REHABILITATION OF PUMPS: CASE STUDY OF UNIVERSAL PUMP SET

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Abstract

Laboratory equipment is meant to impart some modules of knowledge unto students of engineering and applied sciences. In other words they are to bridge the gap between theory in the classroom and practical on the field. When there is no sufficient fund to keep this equipment in good condition other avenues must be looked into to avert the dangers of training Engineers and Technicians without the necessary exposure to Laboratory practicals. Equipment worth millions of Naira are lying waste in many institutions of higher learning because nobody cared to take the bull by the horns. The purpose of this project is to rehabilitate laboratory equipment that had been abandoned for many years due to malfunctioning of one or two components. The approach adopted here was to find out the root cause of the problem and proffered a solution. This was done in the case of Universal Water Pump Set located in the fluid laboratory of Mechanical Engineering Department, University of Ibadan, Ibadan. The rig was tested after the repair and maintenance exercises were carried out. The results of performance characteristics carried out on the equipment confirmed that it has been brought back to life. Two laboratory exercises were prepared for each pump to be used by the students as from the next session. The total cost of rehabilitation excluding labour was ₦1700.00.

Introduction

The P6200 series is designed to give complete characteristics of each of the three types of pump, which can be employed. In the case of the positive displacement pumps that is the reciprocating and gear pumps, characteristics are expressed in terms of changes of volumetric efficiency that is the relationship between brake power and water power, with pump speed.

In the case of the centrifugal pump, where there is an inverse but not necessarily reciprocal relationship between the head developed and the volume delivered, the characteristics are conveniently expressed in terms of variation of overall efficiency and manometric head with pump speed.

The main focus of this work is to carry out repair and maintenance work on the machine to bring it back to the normal working condition. This was done systematically using diagnosis techniques and trouble shooting strategies to get to the root cause of the problem. To do this exercise successfully there is need for close interaction with the machine on daily basis.

In principle two series of test can be run fully using the Cusson universal water pump test to establish a set of pump characteristics. These are the constant and variable speeds.

Performance Parameters

The pump performance parameters are capacity, head, power, efficiency required and available net positive suction head, and specific speed.

Pump Capacity

The capacity of a pump (Q) is the volume of water per unit time delivered by the pump. In S.I units, it is usually expressed in litre per minute, cubic litres per second. Other units are: gallons per minute (gpm) and cubic feet per second (cfs).

Head

This is the network done on a unit weight of water by the pump. It is given by:

$$H = \left(\frac{P}{\rho g} + \frac{v^2}{2g} + z \right)1 - \left(\frac{P}{\rho g} + \frac{v^2}{2g} + z \right)2$$

where P = water pressure (kPa,Psi)

ρg = specific weight of fluid

v = water velocity (m/s)

g = acceleration due to gravity (9.8 m/s^2)
1 = discharge
2 = suction
z = elevation heads in metres

Power

The power imparted to the water by the pump is called water power.

WP = QH / K
WP = water power (kW, hp)
Q = Pump Capacity   (Litre / min, m^3/ s)
H = head (m)

K = unit constant (K = 6116 for Wp in kW and Q in Litre/min, K = 0.102 For Wp in kW and in m^3/s, K = 3960

Efficiency (Ep)

Pump efficiency is the percentage of power input to the pump shaft (the brake power) that is transferred to the water.

E_p = 100. (Wp / $B_{p)}$

where Ep = pump efficiency
W_p = water power (kW)
B_p = brake power (kW)

Required Net Positive Suction Head (Npshr)

The required net positive suction head (NPSHr) is the amount of energy required to prevent the formation of vapour-filled cavities of fluid within the eye of single stage impellers. These cavities, which form when a pressure within the eye drop below the vapour pressure of water. Collapse of this vapour -filled cavities is called cavitation. When these collapses occur violently on interior surfaces of the pump they produce ring shaped indentations on the surface called pits. Continued cavitation and pitting can severely damage pumps and must be avoided. The net positive suction head required to prevent cavitation is a function of pump design and usually determined experimentally for the pump. Cavitation is prevented when heads with the eye of single and first stage impellers exceed the NPSHr values published by the manufacturers.

Specific Speed

Specific speed (Ns) is an index to pump performance derived using dimensional analysis. It consolidates a pump speed, design capacity, and head into one term.

$$N_s = \frac{NQ^{1/2}}{H^{1/4}}$$

where Ns = Specific speed (r p m)
N = pump speed (r p m)
Q = pump design capacity (gpm)
H = design head (H)

Geometrically similar pumps have similar performance characteristics and identical speed regardless of their size.

The operating properties of a pump are established by the geometry and dimension of the pump's impeller and casing. Curves (figure) relating head, efficiency, power and required net positive suction head pump capacity is utilized to describe the operating properties (characteristics) of a pump These are:

(1) Head versus pump capacity.
(2) Brake power versus pump capacity.
(3) Efficiency versus pump capacity.
(4) Required net positive suction head versus pump capacity.

Test Procedure

This Universal water pump set is capable of performing two series of tests and these must b run fully to establish a set of pump characteristics at constant and variable speeds.

Constant Speed Tests
(a) Reciprocating Pump

Gradually increase the voltage applied to the motor until the pump is running at the operatii speed.

. Adjust the delivery pressure to the maximum value.
. Record the shaft speed.
. Measure the water flow rate by recording the time taken to collect a measured volume of water.
. Read suction and delivery pressures and so obtains the total pressure gain.
. Repeat this procedure for lower values of delivery pressure.

(b) Gear Pump

Repeat The Procedure For The Reciprocating Pump in (a)

(c) Centrifugal Pump

Bring the pump gradually up to the selected operating speed and open inlet and ou valves to allow maximum delivery.

. Note suction and delivery pressures
. Note brake load
. Note flow rate
. Repeat for increments of delivery pressure closing the delivery valve in several steps.

Calculation of Pump Characteristics Parameters
(i) Water Power (kW) $= \rho g Q H . 10^{-3}$
where

ρ = Density of water (kgm^{-3})
g = Acceleration due to gravity (m/s^2)
Q = Volumetric flow rate (m3/s)
H = Head gain (m)
P = (Delivery pressure - suction pressure) (bar) This is a negative quantity

(ii) Brake power (kW) $= 2\pi S_m L R . 10^{-3}$
where S_m = motor speed (rev/s)
L = brake load (N)
R = Torgue arm radius (m)

(iii) Overall Efficiency, % = Water Power/Brake Power

(iv) Manometric Head, (Hm): This is the head gain under waterpower above [for centrifugal test only]

(v) Volumetric Efficiency, % = Recorded Volumetric flow rate/Calculated Volumetric flow rate Q/Q_c

The calculated volumetric flow rate Q_c is obtained as follows:

(a) For Reciprocating Pump

Q_C = AP LS_P (m3/s)

where Ap = Total cross sectional area of cylinder (m^2)

L = Stroke of piston (m)

S_p = Pump speed (rev/s)

(b) For Gear Pump

An approximate value for the calculated volumetric flow rate Q_c can be derived from the

$$Q_c = (D_o^2 - D_i^2)\pi t S_p x 10^{-10} (m^3/s)/4$$

formula below, which applies only to involute gears:

in which

D_o = outside diameter of gear wheel (mm)

D_1 = working depth diameter of gear wheel (mm)

t = face width of gear (mm)

S_p = Pump speed (rev/s) and

$D_o = D + 2/P_d$

$D_1 = D - 2/P_d$

where D = pitch diameter (mm)

P_d = diametrical pitch (mm^{-1})

Variable Speed Tests

Variable speed tests as another alternative test type can be carried out with Reciprocating and Centrifugal pumps. The output flow rates of which only vary significantly if the pump speed is changed.

The Test Procedure

.Pump is slowly run up to maximum speed and delivery pressure.

.Readings of delivery pressure, suction pressure, brake load, pump speed and volumetric flow rate are taken.

.The pump speed is reduced in suitable decrements and the delivery valve adjusted to maintain a constant pressure.

.The set of readings above is taken in each case.

This procedure of taking readings at different pump speeds while maintaining various constant pressures across the pump can be repeated at different pressures levels so that carpet characteristics graphs are obtained (Figure 2.0).

Discussion of Results

Observing the results obtained for the three pumps (Gear, Reciprocating and Centrifugal) shown in Tables 1,2 and 3 respectively, as well as Figures 3-8, one can rightly say that:

(1) The three pumps are now perfectly okay, meaning that those parameters obtained are reasonable enough.

(2) The parts that were not functioning properly before the rehabilitation exercise are now in good condition.

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(3) The Universal pump rig is now ready for students as from next academic session to perform relevant experiment on it.

(4) The amount of money incurred in the process of rehabilitation is very small compared to the amount the equipment worth in Naira and the benefits students would derive in using it for practical.

Conclusion

A lot of constraints are militating against effective maintenance operations of our equipment especially in developing countries. Though, the equipment and tools may be available to some extent, if required quantity of craftsmen are not adequate it would result in deterioration of our facilities or over labouring of the available ones. From the results obtained after the necessary repair and maintenance carried out on the equipment, it showed that it is a profitable venture. Apart from making the facilities available for training during practical hours, final year students have the opportunities of good exposure in carrying out these exercises as their project work before they graduate. I will therefore recommend that Lecturers and Students of Engineering Faculties should be more involved in design, fabrication and operation of laboratory equipment, and rehabilitation of broken ones.

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Table 4.0 Cost of Rehabilitation Exercise

S/R	Description	Cost (N)
1	2 Litre of Petrol	40.00
2	Compression Spring	60.00
3	Brush	25.00
4	Screw Driver	45.00
5	Texaco Grease	80.00
6	Set of Spanner	150.00
7	Tape(2)	40.00
8	Porte	50.00
9	Gasket Gum	70.00
10	Foot Valve	350.00
11	Rubber Connector	40.00
12	Repair On Belt	60.00
13	Stop Watch	500.00
14	Transportation	200.00

Figure 3.0 Performance characteristics curves(Gear Pump)

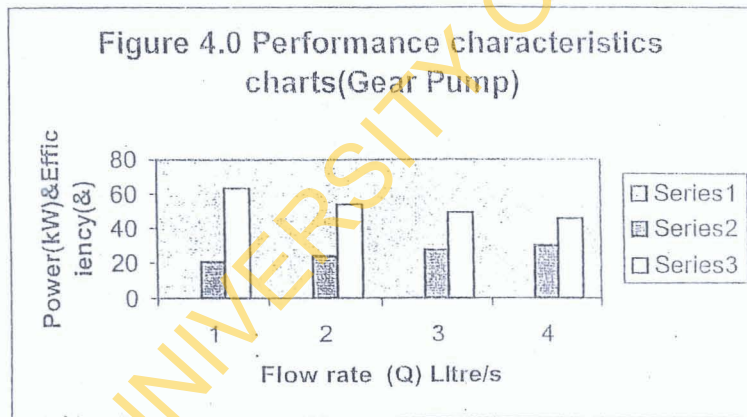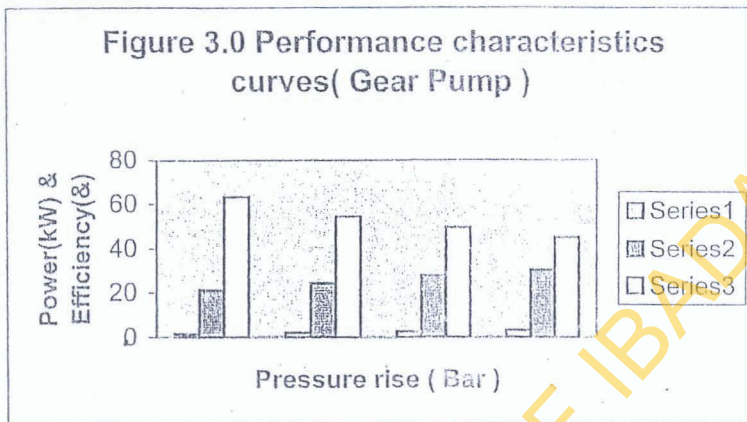Figure 4.0 Performance characteristics charts(Gear Pump)

Table 1: Rehabilitation Test Results

Date: 19-05-2000

Cussion Universal Pump Set Unit P. 6200

Type of Pump Gear Model No: P 6202 — Motor: Pump Speed Ratio 3:1 Torgue ARM Radius) 0.15m

Test No	Motor Speed (Rev/s)	Pump Speed Rev/s	Outlet Delivery P1 (bar)	Inlet Suction P2 (bar)	Outlet Delivery P3 (bar)	Pressure Rise P1-P2 (bar)	Pressure Rise P3-P2 (bar)	Head Gain (m)	Time to Collect 15 litres (Secs)	Flow Rate (Litres/s)	Spring Dynamometer Reading (N)	Water Power (Kw)	Break Power (Kw)	Volumetric Efficiency %	Overall Efficiency %
1	12	4	1.5		0	1.5		15.29	1.5	0.14	6.5	20.999	73513.3	63	29
2	12	4	0	1.5		2		20.387	2.05	0.12		8.75	23999	54	25
3	12	4	2.5	0		2.5	25.484	2.18	0.11	10.75	27500		121579.6	49	23
4	12	4	3	0		3		30.581	2.36	0.1	15.25	29999	163991	45	18

Head gain is applicable to gear and reciprocation pumps. For centrifugal pumps, it is termed manometric head

Table 2: Rehabilitation Test Results

Date: 19-05-2000

Cussion Universal Pump Set Unit P. 6200

Type of Pump Gear Model No: P 6202 — Motor: Pump Speed Ratio 3:1 Torgue ARM Radius) 0.15m

Test No	Motor Speed (Rev/s)	Pump Speed Rev/s	Outlet Delivery P1 (bar)	Inlet Suction P2 (bar)	Outlet Delivery P3 (bar)	Pressure Rise P1-P2 (bar)	Pressure Rise P3-P2 (bar)	Head Gain (m)	Time to Collect 15 litres (Secs)	Flow Rate (Litres/s)	Spring Dynamometer Reading (N)	Water Power (Kw)	Break Power (Kw)	Volumetric Efficiency %	Overall Efficiency %
1	15	3	3	1.5		-0.125	1.625	16.565	1.09	0.22	9	35760	127234	44	29
2	15	3	2	-0.125		2.125		21.662	1.11	0.21	9.5	44630	134303	86	33
3	15	15	2.5	-0.125		2.625		26.758	1.15	0.2	11.5	52499	162577	82	32
4	15	3	3	-0.125		3.125		31.906	1.21	0.19	13	56340	183783	74	31

Head gain is applicable to gear and reciprocation pumps. For centrifugal pumps, it is termed manometric head

Table 3: Rehabilitation Test Results

								Date: 19-05-2000							
					Cussion Universal Pump Set Unit P. 6200										
Type of Pump Gear Model No: P 6202					Motor: Pump Speed Ratio 3:1 Torgue ARM Radius) 0.15m										
Test No	Motor Speed (Rev/s)	Pump Speed Rev/s	Pressure Gauge Reading			Pressure Rise P1-P2 (bar)	Pressure Rise P3 –P2 (bar)	Head Gain (m)	Time to Collect 15 litres (Secs)	Flow Rate (Litres/s)	Spring Dynamometer Reading (N)	Water Power (Kw)	Break Power (Kw)	Volumetric Efficiency %	Overall Efficiency %
			Outlet Delivery P1 (bar)	Inlet Suction P2 (bar)	Outlet Delivery P3 (bar)										
1	12	24		-0.06	0.35		0.41	4.41	1.26	0.17	9.5	24600	107443	24	23
2	12	24		-0.06	0.3		0.36	3.67	1.17	0.19	10	27002	113097	26	24
3	12	24		-0.07	0.25		0.32	3.26	1.01	0.24	10.5	28800	118752	33	24
4	12	24		-0.09	0.2		0.29	2.96	0.57	0.26	12.5	29038	141372	36	21
Head gain is applicable to gear and reciprocation pumps. For centrifugal pumps, it is termed manometric head															