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Performance Evaluation of A Krishak Bandhu Pump Used for Irrigation in Coastal Areas

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Krishak Bandhu pump is a manually operated treadle pump. As the capacity of the operator to operate the pump varies from person to person, it is difficult to evaluate the mechanical performance of the components in the field condition. Therefore, a laboratory experimental study was carried out to evaluate the performance of the components of a Krishak Bandu (KB) pump at College of Agricultural Engineering and Technology, O.U.A.T., Bhubaneswar. The performance evaluation was evaluated by measuring wear and tear of the components. To simulate the field operating condition in the laboratory, a one hp electrical motorized power unit was used to operate the pump after suitably modifying the operating system of the pump. The dimensions of different body parts of the KB pump susceptible to wear and tear were measured at different times of operation. The performance evaluation of the pump was carried out for a total operating duration of 1000 hours. During the test of the pump, the discharge of the pump was about 0.49 lps with suction head varying from 3.92 m to 5.20 m. The volumetric efficiency of the pump was estimated to be 86.5%. The test results revealed that the most vulnerable component of the KB pump to wear and tear was the lever equalizer. If this part is suitably modified, the KB pump can perform better in the coastal areas.

(***Key words:*** *KB pump, Laboratory test, Wear and tear, Irrigation)*

Most of the Indian farmers are poor due to fragmented small land holdings, erratic rainfall, rainfed farming and practice of traditional methods. The uncertainty in the occurrence of rainfall and sometimes long dry spells in between are hazardous to the rainfed farming system creating a moisture deficit stress in the root zone of the seasonal crops. For improving crop production, assured timely irrigation to the crops is required. Rainfed farming is practiced in most parts of India though the productivity is low because of non-development of irrigation resources. Due to the poverty, the poor farmers are unable to invest the high amount initially required to develop the irrigation facility. The poor return from the unpredictable agriculture compelling the new generation farmers to leave their age old profession for getting better livelihood in other sectors such as industry and business. Hence, irrigation is essential for fulfilling the consumptive use of the crop to maximize the crop production. To irrigate the crops, there are different types of conventional water lifting devices such as Don, Rope and Bucket, Tenda, Archemedian screw, Swing basket etc. which are still popular among the Indian farmers (Michael, 1978; Nema and Rao, 1987). But, lifting of water with these devices is labor intensive and not so much effective. Hence, these devices are gradually disappearing from the agriculture. The rich farmers are going for high cost diesel or electrical pumps, which are not affordable by the poor farmers. The fuel prices are also sky rocketing time to time making the cost of irrigation high to higher. The Krishak Bandhu (KB) pump is a low cost manually operated irrigation pump which is used for lifting water by the treadle action (Anonymous, 2002; Mahanta and Sahoo, 2007). This pump does not need any fuel for its operation. This pump has definite advantages over other manually operated water lifting devices because of the treadle action of the pump and involvement of the operator's full body weight to operate the pump (Anonymous, 1996b; Bhanot, 1999). The operator keeps his feet on the pedals and balances the body weight with the help of a support across the pump and presses the pedals downward alternately to create the suction head in the pump. This pump is being promoted by various research institutes and several non-governmental organizations (NGOs) in different states of our country with the help of the local manufacturers (Anonymous, 1996a). But, there is hardly any literature regarding the research and development of this KB pump. Hence, there is need to evaluate the functionality of the KB pump for its further improvement.

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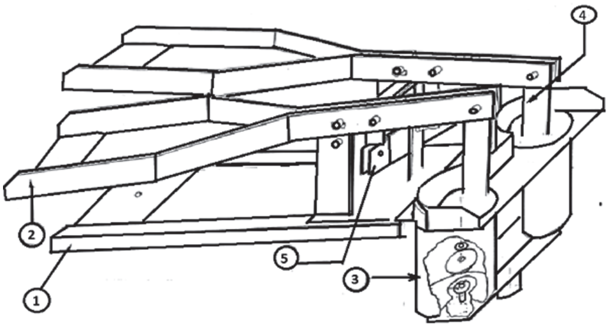

1. Stabilizing stand assembly 2. Pedal assembly
3. Cylinder assembly 4. Plunger assembly
5. Equalizer assembly

Fig. 1. Schematic diagram of the Krishak Bandhu pump

The pump consists of several components as shown in figure 1. During the operation of the pump, the components carry out the different functions and are susceptible to wear and tear because of the friction. Therefore, the performance of the different components of the pump had to be determined through evaluating the wear and tear. By manual operation practically it was not possible to operate the pump steadily for a long time with same frequency. The discharge may vary if the pump is operated by different persons with varying capacity depending on their age, build and sex (Anonymous, 1996b). The KB pumps are also classified according to the materials used for the make such as metallic, bamboo and PVC type. However, the metallic is more robust than the others and easy to maintain. A KB metallic treadle pump with cylinder diameter 3.5", manufactured by the International Development Enterprise (IDE), Bhubaneswar was taken for the study. The objective was to evaluate the wear and tear of different parts of the pump susceptible to friction and suggest further improvement.

Different Components of the KB Pump

The KB pump consists of five assemblies viz., the stabilizing stand assembly, the pedal assembly, the cylinder assembly, the plunger assembly, and the equalizer assembly as shown in Fig. 1. However, from the operational point of view, all the components of the KB pump can be broadly divided into three parts as given below:

i) ***Base frame:*** The base frame consists of stabilizing stand sub-assembly having its major components as: stabilizing struts, end plate and support sub-assembly (viz., pedal support, mounting plate, support plate pivot bar, support plate equalizer and strip locking). It provides the essential framework for the operating system and the pumping unit.

ii) ***Operating system:*** The operating system consists of a pair of pedal sub-assembly, pivot bar pedal, equalizer pivot bar, lever equalizer, pin pedal, washer plain, pin split and equalizer joint sub-assembly (viz., equalizer support lever and equalizer support pedal etc). These components are responsible for transmitting power exerted by the operator for reciprocation of plungers in the cylinders.

iii) ***Pumping unit:*** The pumping unit has mainly two components: the cylinder sub-assembly and the plunger sub-assembly. The reciprocation of the plunger sub-assembly in the cylinder sub-assembly causes the pumping action. The cylinder sub-assembly consists of cylinders- left and right, mounting bracket, spout, valves washer plains and pin lock, whereas the plunger sub-assembly consists of the plunger flat, flexible PVC cup washer, plunger plate and support ring sub-assembly (support bar and support ring).

Except the cup washer and valves, all other components of the KB pump were made up of mild steel (MS). The cup washer and the valves were made up of flexible PVC and Stairin butadin rubber, respectively.

MATERIALS AND METHODS

For evaluating the performance of the KB 3.5" (specified according to the cylinder diameter) metallic treadle pump, a platform was fabricated at 3.55 m above the water sump by using iron channels and angles. The platform was provided with sufficient number of supports and braces, so that the vibration could be minimized while operating the pump. Adjoining to this operational platform, another inspection platform was set up to for the inspection and maintenance work of the pump. A necessary staircase was also provided to reach at the inspection platform.

A one hp, single phase motor with necessary plate, driving unit (for speed reduction and converting rotary motion to reciprocating motion) was used as a power source. For smooth operation of the cam, rollers were fastened on the plate foot-rests. The spout of the KB pump was modified to a funnel type to receive the discharge water and convey it to the discharge measuring device through a discharge pipe. The one end of the suction pipe was connected to the socket and the other end was immersed in water of the sump. Both the suction and delivery pipes were made up of PVC corrugated pipes with a diameter of 88.9 mm. As the pedal is pressed down, the plunger assembly moves up in the cylinder assembly constituting a stroke. The right and left pedals are pressed down alternately. Due to the strokes, suction was created in the cylinders below the plungers and incoming water was delivered through the spout.

The discharge-measuring device consisted of a reservoir and a channel. The reservoir received the discharge water from the delivery pipe and conveyed through the channel. To avoid emergence of any eddy current in the flowing water, metallic sheets with slots were provided across the channel just after the reservoir. A 60 degree V-notch made up of non-corrosive gunmetal was fitted to the channel towards the end away from the reservoir for measuring the discharge head using a hook gauge. The measuring device was calibrated to evaluate the coefficient of discharge (C_d). The actual discharge was quantified using the measured head in the V-notch using a hook gauge by:

$$Q_a = \frac{8}{15} C_d \sqrt{2g} \tan \frac{\theta}{2} H^{5/2} \quad (1)$$

where C_d =coefficient of discharge, g = acceleration due to gravity (9.81 m/sec^2), θ = angle of V-notch (degree), H = head (m).

The theoretical discharge of the pump was calculated based on the effective diameter of the cylinder, stroke length and number of strokes per unit time during the operation. The number of strokes per minute of the reciprocating KB pump was counted by using a stop watch and the length of stroke was measured with a scale. Q_t was evaluated through the equation,

$$Qt = \frac{\pi}{4} \times d^2 \times l \times n \quad (2)$$

where Q_t = theoretical discharge (m^3/s), d = cylinder diameter (m), l = stroke length (m), n = number of strokes per sec. The volumetric efficiency of the KB pump was computed as:

$$\varepsilon = \frac{Q_a}{Q_t} \times 100 \quad (3)$$

where ε = volumetric efficiency (%), Q_a = actual discharge (m^3/s).

Before starting of the experimentation, the pump was dismantled completely. The dimensions of operating parts susceptible to friction viz., pins, holes, bars etc. were measured by means of the vernier calliper. The pump was assembled and lubricated properly to reduce the friction and placed on the set up. Before operating the pump, the pump was primed by pouring water in the cylinders to remove the air inside the suction pipe and the cylinder. The time of start (to), shut down, reason of shutting down, total hours run, discharge and efficiency were noted down daily. The dimensions of the moving parts of the pump were measured again by using the vernier calliper after time, t = 100, t = 528 and t = 1000 hours of operation of the pump.

RESULTS AND DISCUSSION

The coefficient of discharge varied from 0.6047 to 0.6225 in the range of heads of 16.30 to 2.90 cm which was obtained while calibrating the discharge measuring device. The actual discharge, Q_a computed by equation (1) was found to be 0.49 lps (=1782 lph). The number of strokes of plungers in the two cylinders counted using a stop watch was 71 per minute which was similar to the operation of the pump under field conditions (Anonymous, 1996b). The length of the stroke was 75 mm. The theoretical discharge, Qt was computed by Eq. (2) to be 0.5646 lps. There was difference between the actual discharge and the theoretical discharge because little bit gap remains between the cup washer and the cylinder, resulting in some leakage while lifting the water. The volumetric efficiency of the pump was the ratio of the actual discharge and the theoretical discharge, computed to be 86.5%.

The suction heads varied from 3.92 m to 5.2 m (Mahanta, 1998) during the experimental operating period. The discharge of the pump was almost steady and continuous as there was suction of water in one cylinder while the other cylinder was discharging water to the spout simultaneously. The average initial diameter of all the 8 pins which were used at the cross joints was 12 mm. After 100, 528 and 1000 hours of operation of the pump, that became 11.93 mm, 11.87 mm and 11.82 mm respectively. The gradual reduction of the pin dimension was for wear and tear due to friction between the coinciding components. The lever equalizer end of the equalizer pivot bar had a faster rate of wear and tear than the pivot bar support end. The lever equalizer was mild steel flat with dimension, 156 mm x 32 mm x 6 mm with three holes. It provides the balancing act between the left and right operating systems. The wear and tear in the central lever equalizer hole, pedal holes, pedal support holes and pivot support holes were significant. The lever equalizer broke through the central hole after 122 hours of operation. The wear and tear in the central hole of the newly replaced lever equalizer was highest (0.43 mm) among the three holes (Table 1).

Table 1. *Wear and tear of the lever equalizer holes of the KB-3.5” metallic treadle pump during different hours of operation*

Sl. No	Item		Dimensions of the components (mm) after running for the duration of				Diff. bet. Col.3 & 4 (mm)	Diff. bet. Col. 3 & 5 (mm)	Diff. bet. Col. 3 &6 (mm)
			Initial	100hrs	528hrs	1000hrs			
1	2		3	4	5	6	7	8	9
Test 1. Lever equalizer hole									
A	Left	V	12.70	12.80	The component failed after 122hrs of operation and was replaced by a new one for which dimension is given in Col.3 of Test 2		0.10	–	–
		H	12.50	12.61			0.11	–	–
B	Right	V	12.70	12.81			0.11	–	–
		H	12.65	12.72			0.07	–	–
C	Central	V	12.95	13.40			0.45	–	–
		H	12.70	12.83			0.13	–	–
Test 2. Lever equalizer hole									
A	Left	V	12.46	–	12.53	12.58	–	0.07	0.12
		H	12.37	–	12.50	12.56	–	0.13	0.19
B	Right	V	12.28	–	12.37	12.43	–	0.09	0.15
		H	12.37	–	12.45	12.51	–	0.08	0.14
C	Central	V	12.46	–	12.68	12.89	–	0.22	0.43
		H	12.38	–	12.38	12.62	–	0.24	0.43

Symbols: V-Vertical axis H- Horizontal axis

The changes in dimensions of the holes of lever equalizer at different hours of operation are shown in Fig. 2. The time series plot of the wear and tear in the newly replaced lever equalizer is also shown in Fig. 3. The wear and tear was more in the central hole of the lever equalizer because there was more friction as well as pressure than the side holes.

It was observed that there was a reduced rate of wear and tear in most of the components in the initial hours of operation. It may be due to the increase in the smoothness of pins and holes. But,

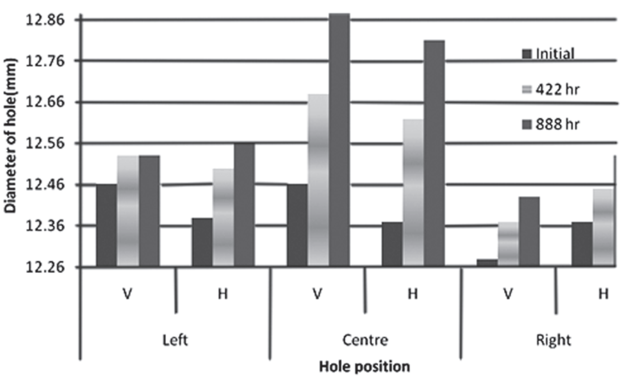

Fig. 2. Schematic representation of change in dimensions of the most vulnerable component i.e. lever equalizer holes at different times of operation

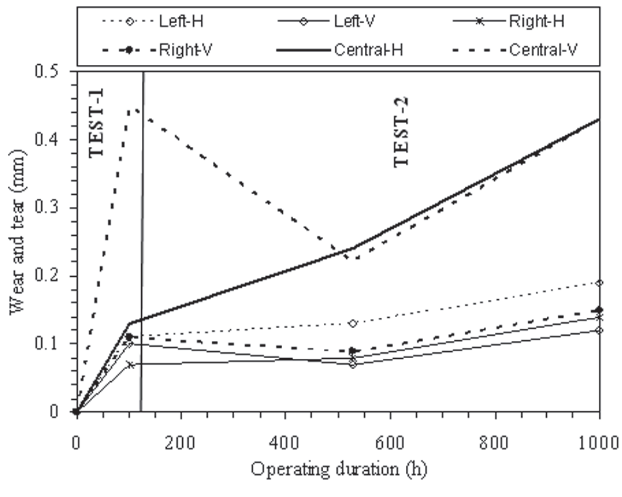

Fig. 3. Time series plot of the rate of wear and tear in the equalizer holes for the two tests corresponding to Table 1

the wear and tear was more in the holes in the later part of operation, due to increase of the size of the holes and consequently development of imbalance in the pump. In case of pedal holes and plunger connecting holes, the rate of wear and tear was more in vertical axis than the horizontal axis since it operates in the vertical plane. Initially, the average weight of the cup washer was 36.05 gm. After 100, 528 and 1000 hours of operation the weights reduced to 35.625 g, 35.340 g and 35.165 g, respectively. The wear and tear in the cylinders of the pump was negligible. The reason was that the water worked as a lubricant between the cup washer and the cylinder, which minimized the friction between the plunger and the cylinder.

CONCLUSIONS

The wear and tear was highest in the central hole of the lever equalizer. In case of the pedal holes and plunger connecting plate holes, the wear and tear rate was more in vertical direction than the horizontal direction. All the components except lever equalizer worked without any problem throughout the operating period of 1000 hours. There was least wear and tear in the cylinder assembly except the cup washer. As the lever equalizer was most susceptible to frictional damage, it is suggested that more resistant metal ring should be put in the central hole to check the rate of wear and tear. So that, the pump can perform better in coastal areas for growing vegetables, cash crops or providing life saving irrigations to other crops.

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