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Performance Investigation of Diaphragm Pump for Various Operating Parameters

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ABSTRACT:

A performance test of a hydraulic diaphragm pump is conducted to analyse the various operating parameters and its effect on the diaphragm pump. A diaphragm pump is a positive displacement pump. This pump works with using a blend of the reciprocating action of a diaphragm an appropriate valve on any face of the diaphragm to push a liquid with high pressure. Diaphragm pump fundamentally different from centrifugal pumps, because of its operating principle. The liquid flows intermittently due to the alternation of suction and discharge. This effect of the diaphragm pump is called as a pulsation. Due to this pulsation effect, it is necessarily to characterize the performance parameter of the diaphragm pump. In this test the interaction relationship of key parameters of pump and its influence on the performance of diaphragm pump is determine, analyse and collate with reciprocating pump. Pump curves are quite useful in the pump selection, testing, operations and maintenance.

Keywords: Diaphragm pump, 3-Plunger Reciprocating pump, Head Capacity, Performanceparameters,Overall Efficiency, Volumetric Efficiency, Characteristics curves

NOMENCLATURE

$I = Current$
V = Voltage
Eff= Effectiveness
PF= Power Factor
Q= Actual Discharge
ΔP= Pressure Difference
n= rpm
V= Volume /Displacement, m3 /min
r= Radius of diaphragm, m
h= Displacement of diaphragm,
d = Outer diameter of Piston (m)
l = Displacement of piston/ stroke of piston(m)
$QAct = Actualdischargemeasured$
$QTh = TheoreticalDischarge$
$\eta overall = OverallEfficiency$
$\eta Vol = VolumetricEfficiency$
$Pinput = PowerInputtoPump$
$Poutput = PowerOutputof$ pump

1.Introduction:

A diaphragm pump is also called as a membrane pump. A diaphragm pump uses a combination of the reciprocating action of a diaphragm and suitable valves on either side of the diaphragm (Check valve, butterfly valves or any other form of shut-off valves) to pump a fluid. Simple Diaphragm pump consists of a diaphragm, displacement chamber two valves and a driving mechanism.

In this performance test, the relationships of the key parameters of the diaphragm pump and its influence and effect on the performance **is** determined and analysed. It then also collates with the reciprocating pump. Basically, characteristic curves are used as a tool to determine and understand the basic parameters. Pump curves are quite useful in the pump selection, testing, maintenance, operation and replacement. The operating parameters mainly used to pick the correct pump for an application.

In this work we have developed

1 Pressure vs discharge

2. Pressure vs Volumetric Efficiency

3. Pressure vs Overall Efficiency

The working principle of the hydraulic diaphragm pump is to deliver working fluid and increase its pressure that relays on the periodic changes of working volume. The hydraulic diaphragm pump has many characteristics, and have small noise, strong sealing, simple maintenance, safe discharge devices and soon.

The diaphragm pump as is a positive displacement pump which is suitable for the high pressure, medium and small mass flow rate due to good airtightness, small volume, light weight and convenient maintenance. Many studies are restricted to obtain actual efficiency and power input of the diaphragm pump at various operating parameters. Very few studies have specially concentrated on the effect of different operating conditions and parameters that is why if is most important to classify the operating parameters as per the requirements of the diaphragm pump.

In this test we have used 'G21' shaft driven with polypropylene pump head type of diaphragm pump of hydra cell. It is basically most suitable pump to determine and analysis of the operating parameter such as maximum inlet and discharge pressure. Each hydra cell pump has different lift capability depending on model size, cam angle, speed and fluid characteristics.

2.EXPERIMENTTAL SETUP

The experimental setup consists of the following components.

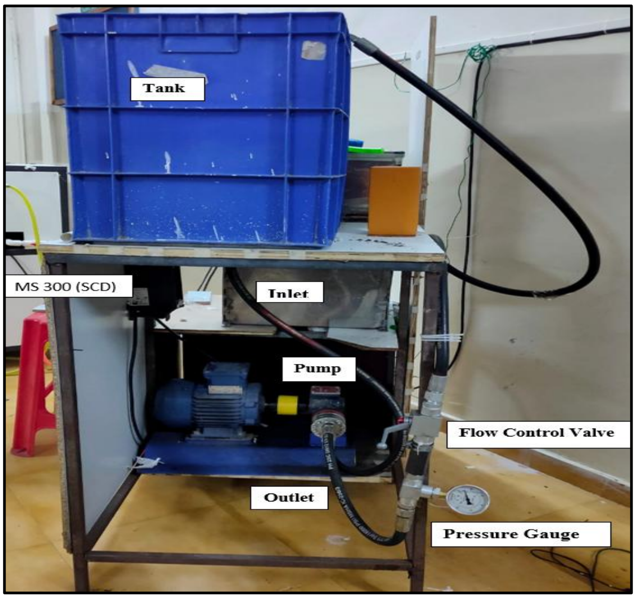

Figure 2. Experimental Setup for Diaphragm Pump

Figure 1. Experimental Setup for Reciprocating Pump

2.1 Diaphragm pump and Electric Motor: A diaphragm pump is a hydraulically or mechanically actuated positivedisplacement pump that uses a combination of reciprocating action and either a flapper valve or a ball valve to transfer liquids.Diaphragm pumps are self-priming and are ideal for viscous liquids. Virtually all major industries utilize diaphragm pumps. They are commonly used to move abrasive fluids, including concrete, or acids and chemicals. They are also common in automobiles and aircraft.

2.2 Pressure Gauge: Pressure gauges are instruments designed to measure the pressure of media in a system. Measuring the pressure in your system is a critical quality step to ensure consistency of a product and safety check to be aware of leaks or building pressure in a system. A Pressure gauge of 1500 psi was used in the setup.

2.3 Flow Control Value: Flow control valves are any devices manufactured for the purpose of modifying the rate of fluid flow or pressure. They are designed to fit complex pneumatic and hydraulic systems. The flow control valves respond to signals generated by devices like temperature gauges or flow meters. The valves have simple tool orifices with a complex set of electro-hydraulic valves to adjust to the different variations in pressure and system temperature

2.4 Tank/ Reservoir:A hydraulic tank is an important part of a hydraulic power unit and represents the heart of the hydraulic system. The primary function of any tank is the storage of substances or fluids. In our case, the tank must retain the total quantity of hydraulic water, which is located in the hydraulic system. In addition, the hydraulic tank should compensate for oil level oscillation due to temperature changes or possible leakage from the system.

2.5 MS 300 – Controller: The Delta MS300 series are new generation compact AC drives that are Vector control capable. Delta MS300 drives are built with Delta's superior drive technology with a significant reduction of size compared to previous drive products. Delta MS300 features flexibility as this drive supports both Induction Motors (IM) and Permanent Magnet (PM) motors and provides Safe Torque-Off (STO) safety capability.

2.6 Hoses:A hose is a flexible hollow tube designed to carry fluids from one location to another. Hoses are also sometimes called pipes, or more generally tubing. The shape of a hose is usually cylindrical. Hose design is based on a combination of application and performance.

3. DATA REDUCTION

3.1Calculation for Overall Efficiency

Power Input

$$P_{input} = V \times I \times Eff \times PF \times 1.732$$

Where,

$I = Current$

$V =$ Voltage

Eff= Effectiveness

PF= Power Factor

Constant for 3 Phase electric motor = 1.732

Power Output

$P_{output} = Q \times \Delta P$

Where, Q= *Actual Discharge*

ΔP= *Pressure Difference*

ΔP = *Outlet Pressure – Atmospheric Pressure*

Overall Efficiency

$$\eta_{overall} = \frac{P_{output}}{P_{input}} \times 100$$

3.2Calculation for Volumetric Efficiency

Theoretical Discharge

$Q_{Th} = n \times V$

Where, n= *rpm*

V= *Volume /Displacement, m^3/min*

$$V = \pi r^2 \times \frac{h}{3}$$

r= *radius of diaphragm, m*

h= *displacement of diaphragm, m*

$$V = \frac{\pi}{4} d^2 \times l$$

d = *outer diameter of Piston (m)*

l = *displacement of piston/ stroke of piston(m)*

$Q_{Act} = Actual\ discharge\ measured$

Volumetric Efficiency

$$\eta_{Vol} = \frac{Q_{Act}}{Q_{Th}} \times 100$$

4.RESULTS AND DISCCUSION

4.1 Head Capacity Characteristic curve

The variation of the discharge with respect to the outlet pressure using two different working fluid pumps is shown in the figure 15. As seen

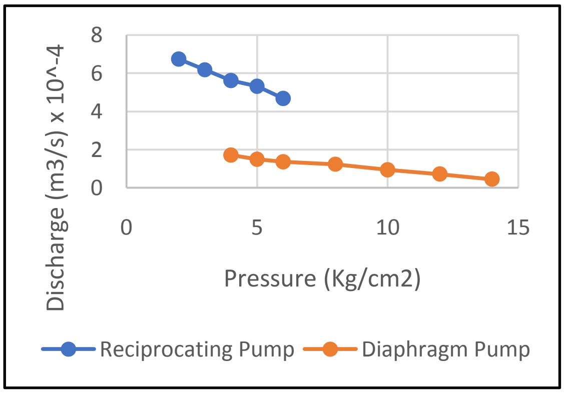

Figure 3. Pressure vs Discharge Curve

in the diagram the discharge of the metering hydra-cell G21 series diaphragm pump varies from 5.1 x 10^{-5} m^3/s to 2.2 X 10^{-5} m^3/s. when it gets compared to the 3-plunger reciprocating pump it varies from 6.73 x 10^{-4} m^3/s to 4.68 x 10^{-4} m^3/s. The discharge gets reduce linearly with increase in pressure, however the reciprocating pump gives more discharge as we compare it with that of metering diaphragm pump.

Metering diaphragm pump provides more concentrated high pressure with that of low discharge while in comparison to 3-plunger reciprocating pump where the high head capacity is required with that of moderate pressure. Metering diaphragm pump should be usable at high pressure and low head capacity just like that in spraying industry, while 3 plunger reciprocating pump is best suitable for using general fluids supply factories and dairy industry.

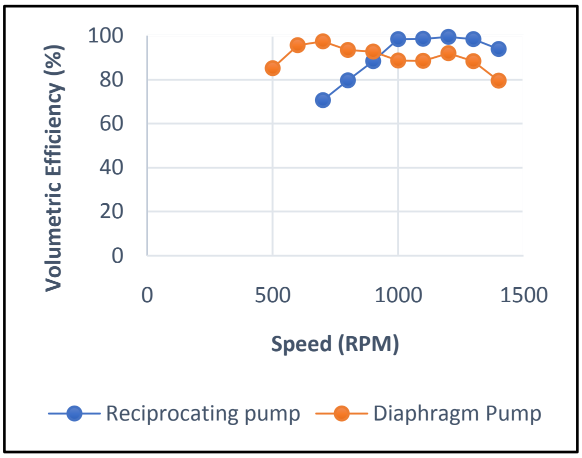

Figure 3. Speed vs Volumetric Efficiency

4.2Volumetric Efficiency curve

The volumetric efficiency of the metering diaphragm pump and three plunger reciprocating pump is analyzed in the fig. The volumetric efficiency vs speed is plotted against each other. The speed and discharge are the parameters measured from the setup and Volumetric efficiency is calculated by the ratio of actual discharge to the theoretical discharge of the pump. Within the speed limit of the pump within the speed limit of a 0 to 1400 RPM. The volumetric efficiency of the metering diaphragm pump varies with that of variation in the speed greatly it increases in first quarter then decreases minimal and moves forward with increase. The variation occurs linearly from the value of 70.64% to the 98.31%. The volumetric efficiency of the three-plunger reciprocating pump varies from the range of the 70.64% to the 99.37%.

The volumetric efficiency when put up against the speed of pump it sometimes gradually increases and decreases. The main causes of the decrease in the volumetric efficiency are the air or a vapor in the inlet line, loose belts for the three plungers reciprocating pump. While volumetric efficiency can decrease significantly due to the pressure of the free gas between the diaphragms of the metering Diaphragm pump. The proper maintenance and cleaning of the both pumps will gradually increase the volumetric efficiency.The volumetric efficiency of the 3-plunger reciprocating pump increases 28.73% more as that of metering diaphragm pump which increases 17.80% with increase in speed.

4.3 Overall Efficiency Curve

Overall Efficiency curve is plotted between Pressure and Discharge. Pressure is measured from the setup by using Bourdon Pressure Gauge and the overall efficiency is calculated as the ratio of output power to the input power of the pump.

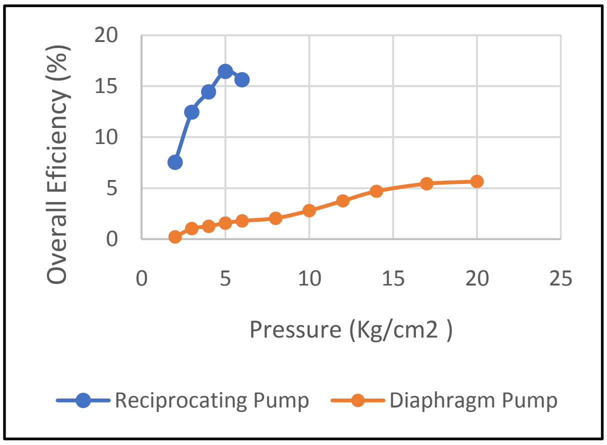

Figure 4. Pressure vs Overall Efficiency

The overall efficiency increases from 7.53-16.45% with increase in pressure from 2-5 kg/ cm2, and decreases overall efficiency from 16.45-15.63% with increase in pressure from 5-6 kg/cm2 for 3-plunger reciprocating pump while for metering Diaphragm pump the overall efficiency varies between 0.22% to 5.65% within the pressure range of 1-21 kg/cm2.The overall efficiency increases with increase linearly with increase in pressure from 1.4 kg/cm2, i.e., 20 PSI to 14 kg/cm2 i.e., 200 PSI. Later that the Overall Efficiency increases logarithmically form 14 kg/cm2 to 21 kg/cm2, the efficiency increases from 3.75-5.65% within this range.

The overall efficiency and pressure of the both pumps are compared. As the pressure of the both pump increases, the overall efficiency increases gradually to the certain limit, then with greater pressure the overall efficiency decreases beyond the 22 kg/cm2 for the diaphragm pump and in case of three plungers reciprocating pump it decreases beyond the range of pressure from 7 kg/cm2 to forward. As the pressure increases gradually the overall efficiency of the metering diaphragm pump increases 5.43% while efficiency for reciprocating pump increases 8.1% with increase in its pressure.

5.CONCLUSION

The performance of diaphragm pump is investigated for different working parameters. The Diaphragm pump have been compared with the 3-Plunger Reciprocating pump. The characteristics curves for various operating parameters like Overall Efficiency, Volumetric Efficiency, Head capacity were calculated. Characteristic curves are used as a tool to determine and understand the basic parameters of a component. Pump curves are quite useful in the pump selection, testing, operation and maintenance.Pump curves are used to pick the correct pump for an application.

At 5 kg/cm^2 pressure the discharge of the 3-Plunger reciprocating pump is 72% more than metering diaphragm pump. The volumetric efficiency of the diaphragm pump is 27.39% more than 3-plunger reciprocating pump at the speed of 700 rpm, And 8% lower at 1200 rpm. The overall efficiency of the 3-plunger reciprocating pump is 84% more at 6 kg/cm^2 pressure.

It is observed that the diaphragm pump is suitable when the pressure need is high and the discharge required is low. It is also observed that the overall efficiency and volumetric efficiency of the diaphragm pump is less than the 3-plunger reciprocating pump. When the requirement for discharge is high then it is suggested to use 3-plunger reciprocating pump like in dairy plants, oil & gas pipelines. As the pressure of diaphragm pump is very high compared to other reciprocating pumps it is used in application like Corrosive chemical, volatile solvents, viscous, Shear-sensitive foodstuffs, Pharma product, Sticky fluids, dirty water, smaller solids, creams, Abrasive slurry, Oils and gels.

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