Structural engineering centrifugal pump test laboratory engineering essay

This report examines the centrifugal pump. Firstly by examining the system head characteristic, then by examining the effects varying the motor speed has on a single pump. Finally the report examines and compares the use of two pumps in series and then in parallel.

Theoretically examination of the system head characteristic should yield a graph of system head against volume flowrate which is curved, the curve should begin above zero from the y axis, due to static lift.

Theoretically examination of the effect of varying motor speed across a system of a single pump should show that higher motor speeds lead to higher efficiency in the pump system along with larger changes of power across the system, and a larger drop in head values.

Finally comparison of a system with two pumps used in series and in parallel should show that the method used will not have an effect on the efficiency of the system. However it should also show that the system in series has twice the head values of that in parallel and that the system in parallel has twice the volume flowrate values of the system in series. Overall they should have the same Mass flow.

Upon comparison of the results obtained with theory, it is evident that for the most part, the experimental results agree with theory. Any minor disagreements between theory and experimentation will be explained in the discussions and conclusions section of this report.

This report serves to display knowledge and understanding of the operation of a centrifugal pump gained from completion of the experiment.

Introduction

The purpose of this laboratory is to study the operation and performance of a centrifugal pump. Centrifugal pumps are an example of a fluid machine. Fluid machines are devices that transfer energy to or from a fluid. Fluid machines include pumps, fans and compressors. This experiment deals with a pump.

Pumps are devices used to move gases or liquids from lower to higher pressure. The difference in pressure is overcome by adding energy to the system. Specifically, centrifugal pumps operate by converting rotational kinetic energy into hydro dynamic energy. The rotational energy is typically supplied by an engine or electric motor or turbine.

Centrifugal Pumps are an important machine to study from an engineering point of view as they are very widely used as a means of delivering liquids. Centrifugal pumps are used in fields such as sewage, petroleum and petrochemical pumping.

For the purpose of this report the centrifugal pump was studied in terms of its performance when a single pump was used and also when two pumps were used (both in series and in parallel). The purpose being to highlight the effects this had on results. The system characteristic was also investigated. The overall purpose of this experiment is to give a better understanding and insight into how this fluid machine works. Below is an image of a centrifugal pump. A greater insight into how it operates and an explanation of the function of the various parts will be provided later in the report.

http://www. pumpfundamentals. com/images/closed_impeller. gif

Figure 1 – Centrifugal Pump Diagram 1

Objectives

The primary aim of this laboratory is to gain a better understanding of pumps, in particular the centrifugal pump. Insight is gained into the principles of operation of a centrifugal pump and the process through which a pump transfers energy to a fluid system.

There are three parts to this experiment:

To determine the system characteristic for the fluid system on which the pump operates.

To determine the performance of a single pump relative to motor speed.

To determine (for a fixed motor speed) the performance of two centrifugal pumps;

Operating in series (ii) Operating in parallel

Theory

Basic theory and workings of Centrifugal pump

As previously stated, the principle operation of a centrifugal pump is to convert fluid velocity into pressure energy. The pump is made up of three components; the inlet duct, the impeller, and the volute.

http://htmlimg2. scribdassets. com/4sp8x32v9cejngi/images/4-dd8b7539b4. jpg

Figure 2: Centrifugal Pump Diagram 2

Fluid enters the inlet duct (D). As the shaft (A) rotates, the impeller (B), which is connected to the shaft, also rotates. The impeller consists of a number of blades that project the fluid outward when rotating. This centrifugal force gives the fluid a high velocity. Next, the moving fluid passes through the pump case (C) and then into the volute (E). The volute chamber has a uniformly increasing area. This increasing area decreases the fluids velocity, which converts the velocity energy into pressure energy. 2

Determining the System Characteristic

The first step of the experiment is to identify the system characteristic of the pump.

When a pump is fitted in a system, it is tested so as to ensure that the volume flow-rate and head of the pump are within required specifications. The Volume flow rate can be defined as the volume of the fluid that passes through a given surface per unit time, and the head of the pump is a measure of the fluid energy.

In order to do this we must find the pump head and the volume flow rate. We then plot the pump head (expressed in metres) against the volume flow rate (expressed in m3/s). This should yield a curve.

The system head characteristic is dependent on static lift which is associated with change in elevation of the fluid, contraction or expansion of the fluid associated with acceleration and deceleration of the fluid, and the losses within the system. Below is a theoretical graph, showing how the curve should appear.

http://www. climatechange. gov. au/what-you-need-to-know/appliances-and-equipment/electric-motors/system-optimisation/optimising-pump-and-fan-applications/~/media/Images/electric-motor/system-curve. ashx? w= 447&h= 324&as= 1

Example graph for system head characteristic3

When a pump is attached to a system the ‘ operating point’ occurs when the pump head hpump equals the system head hsystem. The optimum operating conditions occur when the required ‘ duty point’ of head and flow intersects the ‘ operating point’ and the ‘ design point’, the point of maximum efficiency.

Single Centrifugal Pump Characteristics

The next aspect of the experiment is to determine the performance of a single pump as a function of motor speed. The performance of a pump is generally mapped by plotting pump head (hpump), electrical power (Pelectrical) and pump efficiency (Î·pump) as a function of the volume flow rate Q through the pump.

The use of a single pump is investigated for three different motor speeds, measuring the effect varying the motor speed has on pump head, electrical power and efficiency. These values are then plotted on a graph against the volume flow rate.

Theoretically;

Higher speeds yield higher efficiency

Higher motor speeds lead to a larger change in power across the system.

Higher motor speeds yield higher head values (expressed in metres).

Double Centrifugal Pump Characteristics

The final aspect of this experiment is the investigation of the effects of the use of two centrifugal pumps on the system. The pumps are placed in series and then in parallel. Both systems, i. e. the pump system which is in series and that which is in parallel are set to the same motor speed. In both cases head, electrical power and efficiency are measured and plotted against volume flow rate. The graph for the system in series can then be compared to the graph for the system in parallel, in order to study and compare the different systems.

Centrifugal pumps both in series are used to overcome larger system head loss than one pump can handle alone, whereas centrifugal pumps in parallel are used to overcome larger volume flows than one pump can handle alone. 4

When running in series, the heads are added and the total capacity is equal to that of the pump with the smallest capacity, whereas in parallel, the capacities of the pumps are added, and the head of all pumps will be equal at the point where the discharged liquids recombine. 5

Theoretically whether the system is in series or in parallel shouldn't affect the efficiency of the system.

Experimental Methods

Equipment Used-

The primary piece of equipment used was the centrifugal pump, a detailed explanation of its operation can be found in the theory section of this report (see page 6).

We also use a differential pressure transducer, which is a type of pressure sensor.

We use a computer to measure and record data.

Methods-

System Head Characteristic

Open valve V1 and close valve V2 located in the inlet pipelines to pumps 1 and 2.

Close valve V3 which connects the outlet pipeline from pump 1 to the inlet pipeline to pump 2

Open valve V4 located in the outlet pipeline from pump 1.

Open the discharge valve V5 to approximately 75% of its fully opened position.

Disconnect the low pressure line connecting differential pressure transducer to upstream of pump 1.

Record the motor speed, the discharge volume flow rate, the pressure measured by the differential pressure transducer and the system head.

Increase the speed of motor 1 incrementally, at each increment repeat the above step and continue to do so until the motor speed had reached its maximum.

Plot the system head characteristic against volume flow rate.

Single Pump

Open valve V1 and close valve V2 located in the inlet pipelines to pumps 1 and 2.

Close valve V3 connecting the outlet pipeline from pump 1 to the inlet pipeline to pump 2

Open valve V4 located in the outlet pipeline from pump 1.

Close fully the discharge valve V5.

Set the speed of the motor connected to pump 1 using the motor speed controller to 45 Hz

Record the Volume flowrate Q, the pump head hp, the electrical power consumed Pelectrical and the pump efficiency Î·pump.

Open valve V5 incrementally, at each increment repeating the above step and continuing until the valve is fully opened.

Plot pump head, electrical power and efficiency against volume flow rate Q at that motor speed.

Repeat the procedure for motor speeds of 35 and 40Hz.

Double Pump

In Series

Open valve V1 and close valve V2 located in the inlet pipelines to pumps 1 and 2.

Open valve V3 connecting the outlet pipeline from pump 1 to the inlet pipeline to pump 2.

Close valve V4 located in the outlet pipeline from pump 1.

Close fully the discharge valve V5.

Set the speed of the both motors connected to pump 1 & 2 to 45 Hz using the motor speed controller.

Record the volume flowrate Q, the pump head hp, the electrical power consumed Pelectrical and the pump efficiency Î·pump.

Open valve V5 incrementally, at each increment repeating the above step and continuing until the valve is fully opened.

Plot pump head, electrical power and efficiency against volume flow rate Q at that motor speed.

In Parallel

Open valve V1 and close valve V2 located in the inlet pipelines to pumps 1 and 2.

Open valve V3 connecting the outlet pipeline from pump 1 to the inlet pipeline to pump 2.

Close valve V4 located in the outlet pipeline from pump 1.

Close fully the discharge valve V5.

Set the speed of the both motors connected to pump 1 & 2 to 45 Hz using the motor speed controller.

Record the volume flowrate Q, the pump head hp, the electrical power consumed Pelectrical and the pump efficiency Î·pump.

Open valve V5 incrementally, at each increment repeating the above step and continuing until the valve is fully opened.

Plot pump head, electrical power and efficiency against volume flow rate Q at that motor speed.

Experimental Results

System characteristic for the fluid system

Below is the table of results for the determination of the system characteristic for the fluid system;

Motor speed N (Hz)

Vol FlowrateQ(m3/s)

â^†Psystem Pa

Hsystem (m)

14

0

0. 716

0. 123333

21

0. 188667

3. 223

0. 376667

25

0. 368333

4. 296667

0. 486667

32

0. 477667

6. 911

0. 753333

35

0. 545667

8. 450667

0. 91

39

0. 647667

10. 06167

1. 073333

42

0. 714

12. 71167

1. 346667

47

0. 796333

14. 93167

1. 573333

The graph for the system characteristic (Hsystem against Volume flowrate) is below:

Graph 1 (System Characteristic)

Single Pump Test

Single Pump Test for Motor Speed 45 Hz-

Below is the table of results for the single pump test at a motor speed of 45Hz;

Vol Flowrate Q(m3/s)

Head (m)

Efficiency %

Power W

0

8. 786667

0

109. 9433

0

8. 443333

0

109. 05

0

7. 116667

0

116. 8633

0

6. 98

0

130. 5333

0

7. 306667

0

163. 25

0. 246333

7. 32

9. 7

181. 8867

0. 332667

7. 186667

11. 9

197. 02

0. 427333

7. 016667

14. 3

205. 6467

0. 537

6. 833333

15. 93333

226. 0733

0. 619667

6. 38

16. 53333

234. 2133

0. 738333

5. 876667

17. 1

249. 1867

0. 781333

5. 703333

16. 76667

260. 4133

The corresponding graphs for the single pump test at motor speed 45Hz are below;

Total Motor

Power (W)

Single Pump Test for Motor Speed 40Hz-

Below is the table of results for the single pump test at a motor speed of 40 Hz;

Vol Flowrate Q(m3/s)

Head (m)

Efficiency %

Power W

0

6. 251868

0

128. 0131

0. 376333

5. 406667

10. 96667

178. 8733

0. 55

5. 19

13. 4

208. 5767

0. 675

4. 706667

13. 7

226. 7267

0. 7335

4. 525

13. 7

237. 915

The corresponding graphs for the single pump test at motor speed 40Hz are below;

Total Motor

Power (W)

Single Pump Test for Motor Speed 35 Hz-

Below is the table of results for the single pump test at a motor speed of 35 Hz;

Vol Flowrate Q(m3/s)

Head (m)

Efficiency %

Power W

0. 054

4. 722434

1. 633333

118. 0014

0. 305667

4. 276667

7. 066667

170. 9

0. 592

3. 65

9. 666667

218. 18

0. 632333

3. 546667

9. 666667

226. 3167

0. 630333

3. 343333

9. 166667

225. 1767

The corresponding graphs for the single pump test at motor speed 35Hz are below;

Total Motor Power (W)

Double Pump Test

System in series-

Below are the results of the double pump test for a system in series-

Vol Flowrate Q(m3/s)

Head (m)

Efficiency %

Power Motor 1 (W

Power Motor 2 (W)

Total Motor Power (W)

0

18. 21333

0

109. 2933

55. 99

165. 2833

0

15. 38

0

128. 4167

54. 69

183. 1067

0. 255667

14. 80333

15. 16667

181. 3167

62. 82667

244. 1433

0. 43

14. 38667

23. 5

201. 0067

57. 37

258. 3767

0. 537667

13. 70667

26. 7

218. 67

51. 43

270. 1

0. 618667

13. 08

26. 86667

240. 3967

54. 44333

294. 84

0. 730333

11. 65

26. 96667

256. 1867

52. 89667

309. 0833

0. 852667

9. 826667

25. 06667

272. 6233

54. 68667

327. 31

0. 883333

9. 863333

25. 16667

278. 16

60. 62667

338. 7867

The corresponding graphs for the double pump test for a system in series are below;

Total Motor Speed (W)

System in parallel-

Below is the table of results for the double pump test for a system in parallel;

Volume Flowrate Q (m3/s)

Head (m)

Efficiency (%)

Motor Power 1 (W)

Motor Power 2

(W)

Total Motor Power (W)

0

9. 19667

0

111. 327

63. 8833

175. 21

0. 277

7. 6

11

134. 847

52. 49

187. 3367

0. 47167

7. 67

17. 3

144. 773

60. 1367

204. 91

0. 598

7. 41667

20. 1333

152. 917

62. 7467

215. 6634

0. 72033

7. 33667

22. 8333

165. 443

61. 28

226. 7233

0. 83633

7. 39667

27

171. 06

53. 3867

224. 4467

0. 97033

7. 11667

27. 7

191. 243

52. 7333

243. 9766

1. 11633

6. 85

28. 3667

201. 337

62. 7433

264. 08

1. 29767

6. 70667

31. 9667

210. 613

56. 2367

266. 85

1. 37667

6. 33

29. 9667

228. 597

55. 6633

284. 26

1. 554

6. 02667

30. 9

241. 21

59. 4867

300. 6967

1. 63033

5. 73

30

244. 14

60. 7933

304. 9333

The corresponding graphs for the double pump test for a system in parallel are below;

Total Motor Power (W)

Discussion & Conclusions

This section of the report contains a discussion of the results obtained along with conclusions drawn from said results and also where necessary, comments regarding any unexpected values.

System Head Characteristic

The first part of the experiment was conducted in order to attain a system head characteristic curve. Volume flowrate, measured in m3/s, was mapped against Head, which is measured in metres. We would expect this to yield a smooth curve starting above the zero mark form the y- axis, in order to allow for static lift in the pump system.

As expected the system head characteristic was found to be a curve, starting slightly above the zero mark on the y axis, therefore for the most part, results were conclusive with theory. However there is one discrepancy between expected results and the actual results obtained, as the curve is not entirely smooth.

Some possible reasons for the slightly irregular shape of the curve are;

Single Pump Test

The second part of this experiment was to investigate the effect changing motor speed has on a pump. In order to conduct this investigation pump head (hpump), electrical power (Pelectrical), pump efficiency (Î·pump) and volume flowrate (Q) were measured for a variety of motor speeds. Then hpump, Pelectrical and Î·pump were mapped against Q for each motor speed. The reason for this being to highlight the effects changing motor speed has on the centrifugal pump system. We expect firstly that higher motor speeds yield higher efficiency, secondly that higher motor speeds lead to a larger change in power across the system and finally that higher motor speeds yield higher head values.

Upon studying the results of the experiment we can see that they match up with theory.

Efficiency-

Theory- Efficiency, simply put, refers to how well a pump can convert one form of energy into another. In this case how well the pump converts rotational kinetic energy into hydrodynamic energy. The overall efficiency of a centrifugal pump is defined as the ratio of the water (output) power to the shaft (input) power. By increasing the speed at which the motor rotates the shaft, the shafts power is increased, therefore the value of efficiency is increased.

Results- Higher motor speeds did in the case of this experiment did yield higher values for efficiency. For a motor speed of 45 Hz the highest efficiency value obtained was approximately 16. 7%, for a motor speed of

40Hz Hz the highest efficiency value obtained was approximately 13. 7% and finally for the lowest motor speed used, 35Hz, highest efficiency was approximately 9. 16%.

Power Change-

Theory- Power can be defined as a work/time ratio. The work in the case of this experiment is the rotation of the shaft by the motor, which in turn creates a centrifugal force in the water. For a faster motor speed, the shaft rotates faster, meaning that more work is done per unit time. This means a greater rise in the power value.

Results- In this experiment, as expected, higher motor speeds yielded larger changes in power across the system. For a motor speed of 45 Hz the rise in power in across the system was approximately 150. 47 watts. For a motor speed of 40 Hz the rise in power in across the system was approximately 109. 9 watts. Finally, for the lowest motor speed used, 35 Hz, the change in power in across the system was approximately 107. 18 watts.

Head-

Theory- Head is the height at which a pump can raise water up. The higher the value of pressure, the higher the value of head will be. Since raising rotational speed strongly affects pressure loss of a fluid, we can see that it also affects head loss.

Results- In this experiment, as expected, higher motor speeds lead to a greater loss in head (measured in metres) across the system. For a motor speed of 45 Hz the drop in head across the system was approximately 3. 09

metres. For a motor speed of 40 Hz drop in head across the system was approximately 1. 727 metres. Finally, for the lowest motor speed used, 35 Hz, drop in head across the system was approximately 1. 38 metres.

Double Pump Test

The final part of the experiment was to investigate (for a fixed motor speed); the

performance of two centrifugal pumps; firstly operating in series and secondly operating in parallel. The two results for the system in series and for the system in parallel could then be compared. In order to conduct this investigation pump head (hpump), electrical power (Pelectrical), pump efficiency (Î·pump) and volume flowrate (Q) were measured, firstly for the system in series and secondly for the system in parallel.

Theoretically, when both systems are set at the same motor speed, the pump in series should have twice the Head value of the system in parallel, whereas the system in parallel should have twice the volume flowrate of the system in series. Meaning that both systems end up with the same mass flow. Whether the pumps are in series or in parallel should have no effect on the efficiency of the system.

Head-

Theory-

Results- As expected the system in series has approximately twice the head value of the system in parallel. (Series18. 22m: Parallel 9. 2m)

Volume Flowrate-

Theory-

Results- As expected the system in parallel has approximately twice the volume flowrate value of the system in series. (Series 0. 883 : Parallel 1. 63)

Mass Flow-

Theory-

Results-

Efficiency-

Theory-

Results-