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EFFECT OF SAND CONCENTRATION RATIO ON CENTRIFUGAL PUMP PERFORMANCE AT VARIOUS WORKING TEMPERATURES

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ABSTRACT

Centrifugal pumps are exposed to operate at various operating conditions, such as flow rate ratios, rotational speed, and fluid temperature. Previous studies showed that the pump performance is affected considerably according to the change of these parameters. The centrifugal pumps in some applications are required to handle slurries or solid particles, where the pump characteristic curves are mainly affected by the concentration, density, and size of these particles. Basing on this point, the present experimental study were carried out to obtain the effect of sand concentration ratio on the pump performance curves at different water temperatures under cavitating and non-cavitating conditions. Results showed that at low working temperature, the pump head and pump efficiency decrease with the increase of sand concentration ratio, while at higher working temperatures it was found that the pump head and pump efficiency decrease with the increase of sand concentration ratio till reach its minimum, and then started to increase again. The results showed also that increasing the fluid temperature and sand concentration speed up cavitation.

NOMENCLATURE

Q	Lit/sec	Flow rate
H	(m)	Pump head
BEP	%	Best Efficiency Point
CW	%	Clear water
SCR	% by weight	Sand Concentration Ratio
NPSH	M	Net positive suction head
H	%	Efficiency

INTRODUCTION

Centrifugal slurry pumps are sometimes used to handle or deliver mixtures of abrasive solids and liquid. Pump useful life in these applications can range from a few weeks to a few years depending on the type and the size of slurries or particles handled. Centrifugal pumps are increasingly applied to extensive industrial fields and tend to be operated at a higher rotational speed and under multiphase flow conditions. When the centrifugal pumps transport fluid containing solid particles their performance will be affected. Therefore, to maintain high and stable performance, it is desirable to carry definite experimental and theoretical studies when pumps deliver multiphase flow. Hazim [1] et al. carried out an experimental work to investigate the effect of solid properties such as density, particle size, particle size distribution, and solid concentration up to 40% by weight on the behavior of centrifugal pumps. They observed that the effect of solid concentration on head reduction is linear. Their results were in agreement with the results obtained by Mez [2]. Wilson [3] studied practical methods for predicting the performance of centrifugal slurries pumps with extremely fine and coarse size, density and concentration of solids. The results showed that when pumping slurries, the relative reductions in pump head and efficiency were independent of flow rate and pump speed. Gahlot et al. [4] studied the effect of density, size distribution and concentration of solids on the characteristics of centrifugal pumps. They observed higher drop in the head compared to that in the efficiency. Hazim et al. [5] performed experiments to study the individual effects of particle size, particle size distribution, specific gravity, and concentration of solids on the performance characteristics of centrifugal pumps. They found that the relative reductions in pump head and efficiency, for a constant concentration of solids, were to be fairly constant over the range of discharge investigated. They also concluded that the relative reduction in efficiency was generally lower than the relative reductions in head at any given flow rate and concentration of solids. Sellgren et al. [6] studied the effect of sand-clay slurries on the performance characteristics of centrifugal slurries pumps. They found that the addition of clay to sand led to a reduction in pipe line friction losses, thus lowering the pumping head and power consumption. Engin and Gur [7] have developed a correlation to predict head reductions of centrifugal pumps handling slurries. Their correlation took into account the individual effects of particle size, particle size distribution, specific gravity and concentration of solids and impeller exit diameter on the pump performance. Selim et al. [8] have studied the effects of solids concentration and particle size distribution on the centrifugal pump performance. They concluded that the head and efficiency of the pump decrease with increase of solid concentration and the particle size. They also concluded that the sand size has a strong influence on characteristic of the pump. Engin T. [9] carried out a special work focused on the predictive methods for relative efficiency reduction of centrifugal pumps handling slurries based on empirical and artificial neural network ANN approaches. The applicability of ANN for the same purpose has been investigated using a total of 315 data. The comparisons of both methods showed that the present correlation produced the lowest deviation among some recent correlations in the literature, and, if properly constructed, ANNs could be used as a predictive tool with higher accuracy than the conventional empirical methods.

EXPERIMENTAL SET UP

Series of experiments have been conducted to determine the effect of sand concentration ratio at different working temperatures on the pump performance under cavitating and non-cavitating conditions. The properties of tested sand are shown in table 1 where the mean diameter of sand particles is (1.19mm). The schematic diagram of the test rig is shown in Figure 1. The mixture was prepared using double stirrers (15) in order to obtain a homogenous mixture. The pump discharge was controlled by using delivery valve (10). The slurry was drawn from the mixing tank (14) by the pump and circulated through a closed test loop. The suction and delivery heads were measured by using Bourdon pressure gauges (4) and (5). The flow rate was measured by using an orifice meter (6). The orifice was calibrated at each fluid temperature and mixing ratio of slurry. The centrifugal pump (2) is directly coupled to a 1 hp-AC motor (1). The used centrifugal pump having specifications of un-shrouded impeller with an inlet diameter of 35mm and outlet diameter of 70mm and rotational speed of 2800 rpm. The electric power was measured by using a calibrated wattmeter with an accuracy of ± 2%. The total power of heaters was 4.5 kW. All meters were checked before and after each experiment.

Table 1 Properties of tested sand

Relative density	2.5
Average diameter of sand particles	1.19 mm
Water absorption % dry mass	0.8

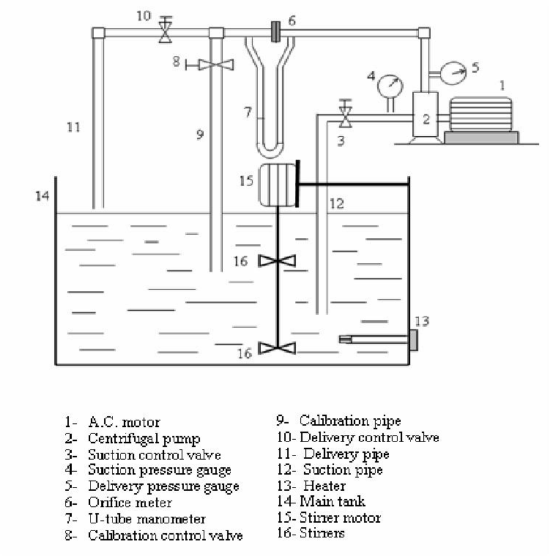


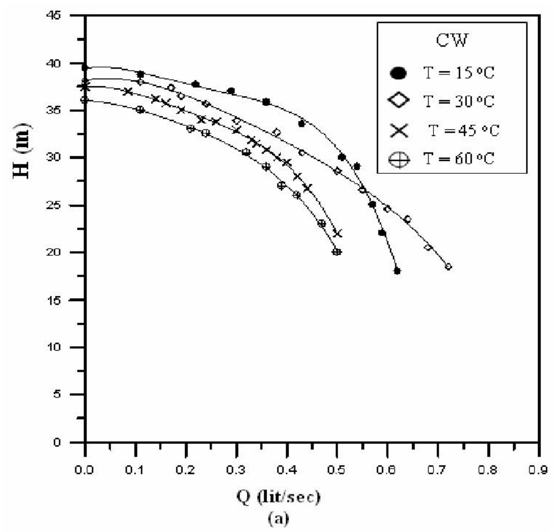
Figure 1 Experimental test rig and instrumentation

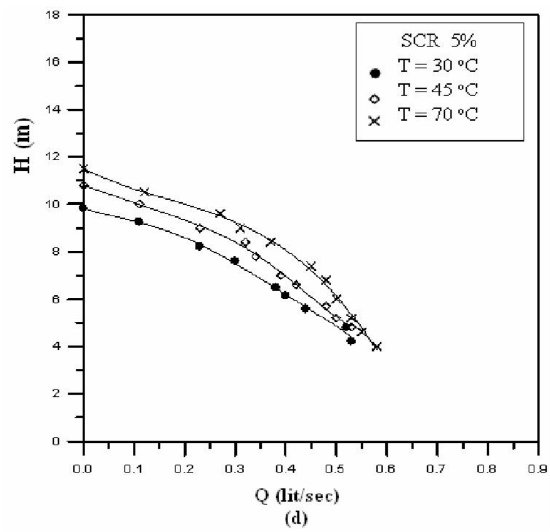
Test method

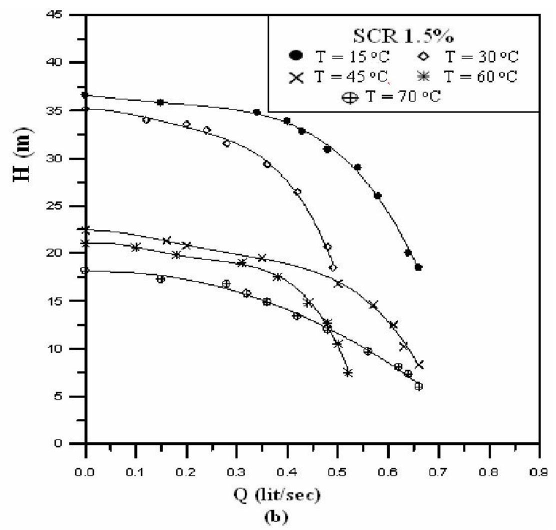
The experiments were started with clear water and temperature varied from 15°C – 70°C, then at the same varied temperature with different mixed ratios of sand. The pump was tested with different sand concentrations by weight (1.5%, 3.5%, 5%, 8% and 11%). Before operating the pump, the mixture was kept in circulation for approximately 15 minutes to assure complete and homogenous mixture before taking any measurements. To obtain accurate results more than one reading have been taken and the average value was recorded. After operating the pump a sufficient duration was kept for heat exchange between the flow and piping system.

RESULTS AND DISCUSSION

The experiments were carried to obtain the effect of fluid temperature at constant sand concentration ratio (SCR), and to find out the effect of SCR at constant fluid temperature, and finally the effect of SCR on pump performance under cavitating condition were studied. To obtain accurate results especially at high working temperatures and high SCR the average of three measured values has been recorded. The experiments were carried at constant pump rotational speed 2900 rpm. Figures (2.a-2.e) and Figures (3.a-3.e) represent the variation of pump head and pump efficiency with flow rate. It can be seen that using clear water and water with sand concentration up to 3% the pump head and efficiency decrease with the increase of fluid temperature. This is mainly occurred due to the decrease of fluid density. But at high SCR it was found that the pump head and efficiency increase with the increase of fluid temperature, therefore the SCR has a strong influence on the pump characteristics at low working temperature, and also at low fluid temperature the mixture has higher relative density than that at high fluid temperature.







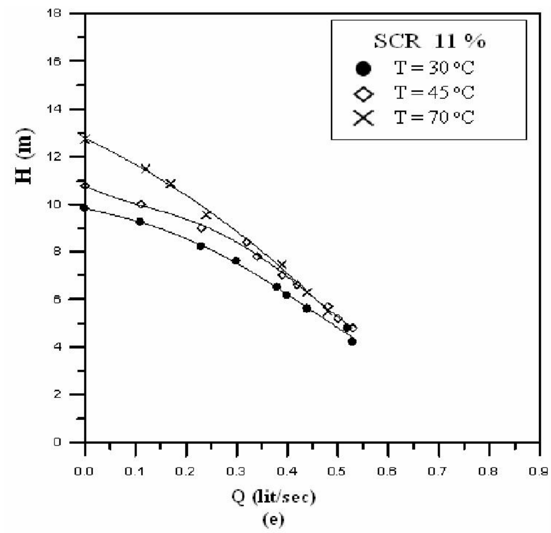
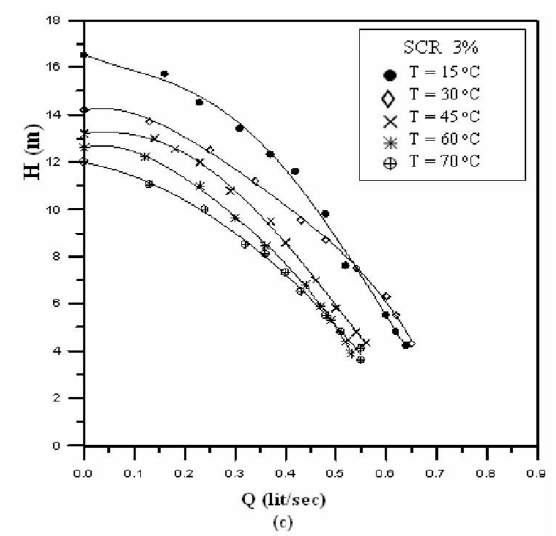
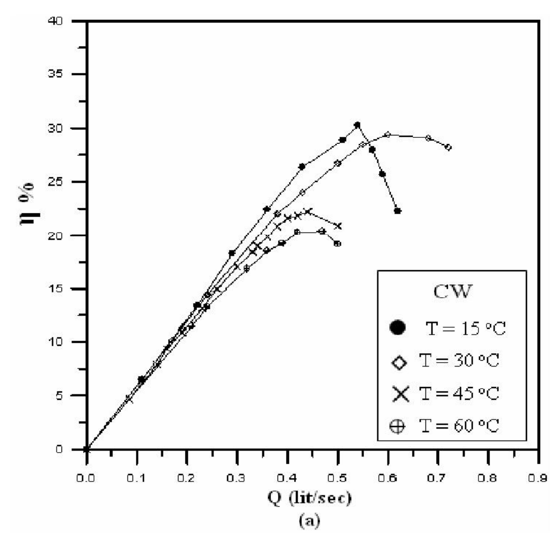


Figure 2 Head - capacity characteristics at constant SCR and various working temperatures





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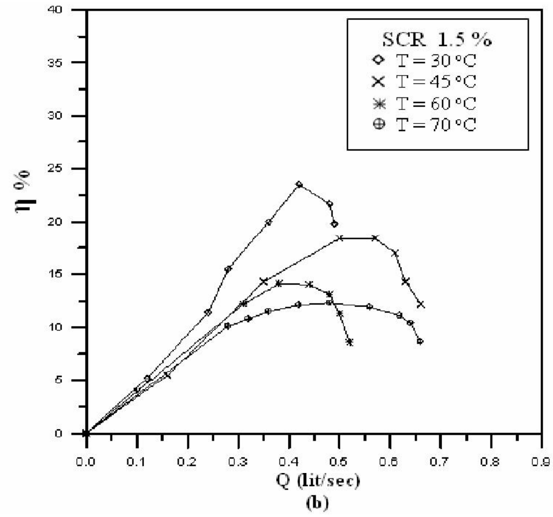
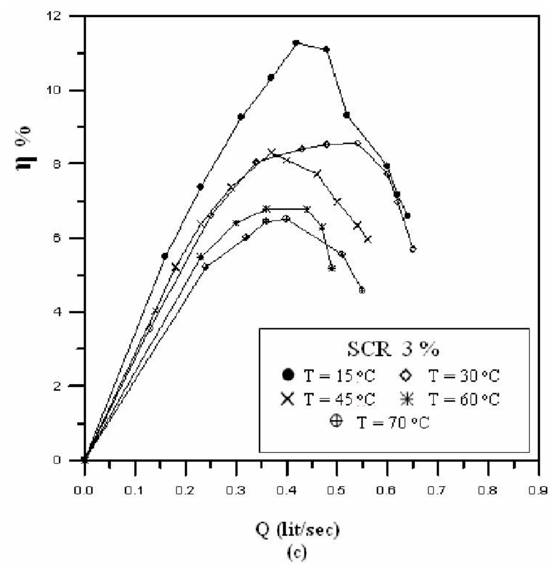
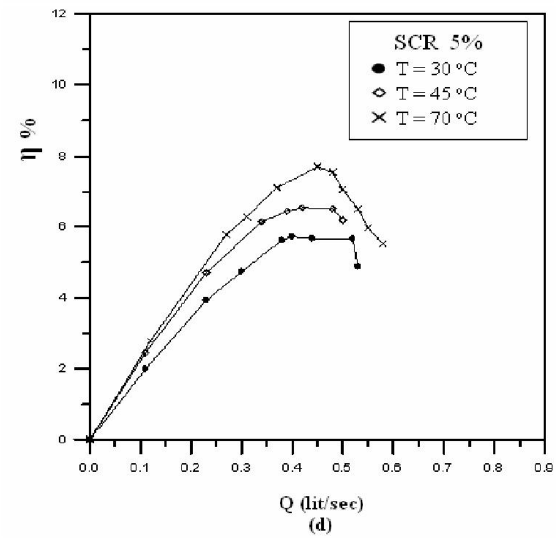






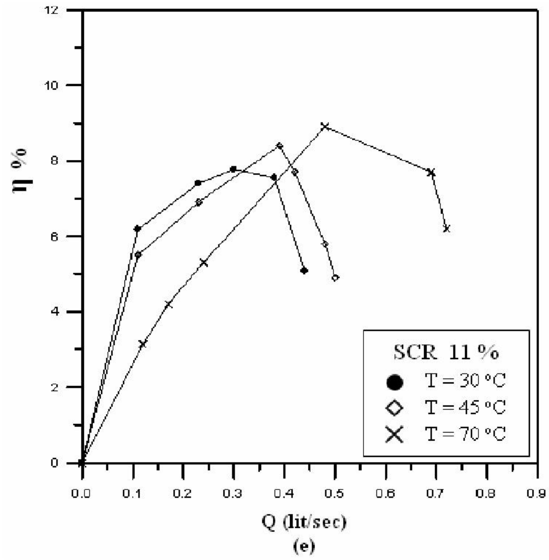
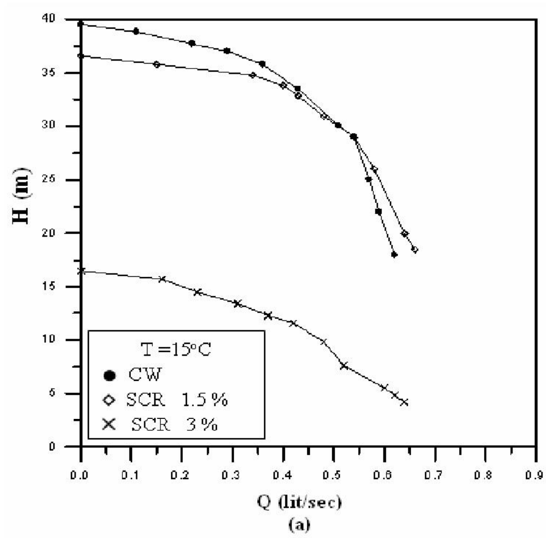


Figure 3 Efficiency - capacity characteristics at constant SCR and various working temperatures

Figures (4.a-4.e) and Figures (5.a-5.e) show the variation of pump head and efficiency with flow rate at constant fluid temperature and different SCR. The results show that at low working temperature (up to 30° C), the pump head and efficiency decrease with the increase of SCR, while at higher fluid temperatures the pump head and efficiency increase with increasing SCR. The main reason for this behavior is that at low working temperature the specific weight of the mixture has higher value, where the particles of the mixture are more cohered, and the flow will be blocked.



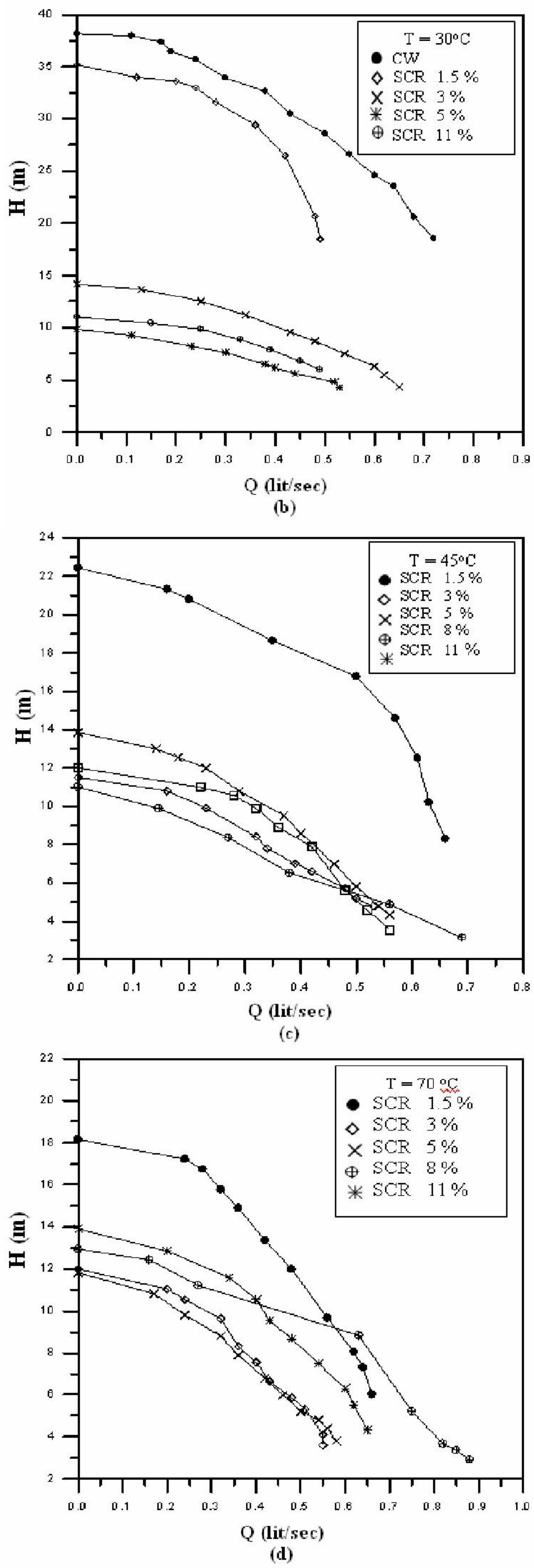
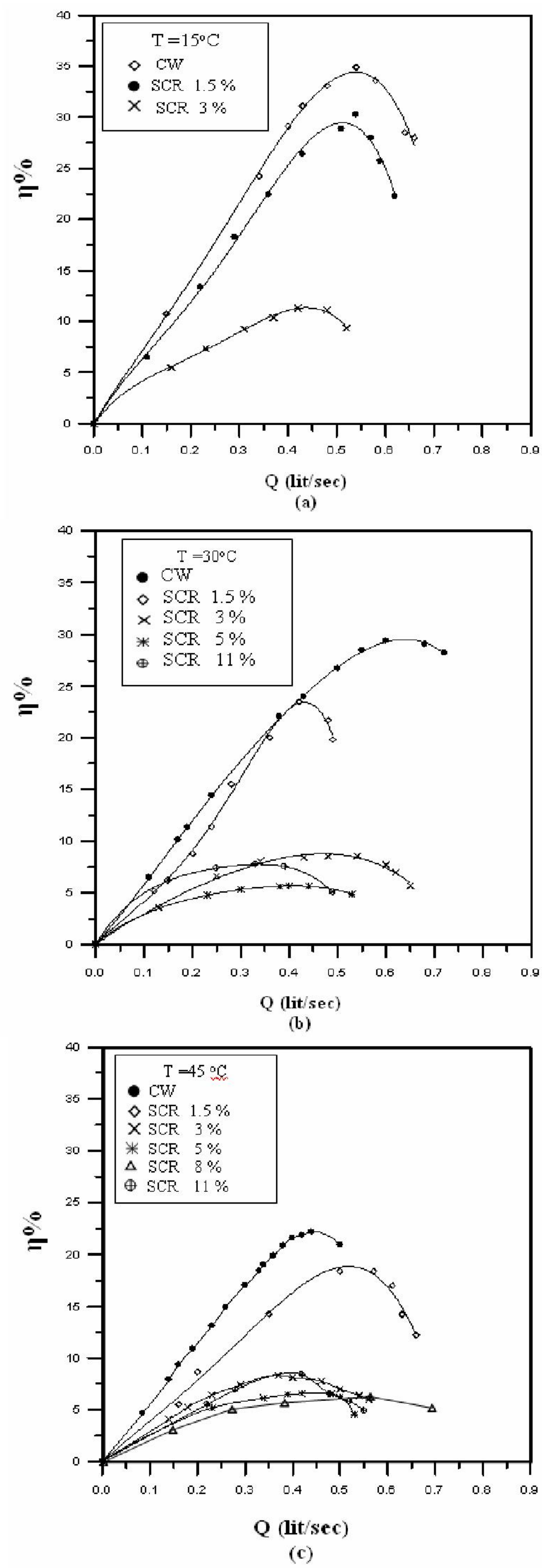
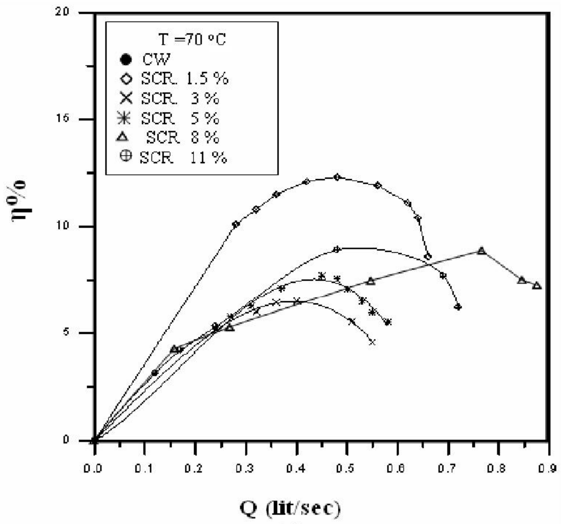


Figure 4 Effect of SCR on head – capacity characteristics

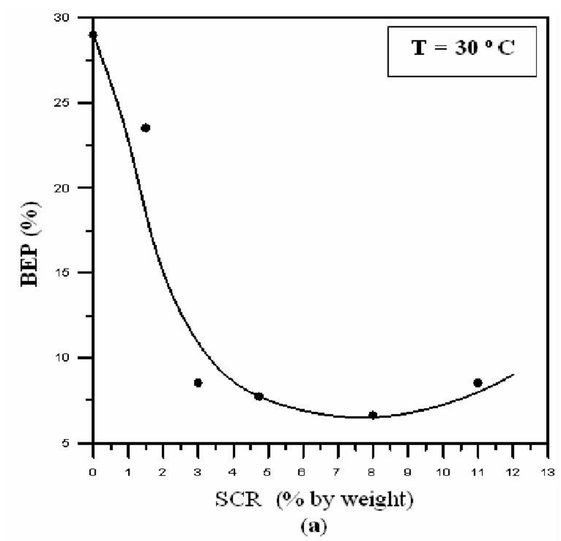




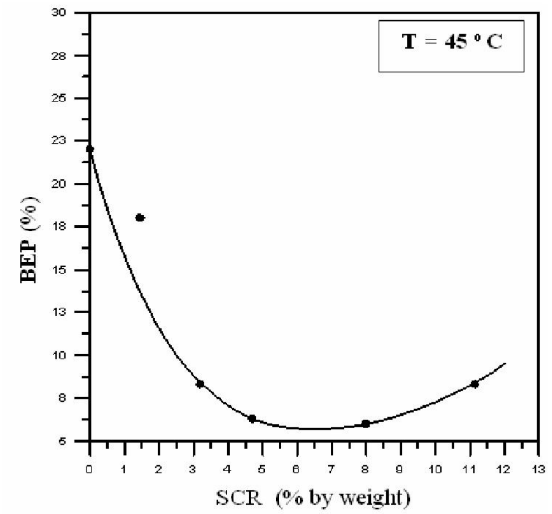
(d)

Figure 5 Effect of SCR on efficiency - capacity characteristics

Results in figures (6.a-6.c) show the effect of SCR on the BEP and working temperatures 30° C, 45° C and 70° C. The results show that the BEP decreases with increasing the SCR till reaches a minimum, then starts increase. It can be seen that at working temperatures 30° C and 45° C the curves are mostly symmetrical and the minimum BEP value was found to be at approximately 8%. It can also be noticed that at 70° C the reduction rate is more sharp and the minimum value of BEP was shifted to about 3%. Therefore increasing mixture temperature at high SCR. improves the pump performance. Figures (7.a-7.c) represent the variation of pump head with the NPSH at various SCR. From these figures it can seen that at temperatures up to 45° C the pump head decreases with the increase of SCR But at 70° C it was found that the pump head increases with increasing the SCR. It can also be seen that increasing the SCR speeds the cavitation occurrence



(a)



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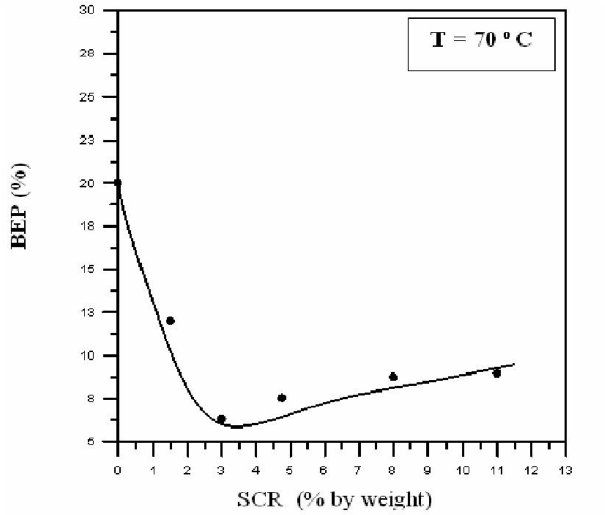
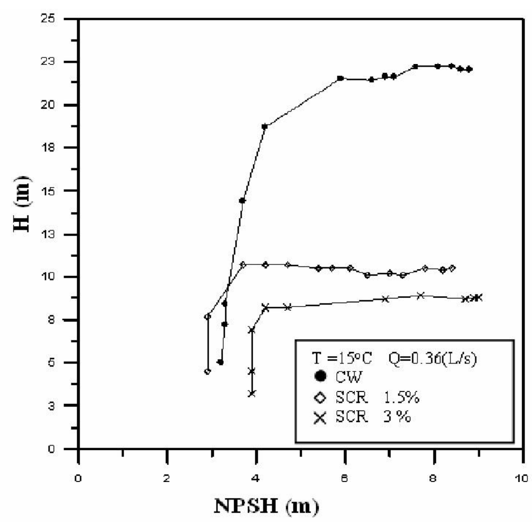


Figure 6 Variation of best efficiency point with SCR



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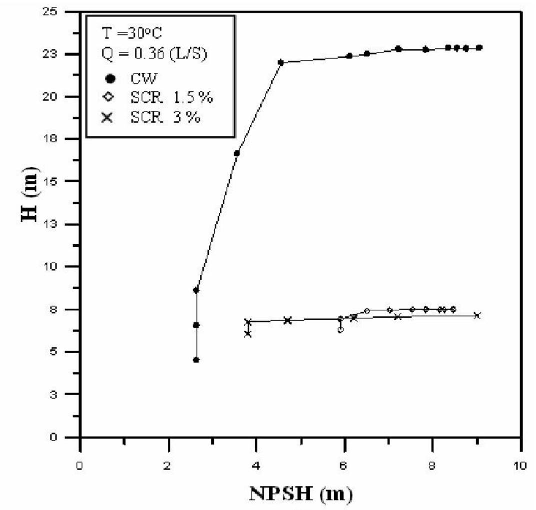

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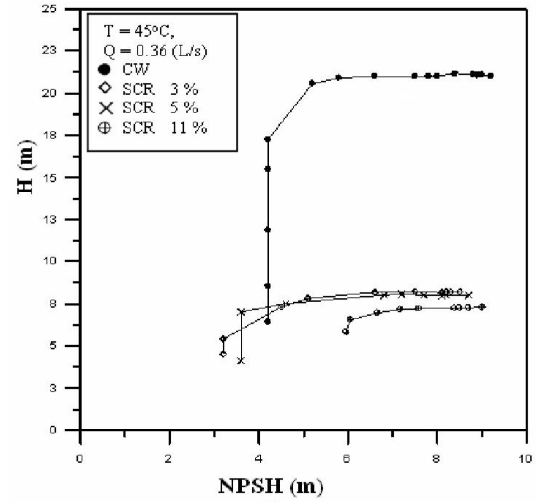

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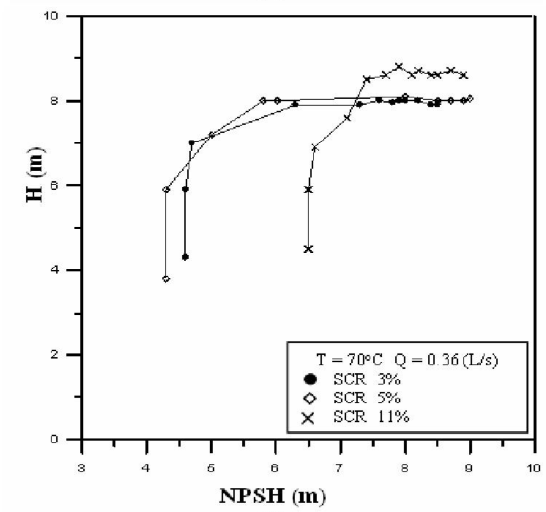

(d)

Figure 7 Variation of pump with the NPSH at various SCR

CONCLUSION

1) Pump head and pump efficiency decrease with increasing of clear water temperature.
2) At low fluid temperature, the pump head and pump efficiency decrease with increasing SCR.
3) At low fluid temperature, the pump head and pump efficiency decrease with increasing SCR till reaches minimum then starts increasing again.
4) At all working temperatures, the best efficiency point decreases with increasing the sand concentration ratio till reaches minimum then starts increasing again.
5) Increasing fluid temperature and SCR speeds up the cavitation.

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