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Modelling and Performance Evaluation of a Duplex Reciprocating Pump

R. Ravivarman* **and U. Mohammed Iqbal****

Abstract: Reciprocating pump uses the pumping action to move fluids by a plunger or piston that travels back and forth inside a cylinder. This research work focuses on the development of a new duplex reciprocating pump model which is based on eccentric cam mechanism with a dual cylinder system. These pumps are self-priming which supplies fluids at high pressure and constant flow rates compared to centrifugal pumps. In this work, a 3D model is developed using CATIA software from the existing reciprocating pump and the modelling parameters were calculated and utilized in fabricating the new system. The performance of the fabricated model was carried out and compared with the existing reciprocating pump. Modelling, reliability analysis and characteristic curves of this duplex reciprocating pump are also presented. It is observed that the performance of the developed duplex reciprocating model increases due to the increase in the axial thrust acting over the liquid. The results also indicated that the wear and tear in the developed system have been reduced due to reduction of moving parts.

Keywords: Reciprocating pump, Duplex pump, CATIA, Modelling, Performance.

1. INTRODUCTION

A pump is a machine used to move liquid through a piping system that uses several energy transformations to raise the pressure of the liquid. There are numerous classes and categories of pumps due to the wide variation of processes and the distinct requirements of each application. Among the various classes of pumps, reciprocating pumps are in use where precise amount of liquid is to be delivered in addition to higher delivery pressure. These pumps are normally used for pushing viscous liquids and injecting chemicals/additives [1]. They can handle a wide range of liquids, including those with extremely high viscosities, high temperatures, and high slurry concentrations due to the pump's basic operating principle, i.e., the pump adds energy to the liquid by direct application of force, rather than by acceleration. In duplex reciprocating pumps there are two piston-cylinders assemblies. Both the pistons are coupled to the single crankshaft through separate connecting rods. The connecting rods are coupled to the crankshaft at an angular distance of 180 degrees from each other. Several investigations have been carried out on the performance characteristics of positive displacement pumps. Paolo Casoli et al [2] have presented a numerical model for the simulation of a swash-plate axial piston pump, focusing on the characterization of fluid properties. Four hydraulic fluid models (simply named as A, B, C and D) have been presented for the simulation of hydraulic components. The models differ as to how they take into account cavitation phenomena. It was observed that model C, that takes into account both gas and vapour cavitation, agrees with experiments over a wider range of conditions. An experimental system for testing valve disc's motion parameters (acceleration, velocity, and displacement) under actual conditions was established by Junfeng Pei et al [3] taking a triplex single- acting reciprocating pump as the research object. The theoretical analysis and experimental results indicated that the calculations of the Approximation Theory had the relatively large deviation because the influencing factors of valve disc motion were not comprehensively considered in the theory. For example, the inertia and spring force effect were ignored. C.F. Lieu et al [4] presents experimental investigations

* Assistant Professor, Department of Mechanical Engineering, Faculty of Engineering and Technology, SRM University, Kattankulathur-603203, Tamil Nadu, India. *Email: varman92@gmail.com*

** Associate Professor, Department of Mechanical Engineering, Faculty of Engineering and Technology, SRM University, Kattankulathur-603203, Tamil Nadu, India. *Email: umiqbal@gmail.com*

of a novel miniature reciprocating ball pump (RBP) as a potential infusion pump or drug delivery system. The experimental results show that the RBP can deliver a higher flow rate with a volumetric efficiency of 120% as compared to a conventional single acting reciprocating pump running under the same operating conditions. Tsuneo Kan et al [5] have patented a method for Velocity control of two plungers provided in a pulsationless duplex plunger pump by detecting pressure of a resultant discharge from the two plungers and positions of the plungers. From the literature studies it was observed that many works have been carried out on reciprocating pumps, but very few works have been carried out on duplex reciprocating pumps. Moreover the details pertaining to duplex reciprocating pumps are available theoretically and not being commercialized. Hence, in this work an attempt is made to develop a new duplex reciprocating pump model which is based on eccentric cam mechanism with a dual cylinder system. The objective of the work is to increase the thrust exerted over the liquid by reducing the moving parts and to increase the reliability of the pump.

2. EXPERIMENTAL DETAILS

2.1. Designing of Duplex Reciprocating Pump

All the designing was carried out using computer aided three dimensional interactive software (CATIA). An existing single acting reciprocating pump is studied and dis-assembled to obtain the dimensions of the parts for the newly proposed design of duplex reciprocating pump. Later these dimensions are used to design a 2D and 3D model in CATIA. Then the simulation of the developed 3D model was carried out and verified in the CATIA software. The assembled view of the newly designed duplex reciprocating pump in CATIA was shown in Figure 1. Then the fabrication process of the duplex reciprocating pump setup was conducted based on the CATIA model.

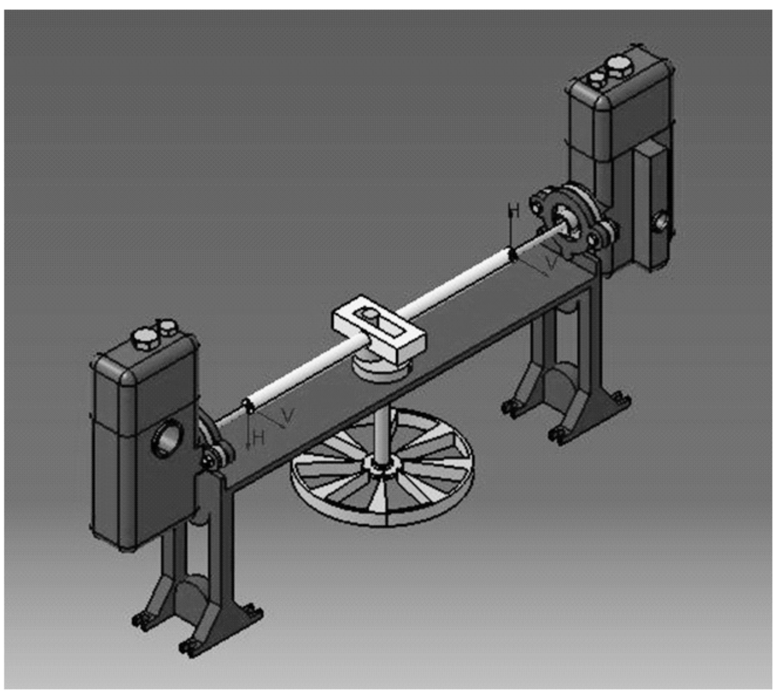

Figure 1: Assembled view of newly designed duplex reciprocating pump in CATIA

2.2. Fabrication of Duplex Reciprocating Pump

The parts of the duplex reciprocating pump were manufactured by pressure die casting process. Cast iron material was used to fabricate the pump body, flywheel, cylinder and air chamber. Mild steel was used for fabricating Cam and dual crank. All the other parts such as Piston, Rod, Cylinder casing, etc are procured from the manufacturer of single acting pump according to the required specifications and numbers. The parts of the duplex pump is shown in the Figure 2. The required number of parts to fabricate the assembly is shown in Table 1. Table 2 illustrates the specifications of the duplex reciprocating pump.

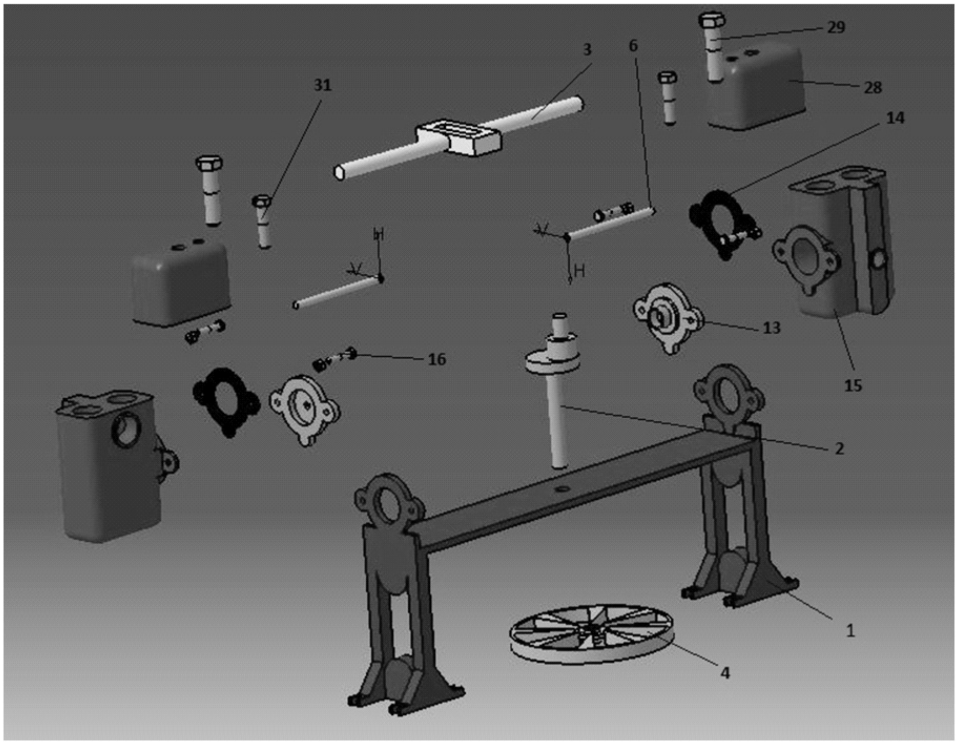

Figure 2: List of Parts Used In Duplex Reciprocating Pump

Then the duplex pump was assembled using the manufactured parts and procured components. The assembled duplex reciprocating pump of dimensions 25.4 mm × 19.05 mm was shown in Figure 3.

Figure 3: Fabricated Duplex Reciprocating Pump

Table 1
List of parts used in Duplex pump

Fig No.	*Part Name*	*Reqd. No.*
3-1	Body	1
2	Cam	1
3	Dual Crank	1
4	Flywheel	1
5	Hex Bolt 3/8’’ BSW X1’’	1
6	S. S. Rod	2
7	Brass Stuffing Box Bush	2
8	Teflon rope 6mm	1
9	Water Seal	2
10	S. S. Nut 5/16’’ UNF	2
11	Mechanical Seal	2
12	Brass stuffing box nut	2
13	Stuffing box	2
14	Stuffing box Gasket	2
15	Cylinder	2
16	Hex Bolt 7/16’’ BSW X 2 ½ ’’ long	4
17	Endoor cap gasket	2
18	Endoor cap	2
19	Hex Bolt 3/8’’ BSW X 1 ’’ long	6
20	3/8’’ Steel plug	4
21	Fiber washer small 3/8’’	4
22	Brass valve plate	8
23	Valve disc rubber	8
24	Brass plate washer 22 SWG	8
25	Valve spring	8
26	Brass valve stem	8
27	Air chamber Gasket	2
28	Air chamber	2
29	Hex Bolt ½’’ BSW X 3 ½’’ long	2
30	Washer, Air chamber dummy	2
31	Brass ¾ Air chamber dummy	2
32	Round cap gasket	4
33	Round cap	4
34	Locking pice	2
35	Hex Bolt ½ ‘’ BSW X 2’’ long	2
36	Brass 38’’ UNF Dummy	4
37	Brass plate water 2mm	2
38	Motor pulley	1
39	V Belt A52	1

Table 2
Specifications of Duplex Reciprocating Pump

Parameter	*Specifications*
Suction Port	1’’ BSP
Delivery Port	¾’’ BSP
Pump Speed	250 rpm
AC motor	0.5 HP, 1440 rpm, 220 V, 0.375 kW

After fabricating the setup, the performance of the duplex reciprocating pump has to be investigated. The following procedure was followed for conducting the tests.

- The discharge valve is opened completely and pump is switched on.
- The reading of the vacuum gauge is noted down.
- The reading of the pressure gauge is noted down.
- The time taken for ‘*h*’ rise in water level in collecting tank is measured.
- The time taken for ‘*n*’ revolutions of energy meter disc is noted down.
- The procedure is repeated for different positions of delivery valve.
- Correction head is measured using steel ruler.

3. RESULTS AND DISCUSSION

To investigate the performance of the duplex reciprocating pump, performance test were carried out. The parameters like discharge, power consumed and the efficiency of the duplex reciprocating pump were obtained and the results are listed in Table 3.

Table 3
Performance test results

S. No	*Total Head ‘H’ m of H_2O*	*Time for filling 20 liters of collecting tank (sec)*	*Discharge Q m^3/sec*	*Time for ‘n’ rev of energy meter disc (sec)*	*Input power (IP) kW*	*Output power (OP) kW*	*Efficiency (%)*
1.	2.935	16.54	12.091	70.8	0.343	0.037	10.78
2.	14.835	17.38	11.50	51.21	0.468	0.167	34.99
3.	25.475	19.01	10.52	43.24	0.555	0.2629	47.36
4.	36.165	22.31	8.964	38.40	0.625	0.3180	50.8
5.	46.331	25.09	7.971	36.64	0.655	0.3622	55.29
6.	56.735	26348	7.55	30.03	0.799	0.4202	52.5

Figure 4 illustrates the performance curves of the pump head Vs efficiency. The operating point of the pump can be selected by combining with the pump system curve. From the graph it can be observed that, the flow rate-head combination of 7.75×10^{-4} m^3/s and 54 m gives the maximum efficiency of 53%.

Figure 5 shows the variation of output power with flow rate. Theoretically it is expected that the head goes on decreasing as the flow rate increases for backward curved blades. The profile is similar to experimental results obtained for similar pump models. The discharge for the newly designed duplex reciprocating pump is doubled by connecting two cylinders at both sides. Table 4 shows the tabulated data in comparison of results of duplex pump over single acting which are obtained from analytical formula and performance test.

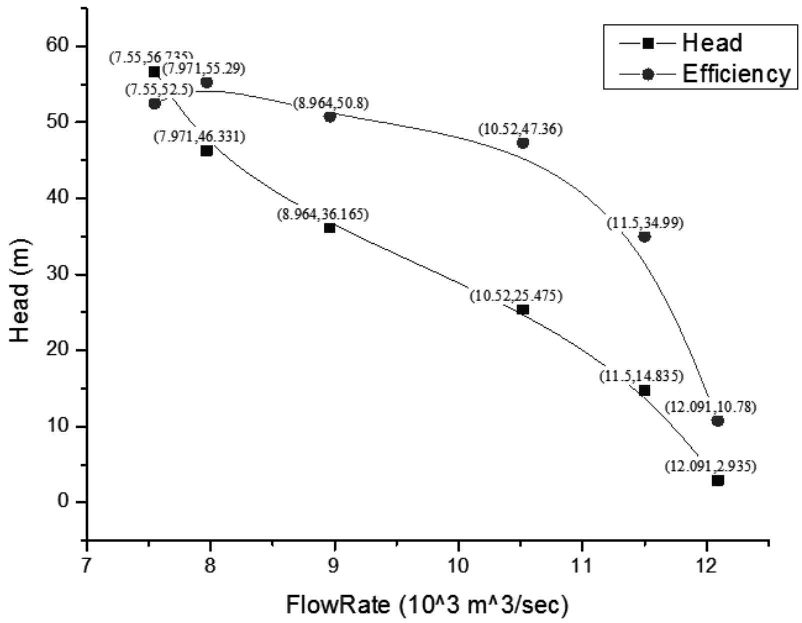

Figure 4: Flow Rates Vs. Head and Efficiency

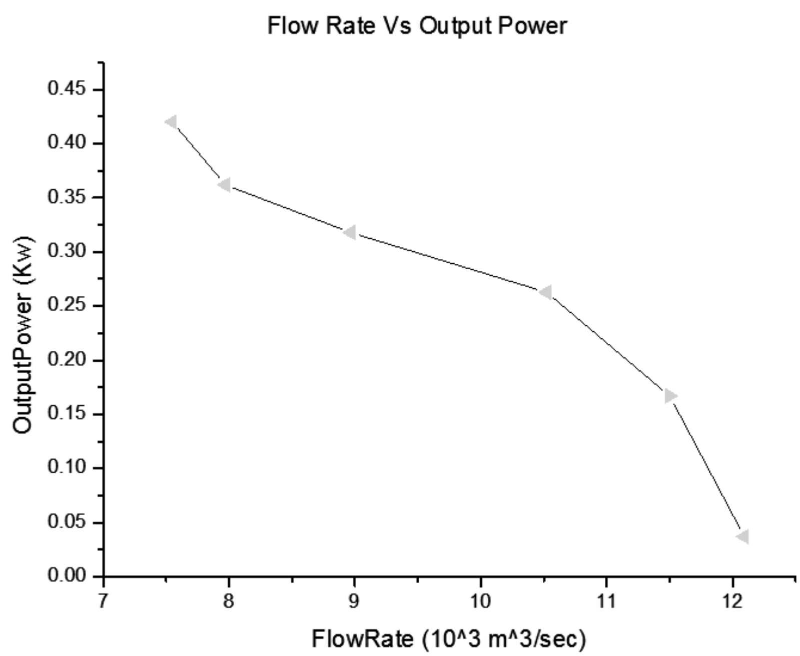

Figure 5: Flow rate Vs. Output Power

Table 4
Comparison of working parameters of single acting and duplex pump

Parameters	*Simplex*	*Duplex*
Theoretical Discharge	3020 LPH	6000 LPH
Actual Discharge	1750-2350 LPH	3000-4400 LPH
Co-efficient of Discharge	0.75	0.735
Theoretical Output power	0.495 kW	0.990 kW
Actual Output power	0.271 kW	0.4202 kW
Theoretical Input power	0.99 kW	1.98kW
Actual Input power	0.850 kW	0.994 kW

4. CONCLUSION

This paper focused on the construction and operation of the duplex reciprocating pump. Duplex reciprocating pumps produce a fixed discharge volume of fluid pumped for each rotation, regardless of the fluid being pumped. Efficiency of the pump is directly related to the energy consumption. The overall efficiency of a duplex reciprocating pump is above 55% which is not common in a reciprocating pump (single acting of efficiency 35% in general). This reciprocating pump can provide fluid at constant flow rates over a wide range of pressure. It is expected that the convenience, efficiency and advantages offered by duplex reciprocating pump will make it commercial for its use There is likely to be a significant increase in the application due to its energy efficient. Some of the important conclusions obtained from the study is listed below.

1. The efficiency of the pump is increased by around 20% (simplex acting 35% and duplex acting 55%).
2. The discharge of the pump is increased by two times.
3. The power utilized by the pump is increased only around 15% whereas the discharge is doubled.
4. The reliability of the system was studied.

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