International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 07 Issue: 04 | April - 2023 Impact Factor: 8.176 ISSN: 2582-3930

Design and Fabrication of Reciprocating Pump Test Rig

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ABSTRACT

The design and fabrication of a reciprocating pump testing rig involves the creation of a system for testing the performance of reciprocating pumps. The rig consists of a pump, a motor, a control panel, and a data acquisition system. The design process involves selecting the appropriate components, sizing them, and integrating them into a functional system. The fabrication process involves assembling the components, testing the system for functionality and safety, and calibrating it for accurate performance measurement. The rig can be used to evaluate the pump's capacity, efficiency, and reliability under various operating conditions. This information can be used to optimize pump design and operation, as well as to diagnose and troubleshoot any issues that may arise.

Key words: discharge, reciprocating, velocity, force.

1. INTRODUCTION

A reciprocating pump test rig is a device designed to measure the performance and characteristics of reciprocating pumps. This rig consists of various components, including a reciprocating pump, a motor, a control panel, a flow meter, a pressure gauge, and valves. The pump is driven by an electric motor, which is controlled by the control panel. The flow meter measures the flow rate of the fluid, while the pressure gauge measures the pressure of the fluid. The reciprocating pump test rig is used to evaluate the performance of the pump, such as the discharge pressure, flow rate, power consumption, and efficiency. It is also used to determine the optimum operating conditions of the pump, such as the pump speed and valve positions. The test rig is capable of measuring various parameters, including the head, discharge, suction, and power consumed by the pump. The reciprocating pump test rig is widely used in industries such as oil and gas, chemical, and water treatment plants. It is essential in ensuring the efficient and reliable operation of the pump and minimizing downtime due to pump failure. By testing and evaluating the pump performance, engineers and technicians can identify any issues or potential problems and take corrective actions to maintain the pump's performance and prolong its lifespan. Figure 1 shows a single-acting reciprocating pump.

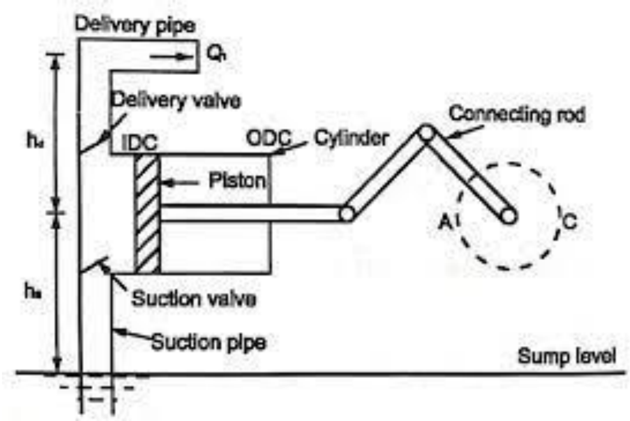

Fig. 1 Single-acting reciprocating pump

2. LITERATURE REVIEW

Libou et al. [1] compared theoretical solutions with experimental measurements of induced flow in a reciprocating pump. Kilsung et al. [2] integrated an electromagnetic air pump with a proton exchange membrane fuel cell. Deliang Yu et al. [3] proposed a new method for identifying the working conditions of a submersible reciprocating pumping system. Ragoth Singh and Nataraj [4] used computational fluid dynamics to simulate the flow within a triplex-reciprocating pump and compared the results with experimental data. Herbert [5] discussed the selection of components for a reciprocating pump for good operating and reliability. Mahmoud [6] presented a theoretical study to reduce the starting torque of a non-conventional reciprocating piston pump using new methods. Shuaibu [7] designed and fabricated a hydraulic pump capable of lifting water from a depth of 2 m without an external energy source. Junfeng et al. [8] developed a finite element analysis model of a reciprocating pump valve’s collision contact and its effect on pump performance. Krishnan et al. [9] studied the behavior of dense slurry flow in a centrifugal pump casing using computational fluid dynamics. Pagalthivarthi and Visintainer [10] solved the continuity and momentum equations governing multi-size slurry flow through pump casings using a penalty finite element formulation.

3. MATERIALS AND METHODS

The design of piston and cylinder dimensions are taken from the single-acting pump [11]. The dimensions of the cylinders are: cylinder (C1) diameter =160 mm, thickness of the cylinder =20 mm, length of the cylinder (C1) =284 mm. The dimensions of the pistons are: diameter of the piston (P1) =70 mm. Length of the piston (P1) =264 mm. The dimensions of other components: crank radius =192 mm, difference in valve between the centre =0.94, crank speed =440 rpm, crank angle =360°, input power =0.15625 kW, total head =5.48 m, pump efficiency =88 %, maximum percentage of slip =39.2 %, coefficient of discharge =0.6427, pressure head =0.3 kg/cm^2, actual discharge =0.0023 m^3/sec and theoretical discharge =0.00030 m^3/sec.

3.1 Model of single -acting reciprocating pump

A single-acting reciprocating pump is a type of positive displacement pump that is designed to move fluid in both directions of the pump stroke. This type of pump is commonly used in a variety of applications, including water treatment, oil and gas production, and chemical processing .The basic design of a single-acting reciprocating pump consists of a piston that moves back and forth within a cylinder. The cylinder is filled with fluid, and as the piston moves forward, it compresses the fluid and forces it out of the pump through a discharge valve. As the piston moves back, it creates a vacuum that draws fluid into the pump through an inlet valve.

The key components of a single-acting reciprocating pump include:

Piston: The piston is a cylindrical component that moves back and forth within the pump cylinder. It is usually made of metal or other durable materials and is designed to create a seal between the pump cylinder and the fluid being pumped.

Cylinder: The cylinder is the main body of the pump and is typically made of metal or other durable materials. It contains the piston and the fluid being pumped.

Inlet valve: The inlet valve is a one-way valve that allows fluid to enter the pump on the intake stroke of the piston.

Discharge valve: The discharge valve is a one-way valve that allows fluid to exit the pump on the discharge stroke of the piston.

Crankshaft: The crankshaft is a rotating shaft that is connected to the piston and is used to convert the reciprocating motion of the piston into rotational motion.

Connecting rod: The connecting rod is a component that connects the piston to the crankshaft and transfers the reciprocating motion of the piston to the rotating motion of the crankshaft.

3.2 Cross-sectional model - Single-acting pump

Figure 3 shows the cross-sectional model of a two-acting reciprocating pump typically consists of several components that work together to increase the discharge rate of fluid.

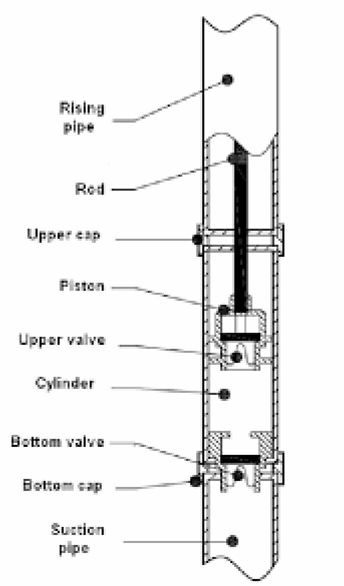

Fig. 3 Cross-sectional model –Single-acting pump

3.3 Analysis of Single-acting cylinder

A single-acting cylinder is a type of hydraulic or pneumatic actuator that is capable of providing force in both directions. It consists of a cylindrical body with a piston and piston rod assembly that can move in both directions inside the cylinder. The two ends of the cylinder are fitted with ports, which allow fluid to enter and exit the cylinder.

When fluid is pumped into one port of the cylinder, it pushes the piston in one direction, creating force and motion. The fluid on the opposite side of the piston is allowed to escape through the other port. When the fluid is pumped into the other port, the piston moves in the opposite direction, creating force and motion in the opposite direction. The cycle continues as fluid is alternately pumped into each port, allowing the piston to move back and forth

Observation Table: -

Sr. No	Delivery Pressure In KG/CM^2 (P)	Suction Pressure mm of Hg (Pv)	Time for 30 Sec of energy meter(t) sec	Rise in Water Level(R) in mm	Discharge Time Of Collection (T) in sec
1	1	30	100	100	38
2	2	20	94	100	40
3	3	10	87	100	55

Formulae:

1. Electric power (HPelec) as indicated by Energy meter

$$HP_{\mathrm{elec}} = \frac{5}{375} \times \frac{1000}{736} \times \frac{3600}{\mathrm{T}} \times \eta$$

T = time taken by the energy meter for 5 revolutions in 'sec'
n = considering the efficiency of the motor 70% = 0.7

2nd reading calculation
1. Electric power (HP elec) as indicated by Energy meter

$$\mathrm{HP_{elec}} = \frac{5}{375} \times \frac{1000}{736} \times \frac{3600}{\mathrm{T}} \times \eta$$

$$\mathrm{HP_{elec}} = \frac{5}{375} \times \frac{1000}{736} \times \frac{3600}{94} \times 0.7 = \mathbf{0.479}$$

$$2.\ \mathrm{Q} = \frac{\mathrm{AR}}{\mathrm{t}} = \frac{0.12\times0.1}{40} = 3 \times 10^{-4}\ \mathrm{m^3/s}$$

$$3.\ \mathrm{H} = 10\left(\mathrm{P} + \frac{\mathrm{p_v}}{760}\right) = 10 \times \left(2 + \frac{20}{760}\right) = 20.263$$

$$4.\ HP_{\mathrm{pump}} = \frac{\rho QgH}{736} = \frac{1000\times3\times10^{-4}\times9.81\times20.263}{746} = \mathbf{0.079}$$

$$5.\ \eta_{pump} = \frac{HP_{pump}}{HP_{elec}}\times100 = \frac{0.079}{0.479}\times100 = \mathbf{16.492}$$

4. RESULTS AND DISCUSSION

Reciprocating pumps are positive displacement pumps that use a reciprocating motion to transfer fluids. They are commonly used in a variety of industrial and commercial applications such as oil and gas production, chemical processing, and water treatment.

To test the performance of a reciprocating pump, a test rig is typically used. The test rig is a setup that simulates the actual operating conditions of the pump and allows engineers to measure and analyze various parameters such as flow rate, pressure, power consumption, and efficiency.

During the testing process, the pump is operated under different conditions such as varying flow rates, pressures, and fluid types. The data collected from these tests can be used to optimize the pump's design, identify potential issues, and improve its overall performance.

In the discussion section of a reciprocating pump test rig report, the engineers may analyze and interpret the results obtained from the tests. They may discuss the efficiency of the pump under different operating conditions, identify any limitations or issues encountered during the testing, and suggest recommendations for improving the pump's performance.

Additionally, the report may include comparisons between the test results and the pump's design specifications or industry standards. The engineers may also discuss the potential applications and limitations of the pump based on the test results.

Overall, the result and discussion section of a reciprocating pump test rig report provides valuable insights into the performance and potential applications of the pump, and can guide further research and development efforts.

5. CONCLUSION

Reciprocating pumps are a type of positive displacement pump, which means that they displace a fixed amount of fluid with each cycle of operation. In the case of reciprocating pumps, this is achieved through the reciprocating action of the piston in the cylinder.

The single-acting piston pump is designed to discharge water during both the forward and return strokes of the piston. This allows for a more continuous flow of fluid compared to a single-acting pump, which only discharges fluid during the forward stroke. To test the performance of a reciprocating pump, various parameters such as flow rate, pressure, and power consumption are measured under different operating conditions. These tests help to determine the efficiency and reliability of the pump and identify any potential issues that may need to be addressed.

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