Experimental Investigation of Performance Modification of Centrifugal Pump

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Abstract - Major industrial sector are using, most pumps are of centrifugal type. Centrifugal pumps are widely used because of their design simplicity, high efficiency & low maintenance. Modern centrifugal pumps are not complex machines. Despite the simplicity of design and production, centrifugal pumps are still capable of posing complex puzzles during their operation. The performance of a pump must be modified sensibly, adapting the pump to ever-changing needs of systems. Several methods are available to do so. In present work, one among the two most efficient methods, namely "Speed change" and "Impeller diameter trimming" method of speed change is used for analysis, and are experimentally investigated. Their effects on performance characteristics are comparatively evaluated. Effects of "Overfiling" are also investigated. The pump used here is a low specific speed pump with overhung, enclosed, backward-swept, radial flow impeller and single volute casing. Experimentation is fully compliant with Hydraulic Institute (HI) standards. The end results indicate that the methods give similar outcomes in terms of efficiency and financial saving as it is economical

I. INTRODUCTION

Simply stated, "A pump is a machine that expends energy from some source to increase the pressure of the liquid, in order to rise and/or transport it through a piping system". Pumps are also called fluid movers. The performance of a pump can be defined as its capability at various operating conditions. A typical performance curve displays the total dynamic head (TDH or H), brake horsepower (P), efficiency (η), and net positive suction head (NPSHR) all plotted versus the flow rate (Q) range of the pump.

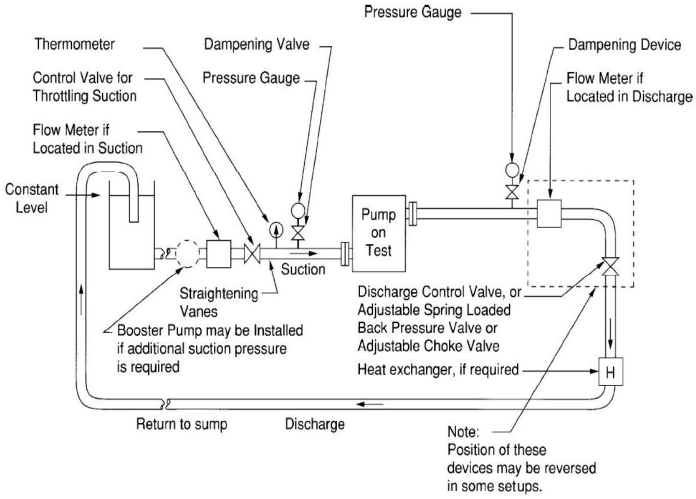
Several methods can be utilized to regulate the flow i.e. to modify the performance of a pump. But, modifications using Impeller diameter trimming & Variable frequency drives (VFD) are most economical [1, 2]. However, both have own pros and cons. It has been claimed in many references that, the adverse effects of impeller trimming, such as, efficiency deterioration, uncertain best efficiency point (BEP) location, small operating region, increased NPSHR etc. can be avoided, if speed change method is employed [3]. However, there is no sufficient data available to authenticate this argument, especially for low specific speed (NS) pumps. Gulich [4] says that the highest efficiency and the BEP location are affected significantly by volute casing characteristics, regardless of any modification method employed. Hence, there is a scope of further research.

II. TEST-RIG SETUP AND EXPERIMENTATION PLANNING

Before establishing test-rig, nearly all popular pump standards were studied thoroughly, such as API 610, JIS B 8327, ANSI/ASME B73.1, ASME PTC 8.2, IS 5120 5659 6595 10981 9694, ANSI/HI. ANSI/HI standards are chosen as they are the most detailed and comprehensive standards for water applications. They are acceptable worldwide.

2.1Intake design for the pump

The design has been done according to HI 9.8 [7]. See a schematic diagram of pump test-rig for performance test in Figure 1. Actual test-rig photograph is shown in Figure 2. Horizontal side outlet with cone fitting is used in the present test-rig.



Initially the velocity at tank connection was calculated to be V = 2.35 m/s for suction pipe ID = 52 mm and Q = 300 liters per minute (lpm). So, the cone type outlet fitting was fabricated while keeping in mind that higher velocities increase head loss and thus decrease the NPSH Available at the pump inlet. With Cone IDmax = 70 mm, the modified V = 1.29 m/s, which is well under the recommended Vrec = 1.7 m/s. Minimum submergence required for minimizing surface vortices was calculated to be Smin = 32 cm. So, a submergence S = 55 cm was provided above the above the centerline of the cone. The recommended minimum distance between the cone and floor Cmin = 3.5 cm, and minimum cone entrance width Wmin = 14 cm were also satisfied. The discharge line was submerged in the water. A baffle plate was used as a partition because the suction line and the discharge line both were in a single tank.

2.2 Performance test prerequisites

HI 1.6 [7] defines two acceptance levels of tests; A & B. Level “A” is usually applied to those pumps that are manufactured for specific conditions according to customer’s requirement. Level “B” is usually applied to those pumps that are produced for stock. That’s why Level B test covers a wide range of operation points. As the present investigation work is comprehensive type rather than related to few points, Level B is chosen to test the pump.

Parameters measured were (1) suction gauge reading (2) discharge gauge reading (3) flow rate (4) rpm (5) motor output power or pump input power.

For measurement of pressure, pressure taps should be located a minimum of 2DS (suction pipe ID) upstream from the pump suction flange, and a minimum of 2DD (discharge pipe ID) downstream from the discharge flange as in Figure 3(a). Four static pressure taps shall provided around periphery of the pipe cross-section as in Figure 3(b). The pressure tap opening shall be flush with the interior of the pipe and normal to the wall of liquid passage as in Figure 3(c). All recommendations [7] were considered while fabricating the pressure taps.

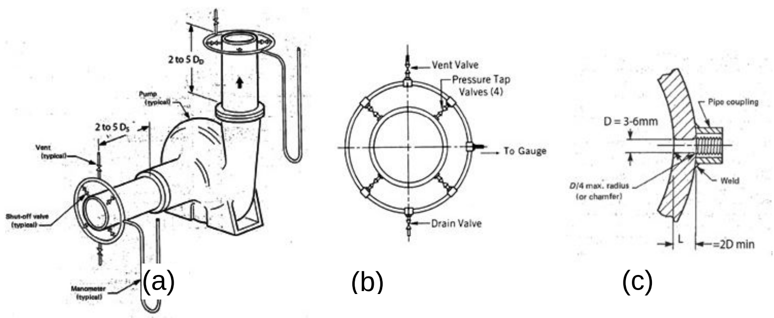


Figure 3: Pressure tap location and cross-section details

For measurement of capacity more than 10D long straight pipe was provided upstream to the rotameter for uniform velocity approach. A butterfly valve was used in the suction line. After suction valve, more than 10D long straight pipe is provided upstream of pressure tap location to settle down turbulences. A globe valve was used to throttle the discharge line. A bypass discharge line with a gate valve, which bypasses the rotameter, is also provided for safety purposes. Variable frequency drive ACS350, manufactured by ABB Ltd., is used to vary motor speed. The drive has 3 control functions namely (1) Scalar frequency (2) Vector speed and (3) Vector torque. Pump installation was done according to HI 1.4 [7]. Pump & motor shafts were aligned with wedges for parallel and angular misalignment. Details of instrumentation are given in Table 1.

Table 1: Instrumentation details

Property	Instrument	Range	Resolution	Accuracy	Calibration
Discharge pressure	Digibar APCAL 6100, Altop Industries	-1 to 6 kg/cm^2	0.0001 kg/cm^2	±0.15% of FSD	Dead-weight tester
Suction pressure	Bourdon Tube Vacuum Gauge, Fiebig	-0.1 to -0.95 kg/cm^2	0.01 kg/cm^2	±0.5% of FSD	Digibar APCAL 6100
Flow rate	Glass-Tube Rotameter, Flowtech Instruments	0 to 350 lpm	2 lpm	±1.5% of FSD	Venturi meter
Speed	ACS350 variable frequency drive, ABB	0 to 30,000 rpm	1 rpm	± 5 rpm	Digital techometer
Motor o/p power	ACS350 variable frequency drive, ABB	0 to 2000 watt	1 watt	±0.5% of FSD	Calibrated motor

2.3 Test procedure

The procedure of acceptance Level B test is recommended in HI 1.6 [7]. It was followed throughout. Accumulation of test data shall begin only when steady-state test conditions have been settled down. Test shall include a sufficient number of points, but not fewer than 5 to accurately define the H→Q, P→Q, η→Q and curves. Test points shall include a minimum range of 25% to 120% BEP flow rate, plus the shut-off. Test arrangements shall be free from any hydraulic conditions which adversely affect pump performance. NPSHA shall be greater than NPSHR at all test flow rates during the test. See Table 2. Level B performance testing was done for speed change method.

Table 2: Test Summary Table

D_2	147mm		138mm	128mm	
β_2	18°	18°	20°	24°	5° (overfiling)
RPM	2800	3188-3060 (55Hz)	3259-3150 (56Hz)	3352-3245 (57.4Hz)	2939-2872 (50Hz)
	2600	2919-2807 (50Hz)	2923-2834 (50Hz)	2938-2870 (50Hz)	
	2400	2336-2266 (40Hz)	**Total pump running hours = 104** **Total kWh consumed = 93**		
	2200				

III. TEST RESULTS AND DISCUSSION

From Figures 4, 5, it is observed that the actual H→Q curve satisfies the predicted curve very closely for speed change method. From Figures 4-5, it is observed that the actual BEP lines are different from the predicted ones. Thus, BEP moves less than predicted. Such phenomenon occurs when the volute casing has significant effect on BEP location.

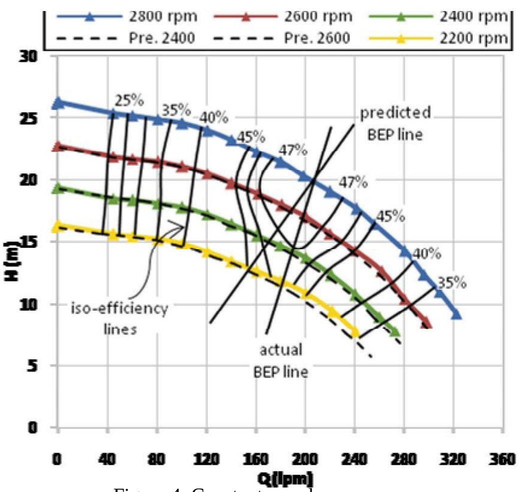


Figure 4: Constant speed

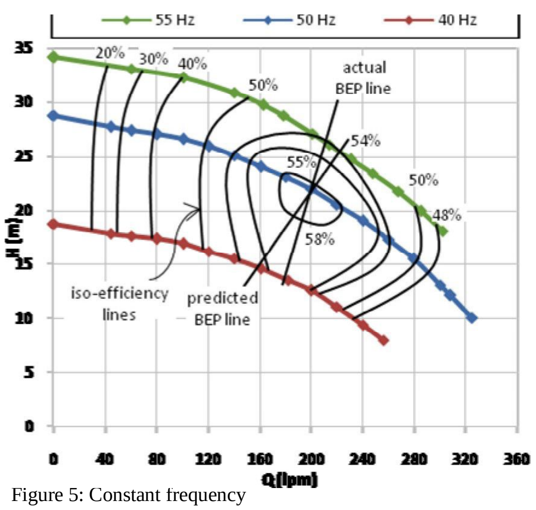


Figure 5: Constant frequency

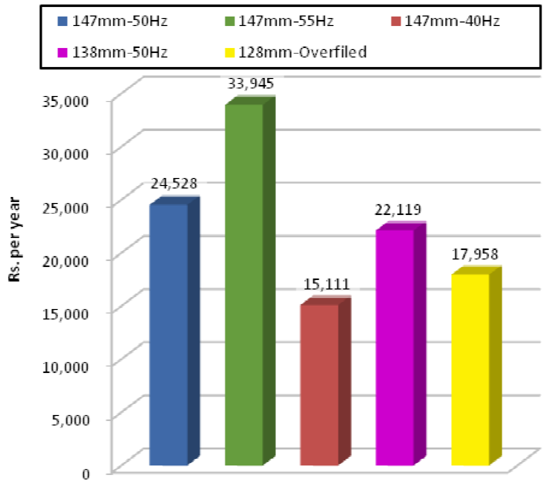


Figure 9: Electricity bill

As the speed change method is advantages in terms of efficiency. It is observed that for all modified operations, the highest efficiency possible is less than the original (147mm-50Hz) operation. However, the power consumption may be more. So, if system requirement change from 200 LPM – 22 m to 160 LPM – 15 m then the calculated bill is as in Figure 9 for 12 hours/day operation @ 5/- Rs. per unit. Thus, pump's performance must be modified sensibly if system requirement changes.

IV. CONCLUSIONS

Pump's performance must be modified sensibly if system requirement changes, in order to save money. The speed change method give best results if the system has high friction head and low static head.

For speed change method the affinity laws predict the H→Q curve satisfactorily, whereas the power and the efficiency predictions are not as good. Higher speeds quickly overload the motor which limits the maximum running speed.

Method is equally advantageous in terms of efficiency. If the system requirement changes on daily basis, speed change method shall be utilized. The speed change method has limitations due to its initial cost as seen in the present case, VFD costs.

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