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Performance Analysis of Foot Operated Treadle Pump

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ABSTRACT

A study was undertaken to improve the performance of treadle pump was constructed with larger cylinder diameter (152mm) and piston valves of varying sizes and shapes were using wood. The piston valve type-I, type-II, type-III were constructed with slot numbers of 4,6 and 8 having different sizes, respectively. The constructed treadle pump was tested at different suction heads to collect the data for pump speed, discharge, slip, coefficient of discharge input power exerted by operator output power produced by pump and pump efficiency. The test results of the pump revealed that the performance of the pump is satisfactory up to two meter suction head. Thus the piston valve made of timber can be used in foot operated treadle pump for pumping surface water.

Keywords: Treadle pump, Pump speed, Discharge, Slip, Coefficient of discharge.

INTRODUCTION

The goal of this project is to build a functional and fundamental well established prototype foot operated treadle pump, which is capable to improved on various areas where the original foot operated treadle pump is lacking. Instruction and methodology that is required to show the re-designed, newly invented foot operated treadle pump were to then be disseminated to rural farmers in India. Benchmarking, reverse engineering, and re-construction of the original model were some of the many tools that were utilized to solve the design problem this project presented.

LITERATURE REVIEW

Alison[1] mentioned the criteria for foot operated treadle pump design based on the biomechanics and work physiology. The Design should aim to meet the following criteria: A foot operated pump operating force at each foot should not exceed 450 N. Pump power input for all day operation should not exceed 40 W. The treadling frequency should be between 40 and 50 cycles/min. Treadle movements at the feet should not exceed 200mm. Carpene[2] Evaluated a prototype diaphragm pump, a twin treadle pump and a rower pump.Field experiments were carried out to access the performance of these pumps and examined their comparative irrigation costs.. Chancellor et al [3] Life water International is a Christian organization that strives to provide clean water in developing countries. Currently Life water International has installed over 2500 water pumping systems worldwide, and is constantly working on ways to improve them. Abdullah et al [4] A study was undertaken to design and construct a low-lift pedal pump for use in small irrigation project areas. For this purpose, different types of piston valves and check valves were constructed and tested at different suction heads in the laboratory to evaluate their performances. Danclerk[5] After much research, calculations and experimental tests the MSU Rope Pump team were able to find the best combination of improvements to improve output nearly 200% over traditional rope pumps.

2. PUMP CONSTRUCTION AND DESIGN

2.1Material required for Pump design

To fabricate a foot operated treadle pump, the following materials were collected and the intended pump was constructed in a workshop according to design:

- Two G.I. cylinder having diameter 154 mm and height 360 mm.
- Timber for Piston valve
- Rubber flaps
- Angle bar for pump base
- MS rod or angle bar for fulcrum and for handle
- Flat bar
- Nuts and bolt
- 3m length PVC pipe(suction pipe)
- Rubber flap and GI sheet for foot valve
- Rubber bucket

2.2. Piston valve

Valve type-I : Rubber flap mounted slotted wooden disc of slot size 16.68 square cm with 4 slots in 154.0 square cm areas. Piston valve type-I is shown in figure 1.

Valve type-II: Rubber flap mounted slotted wooden disc of slot size 7.61 square cm with 6 slots in 154.0 square cm areas. piston valve type-ii is shown in figure 2.

Valve type-III: Rubber flap mounted slotted wooden disc of slot size 4.10 square cm with 8 slots in 154.0 square cm areas. Piston valve type-III is shown in Figure 3.

Fig.1 Valve type-I

Fig.2 Valve type -II

Fig.3 Valve type-III

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Table 1. Specification of design

Constructional Material	CRC (Cold Rolled Coil) sheet & mild steel
Pump Type	3.5 inch diameter (each) twin barrels
Maximum Stroke Length	100 mm
Weight	6 kg
Operator's weight	Operates easily with 35-40 Kg operator's body weight
Maximum Suction Lift	8 meter
Delivery System	Open channel flow at atmospheric pressure
Pedaling System	A pair of 6 ft long metal rod pedals used to leverage the pedal's up& down movement.
Maximum Flow	4500 liters per hour
Water Quality	Resistant to silt particles but not suitable for saline water (EC>4dS/m).
Bore Size	Suitable to install on 1.5" diameter bamboo/ plastic/ GI Tubewell.
Durability	8 to 10 years

Fig.4 Pump

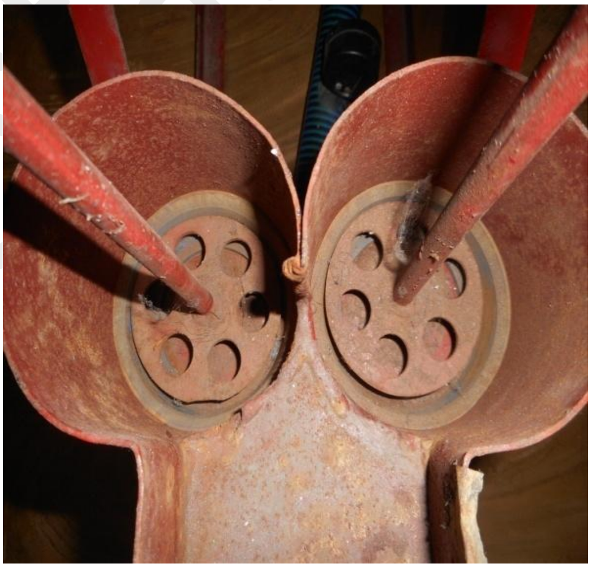

Fig.5 Piston cylinder arrangement

3.EXPERIMENTATION AND RESULT ANALYSIS

Table 2 Performance test data of the pump for piston valve type-I

Suction head , m Pump speed Pump discharge, Q(lpm) Slip (%) Coefficient of discharge, C_d Operators weight , Kg Input power, P_i, (KW) Output power, P_o, (KW) Effciency, ɳ _pump(%)

Suction head , m	Pump speed	Pump discharge, Q(lpm)	Slip (%)	Coefficient of discharge, C_d	Operators weight , Kg	Input power, P_i, (KW)	Output power, P_o, (KW)	Effciency, η_{pump} (%)
039	60	109.20	41.10	0.589	49	0.0818	0.0125	15.28
	59	107.40	41.31	0.587	50	0.0824	0.0123	14.93
	55	116.40	30.96	0.690	49	0.0744	0.0135	18.15
0.97	49	103.10	30.80	0.692	59	0.0798	0.0217	27.19
	52	101.40	36.70	0.633	50	0.0722	0.0212	29.36
	50	91.20	40.86	0.591	50	0.0694	0.0191	27.52
1.53	48	73.20	50.61	0.493	50	0.0668	0.0220	32.93
	47	75.00	47.92	0.521	50	0.0648	0.0226	35.88
	43	74.40	44.39	0.556	59	0.0711	0.0224	31.52
2.0	41	84.00	34.27	0.657	51	0.0586	0.0317	54.09
	38	93.60	20.00	0.800	59	0.0623	0.0354	36.81
	43	83.40	37.10	0.629	52	0.0622	0.0315	50.61

Table 3 performance test data of the pump for piston valve type-II

Suction head , m	Pump speed	Pump discharge, Q(lpm)	Slip (%)	Coefficient of discharge, C_d	Operators weight , Kg	Input power, P_i, (KW)	Output power, P_o, (KW)	Effciency , η_{pump}(%)
0.39	59	121.80	32.78	0.672	53	0.0864	0.0139	16.09
	63	105.0	46.32	0.537	53	0.0934	0.0120	12.35
	56	116.40	32.64	0.674	59	0.0918	0.0133	14.49
0.97	51	89.40	42.69	0.573	59	0.0830	0.0187	22.53
	47	88.20	38.75	0.613	50	0.0648	0.0185	28.55
	47	83.40	42.80	0.572	50	0.0658	0.0175	26.60
1.53	48	76.20	48.58	0.514	50	0.0667	0.0229	34.33
	46	73.80	48.10	0.519	50	0.0639	0.0222	34.73
	44	78.00	42.48	0.575	59	0.0722	0.0235	32.57
2.0	41	84.60	32.54	0.675	51	0.0576	0.0320	55.52
	41	85.80	31.58	0.684	59	0.0667	0.0322	48.29
	45	91.20	34.76	0.652	51	0.0643	0.0344	53.52

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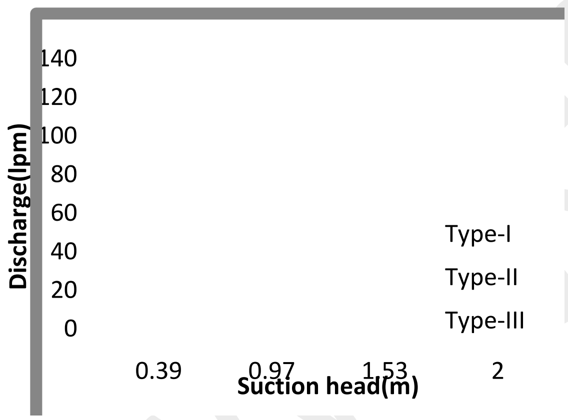
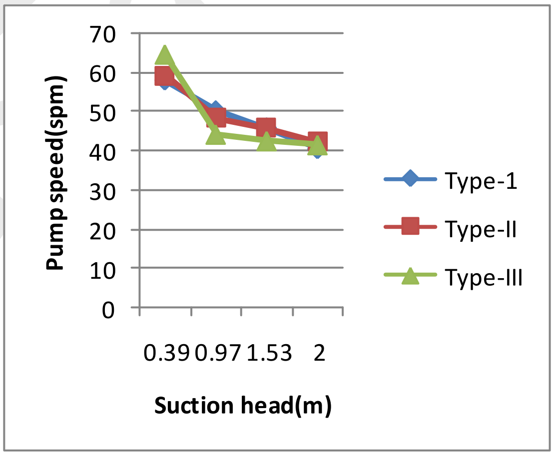
Table 4 performance test data of the pump for piston valve type-III

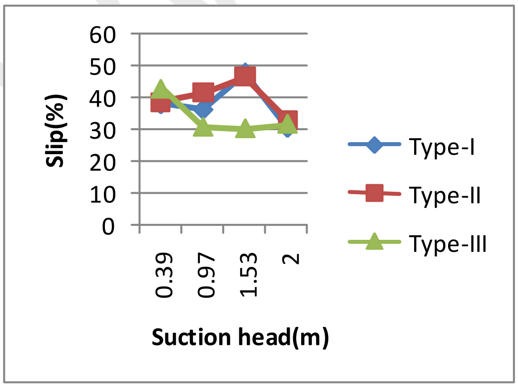
Suction head, m	Pump speed	Pump discharge, Q(lpm)	Slip (%)	Coefficient of discharge, C_d	Operators weight, Kg	Input power, P_i, (KW)	Output power, P_o, KW)	Effciency, η_{pump}(%)
0.39	63	133.20	31.06	0.689	53	0.0924	0.0152	16.45
	65	127.20	36.90	0.631	53	0.0962	0.0146	15.18
	66	116.40	60.67	0.572	53	0.0972	0.0133	13.64
0.97	45	114.00	35.21	0.648	50	0.0620	0.0187	30.16
	42	94.20	27.31	0.727	50	0.0584	0.0197	33.73
	46	100.20	29.53	0.705	59	0.0754	0.0210	27.85
1.53	44	92.40	31.86	0.681	59	0.0722	0.0278	38.50
	41	93.60	26.76	0.732	50	0.0574	0.0282	49.13
	43	89.40	31.96	0.680	50	0.0592	0.0269	45.44
2.0	41	87.60	31.46	0.685	59	0.0678	0.0402	59.30
	43	91.20	30.59	0.694	51	0.0614	0.0344	56.02
	41	85.80	32.86	0.671	51	0.0586	0.0324	55.20



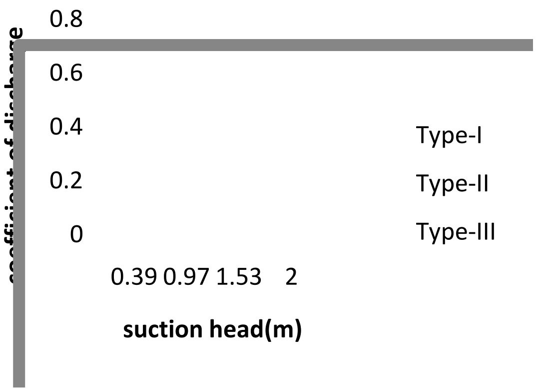
Graph.1 Relation between suction head and pump discharge for piston valves type-I, type-II, type-III



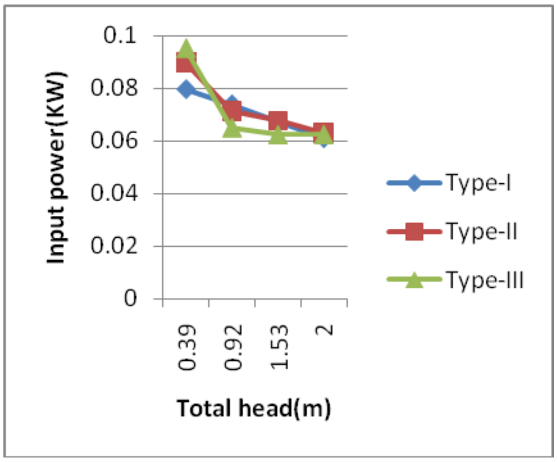
Graph.2 Relation between suction head and pump speed for piston valves type-I, type-II, type-III



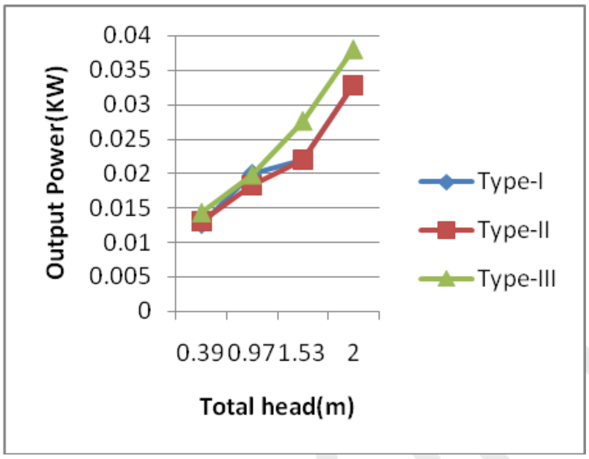
Graph.3 Relation between suction head and slip for piston valves type-I, type-II, type-III



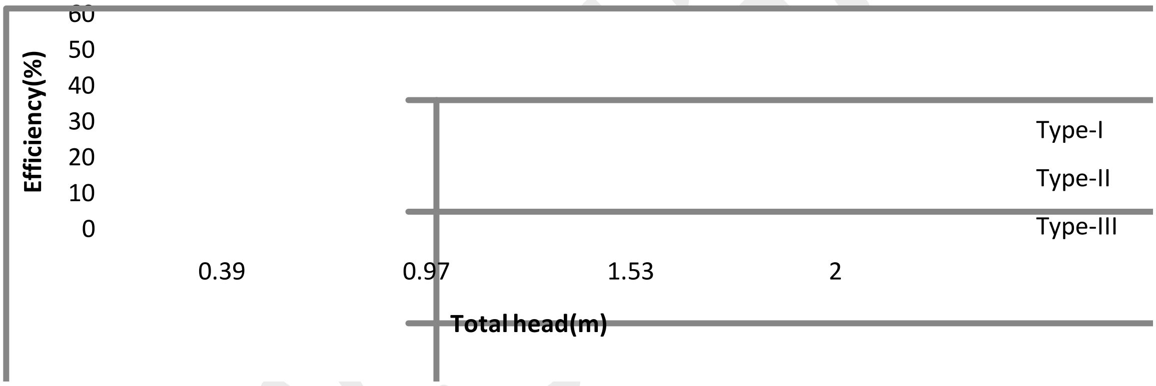
Graph.4 Relation between suction head and C_d for piston valves type-I, type-II, type-III



Graph.5 Relation between suction head and Input power for piston valves type-I, type-II, type-III



Graph.6 Relation between suction head and Output power for piston valves type-I, type-II, type-III



Graph.7 Relation between suction head and efficiency for piston valves type-I, type-II, type-III

CONCLUSIONS

The following conclusion are made based on the test results;

i. The pump is capable to draw surface water up to two meter depth effectively and is, therefore can be used for irrigation in small fragmented land holdings.

ii. The piston valve type-III with 8 slots of size 4.10 squre centimetre was found to be better in respect of discharge and efficiency than that of other two piston valves (type-I & Type-II) and 21.13% opening areas for the slots seemed to be suitable for optimum discharge.

iii. Piston valve made of wood can suitably be used for treadle pump. Wooden piston valve facilities construction using local skill and material and reduced cost.

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