Experimental Setup of Centrifugal Pump

Akash Narwade[1], Laxmikant Patil[2], Akshay Munot[3], Shardul Nikam[4], Sachin R. Kulkarni[5]

[1,2,3,4]*Sinhgad College of Engineering, Pune*
[5]*Professor, Dept. of Mechanical Engineering, Sinhgad College of Engineering, Pune*

Abstract – *Nowadays centrifugal pumps are being widely used in commercial, industrial and power plant applications and most of the pumps are operated by constant speed drive systems. The purpose of this study is to investigate the pump performance, characteristics, of centrifugal pump with variable drive system. For this study an experimental setup of the setup was constructed to achieve the centrifugal pump performances such as Head vs Discharge, Efficiency vs Discharge, Input power vs Discharge curves. In the variable drive system a dimmer-stat was installed in experimental system. The test rig used in the present investigation was well planned, designed, fabricated and tested. All the components of the experimental test rig were fabricated in department workshop. The results shows significant change in performance of the centrifugal pump when dimmer-stat is used for speed variation.*

***Key Words*: Centrifugal Pump, Dimmer-stat, Main and Operating Characteristic Curves, Constant Head and Constant Discharge Curves Efficiency**

1. INTRODUCTION

A centrifugal pump is a type of fluid machine which is driven by a prime mover (e.g., an electric motor) used to impart energy to fluids, and continuously feed the required amount of such fluids to an intended height or distance. Typical applications include municipal water supply systems, circulating water in heating and cooling system for buildings, pumps in dishwasher, cloth washing machine, cooling water circulating pump in an automobile engine and in power plants. For very high pressure, low discharge applications, positive displacement pumps are more suitable. Positive displacement pumps move fluids using pistons, gears or vanes and flow rate is a function of rotational speed and has little dependence on pressure rise. A common application of a positive displacement pump is that it is used to supply high pressure oil for hydraulic actuators, such as those on large earth moving machines. According to statistic, pump consuming around of 20% of world's total energy. The energy efficiency depends not only on design of the pump but also, and more so, on its operating conditions and system design [1]. Fluid which flows into the impeller at the inner radius is given significant angular momentum and kinetic energy as it flows radially outwards. After the fluid leaves the outer radius of the impeller, it is diffused or slowed down resulting in significant increase in pressure. The actual head rise (H) produced by a centrifugal pump is a function of flow rate (Q). It is possible to determine head and flow relationship by appropriate selection of geometry of impeller blades. Normally, pumps are designed so that the head decreases with increasing flow since such a design results in a stable flowrate when the pump is connected to piping system. The pump is designed for a discrete value of flow rate, differential head, and speed. This is the best efficiency point of operation or 'BEP'. However, in practical applications, the pumps are rarely operated at the operating parameters for which the pump has been designed. Among the parameters stated, the flow rate Q and differential head H of the pump vary a great deal during normal operation. Consider this case where a pump discharges into a delivery pipe that is connected to the bottom of a vessel situated at a certain height. As liquid is discharged into the vessel, the height of the liquid in the vessel increases and this increases the differential head that the pump has to generate. As the differential head H increases, the flow rate of the pump Q decreases. If in the above case, the power requirement increases then the load on the motor could result in a possible drop in speed of the prime mover. Even though a pump may perform with wide variations in the parameters and conditions, the pump performance is not unaffected by these changes. It is therefore important to determine the behaviour of the pump as it responds to the variation in the parameters under operating conditions that are different from parameters that were considered during the design of the pump.

1.1 Priming

In priming the suction pipe, casing of the pump and portion of delivery pipe upto delivery valve are completely filled with the fluid which is to be pumped. Priming is necessary as energy imparted on air is much lesser as compared to fluid. So impeller cannot impart enough energy to air to go out of the casing and suck water. So priming is compulsory in case of centrifugal pump.

1.2 Working Principle

The centrifugal pump is so named because the pressure head is generated by centrifugal action. With the delivery valve closed the impeller is made to rotate. As a result a forced vortex is developed which imparts a centrifugal head to the liquid. The change in the angular momentum causes pressure rise. When the delivery valve is opened the liquid is forced to flow in an outward radial direction, thereby leaving the vanes of impeller at outer circumferences with high velocity and pressure. The high pressure of liquid leaving the impeller enables the liquid to rise to a high level. The action is a continuous process because the eye of impeller is continuously supplied with replacement liquid form the pump as a result of pressure gradient in the suction pipe. (A partial vacuum exists at the eye of the impeller and the liquid in the sump is at atmospheric pressure). The high absolute velocity at the outlet of the vanes is converted to useful pressure energy by shaping the casing such that the liquid flows through a gradually expanding passage. The centrifugal pump is well suited to situations requiring moderate to high flow rates and modest increasing head. The dynamic unit consists of a centrifugal pump driven by ac motor. A transformer is connected to motor to vary the speed of the pump.

The advantages of centrifugal pump over other pumps are high discharging capacity, low maintenance cost, almost no noise, able to work on medium to low head, steady and consistent output.

For obtaining the main characteristic curves of a centrifugal pump, the speed variation is must and in our previous setup the speed variation is obtained through belt and pulley drive which was inconvenient and one of the reasons for reduction in the overall efficiency which includes hysteresis loss and friction loss. In new setup we are using an autotransformer for speed variation.

Generally the pump is designed for one speed, flow rate and head but in actual practice the operation may be at some other conditions of head, flowrate, and for the changed conditions the behaviour of the pump may be quite different and if the flow through pump is less than designed quantity, the value of velocity of flow of liquid through the impeller will be changed and thereby changing the head developed by the pump and at the same time the losses will increase so that the efficiency of pump is lowered. Therefore in order to predict the behaviour and performance of a pump under varying conditions tests are performed, and the results of the tests are plotted. The curves thus obtained are known as characteristic curves. The following three types of characteristic curves are usually prepared for centrifugal pumps:

a) Main and operating characteristics

b) Constant efficiency or Muschel curves

c) Constant head and constant discharge curve

a) Main and operating characteristics:

The hydraulic properties of any centrifugal pump are studied taking the shaft speed of the pump N as a constant. After the speed is considered constant, the behaviour of the differential head H with respect to the flow rate Q is obtained by throttling the discharge valve of the pump. The various openings of the discharge valve result in different flow rates and corresponding heads. This experiment provides the relationship of Q with H that can be represented as Differential Head: *H= f(Q),* as shown in chart-2.

This is the fundamental characteristic of any centrifugal pump. During this experiment, simultaneous readings of Power are noted and the efficiency values are also computed. Even these can be represented as

Hydraulic power: *P = f(Q), as shown in Chart-3.*

Pump efficiency: *η = f (Q), as shown in Chart-4.*

The curves generated from the above functions are called 'performance curves' or the centrifugal pump characteristic curves. The fourth characteristic representing the function of NPSH with respect to the flow rate Q is a supplementary characteristic. In the first case, the values of the flow rate Q is plotted along the X-axis (abscissa). The units that maybe used are m3/h, m3/s, l/s, and 1/min, US-gpm, Imp-gpm. The values of differential head H (meters, feet), Power P (kW, HP), and Efficiency (as percentage, decimal fractions) are plotted on the Y-axis (coordinates). The performance of most centrifugal pumps is given in terms of its capacity, discharge head, efficiency, and input power. Because these quantities are directly interdependent, a series of curves are used to express pump performance. Pump manufacturers provide the design characteristic curves for their individual pumps. These curves are then used as a basis for pump acceptance tests. In Figure 2 and Figure 3, the above-mentioned curves for some representative pumps are shown,. As the three graphs indicate, the specific speeds of the pump have quite an impact on the nature of these characteristic curves. The shape of the curves for each characteristic may appear different but the trends are similar. We shall discuss these after having a look at the curves [3].

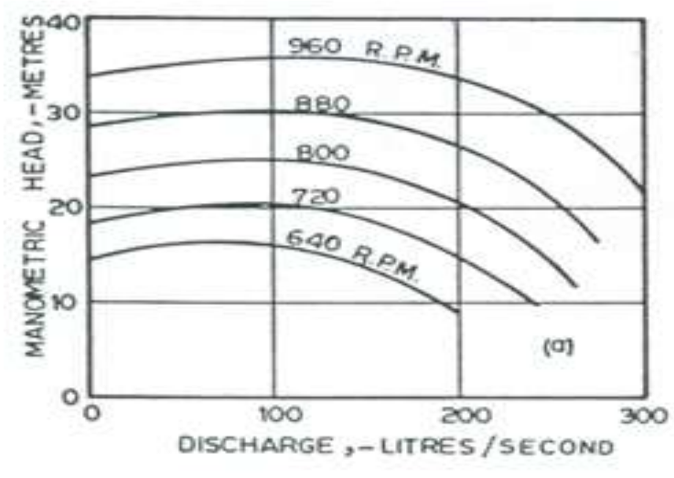

Fig -1: Manometric Head vs Discharge

The above graph is plotted for manometric head vs discharge for various constant speeds.

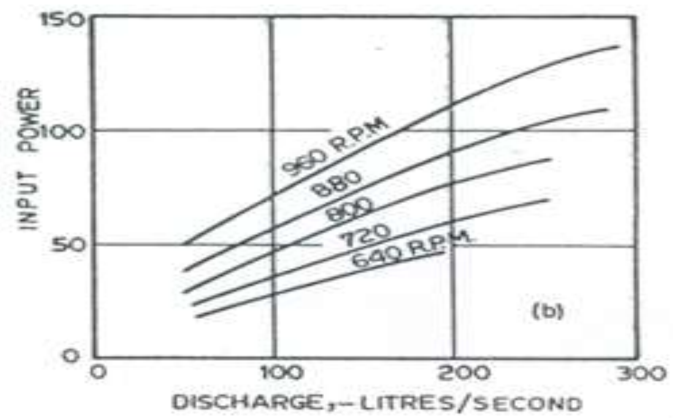

Fig-2: Input Power vs Discharge

The above graph is plotted for input power vs discharge at various constant speeds.

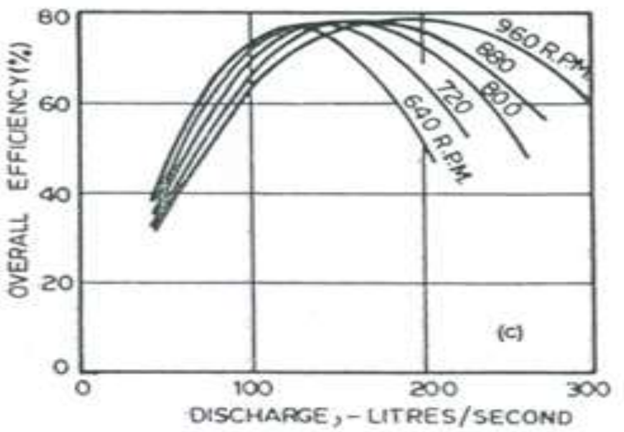

Fig-3: Overall Efficiency vs Discharge

The above graph is plotted for overall efficiency vs discharge for various constant speeds.

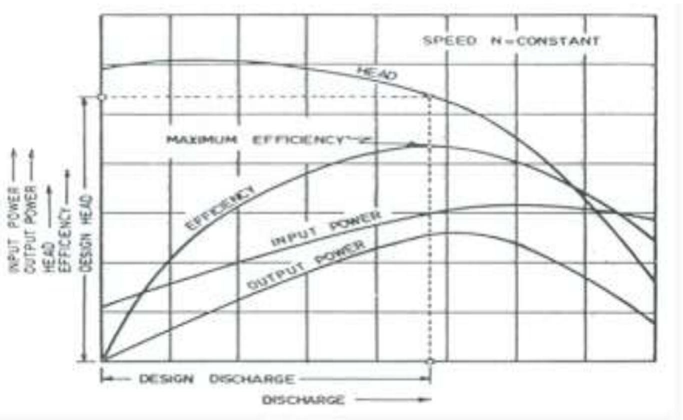

Fig-4: Operating characteristic curves

The speed is kept constant, the variation of manometric head, power and efficiency with respect to discharge gives the operating characteristic curves of the centrifugal pump.

b) Constant head and constant discharge curve:

These curves are useful in determining the performance of a variable speed pump for which the speed constantly varies. In such cases if the head H is maintained constant then as the speed N varies the rate of flow Q will vary. As such a plot of Q-N can be prepared which can be used to determine the speeds required to discharge varying amounts of liquid at a constant pressure head. It is obvious that Q~N and hence Q-N plot will be a straight line as shown in fig. Similarly if a constant rate of flow Q is to be maintained then as N varies, H will vary. Thus a plot of H-N can be prepared which can be used to determine the speeds required to discharge a certain quantity of liquid at different pressure heads. It is evident that $H \sim N^2$ and hence H-N is a parabolic curve as shown in figure. Similarly it is obvious that $P \sim N^3$ as shown in figure.

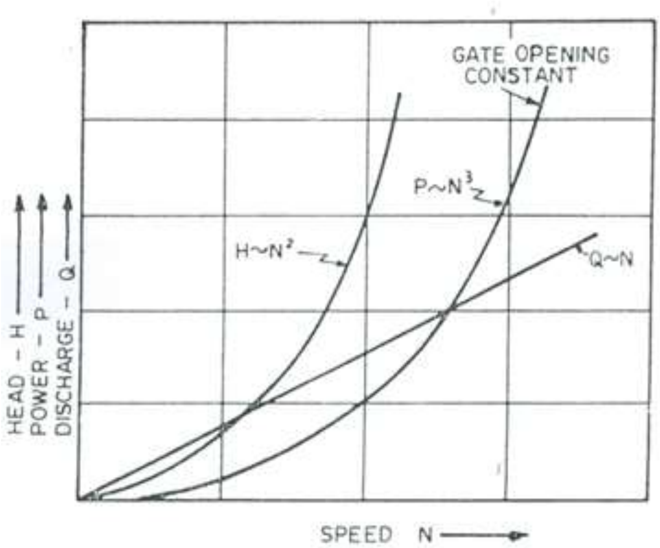

Fig-5*:* Constant Head and constant discharge

These curves signify the performance of a variable speed pump for which the speed varies constantly.

2. METHODOLOGY

The various methods to achieve speed variation are as follows:

1) Dimmer-stat

2) Variable Frequency Drive

3) By using various mechanical drives

In this study the dimmer-stat was used. It is also known as auto-transformer. A controlling device, it is used in electrical circuits. It consists of a resistance or induction coil which serves like a potentiometer. Dimmer-stat is used to adjust output voltage of an electrical circuit. In resistance type when knob is at zero position, the voltage drop across the resistance is maximum and thus the output voltage will be minimum (0 V). When the knob is kept at maximum position, the voltage drop across the resistance is minimum (maximum voltage). These voltage variations resulted in the speed variation of the motor shaft.

3. CIRCUIT CONFIGURATION

The centrifugal pump is connected to dimmer-stat via ammeter and voltmeter in parallel connection and input power is supplied to dimmer-stat.

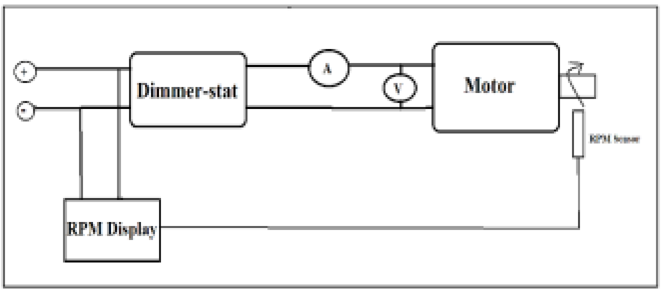

Fig-6: Circuit diagram of test setup

3. EXPERIMENTATION

With the required and available equipments the testing of centrifugal pump test rig setup was done and the main & operating characteristic curves for centrifual pump were plotted using the recorded observations.

a) Operating characteristics curve

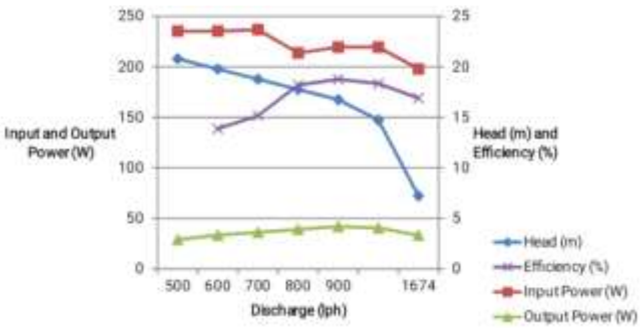

Chart -1: Operating characteristics curve

Chart-1 shows graph of input power, output power, head and efficiency vs discharge for centrifugal pump by using dimmer-stat for speed variation that indicate as discharge decreases the input power increases, output power increases and reaches its maximum value and then decreases, head increases and efficiency increases up to a certain value and then starts decreasing.

b) Main characteristics curve

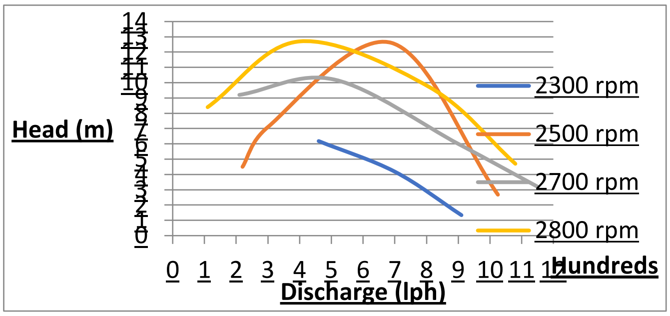

Chart-2: Head vs Discharge

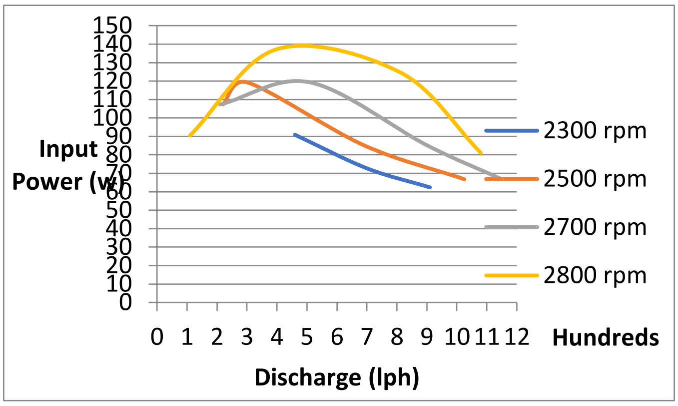

Chart-3: Input Power vs Discharge

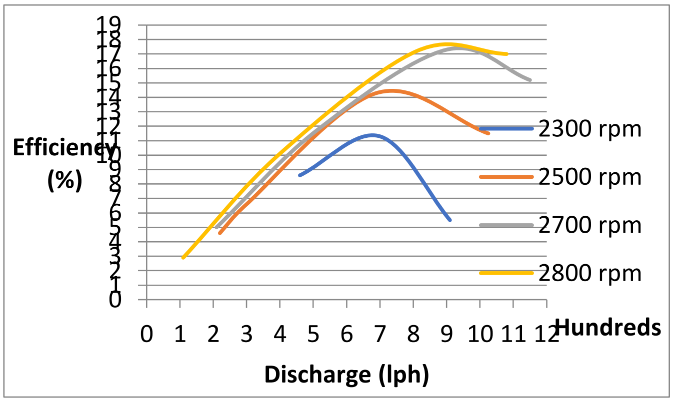

Chart-4: Efficiency vs Discharge

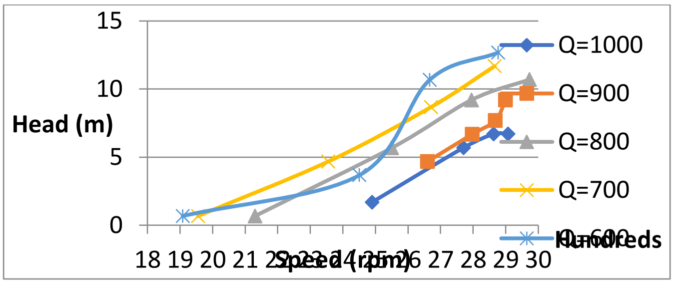

Chart-5: Head vs Speed at constant discharge

Chart-5 shows the variation of manometric head with respect to speed at various constant discharge.

3. CONCLUSION

After survey of the relevant literature on centrifugal pump test rig, the different characteristics curves of centrifugal pump were plotted in this study. The autotransformer was used for speed variation. After taking number of observations, main and operating characteristics and constant head and constant discharge curves were plotted. It helped to understand performance of centrifugal pump in different operating conditions practically. The maximum efficiency for operating characteristics curves was 18.7%. The maximum efficiency in case of main characteristics curves was 17.3%.

REFERENCES

Rakibuzzaman, "A study on multistage centrifugal pump performance characteristics for variable speed drive system," 6th BSME(ICTE 2014)

Paresh Girdhar, "Practical centrifugal pumps" book published on 13th Nov. 2004

R.K. Bansal; "Fluid mechanics and hydraulic machines" book, 9th edition, 2010

BIOGRAPHIES

Akash Narwade
Bachelor of Engineering, Mechanical Department, Sinhgad College of Engineering, Pune 411041