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DESIGN, FABRICATION AND PERFORMANCE EVALUATION OF A TEST RIG OF CENTRIFUGAL PUMPS IN SERIES AND PARALLEL COMBINATION

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ABSTRACT

Centrifugal pumps find vast applications in modern machineries and often works either in series or parallel. In this experimental work, an attempt has been made to design and fabricate an experimental set-up that comprises of two centrifugal pumps arranged in such a manner that the experimental set-up works either individually or in series and in parallel combinations. The maximum value of efficiency estimated is 62.45% for C1 and 65.30% for C2, 55.10% and 58.15%, when pumps operate individually, in series and in parallel combination, respectively. The designed and fabricated test rig has efficiently served the purpose of providing a clear idea about the effectiveness of experimental set-up in transmitting fluid to distant work stations. This study indicated the methodology could be used to transfer gases or liquid to long distances by using more number of pumps in series and parallel combinations.

Keywords— Centrifugal Pump; Efficiency; Series Combination; Parallel Combination; Best Efficiency Point (BEP).

1. INTRODUCTION

This Centrifugal pumps have found enormous industrial and commercial applications and in particular in oil and gas industry, steam power plants, buildings, agriculture and irrigation works, food industry, paper and pulp industry etc. These enable fluid transmission between two places by utilizing power from some other external source. Centrifugal pumps belong to dynamic pressure pumps that generate head and flow by increasing the velocity of the liquid with the help of a rotating vane impeller followed by a diffuser. Specific speed, blade orientation, casing insulation, impeller diameter, number and pitch of blades, surface finish of the internal surfaces, viscosity of fluid etc. are the parameters that influence the performance of such pumps.

Hallam (1982) studied the effect of suction specific speed on the performance reliability of centrifugal pump. The trend for frequency of centrifugal pump failure increased above a certain value of specific suction speed (Ns = 213). The reason behind was that at high suction specific speed large impeller eye diameter is required, which caused high suction recirculation at high flow rates and this became responsible for cavitation, piercing noise and vibration, premature wear and all sorts of components failures. Fraser (1981) explains relationship between onsets of the impeller inlet recirculation and average impeller blade inlet angle. Li (2000) studied the effect of viscosity on the performance of centrifugal pump and flow pattern within impeller. The results obtained from this study conclude that high viscosity results in rapid enhancement in the friction and hydraulic losses and correspondingly decrease in the centrifugal pump performance. The flow pattern near the suction side was observed to be greatly affected, as compared to the outlet side, by fluid viscosity which was accurately measured using LDV (Laser Doppler velocimetry).

The common causes of failure of pump during operation are briefly discussed in (Hartigan, 2001; World Pump, 35-39, 2001). For example, a mono-block centrifugal pump often cause serious problems like abnormal noise, leakage, high vibration, and cavitations etc. due to defect in bearing, seal,

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impeller and insulation. Cavitation deteriorates hydraulic performance of the pump by decreasing head-capacity and efficiency, too much erosion of parts, pump malfunctioning and structural vibration. Now-a-days, owing to huge applications in machineries, scholars are challenged to develop a better system. Henceforth, research related to basics (World Pumps, Waterworks, 30-31, June 2010), selection of pump systems for different applications (Larralde & Ocampo, 2010), commissioning/start-up and a magnetic drive pump (World Pumps, 24-26, Dec. 2000) has been paid attention. Recently, research related to optimization of pump casing (Golbabaei, Torabi, and Nourbakhsh, 2009), working under multi-phase flow conditions, improvements in design of impeller (Šavar, Kozmar, & Sutlović, 2009) and simulation of a low-specific-speed high speed centrifugal pump has been carried out (Jafarzadeh, Hajari, Alishahi, & Akbari, 2011). Derakhshan and Nourbakhsh (2008) have been estimated best efficiency point (BEP) of reverse pump based on geometric and hydraulic mode characteristics. The values predicted in this study using CFD at Ns = 23.5 were found to be slightly lower than the experimental values. Caridad et al. (2008) presented biphasic characterization of a centrifugal pump impeller of an ESP (Electrical Submersible Pump) carrying air-water mixture at specific speed (Ns = 2063) by means of CFD (Computational Fluid Dynamics) tools.

Inspired by the above literature, the present work experimentally investigates performance of centrifugal pumps individually, in series and parallel combinations on one test rig and also discusses their characteristic curves.

2. EXPERIMENTAL SETUP DESCRIPTION AND PROCEDURE

The general components and direction of fluid flowing in the fabricated centrifugal pump setup are presented in Fig. 1 and Fig. 2. The schematic diagram and actual fabricated experimental set-up is shown in Fig. 3 and fig. 4, respectively.

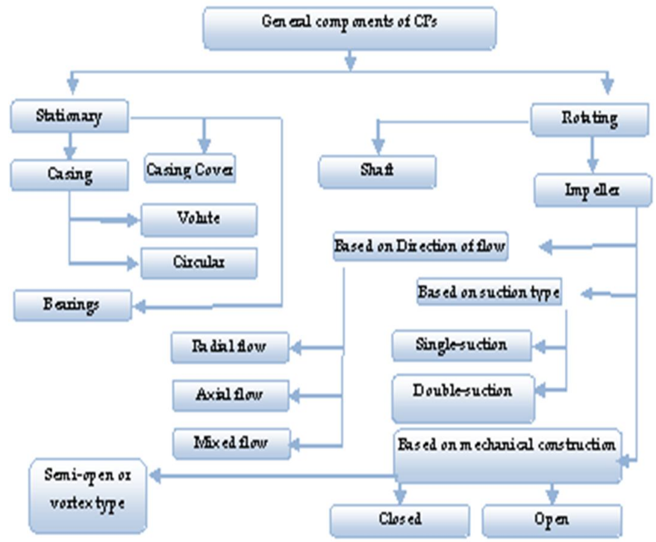

Figure. 1 General components of centrifugal pump

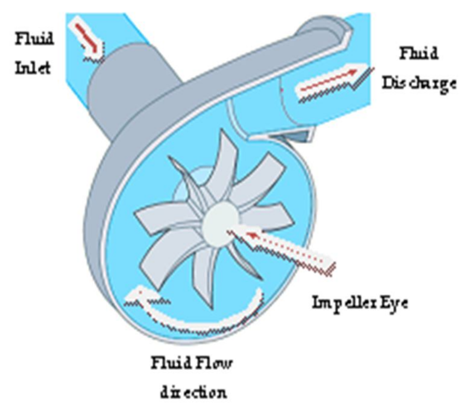

Figure. 2 Direction of fluid flow in centrifugal pump (http://www.britannica.com/EBchecked/topic/632655/volute-centrifugal-pump)

It consists of two identical mono-block centrifugal pumps C_1 and C_2 (technical specifications of the centrifugal pump as show in Table 1), piping network, strainers (S_t), valves (V_1-V_5), measuring instruments, sump (S_1) of 1.20 m × 0.54 m × 0.40 m and a collecting tank (S_2) of 0.75 m × 0.61 m × 0.46 m.

A. Instrumentation

1) *Pressure Gauge (P_2, P_4)*

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Used to measure pressure at inlet and outlet sections of the CPs. Different categories were available, but as per the requirement for this test rig 7 kgf/cm^2 has been used.

2) *Vacuum Gauge (P_1, P_3)*
Here 760 mm of Hg vacuum gauge has been used for measuring the suction pressure at the inlet of CPs.

3) *Thermometer (T_1-T_4)*
In the experimental set-up sensor thermometers have been used ranging from 0°C-150°C to measure temperature variation of the test rig at different positions.

4) *A Graduated Glass Tube With a Linear Scale (M)*
Used to measure the height of water in the collecting tank through which discharge has been calculated.

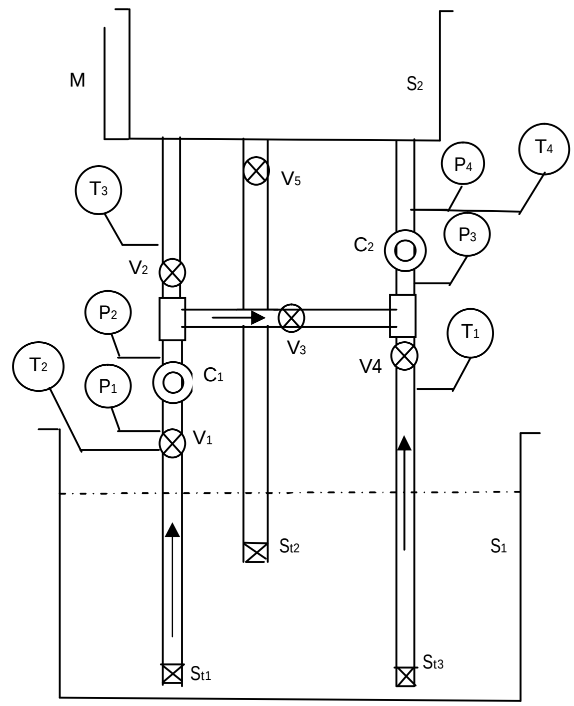
Table 1 Technical Specifications Of The Centrifugal Pump As Per Pump Manufacturer

S. No	Specifications	
1	Motor	Crompton Greaves
2	Power	0.37 HP/0.5 kW
3	Phase	AC, 50 Hz
4	Voltage	220 V
5	Speed	2780 rpm
6	Current	2.8 A
7	Size	(25) x (25) mm
8	Head	28.5 m
9	Discharge	2600/570 lph.
10	Insulation	'B' class

The set-up runs to collect the data for head, discharge, pressure and temperature. Four sets of experiment were conducted on the test rig. The positions of operating valves for different experiments were given in Table 2.

Table 2 Operating Conditions for Conducting Four Experiments

Centrifugal Pumps (C_1 & C_2)	Valve Position		Experiment
	Open	Close	
C_1(on), C_2(off)	V_1, V_2	V_3, V_5	Individual
C_2(on), C_1(off)	V_4	V_3, V_5	Individual
C_1 & C_2 (both on)	V_1, V_3	V_2, V_4, V_5	Series
C_1 & C_2 (both on)	V_1, V_2, V_4	V_3, V_5	Parallel



(A) Pressure Gauge (P_2, P_4)
(B) Vacuum Gauge (P_1, P_3)
(C) Thermometer (T_1-T_4)
(D) Graduated Glass Tube (M)

Figure 3 Schematic diagram of the centrifugal pump test rig

Figure. 4 Actual fabricated the centrifugal pump test rig

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The most important steps involved in carrying the operation were as described in "Pumps-principles and practices," by Jaico publishing house, p 89-99.

1) *Priming*
Priming involved the removal of air, gas or vapour from the suction piping network and pump casing. Centrifugal pump must be primed prior to start up. Venting is an operation carried out to remove any trapped air pockets in the system and may be necessary on the suction pipeline as well as the pump. Many modern designs of pump are inherently self-primed from shut down to start up and self-venting. In the experimental set-up two self-primed centrifugal pumps have been used.
2) *Starting*
Standard start-up procedure was followed Before initial start-up, the drive coupling was disconnected and the rotation of the driver checked. An arrow on the pump casing indicated the correct direction of rotation.
3) *Stopping the pumping equipment*
A typical sequence of operation for shutting down the pump set was:
    - First shut down the driver.
    - If the pump is not required for some time, the suction and discharge isolating valves can be closed and any ancillary services such as cooling or flushing lines can be shut down.
    -

The following parameters were measured for each conducted experiments: Suction Pressure, Discharge Pressure and Discharge.

3. DATA REDUCTION

The correlation used to calculate total head, discharge, efficiency, specific speed and power has been given by the expressions.

Input power of motor to the shaft =
(Number of revolution × 3600) ÷ (time × Z × W). (1)

Input power to the pump = (Input power of motor to the shaft) × (mechanical efficiency) × (transmission efficiency) (2)

$$Q = \frac{(W \times L \times h)}{t} \quad (3)$$

where h is the height of water in collecting tank and W & L are width and length of the collecting tank respectively (all in m). Discharge denoted by Q (m^3/s).

The total head (H) estimated by the relation

$$H = H_s + H_d \quad (4)$$

where H_s and H_d used for suction pressure and discharge pressure in m respectively.

$$P_0 = \rho \text{ g Q H} \quad (5)$$

where ρ, g and P_0 represents the density of water, acceleration due to gravity and output power (P_0) respectively.

The efficiency estimated through the relation given:
Efficiency (η) = (Hydraulic power output) ÷ (Input power) (6)

4. RESULTS AND DISCUSSION

A. *Application of Performance of an Individual Pump*

The variation of head, input power and pump performance (efficiency) with discharge have been evaluated and presented in Fig. 4 for C1 and Fig. 5 for C2. From the figures, it is clear that as flow rate increases from 0.002 to 0.008 m3/s head decreases from 8.60 m to 3.20 m, power input to pump increases and performance of the pump increases for both the pumps. The efficiency varies from 36.35% to 62.45% for C1 and from 37.15% to 64.54% for C2. The best efficiency points located at QBEP=0.0072 and 0.0064 m3/s, matching to the best efficiencies 62.45% and 60.98% for C1 and corresponding to C2 the best efficiency points located at QBEP=0.008 and 0.0072 m3/s, corollary to the best efficiencies 64.54% and 62.80%.

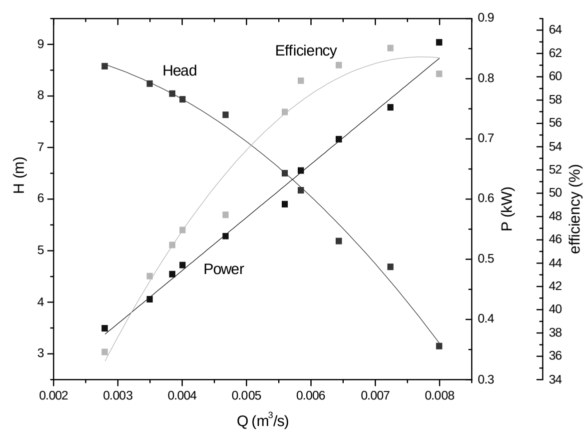

Figure. 4 Variation of head (m), input power (kW) and efficiency (%) with flow rate (m^3/s) for C_1

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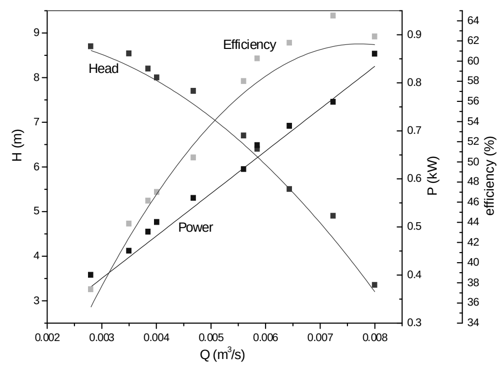

Figure. 5 Variation of head (m), input power (kW) and efficiency (%) with flow rate (m^3/s) for C_2

B. ***Performance of Centrifugal Pumps in Series Combination***

As the centrifugal pumps operated in series, input power required to operate two centrifugal pumps increased. Head produced in this case also increases, nearly becomes double as compared to single centrifugal pump. The characteristics curve in series operation as shown in Fig. 6. The best efficiency points located at QBEP = 0.008 and 0.0094 m3/s, corresponding to the best efficiencies are 55.10% and 53.22%, respectively. Head varies from 5.5 m to 15.42 m corresponding to discharge of 0.0094 m3/s to 0.0035 m3/s, respectively.

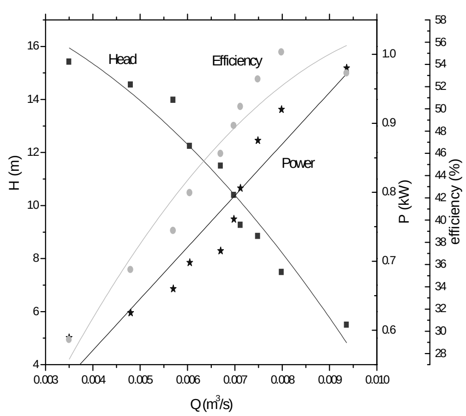

Figure. 6 Variation of head (m), input power (kW) and efficiency (%) with flow rate (m^3/s) in series

C. ***Performance of Centrifugal Pumps in Parallel Combination***

If the flow rate of one pump is insufficient, the desired flow rate can be obtained by operating two or The characteristics curve for parallel operation is shown in Fig. 7 and Fig. 8. The combined head discharge curve is found by the individual flow rates at the same level. The pump having steep characteristic curves have been operated in parallel to obtain high flow rates. The best efficiency points located at Q_{BEP}=0.015 and 0.016 m^3/s analogous to the best efficiencies 58.45% and 56.23%, respectively. The discharge in case of parallel combination is varying as 0.0056-0.016 m^3/s.

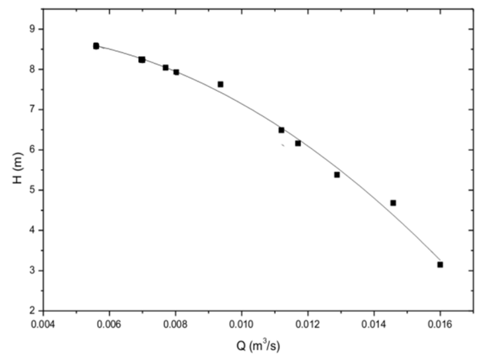

Figure. 7 Variation of head (m) of centrifugal pumps with discharge (m^3/s) in parallel

II.

5. CONCLUSION

The present work was undertaken with the objective of detailed investigation of the centrifugal pumps performance when operated in different conditions either individually or in combinations of series or parallel. The evaluated results have been presented in graphical form for variation of Head, Input power and Efficiency with flow rate (Discharge). From this study, an insight about the characteristics of centrifugal pump and their behaviour corresponding to different conditions and combinations has been examined.

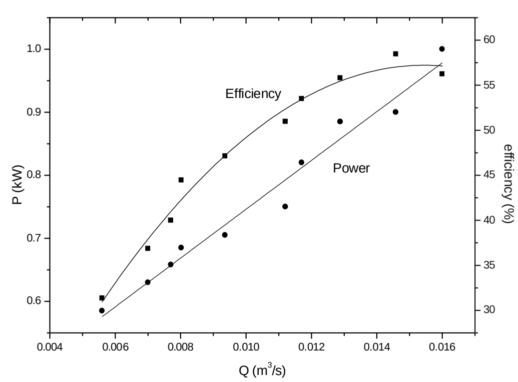

Figure. 8 Variation of input power (kw) and efficiency (%) with flow rate (m^3/s) for centrifugal pump in parallel

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The result shows that in series combination head increases whereas in parallel flow rate increases. This experimental study has been proved very crucial for industries in transferring fluid form one place to another and in common day life as well.

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