gives its reading with an accuracy of (±0.05) W.

Experimental Procedure

After installing and testing all components in the experimental test-rig, the tank is filled with water till a level of 40 cm from the suction line of the pump, to maintain the suction pressure constant, for all experiments. The centrifugal pump is operated for 5 minutes to purge all trapped air inside the system. First, the performance of the centrifugal pump is performed by recording different discharge head at different flow rates at a speed of 2900 rpm. After that, the jet pump is adjusted in different configurations ratio at (0.333, 0.4, 0.5, and 0.666). At each ratio, the jet flow rate is adjusted at a certain value to cover the range from no jet flow (Q_j=0) to the maximum jet flow (Q_{jmax}). At each case the performance (H, Q) curve, the consumed power and the system efficiency are performed as following:
the hybrid system discharge head can be calculated as following:

$$H = \frac{P_2 - P_1}{\rho g} \quad (1)$$

Where P_2, P_1 are the discharge and the suction pressures of the hybrid system respectively, **ρ** is the water density and **g** is the acceleration gravity. The system efficiency can be calculated as:-

$$\eta = \frac{output}{input} = \frac{Hydraulic\ power}{Electric\ power} = \frac{\rho g Q_p H}{P} \quad (2)$$

Where P is the consumed electrical power at flow rate Q and discharge head H. From the above data a correlation which may be used as a fit of the H-Q curve is proposed as following:-

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$$H=H_o\left[1-\left(\frac{Q}{Q_{max}}\right)^2\right] \quad (3)$$

Where H_o and Q_{max} are the maximum head and flow rate for each case respectively. To perform the performance map of this system the following similarity laws are used

$$\frac{Q_2}{Q_1}=\frac{N_2}{N_1} \quad (4)$$

Where Q_2 and Q_1 are the flow rate of the hybrid system at rotating speed of N_1, N2 respectively

$$H_2=H_1\left(\frac{N_2}{N_1}\right)^2 \quad (5)$$

where H_1 and H_2 are the discharge head of the hybrid at system at rotating speed N_1, N_2 respectively.

RESULTS AND DISCUSSION

4.1 centrifugal pump performance.

Figure (3) shows the characteristic curve of the centrifugal pump only at impeller speed of 2900 rpm. It is observed that the maximum head is 24 m where the maximum flow rate is 165 LPM. The maximum consumed power is 1280W, while the maximum recorded efficiency is 30 at flow rate of 165 LPM and discharge pressure of 24 m.

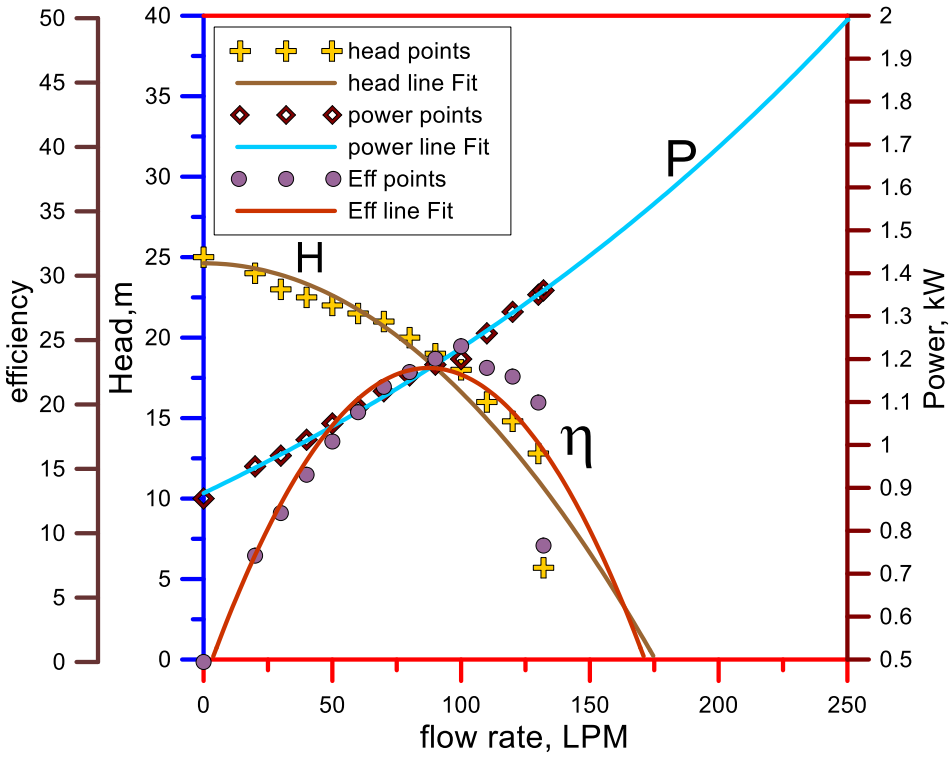

Figure (3) Characteristics curve of the hybrid system, head, power and efficiency at speed 2900 rpm

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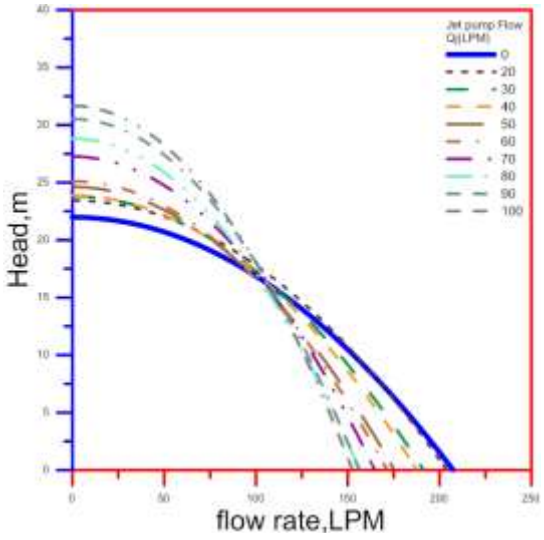
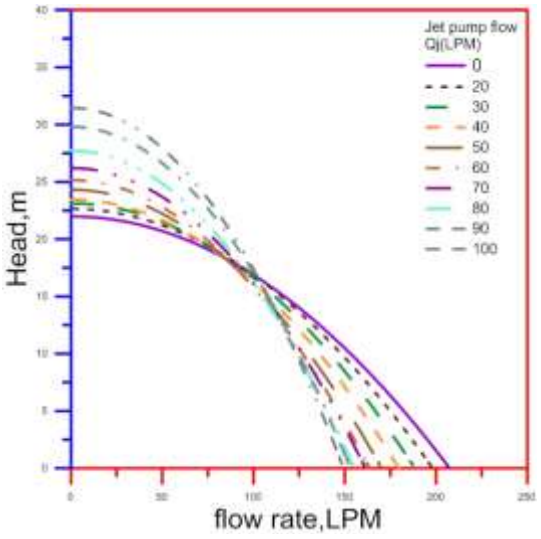
4.2 Hybrid centrifugal-jet pumps performance.

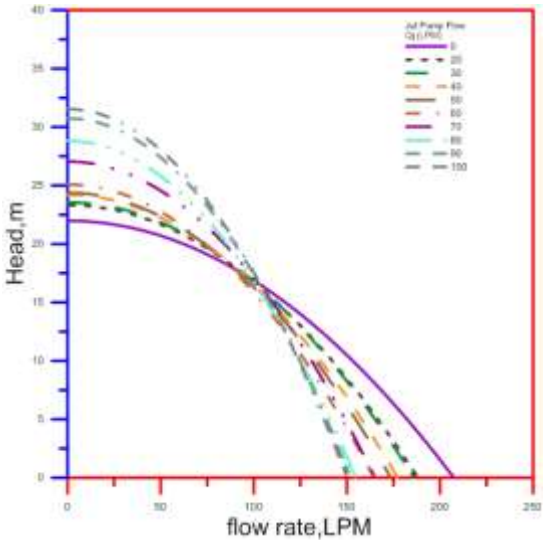
Figure (4) depicts the performance a curve of the hybrid system at different jet flow rate (Qj) and different D/L ratios. It can be noticed that as the jet flow increases the gained hybrid system discharge head increases to reach its maximum at jet flow rate of 100LPM. The gained area of performance above the centrifugal pump (H, Q) curve decreases with increasing the hybrid system flow rate till a turning point (15 m, 100 LPM) after this point the degradation of discharge head is observed which increases with farther increasing of the system flow rate. Also, it is noticed that the variation of the D/L ratio doesn't have an observed effects in this case, it may be due to the constant rotating speed and the jet pump flow is controlled by a valve instead of self adapting of the jet pump flow rate. The maximum increasing in the discharge head is 43.8% while the maximum degradation of the system flow rate is 26%.



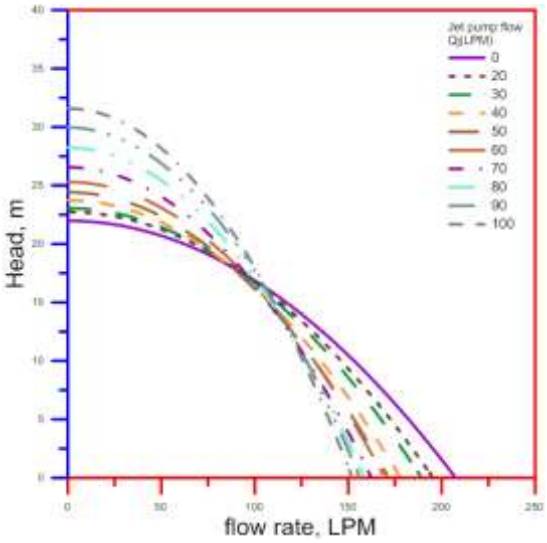
(a) D/L=0.33



(b) D/L=0.4



(c) D/L=0.5



(d) D/L=0.66

Figure(4) Hybrid system performance at different configurations ratio D/L

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From figure (5) concludes the variation of the different hybrid system performance parameters versus jet flow rate variation, it is observed that the maximum discharge pressure as well as the maximum consumed power increases with increasing the jet flow rate while the system flow rate decreasing with increasing the jet flow rate.

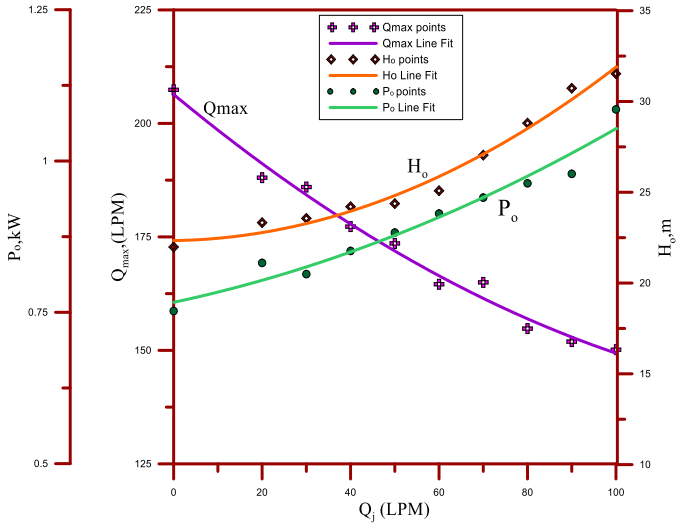

Figure (5) Relationship between (Q_{max}, H_o and P) at speed (2900) and (D/L=0.5) rpm

4.3 Performance map of the hybrid system.

Figure (6) illustrates the performance map which concludes all performance parameters as H, Q, η and consumed power at different speeds which deduced from the pre-mentioned similarity laws. And by using the SURFER software and MATLAB to draw a chart or map of the performance of the system in general terms through which can provide us with all required variables for each case, and at any point, the performance of the system will be as in the following charts

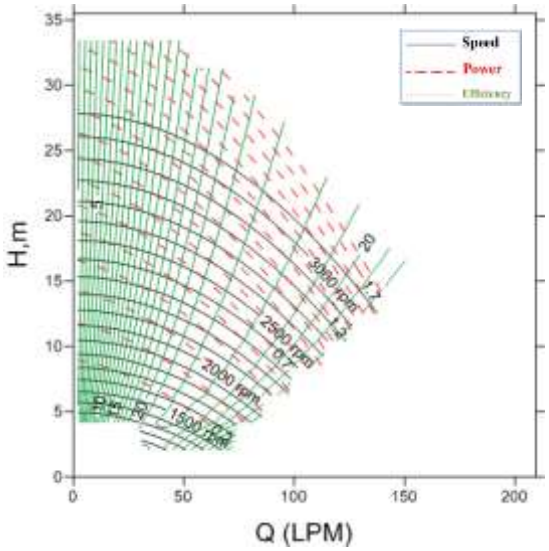

Figure (6) Performance map of the hybrid system
for D/L=0.5

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CONCLUSIONS

An experimental investigation of the hybrid centrifugal–jet pump system using a centrifugal pump 1.5 hp which gives 165 LPM at discharge head of 24 m at impeller speed of 2900 rpm is performed. The jet pump is used at different D/L ratios (0.333, 0.4, 0.5, and 0.666). The performance of the proposed system is analyzed and the following conclusion may be summarized:

1- The hybrid centrifugal-jet pump system be viewed as a multistage system without increasing of the initial cost of multi-system pump or the running cost of maintains.
2- The simplicity of adapting of the required flow rate and discharge by only adapting the jet flow rate is a promising option to overcome the variation of the required operating point.
3- The investigated system gives an increase in the discharge head of 43% and degradation of the flow rate of 21%.
4- For the constant rotating speed and using a jet pump control valve, the D/L ratio has no observed effect on the hybrid system performance.

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