Effect of Variable Speed on Discharge of Centrifugal Pump

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Abstract— Nowadays, centrifugal pumps are often controlled by adjusting their rotational speed, which affects the resulting flow rate and output pressure of the pumped fluid and the changing rotation speed is the most effective and economical way of improving the pump efficiency. In this paper it is proved that the variable frequency drive induced in the stepper motor of the centrifugal pump do affect the discharge of the centrifugal pump. The motor speed here is varied between 2200-3100 rpm and the change in value of discharge is plotted in a graph. The value of discharge increases with increase in speed in motor of centrifugal pump.

Key words: Centrifugal Pump, Performance Characteristics Curve, VFD, Variable Speed

Nomenclature:

A=Cross sectional areaA_{1q}=Impeller inlet throat area
A_{2q}= Area between vanes at outlet impeller
A_{3q}=diffuser/volute throat inlet area
a = distance between the vanes
b=channel width in meridional section
c_f=friction coefficient of flat plate
D,d=Diameter
d_{3q} = diameter equivalent of volute throat
d_b= Arithmetic average of diameter at diffuser or impeller
d_m=geometric average of diameter at diffuser or impeller
d_n = diameter of hub
r= radius
r_{3q}= equivalent radius of volute throat area
s= Width of gap
s_{ax} = Axial distance between casing and impeller shrouds
w= Relative velocity
H_{exp}= experimenetal pressure head
H_{th}= theoretical pressure head
H_{slip} =head with slip factor consideration
$H_{withoutslip}$= Head without slip factor consideration

I. INTRODUCTION

A. Centrifugal Pump

Centrifugal pumps are turbomachines utilized for transmitting liquids by increasing a predetermined volume flow to a prescribed level of pressure, which utilizes the dynamic principle of increasing speed of fluid, with the help of centrifugal action, and transfiguring of the kinetic energy into pressure

B. Characteristics Curve

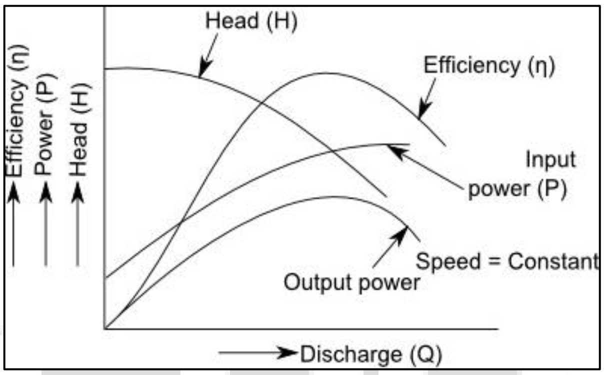


Fig. 1: Characteristics Curve

C. Working of Centrifugal Pump

The liquid to be pumped flows through the suction nozzle to the impeller. The overhung impeller mounted on the shaft is driven via a coupling by a motor. The impeller transfers the energy necessary to transport the fluid and accelerates it in the circumferential direction. This causes the static pressure to increase in accordance with kinetics, because the fluid flow follows a curved path. The fluid exiting the impeller is decelerated in the volute and the following diffuser in order to utilize the greatest possible part of the kinetic energy at the impeller outlet for increasing the static pressure. The diffuser forms the discharge nozzle.

Sr. No.	Author	Year	Conclusion
1.	Nemdili, Ali and Dieter-Heinz Hellmann	2004	Loss due to disk friction rely on Reynolds number, axial gap, width of volute and roughness of surface
2.	SWarren H. Fraser	1981	Ennumerates indications of the recirculation and individual diagnosis.
3.	W. G. Li	2011	The total hydraulic loss in the pump rely on blade exit angle, as it influence the head,shaft power and efficiency of the centrifugal pump.
4.	Johann F. Gülich	2008	Elaborated study and analysis of every aspects of centrifugal pump considering every parameter.
5.	Memardezfouli, Mohamad, and Ahmad Nourbakhsh	2009	Slip factor in the centrifugal pump rely on Reynolds number, the geometrical shape of the impeller and the conditions of operation, and velocity profile of impeller-outlet.
6.	M.G. Patel and A.V. Doshi	2013	Increase in blade exit angle also increase the performance of the centrifugal pump.
7.	Khalid Rababa	2011	Effect of number of blades on the performance of centrifugal pump rely on viscosity of the working fluid.
8.	Thin, Khin Cho, Mya Mya Khaing, and Khin Maung Aye	2008	Taking in account the losses in the centrifugal pump, prediction of the best performance point on the performance curve is estimated.

9.	Thummar A., Pipalia V., Javiya T	2012	Experimental analysis of pump with impellers with various impeller width.
10.	Sahoo T	2012	Included strategies to increase performance of centrifugal pump to save energy.
11.	Gölcü, Mustafa, and Yaşar Pancar	2005	Comparation in study of performance of the pump with and without splitter blades.
12.	Andrzej WI LK	2010	Included parameters that affects performance of centrifugal performance and their relationship with the performance.
13.	Craig I. Walker, Greg C. Bodkin	2000	Predicted the empirical relation between the parameters, that results in wear in pumps.
14.	Mohamed F., Ali Khalil, Sadek Z. Kassab, Ahmed A. Abdel Naby Azouz	2013	Experimental and theoretical ennumeration of the centrifugal pump performance has been done based on model given by J. F. Gulich
15.	Thanapandi P., and Rama Prasad	1995	The dynamic characteristics of the testing pump is checked by a numerical model using the method of characteristics. The model predicts well the pattern of the dynamic head characteristics with transients.
16.	Shi, Weidong, Ling Zhou, Weigang Lu, Bing Pei, and Tao Lang	2013	Predicts the effects of oversize and undersize impeller on the performance of the centrifugal pump.
17.	W. G. Li et. al.	2012	Predicts the effect of number of impeller blades on performance of industrial centrifugal pumps
18.	Sverre Stefanussen Foslie	2013	Contrasted the methods to analyze the performance characteristics of the centrifugal pump and predict the characteristics curve by J.F.Gulich.

Table 1:

D. Objective

The biggest advantage of a VFD is that it matches the amount of work or load on a motor to the amount of energy it needs for that respective load. This makes the system more efficient and also saves the user money by reducing excess energy from being wasted.

When a user implements a VFD in a system benefits are experienced over the life cycle of the pump. On an average 85 percent of a pump's life cycle cost is attributed to its energy consumption and only 15 percent the actual cost of the pump motor.

Motors associated with pumps tend to be sized where the pump may to meet peak loads, but not necessarily for normal continuous operation or sized for a duty condition where the pump may no longer be required to operate as result of changes in a given system.

In such systems VFDs can have a considerable impact in cost savings. Typically, for every 1 percent reduction in VFD output the user can save 2.7 percent of energy costs. Let us assume that we can operate the motor at 85 percent (51 Hz) of its maximum speed, it is important to note that any reduction pays that reduction cubed. If you cube 85 percent that result be: 0.85 x 0.85 x 0.85 = 0.614. This means the true energy consumption would only be 61.4 percent of total energy consumption. In other words, a 15 percent reduction in speed will result in an approximate 39 percent savings in energy costs.

As energy costs continue to rise, it will become more imperative to find ways to cut energy consumption. Variable frequency drives in pumping applications is a key aspect to this effort.

II. PROPOSED METHODOLOGY

A. Loss calculation method - Based on the work by J.F. Gulich

This method is based on calculating the hydraulic losses in the impeller and diffuser, based on relations given by Gulich in the Centrifugal Pumps. Detailed description of calculation of volumetric losses would not be included, as extensive information about the clearances in pump is needed, and it usually does not exceed 1-2% of total volume flow. Calculation of leakages will therefore be based on the procedure described in the further subsection. By taking slip from equation into account in the relation between theoretical head and volume flow the following relation for theoretical head including the slip is gained:

$$H_{th} = \frac{u_2}{g}\left(\gamma u_2 - \frac{Q_{La}}{\pi d_2 b_2 tan\beta_{2B}}\right) \quad (1)$$

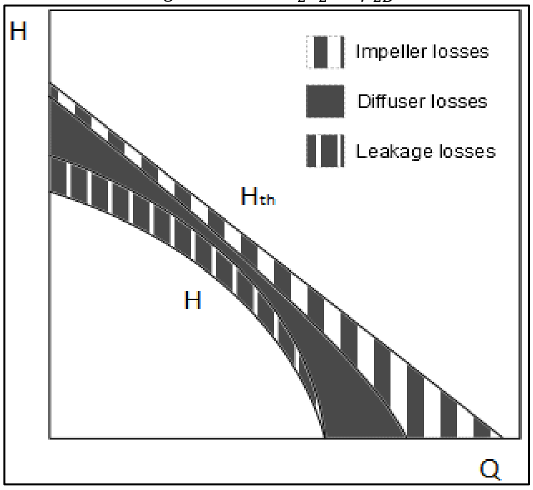


Fig. 2: Total Head Including Losses

J.F Gulich divides hydraulic losses into two main parts, losses in an impeller and the losses in the diffuser. Losses in an impeller are further divided into shock losses at impeller inlet and friction and mixing losses through impeller. Diffuser losses consists of losses in vaneless space between impeller and diffuser, losses in diffuser, and losses in return channels. The calculation of all losses is complex.

By the discussions in the trailing portions, the method given by J.F. Gulich would be adopted to predict performance characteristics of the centrifugal pump. Different parameters required for the calculation of the head of the centrifugal pump are to be calculated.

III. LAYOUT OF THE PROPOSED EXPERIMENTAL SETUP

Following figure is the layout of the proposed experimental setup. Test setup consists of three sections:

1) Water supply section: the water tank, inlet pressure gauge and regulating valve;
2) Pump section: centrifugal pump and motor;
3) Outlet section: pressure gauge, flowmeter and regulating valve

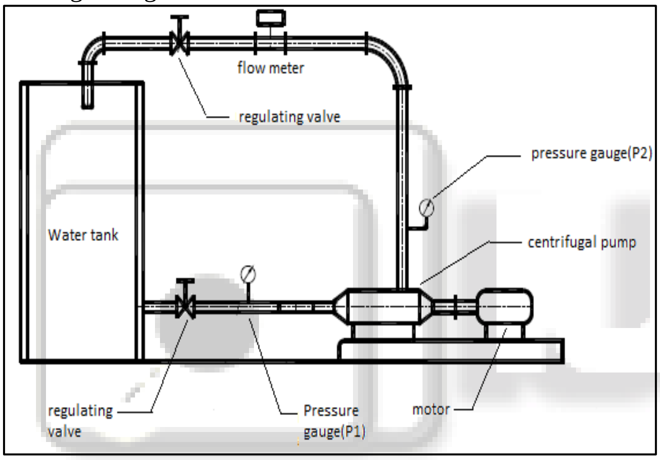
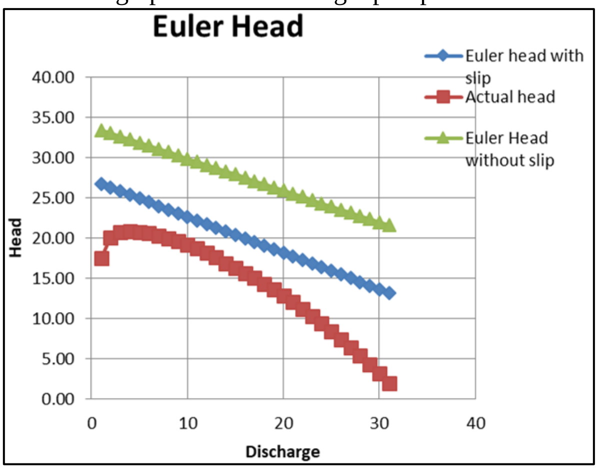


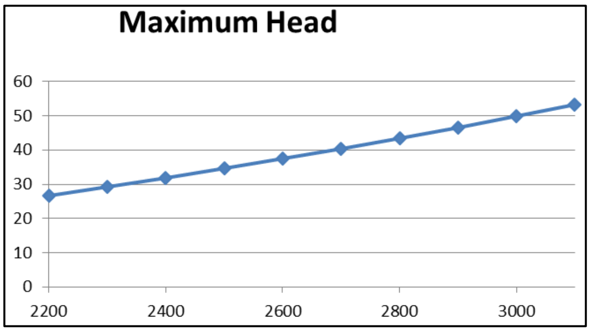
Fig. 3: Experimental Setup

IV. SUMMARY

Summarized graph of the centrifugal pump is obtained.



Graph 1: H-Q Characteristics Curve Indicating Theoretical & Actual Head



Graph 2: Maximum Head with Respect to RPM

V. CONCLUSION

It can be concluded that by applying the variable frequency drive to the centrifugal pump we can obtain different values of head by varying the speed and can be used for variety of applications.

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