

# Performance of a Centrifugal Slurry Pump with Clinker Slurry

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## Abstract

**Background/Objectives:** Slurry pumps are used to transport liquids that contain some solid content. The subject matter of this investigation is to find the effect of size of clinker and its concentration on the performance of slurry pump at different pump speeds. **Methods/Statistical Analysis:** The investigation was carried out experimentally at three pump speeds (2200 rpm, 2600rpm, 300 rpm), for three clinker sizes (4 mm, 13 mm, 20 mm) and three slurry concentrations (5%, 10%, 15%). The test loop was incorporated with pressure sensors and magnetic flow meter and digital output devices. For comparison tests were also carried out with clear water. **Findings:** The investigations points out that pump speed, clinker size and slurry concentration grossly affect the performance of the pump. The maximum decrease in the head developed by the pump at operating point was 64% for 4 mm clinker size with 5% slurry concentration for a pump speed of 2200 rpm. The decrease in the maximum efficiency of the pump at the operating point was observed to be 58% for clinker size of 20 mm with 5% slurry concentration at the pump speed of 2200 rpm. The maximum decrement in efficiency at operating point for clinker was found to be 58% for 20 mm size, 5% concentration and at 2200 rpm. The maximum increase in the power input to the pump was found to be 15% in case of 4 mm clinker size for 15% slurry concentration at 2200 rpm.

**Keywords:** Clinker, Concentration, Pump, Settling Slurry

## 1. Introduction

The characteristics of slurry, which is formed by adding solid to the flowing liquid, mainly depend on its size, concentration of slurry and level of turbulence, temperature and viscosity of the carrier fluid. Slurry is either settling or non-settling. The slurry that settles after some time is called settling slurry whereas non settling slurry remains in suspension for a long time. Slurry pumps constitute a wide range of centrifugal pumps. Slurry pump is not as efficient as water pump. Its vanes are thicker than a common water pump so as to allow for wear that is caused by the flow of slurry through it. Compared to normal pumps the slurry pumps have fewer vanes. The presence of fewer vanes does not allow proper guidance fluid in this impeller as in a normal pump that result in reduced pumping

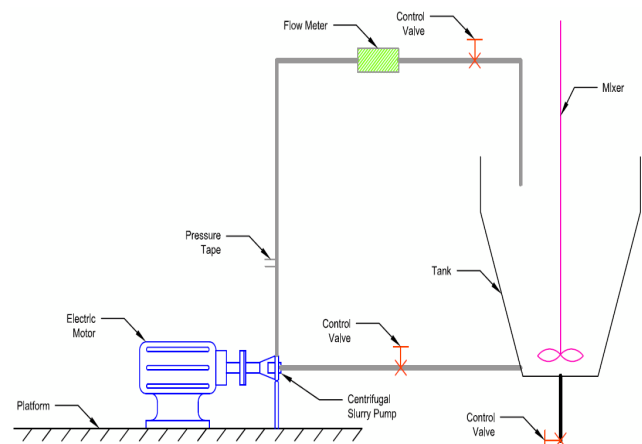
head and efficiency. Presence of solids in the slurry itself also causes degradation in both head and efficiency of the slurry pumps because the velocity of slurry and the carrier fluid are not the same the difference is called slippage. The average velocity of the slurry is somewhere between the velocity of water and that of the solids. Mostly the slurry pumps are used in pipeline transportation due to their capability to economically convey large size abrasive solid. Slurry pumps are used in mining, chemical and industrial applications. For the pumps carrying fly ash, sand, iron ore and coal dust Chand et al.<sup>1</sup> have reported improvements in head and efficiency of the pump with increase in concentrations of solid as well as polymer additives. They used slurry concentrations up to 26% by volume and three speeds of the pumps. Fair Bank<sup>2</sup> found that the head produced by the pump decreases with the

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increase in either concentration of medium particle size of sand/clay. Wiedenroth<sup>3</sup> attributes the head reduction to the additional friction losses in the flow passages due to the suspension solids. Vocaldo et al.<sup>4</sup> compared the performance of rubber-lined and metal centrifugal slurry pumps handling sand material of different particle sizes and speeds. Rubber-lined pump produced more head loss than the metal pump which they attributed to the higher absorption of particle kinetic energy by the lining. The decrease in the head developed and efficiency was not affected by the concentration of slurry. Burgess and Riezes<sup>5</sup> have shown that the head loss of the slurry pump depends on the size and specific gravity of solid and concentration of slurry. Walker and Gouldas<sup>6</sup> has pointed out the decrease in the pump head and efficiency of pumps, that are used for non-Newtonian slurries, depend on rheological properties of the slurry and the Reynolds number of slurry flow. Sellgren and Vappling<sup>7</sup> studied the effect of slurry concentration on the performance of a pump with two tailings materials and found that the head and the efficiency of the pump decrease with the increase in slurry concentration. Gahlot, et al.<sup>8</sup> tested two slurry pumps made of metal and rubber lined material with coal and zinc tailings and found that pump head and efficiency decreased with slurry concentration, particle size and specific gravity of solids whereas they are fairly independent on the pump flow rate. Ni, et al.<sup>9</sup> have observed a 15% decrease in the head and efficiency reduction factors for centrifugal pumps which were used for pumping narrowly graded sand with a d50 value of 370 microns and for a delivered volumetric solid concentration value of 35%. Sellgren, et al.<sup>10</sup> observed experimentally that in case of industrial suspension the pump head and efficiency reduces in the best efficiency region. The efficiency is more affected by this suspension than head. Operation with highly non-Newtonian suspension at lower flow rates shows an unstable head curve. It was investigated that with the scrubber sludge there was sharp reduction in head at flow rates below 40% of the BEP-value. Sellgren, et al.<sup>11</sup> observed that mixing of clay with the sand slurry reduces the friction losses in the pump system that lowers power input of the pump. Pump water heads and efficiencies are decreased by the presence of solid particles.

Ni, et al.<sup>12</sup> evaluated slurry pump performance for three types of narrow graded sands with volumetric concentration up to 44% experimentally. The pump efficiency in the coarse sand slurry drops almost 60%, compared to that of water. The head ratio and efficiency ratio drops

faster at solid volumetric concentration of about 35%. However, the pump efficiency drops much faster than pump head when volumetric concentration is less than 15%. Gandhi, et al.<sup>13</sup> reported the performance of two centrifugal slurry pumps for three solids materials having different particle size and found that head and efficiency of the pump decrease with increase in solid concentration, particle size and slurry viscosity. Satoshi, et al.<sup>14</sup> has found that pump efficiency with surfactant solutions was higher than that with tap water and increased with an increase in surfactant concentration. The value of maximum flow rate also increased. The total pump head increased with an increase in concentration and the shaft power decreased with a decrease in the impeller rotating speed. The present experimental investigation dealt with finding the effect of a slurry pump with clinker and finding effect of the size of clinker, the concentration of slurry and pump speed on the performance. Three clinker sizes with three slurry concentrations at three impeller speeds have been used in this investigation.



**Figure 1.** Schematic diagram of test loop.

## 2. Materials and Methods

The performance of the slurry pump was tested in an experimental set up shown in Figure 1. The tests were carried out under controlled conditions. The loop was built around a pipe of 50 mm diameter which had a total length of 30m. The slurry was made in a carbon steel tank having a size of 1 m×1 m×1 m. The pump under investigation was AWEMCO-WEIR centrifugal slurry pump. The suction side of the pump was connected to the slurry tank through a non return valve. Pressure transducers were incorporated on both suction and delivery sides of slurry

pump for head measurement purposes. A magnetic flow meter was fitted in the loop for the flow rate measurement. The motor was run through the use of an electrical panel with variable speed drive so as to ascertain the effect of pump speed. The flow rate was controlled by a flow control valve that was built in at the end of the loop. The tank had also a drain out valve that was used for cleaning the tank and also during the change of test conditions.

To start with the test loop was cleared of all the possible presence of air bubbles by filling the loop with clear water and closing all the valves of the test bed. After purging of all the air bubbles from test bed, the performance of the slurry pump was investigated with clear water as fluid. The delivery valve was opened and adjusted to desired flow rate. The measurements indicated by magnetic flow meter, power analyzer, pressure transmitter and tachometer were noted. These measurements were repeated at different flow rates that were obtained by the adjustment of delivery valve for various valve openings so as to cover entire operating range of pump flow rate. During every flow rate measurement proper time were given to stabilize the indicated values of the instruments. The test was repeated at 1000 rpm, 1400 rpm, 1800 rpm, 2200 rpm, 2600 and 3000 rpm speeds. The main measurement included in the test runs were pressure rise in the pump using pressure sensor, flow rate of the fluid by using magnetic flow meter, speed of the pump by a non contacting tachometer and power consumed by the pump by measuring power outside volt and ampere.

### 3. Results and Discussion

The head generated, power input and efficiency of the slurry pump were measured with clear water and clinker slurry, for three sizes and three concentrations of the slurry and at three speeds of the pump. The results have been presented as variation of head generated, power input and efficiency with flow rate. The presentation is classified as effects of concentration and size of slurry with three speeds.

Effect of concentration of slurry on the performance of a pump has been presented in the literature either on the basis of weight or volume. This study presents the effect of concentration of slurry on the basis of weight. The concentrations used were 5%, 10% and 15% by weight. Figures (2 to 4) show head characteristics for 4 mm size of clinker for different concentrations at differ-

ent speeds. It is observed that the head decreases with the increase in concentration and decrement in the head ( $\Delta H$ ), which is the difference between maximum head produced with water and the present condition decreases with the increase in speed. This is attributed to the internal losses in the pump passage which decreases with the increase in speed because of less stay time of slurry in the pump. The differences in decrease between the different concentrations vary from 10 to 4% for 5 to 15% change in concentrations. Similar variation of the head can be observed for slurry size of 13 mm (Figure 5 to 7) and for 20 mm (Figures 8 to 10) except that variations in the head are observed to be more at higher sizes. As expected for the same size the pump head increases with speed but the variations amongst the concentrations remains almost the same. With the change in size variations become more amongst various concentrations. Further the head developed is seen to decrease with the increase in size. Thus the head developed by the slurry pump, which normally is effected by the speed of the pump, also gets affected by both the size and concentration of the slurry. The decrement of the maximum head developed by the pump, from that developed with clear water, at different concentrations of clinker for different sizes and the concentration as shown in Table 1.

The variation of input power to the slurry pump for different speeds with various concentrations and sizes of the slurry and speeds is presented in Figures (11 to 19). From the variation it can be seen that the power consumed by the slurry pump increases with the increase in the flow rate and concentration at all the speeds and for all the sizes. The different in the power consumed ( $\Delta P$ ), which is difference between the power consumed at operating point for water and the slurry, for different concentration for various sizes and pump speeds is presented in Table 1. This increase in power consumption by the pump, as a consequence of presence of slurry, is significantly effected of by speed where as the change in sizes and concentration also effect to a small level. The variation in the power consumed increases with the size and speed. The different in the power consumed is highest for clinker size of 20 mm at 3000 rpm. It decreases with the decrease in both size and concentration.

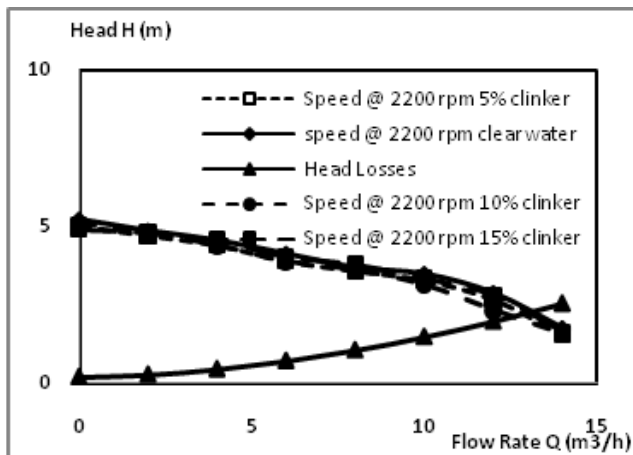
Figures (20 to 28) depict the variation of efficiency in case of clinker slurry at different concentration, size and speeds. From these graphs it is evident that the maximum efficiency decreases with increase in the flow rate and concentration at all the speeds and for all sizes. The

maximum efficiency is at flow rate of 10m<sup>3</sup>/h. The difference in the efficiency ( $\Delta\eta$ ), which is difference in the efficiency of the pump at operation point for water and the slurries at different concentrations, is significantly effected of by speed where as the change in sizes have significant effect on the efficiency decrease. The difference in the efficiency is highest for aggregate size of 20 mm at 3000 rpm. It decreases both with the decrease in the size and concentration of the slurry. After the point of maxi-

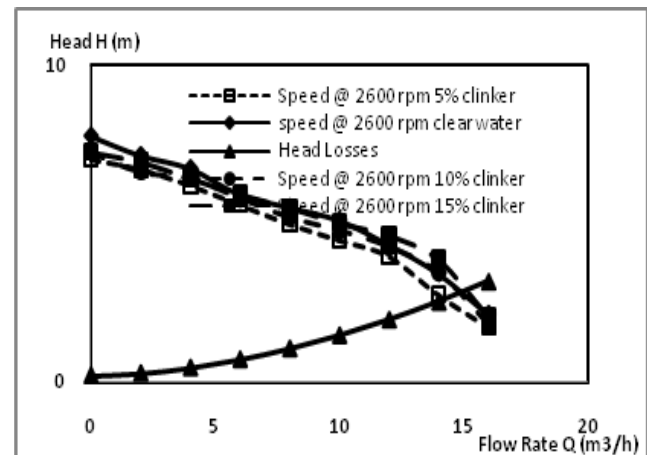
imum efficiency of pump for any condition the variations in the efficiency with the change concentration increases drastically and size. Higher sizes show higher changes in the variations. The reason for this is the nature of clinker slurry. It is settling type slurry and hence the power consumed to make the slurry flow shows a consistent increase with size, concentration and speed of the slurry pump that result in the decrease in the efficiency of the pump for these conditions.

**Table 1.** Variations in operating point performance of a pump with clinker

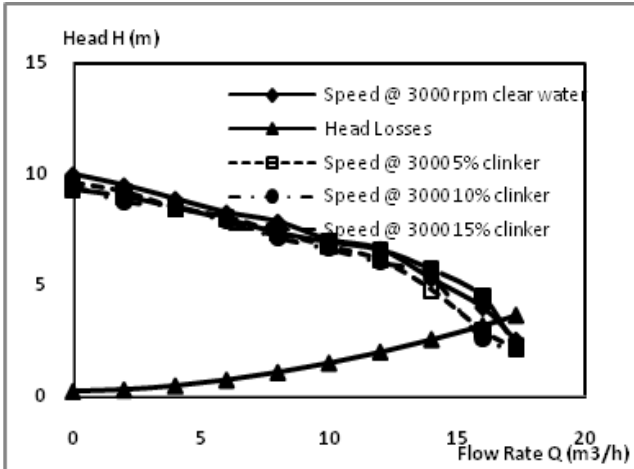
Concentration (%)	Size (mm)	Head Decrease $\Delta H$ (%)			Power Increase $\Delta P$ (%)			Efficiency Decrease $\Delta \eta$ (%)		
		2200 rpm	2600 rpm	3000 rpm	2200 rpm	2600 rpm	3000 rpm	2200 rpm	2600 rpm	3000 rpm
5%	4	63.73	56.59	57.12	-6.95	-1.09	-4.9	54.59	52.56	53.194
	13 mm	3.78	-0.03	7.18	-0.28	3.6	4.25	6.32	4.27	2.87
	20 mm	3.78	-0.03	7.18	3.82	5.79	2.4	58.63	54.49	53.178
10%	4	16.94	15.27	20.68	-9.21	-4.91	-6.19	27.59	21.96	32.48
	13 mm	37.62	10.79	23.722	-9.6	4.9	-0.63	41.61	15.63	28.77
	20 mm	12	5.56	22.73	-7.8	-3.06	-7.03	29.24	24.312	32.16
15%	4	34.14	26.07	38.53	-14.7	-9.28	-10.9	38.17	29.79	37.52
	13 mm	15.25	1.867	24.95	6.38	7.1	3.329	24.72	14.017	31.94
	20 mm	19.81	9.39	23.47	-10.3	-4.9	-5.85	41.64	33.317	39.69



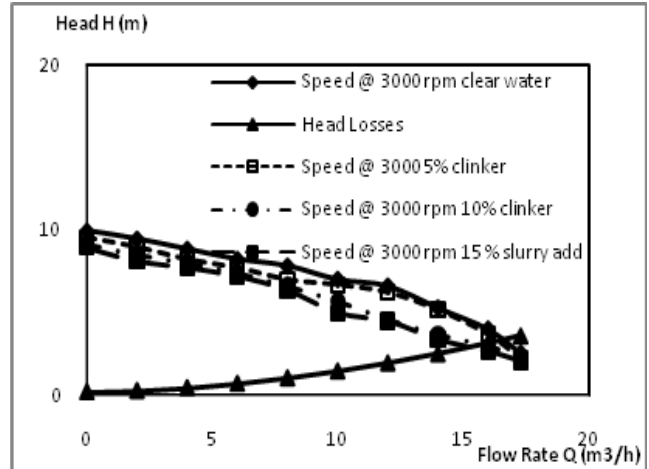
**Figure 2.** Head characteristics with 4mm clinker at 2200 rpm



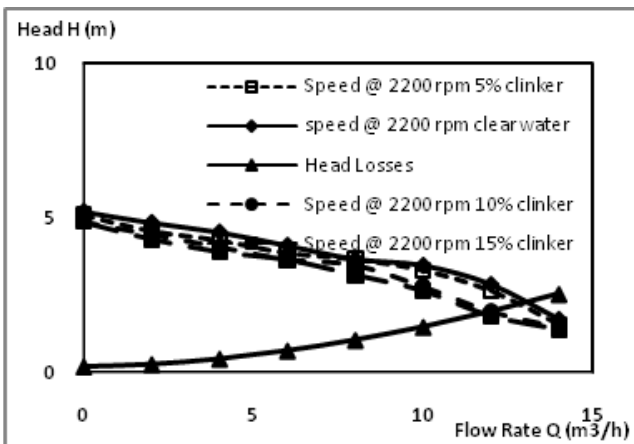
**Figure 3.** Head characteristics with 4mm clinker at 2600 rpm.



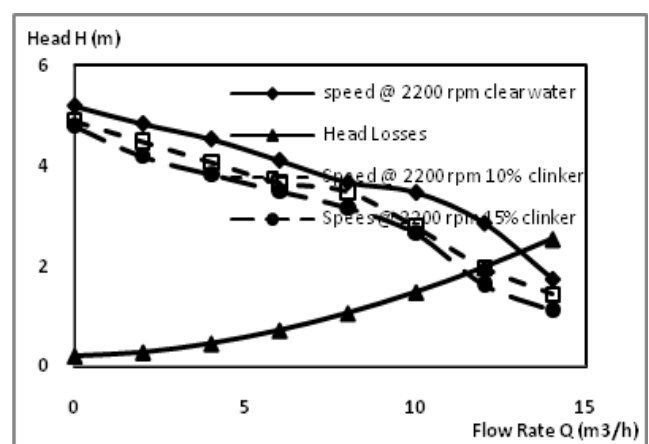
**Figure 4.** Head characteristics with 4mm clinker at 3000 rpm.



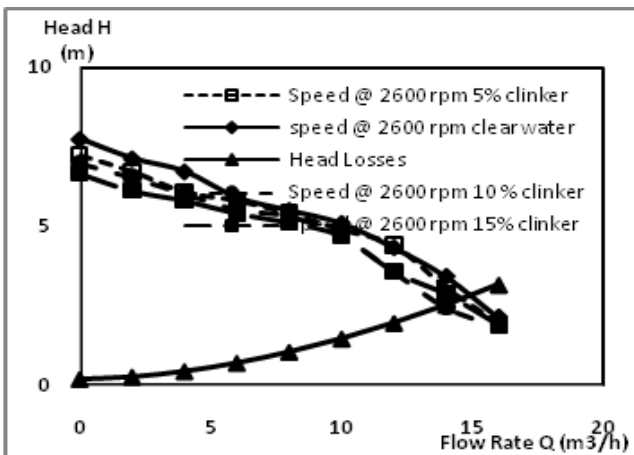
**Figure 7.** Head characteristics with 13mm clinker at 3000 rpm.



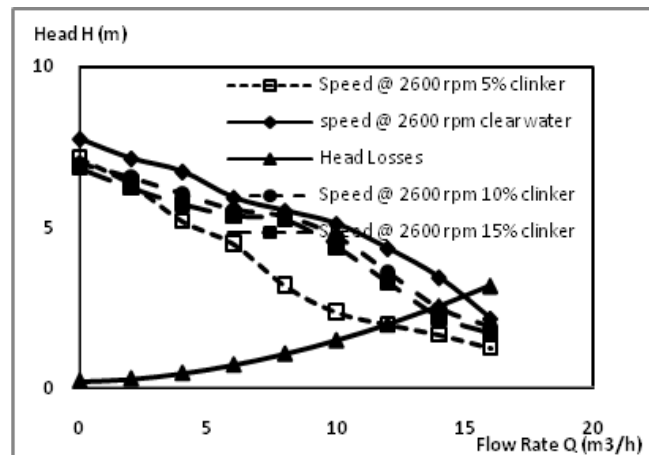
**Figure 5.** Head characteristics with 13mm clinker at 2200 rpm.



**Figure 8.** Head characteristics with 20mm clinker at 2200.



**Figure 6.** Head characteristics with 13mm clinker at 2600 rpm.



**Figure 9.** Head characteristics with 20 mm clinker at 2600 rpm.

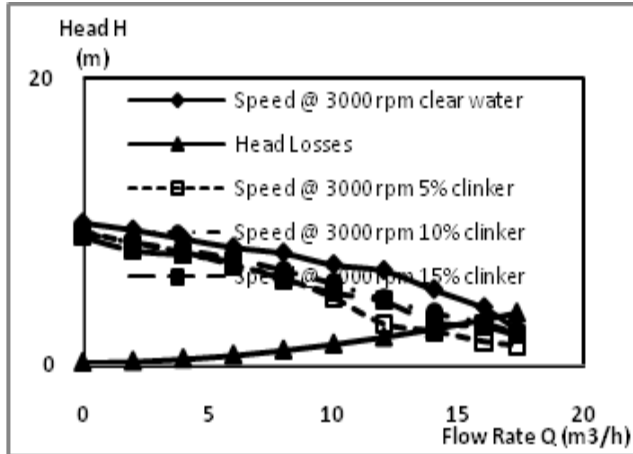


Figure 10. Head characteristics with 20mm clinker at 3000 rpm.

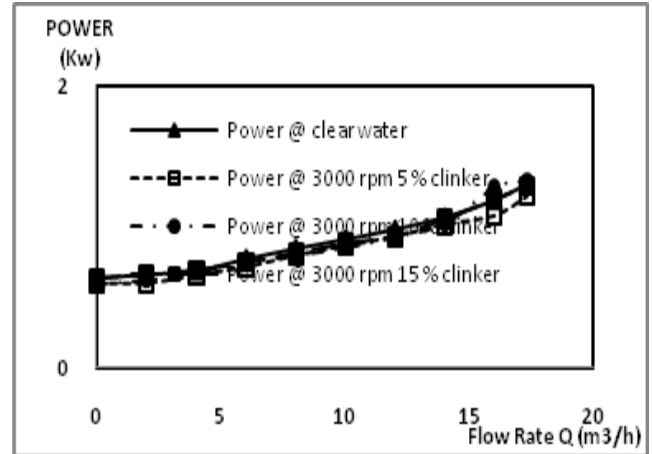


Figure 13. Power characteristics of pump with 4mm clinker at 3000 rpm.

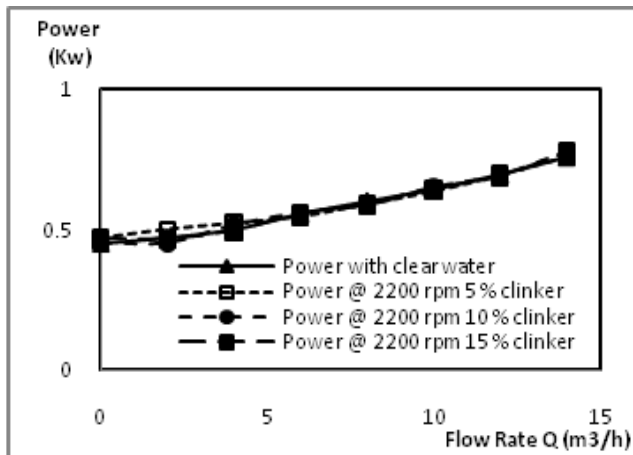


Figure 11. Power characteristics with 4mm clinker at 2200 rpm.

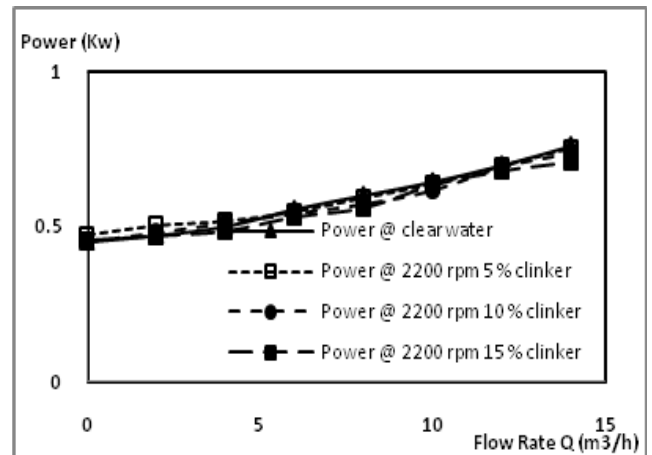


Figure 14. Power characteristics with 13mm clinker at 2200 rpm.

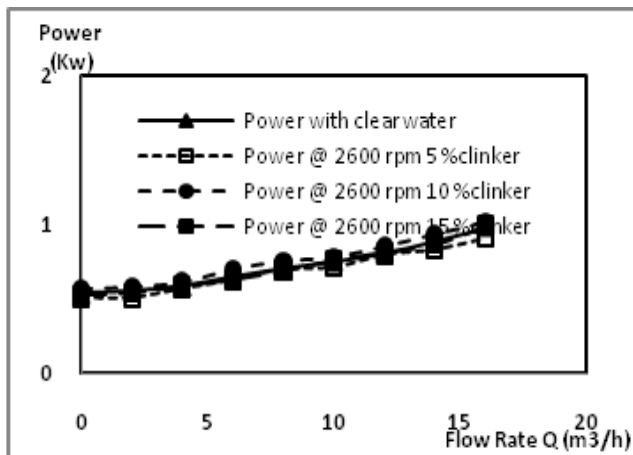


Figure 12. Power characteristics with 4mm clinker at 2600 rpm.

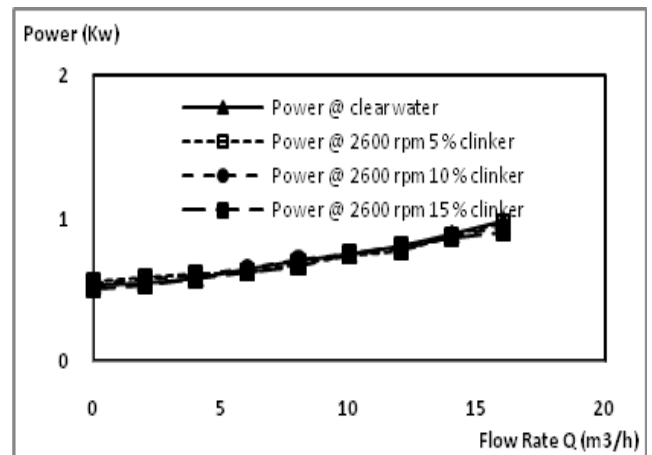


Figure 15. Power characteristics with 13mm clinker at 2600 rpm.

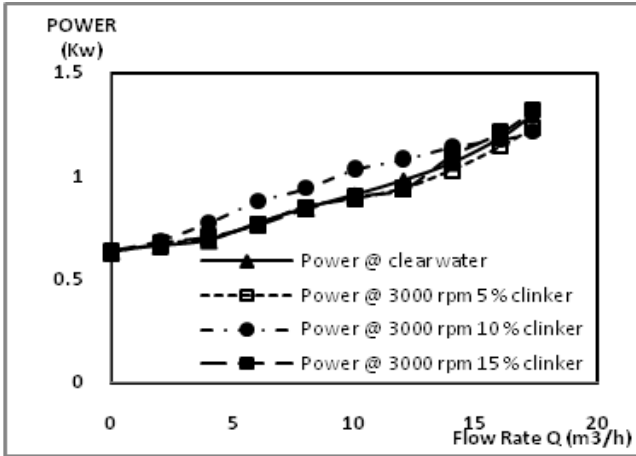


Figure 16. Power characteristics with 13mm clinker at 3000 rpm.

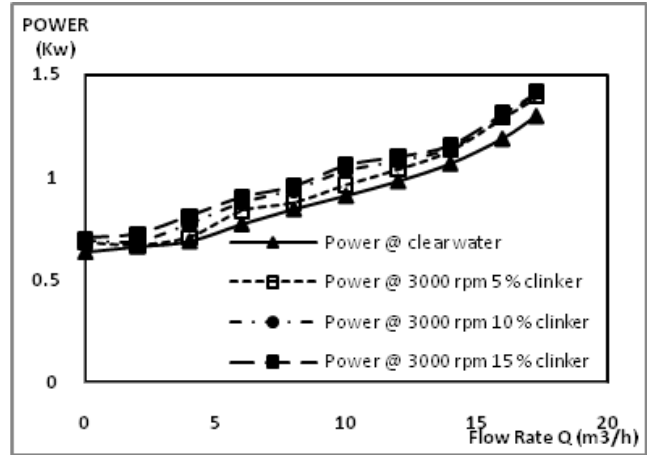


Figure 19. Power characteristics with 20mm clinker at 3000 rpm.

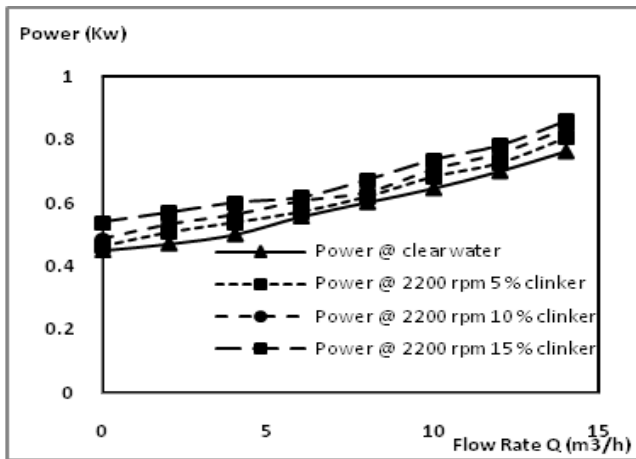


Figure 17. Power characteristics with 20mm clinker at 2200 rpm.

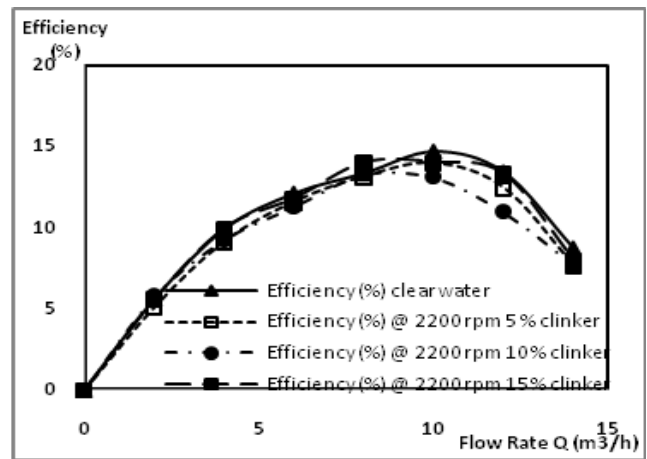


Figure 20. Efficiency with 4 mm clinker at 2200 rpm.

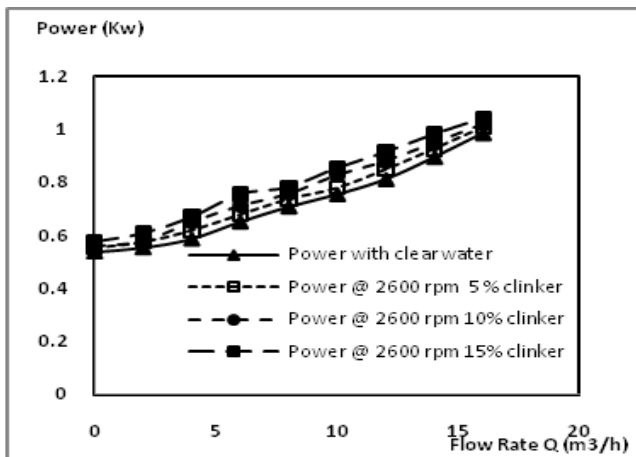


Figure 18. Power characteristics with 20mm clinker at 2600 rpm.

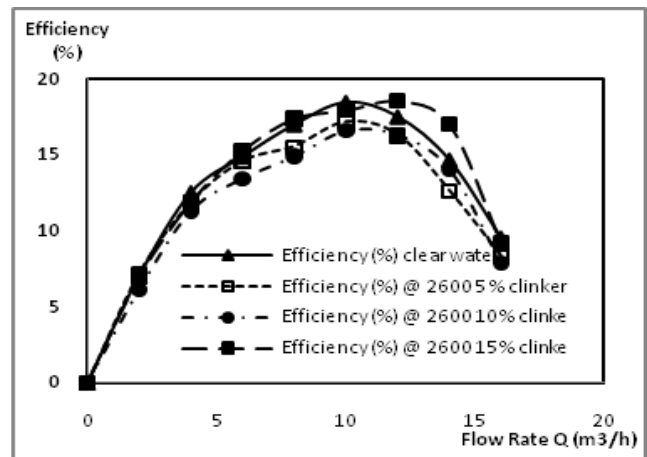


Figure 21. Efficiency with 4mm clinker at 2600 rpm.

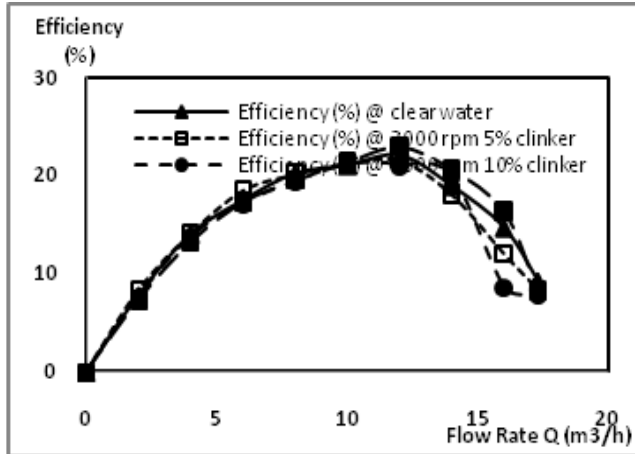


Figure 22. Efficiency with 4 mm clinker at 3000 rpm.

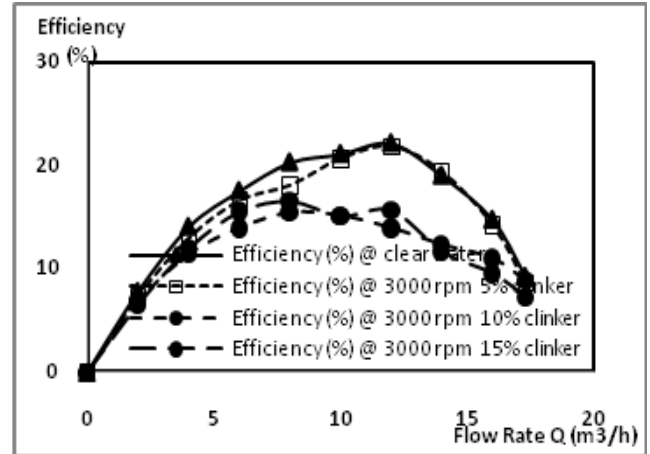


Figure 25. Efficiency with 13 mm clinker at 3000 rpm.

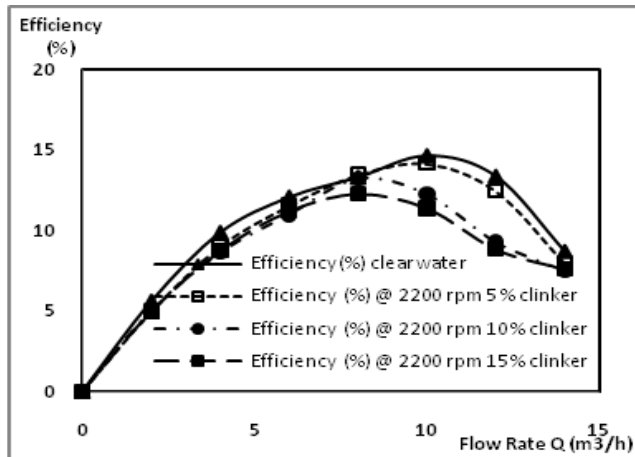


Figure 23. Efficiency with 13 mm clinker at 2200 rpm.

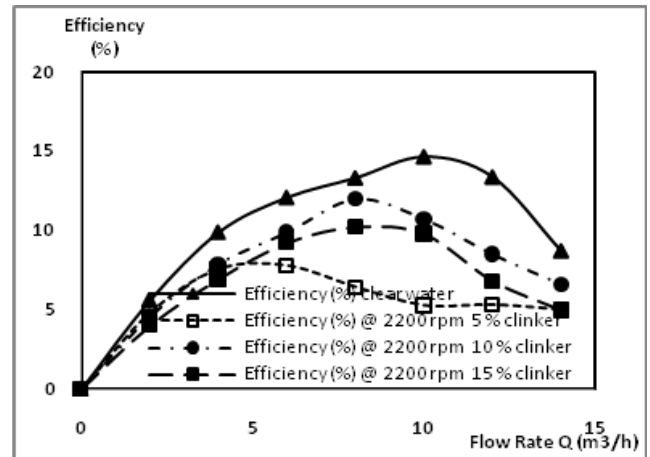


Figure 26. Efficiency with 20 mm clinker at 2200 rpm.

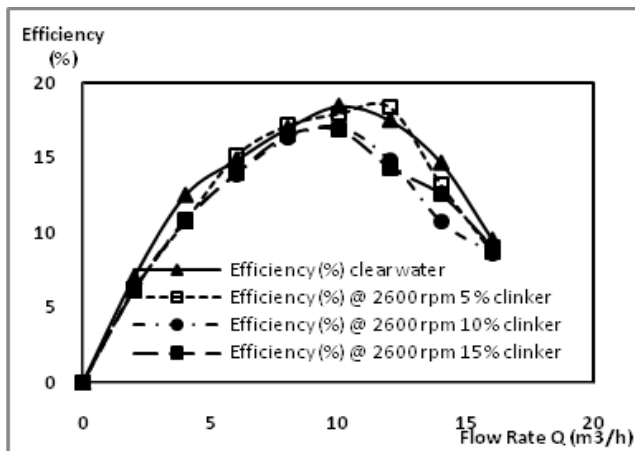


Figure 24. Efficiency with 13 mm clinker at 2600 rpm.

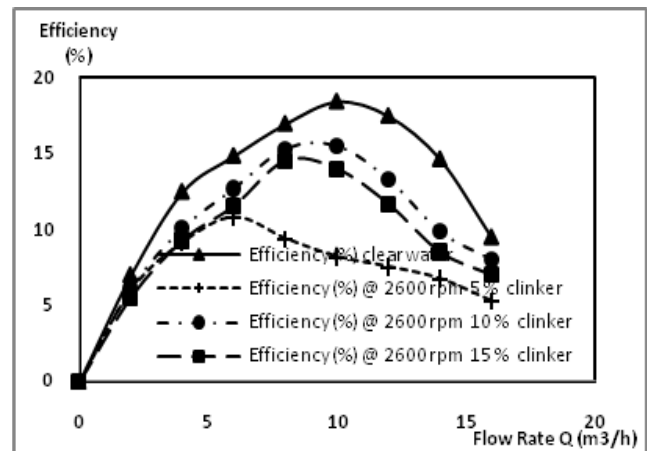


Figure 27. Efficiency with 20 mm clinker at 2600 rpm.



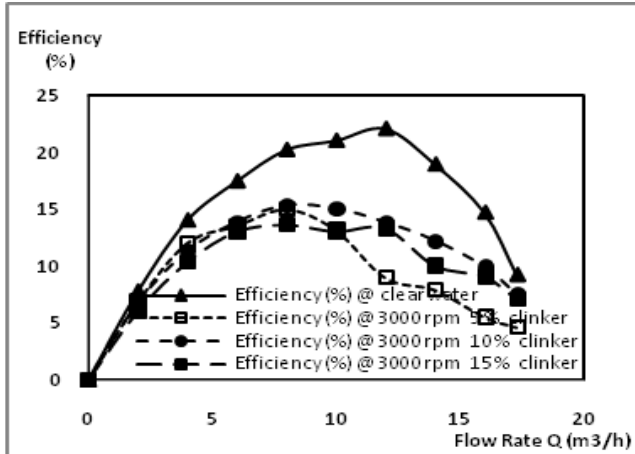


Figure 28. Efficiency with 20 mm clinker at 3000 rpm.

## 4. Conclusion

The following conclusions have been observed in these investigations.

- The head developed by pump and pump efficiency decreased with the increased concentration of the slurry.
- Power input to the pump increase with increase in concentration.
- The head developed by pump and its efficiency decreased with the increased size of the slurry.
- Power input to the pump increase with increase in size of slurry.
- Compared to water the maximum decrease in the head produced by the pump at operating point was found to be 64% for clinker size 4mm for 5% slurry concentration and at 2200rpm.
- The maximum efficiency loss at operating point for clinker was found to be 58% for clinker size of 20mm with 5% slurry concentration at 2200rpm.
- The maximum increase in power consumption at operating point was found to be 15% for clinker size of 4mm size with 15% slurry concentration at 2200rpm.

## 5. Acknowledgement

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