

Effect of Water Temperature on Centrifugal Pumps Performance under Cavitating and non-cavitating Conditions

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ABSTRACT: The effect of water temperature on performance and cavitation inception of a centrifugal pump has been studied experimentally. A special test rig with a testing centrifugal pump was constructed in the laboratory of fluid mechanics at Higher Institute of Engineering - Hoon. The rig was designed so that the flow rate ratio, suction pressure, rotational speed and water temperature could be varied independently. The temperature and speed were varied from 15°C to 60°C, and from 1800 rpm to 2800 rpm respectively, while the ratio of flow rate to optimum flow rate was varied from 0.245 lit/sec to 0.767 lit/sec. The results showed that the pump head and pump efficiency increase with the decrease of water temperature. The results showed that increasing water temperature speeds up cavitation. The inception net positive suction head (NPSH_i) was found to increase with the increase of temperature up to a maximum value and then decreased again.

NOMENCLATURE

P_{atm} – The atmospheric pressure
 P_v – The vapour pressure at corresponding temperature.
 P_{ss} – The suction static pressure.
 γ – The specific weight of water
NPSH – Net positive suction head
NPSH_i – Inception net positive suction head

1. INTRODUCTION

When operating centrifugal pumps at temperatures higher than the ambient temperature, especially in industrial and pumps used for out door applications that exposed to atmospheric temperature in the hot climate zones. Therefore, more care must be taken to avoid any troubles that may occur due to higher fluid temperature. High-temperature applications are becoming more prevalent in the fluid handling industry [1].

Cavitation phenomenon in centrifugal pumps is a basic problem for its effect of head breakdown, increase in consumed energy, erosion in pump impellers and vibration. Pump cavitation is defined as the formation of cavities on the surface of the blade of pump impeller and the resulting loss of contact between the impeller and the water being pumped. It is believed, that the water temperature plays a major role in the cavitation inception, and pump performance. **Rudnev et.al., (1978)** have studied the effect of water temperature on cavitation characteristics. The temperature range was 60°-280°C. The method is based on scaling the change in cavitation characteristics as a function of water temperature. The work was carried out to solve out the problems caused by cavitation on the pumps of boiling water reactors. They had established a correlation between vapor liquid ratio and the temperature on logarithmic scale [2]. The boiling of liquid in the process of

cavitation is a thermal process and is dependent on the liquid properties such as: pressure, temperature, latent heat of vaporization, viscosity and specific heat. During cavitation conditions drop in the pump head and efficiency is caused by the appearance of vapor cavities in the lower pressure zone that disrupt the dynamic conditions during normal pump operation when the flow is all liquid [3].

Zika (1984) had studied the effects of thermodynamic properties of incipient cavitation (3% head drop) in centrifugal pumps. The temperature range was varied from 21°C to 148°C. He concluded that the relationship between NPSH depression and vapor pressure was a linear relationship. He established a general relationship between NPSH depression and latent heat for some fluids [4]. **El-kadi (2001)** had studied the effect of hot water on the cavitating centrifugal pumps. The temperature was varied from 28°C to 58°C, in order to obtain the effect of water temperature on cavitation inception and breakdown in centrifugal pumps. He concluded that increasing the water temperature speeds up to the cavitation occurrence, and the maximum and minimum values of Thoma cavitation number are affected strongly by temperature [5]. **Zika (1984)** had studied the influence of thermodynamics effect and their correlation with the minimum NPSH required for a cavitation – free performance of centrifugal pumps. The results were found for different liquids and different pumps. Zika has found that, using the NPSH difference, the relation between NPSH difference and vapor pressure is a straight line, and small deviation was found due to changing the pumps [6]. **Al-Arabi A. A. B. and Selim S. M. A., (2007)** built a theoretical model to predict cavitation inception in centrifugal pumps. The model includes the physical fluid parameters and

the real working phenomena at off-design condition. The parameters considered in the model were flow rate ratio, pump rotational speed, water temperature, thermodynamic properties of water, nuclei and gas content, relative velocity and incidence angle [7].

2. EXPERIMENTAL OPERATION

The general arrangement of the test rig is indicated in a schematic diagram shown in figure 1. The flow system consists of 1 hp centrifugal pump using DC current and maximum rotational speed of 3000 rpm, the flow orifice meter, pressure measuring devices, suction and delivery pipelines, speed control unit, and valves. The temperature has been measured by a thermometer, ranging from -50°C to 110°C with an error of $\pm 1^\circ\text{C}$. The temperature has been checked continuously at different points in the system such as at the tank suction point, at the pump inlet, and at the end of the delivery line, in order to avoid any deviation in temperature measurements. The maximum allowed deviation in temperature was $\pm 2^\circ\text{C}$. The accuracy of suction and delivery pressure gauges was ± 0.02 bar. The heat was supplied by two electrical heaters of 1000 Watt each.

3. EXPERIMENTAL PROCEDURE

After assembling the system and connecting all the measuring devices, the driving pump is operated via the speed inverter, at three different operating speeds 1500, 2300, and 2800 rpm. The temperature had been changed from 15°C to 60°C. The pump performance test and cavitation test had been carried out at each temperature, had been carried out at each temperature, and at different values of flow rate ratios.

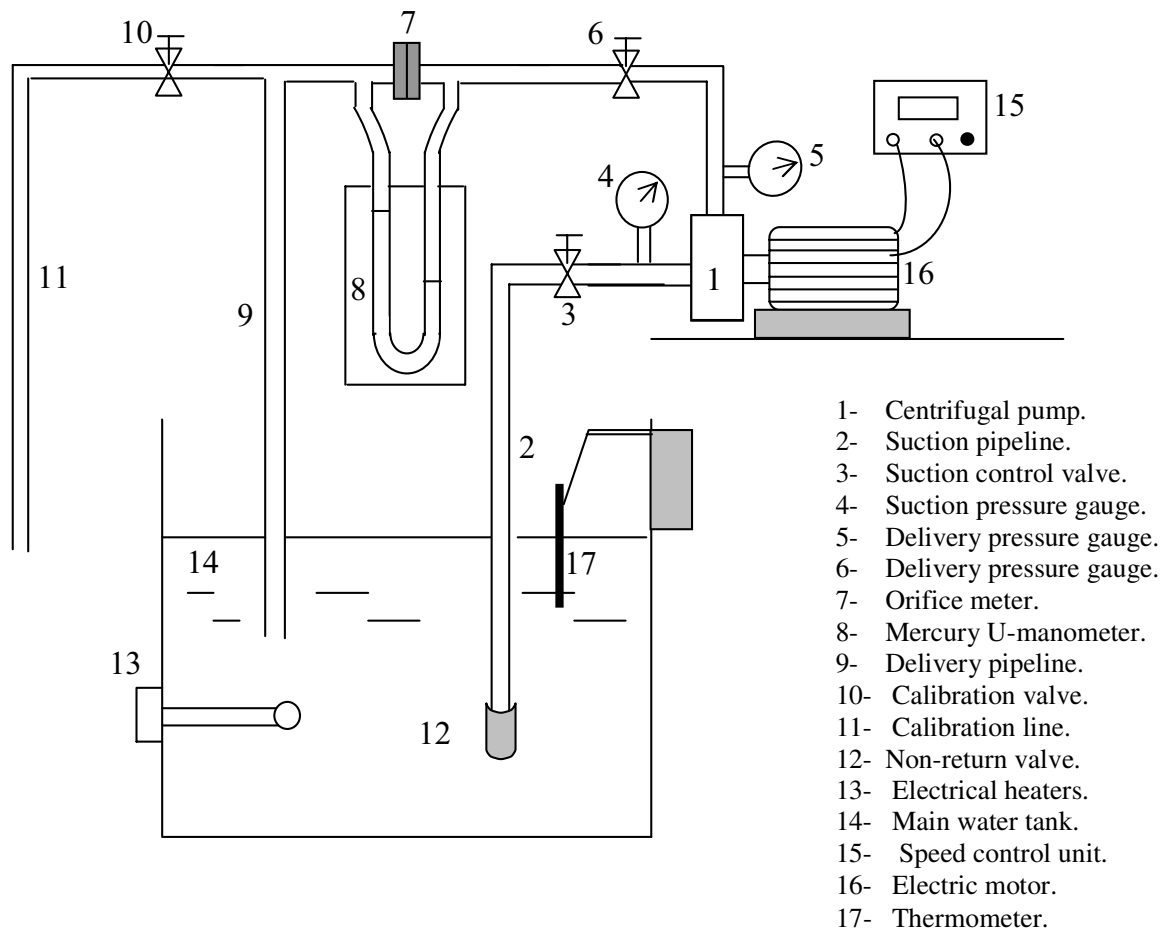


Figure 1 Construction of test rig

The cavitation test on the pump has been carried out by keeping the pump running at the required speed, temperature, and flow rate ratio, and then reducing the inlet pressure step by step until the inception condition occurred. At each step, the flow rate was adjusted through the delivery valve, then the inlet pressure further reduced until developed cavitation and fall off head and efficiency was noticed. At each setting of inlet pressure and inception condition, the measurements of suction and discharge pressures, flow rate, and input power were recorded.

The NPSH at each condition was calculated using the following equation:

$$NPSH = \frac{P_{atm}}{\gamma} - \frac{P_v}{\gamma} - \frac{P_{ss}}{\gamma}$$

4. RESULTS AND DISCUSSION

The effect of water temperature on the pump head and NPSHi was studied experimentally at different flow rates and different rotational speeds. Figures (2 – 5) show the relation between the pump head and NPSH at different water temperatures, while Figures 6 and 7 show the variation of NPSHi with water temperature. The water temperature was varied from 15°C to 60°C. From Figures (2-5) it can be seen that the head of the pump is maintained nearly at constant value from the maximum NPSH down to inception condition and close to the breakdown of the pump head.

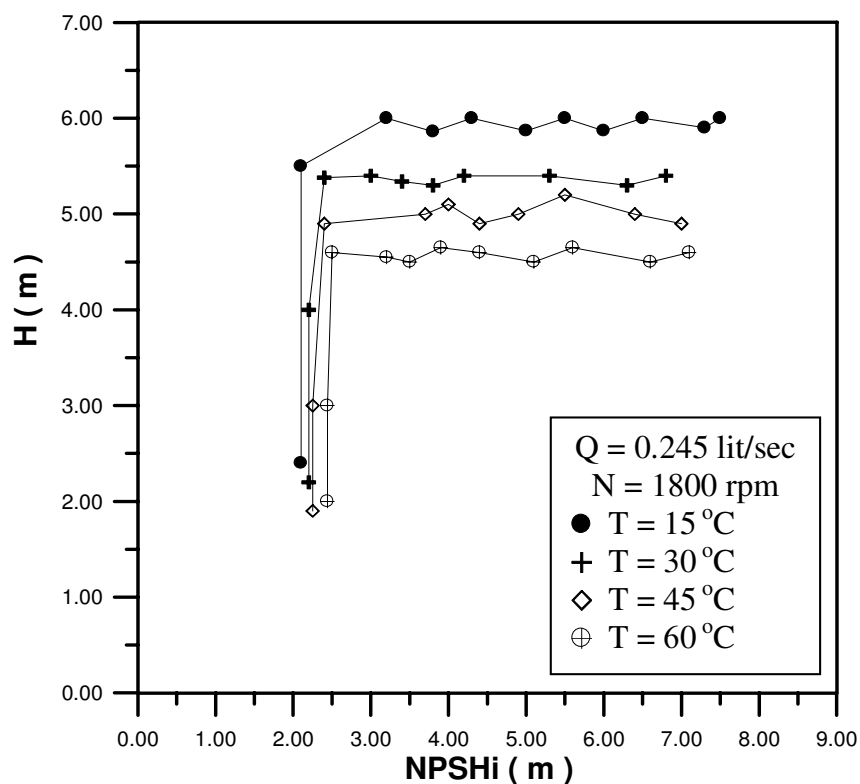


Figure 2: Variation of pump head with NPSH at different water temperature

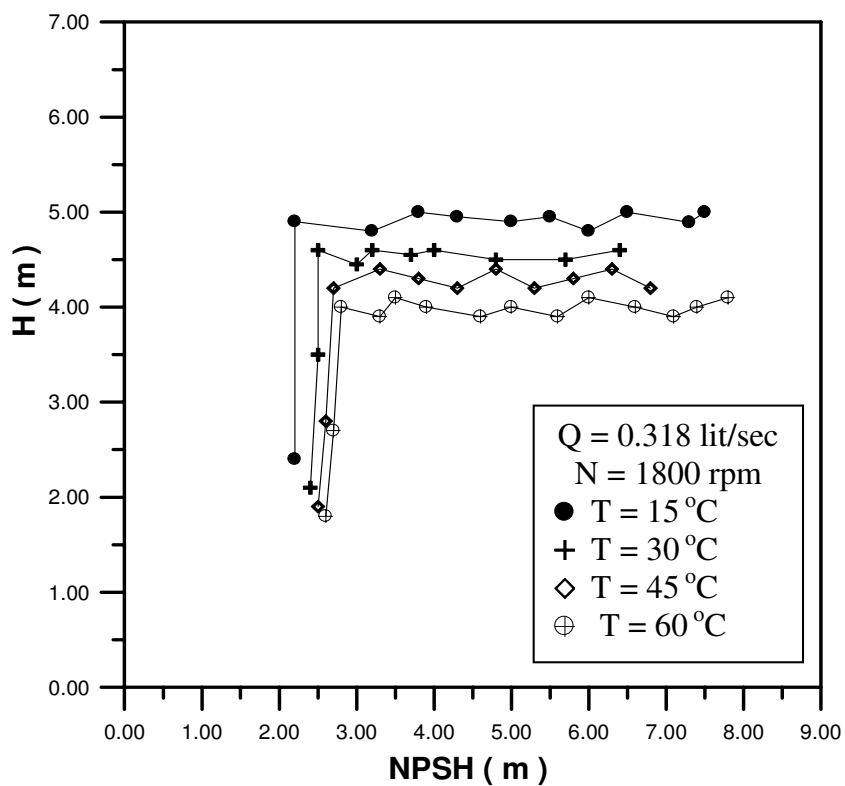


Figure 3: Variation of pump head with NPSH at different water temperature

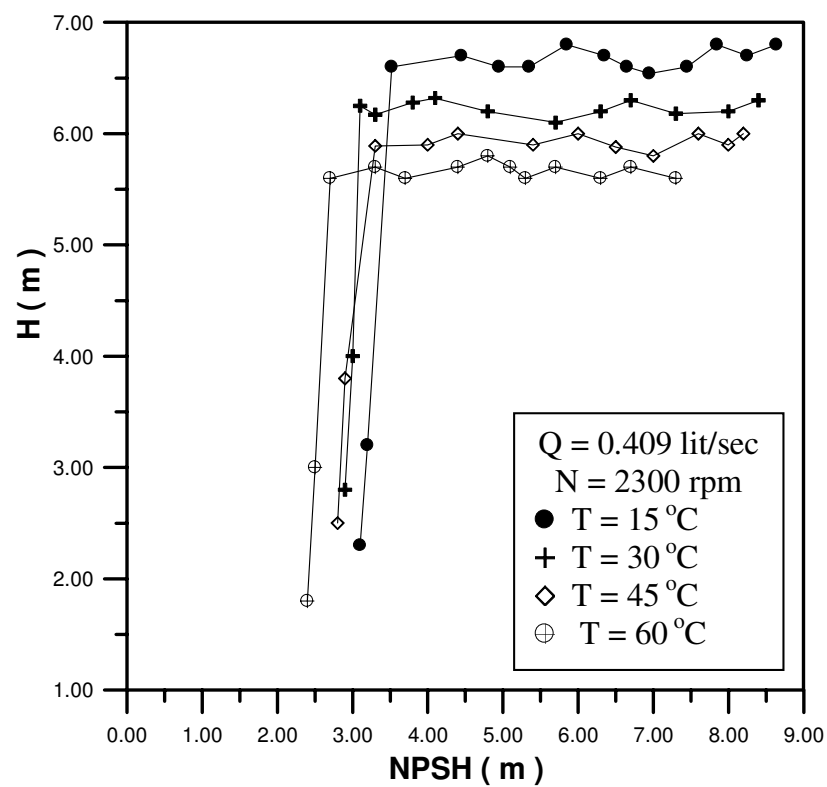


Figure 4: Variation of pump head with NPSH at different water temperature

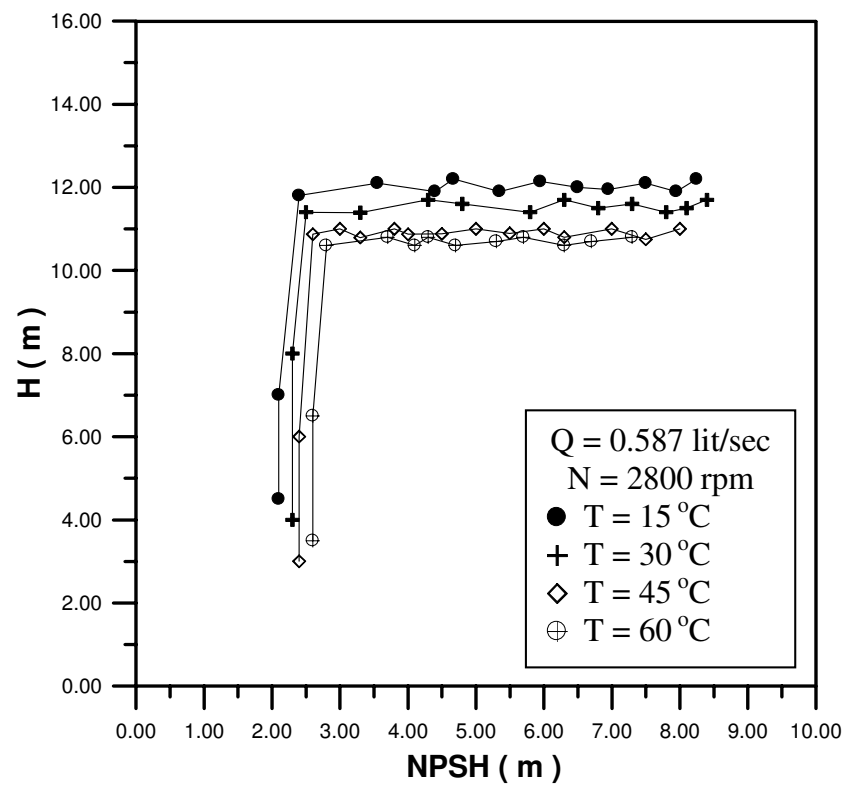


Figure 5: Variation of pump head with NPSH at different water temperature

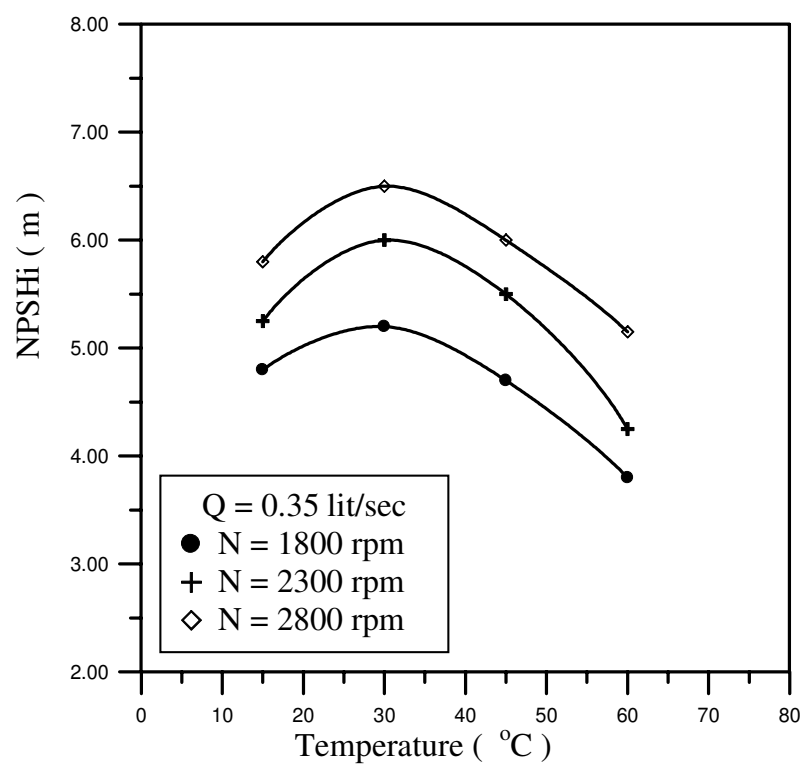


Figure 6: Variation of NPSHi with water temperature at constant flow rate

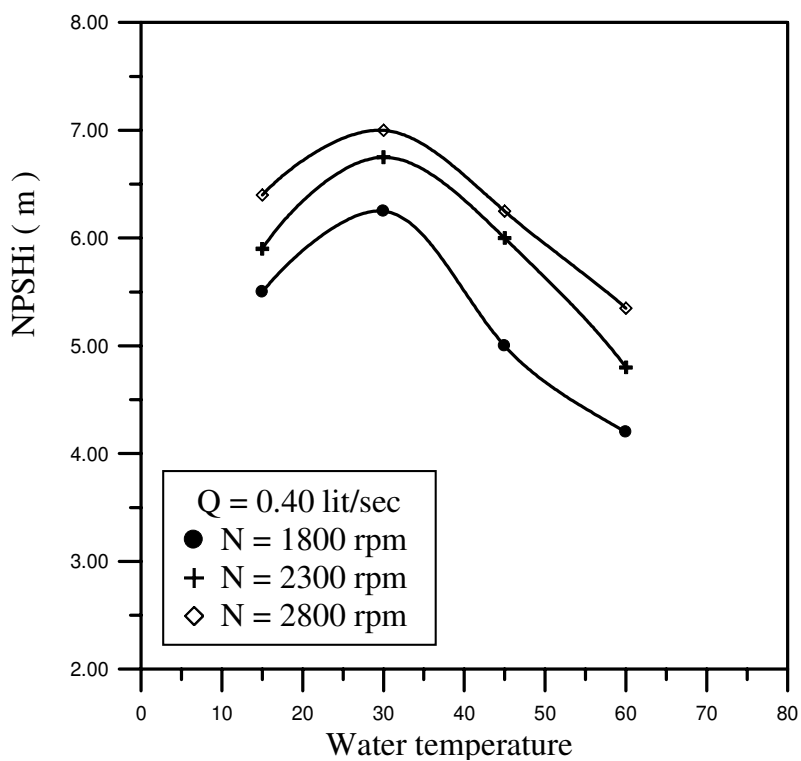


Figure 7: Variation of NPSHi with water temperature at constant flow rate

For further reduction in NPSH the pump head reduced rapidly and the performance breakdown occurred. The results show that the pump head decreases with the increase of water temperature. This drop occurs mainly due to the increase of vapour pressure value, which in turn reduces the value of NPSH, and then the cavitation will appear earlier. From these Figures it can also be seen that there is interference between the points of break-down conditions with respect to variation of water temperature, and the reason may be due to some factors, such as the tensile strength, static pressure, vapour pressure, the number of bubbles, the bubble volume and the gas content. Figures 6 and 7 show the variation of $NPSH_i$ with water temperature. These Figures show that the $NPSH_i$ increases with the increase of water temperature till reaches its maximum value, then started decreasing with the increase of water temperature. This occurs mainly due to that at low temperature values, the effect of suction pressure is stronger than the effect of vapour pressure, while at higher temperature values the effect of vapour pressure becomes stronger.

5. CONCLUSION

Based on the experimental results obtained for different water temperatures, pump flow rate ratios and pump speeds, the following important conclusions can be drawn:

- (1) The pump head decreases with increasing water temperature.
- (2) For all temperatures test at various flow rate ratios and pump speeds, it was found that the inception net positive suction head ($NPSH_i$) increased as the temperature increases reaching its maximum value at nearly 30°C then decreased with increasing temperature

- (3) It was observed that the maximum $NPSH_i$ was likely independent of the flow rate ratio and speeds.
- (4) Increasing water temperature accelerates cavitation occurrence.

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