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# Modification And Performance Evaluation Of Hip Pump

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***Abstract*—Diesel pumps are effective for irrigation yet the capital cost and fuel costs are too high for diesel pumps to be commonplace. Human-powered pumps with low capital cost and minimal ongoing cost have become a popular option for farmers with small plots of land. The operation of the hip pump is simple and one adult man can operate the pump easily. The aim of this study was to modify the hip pump parts with local materials and to evaluate the performance of the pump. Maintainable hip pumps were manufactured in Jimma Agricultural Engineering Research Center. The pumping chamber was modified to make the internal part (the valves) maintainable. The pump was tested at different suction heads and was operated manually by an average sized men and women under normal operating conditions. For each operation head, average discharge per strokes and discharge per second were calculated. The collected data were analyzed using R software. Modified hip pump can be maintainable with available raw materials. It could be easily manufactured from locally available materials and it could be possible to manufacture in the microenterprise level. The modified hip pump can pump water from the depth up to 6 m suction head and delivery head is up 4 m. The pump total head is about 10 m. The modified hip pump (MHP) mean discharge is 0.33 l/s and 38 stroke/min. The mean discharge per stroke is 0.58 l/stroke. The imported hip pump (IHP) mean discharge is 0.38 l/s and 35 stroke/min. The mean discharge per stroke is 0.69 l/stroke. Therefore, the modified hip pump can replace the imported one and save foreign currency. The pump is affordable, easy to maintain, culturally appropriate and could be accepted by the farmers.***

***Keywords—Delivery Head; Discharge, Hip pump; Modified; Suction Head;***

## I. INTRODUCTION

The problem of food security is exacerbated by the rapid growth of population and hence of the demand for food. In fact, the prices of food stuffs in the world market have recently begun to rise. Beyond that looms the specter of a fundamental change in climate that may increase the severity and variability of weather and thus disrupt established systems of production.

Clearly, irrigation can and should play an important role in raising and stabilizing food production, especially in the less-developed parts of Africa-south of the Sahara. Rural villages in developing countries are typified by many hardships, lack of basic infrastructure, little or no health care facilities, limited educational opportunities, poor access to clean water and energy, and limited opportunities for jobs and economic growth.

Ethiopia is an agrarian country, agriculture is the leading sector as source of income, employment and foreign exchange and national economic growth is determined by the performance of agriculture. Irrigation plays the key role in the performance of agriculture, which increases income growth. Developing countries that ensure sustainable economic growth can be able to reduce their poverty levels, building up their democratic and political stability.

Agriculture in Ethiopia is dominated by smallholder rain-fed systems but, low and erratic rainfall limits productivity and food security. Consequently, investment in small-scale irrigation has been identified as a key poverty reduction strategy.

Even though agriculture plays great role in the country's economy, it suffers from frequent drought and poor cultivation practices. Therefore, there should be continuous agricultural production through irrigation which is independent of seasonal rain water. Farming is the primary occupation in rural areas, many organizations have worked to increase crop yield through improved irrigation techniques [1]. Reliable irrigation techniques have been shown to increase crop yields between 100%-400% [2]. The resulting increase in grain volume translates to increased sales and income, and allows farmers to cultivate higher-value crops, adopt new technologies, and increase financial returns. Despite the benefits of irrigation, too few farmers have a steady source of irrigation due to the financial limitations of acquiring commercial irrigation technologies.

Diesel pumps are effective for irrigation yet the capital cost and fuel costs are too high for diesel pumps to be commonplace. Human-powered pumps such as a

treadle or hand pump with low capital cost and minimal ongoing cost have become a popular option for farmers with small plots of land [3].

The operation of the pump is simple and one adult man can operate the pump easily. During the upward movement of the plunger a negative pressure (vacuum) is created in the cylinder and causes the check valve to open (i.e. the rubber flap moves upward) and water enters into the pumping chamber of the cylinder. When the plunger moves downward the check valve is closed due to positive pressure and a high pressure is created in the pump chamber due to compression of water which in turn opens (the rubber flap moves upward) the plunger valve and water flows across the plunger valve from the suction to the delivery side of the cylinder. Water thus accumulates in the cylinder on the upper side of the plunger valve. When the operator pull up the with hand to move upward, the plunger moves upward to create negative pressure in the cylinder and when press downward accumulated water is then discharged through outlet.

When the first hip pumps were brought to market, rural African farmers as affordable, versatile, durable, easy to maintain, and culturally appropriate accepted. Although their design constituted a major success, the designer subsequently faced significant challenges manufacturing the hip pumps in sufficient volumes and at a reasonable cost. In Ethiopia, it is difficult for manufacturing the prototype due to the availability of requisite raw materials; once the valve was damaged repairing is difficult since it is compact and permanently welded [4]. So Additional research was needed to make manufacture able and maintainable with available raw material, reduce cost, and evaluate performance of the pump. The aim of this study was to modify the hip pump parts with local materials and to evaluate the performance of the pump.

## II. MATERIALS AND METHODS

### A. Materials

Materials that were used for manufacturing the modified hip pump, U PVC, different type of seal, hollow shaft, bolt and nut, union, and others material were used. Graduated cylinder, container, meter, data sheet, stopwatch, rope and others were used for data collection.

### B. Methods

Maintainable hip pump were manufactured in Jimma Agricultural Engineering Research Center's metal workshop. The modified hip pump was manufactured from locally available materials including its parts.

The cylinder part was made from both metal and plastic pipe (U PVC). The pumping chamber was modified to make the internal part (the valves) maintainable. The modified hip pump (MHP) assembled and dissembled easily.

The following parameters were estimated:

- Suction Head,
- Delivery Head
- Total Head,:

#### 1) Pump discharge

The pump discharge in l/s was calculated by dividing the amount of water pumped by the measured pumping time.

The discharge or capacity of the pump was calculated by

$$Q = V/T \quad \text{.....1}$$

Where

Q = discharge of the pump litres per second, (l/s)

V=volume of water to fill the measuring drum, litres, l

T = time required to fill the drum in second (s)

#### 2) Performance Testing

The pump was tested at different suction heads and was operated manually by an average sized man under normal operating conditions. The pump was setup over a platform for different suction and delivery head. The number of strokes that an operator was capable gives in one minute was termed as stroke per minute. For each operation head, water was collected in a large plastic bucket for a few minutes and the collected water was measured by a plastic jug graduated to litres marks. Each test was repeated five times and in each case, operation period, number of strokes, and water volume was measured. Average discharge per strokes and discharge per second (Q) was then calculated.

### C. *Collected Data and statistical analysis*

Data for the parameters (Suction head, delivery head, discharge) were collected and analyzed using R statistical software.

## III. RESULT AND DISCUSSION

The result of modified hip pump (MHP) that was manufactured in Jimma Agricultural Engineering Research Center's metal workshop and Imported hip pump (IHP) their estimated parameters were described in table below. The parameters that were estimated are Suction Head (Hs), Delivery Head (Hd), and Pump discharge.

**Table 1.** Result of MHP pump at 2 m and 0.7 m

| Operator code | Pump type | Discharge (l/s) | Head(Hs) | Head (Hd) | Discharge per stroke | The number of strokes t(stroke per minute) |
|---|---|---|---|---|---|---|
| AD | MHP | 0.31 | 2 m | 0.70 | 0.55 | 34 |
| ADU | MHP | 0.36 | 2 m | 0.70 | 0.66 | 32 |
| AAQ | MHP | 0.37 | 2 m | 0.70 | 0.70 | 32 |
| DAD | MHP | 0.40 | 2 m | 0.70 | 0.51 | 47 |
| KS | MHP | 0.42 | 2 m | 0.70 | 0.48 | 53 |
| **Mean** | **MHP** | **0.37** | **2 m** | **0.70** | **0.58** | **40** |

**Table 2.** Result of IHP pump at 2 m and 0.7 m

| Pump type | Discharge | Head(Hs) | Head (Hd) | Discharge per stroke | The number of strokes t(stroke per minute) |
|---|---|---|---|---|---|
| IHP | 0.40 | 2 m | 0.7 m | 0.93 | 26 |
| IHP | 0.43 | 2 m | 0.7 m | 0.81 | 32 |
| IHP | 0.41 | 2 m | 0.7 m | 0.73 | 34 |
| IHP | 0.40 | 2 m | 0.7 m | 0.50 | 48 |
| IHP | 0.43 | 2 m | 0.7 m | 0.48 | 55 |
| **IHP** | **0.41** | **2 m** | **0.7 m** | **0.69** | **39** |

**Table 3.** Result of MHP pump at 3 m suction and 0.7 m delivery head

| Operator code | Pump type | Discharge (l/s) | Head(Hs) | Head (Hd) | Discharge per Stroke | The number of strokes t(stroke per minute) |
|---|---|---|---|---|---|---|
| ADU | MHP | 0.34 | 3 m | 0.70 m | 0.69 | 29 |
| DAD | MHP | 0.38 | 3 m | 0.70 m | 0.48 | 47 |
| AD | MHP | 0.26 | 3 m | 0.70 m | 0.51 | 31 |
| KS | MHP | 0.36 | 3 m | 0.70 m | 0.42 | 51 |
| AAQ | MHP | 0.34 | 3 m | 0.70 m | 0.73 | 28 |
| **Mean** | **MHP** | **0.34** | **3m** | **0.70** | **0.57** | **37** |

**Table 4.** Result of IHP pump at 3 m and 0.7 m

| Pump type | Discharge | Head(Hs) | Head (Hd) | Discharge per Stroke | The number of strokes t(stroke per minute) |
|---|---|---|---|---|---|
| IHP | 0.44 | 3 m | 0.7 m | 0.75 | 35 |
| IHP | 0.33 | 3 m | 0.7 m | 0.53 | 37 |
| IHP | 0.33 | 3 m | 0.7 m | 0.85 | 23 |
| IHP | 0.40 | 3 m | 0.7 m | 0.55 | 43 |
| IHP | 0.41 | 3 m | 0.7 m | 0.79 | 31 |
| **IHP** | **0.38** | **3 m** | **0.7 m** | **0.69** | **34** |

**Table 5.** Result of MHP pump at 4 m suction and 0.7 m delivery head

| Operator code | Pump type | Discharge (l/s) | Head (Hs) | Discharge per Stroke | The number of strokes t(stroke per minute) |
|---|---|---|---|---|---|
| ADU | MHP | 0.30 | 4 m | 0.73 | 27 |
| AD | MHP | 0.24 | 4 m | 0.66 | 32 |
| DAD | MHP | 0.32 | 4 m | 0.45 | 43 |
| AAQ | MHP | 0.28 | 4 m | 0.44 | 28 |
| KS | MHP | 0.29 | 4 m | 0.59 | 51 |
| **Mean** | **MHP** | **0.29** | **4 m** | **0.35** | **36** |

**Table 6.** Result of IHP pump at 4 m suction and 0.7 m delivery head

| Pump type | Dischage | Head(Hs) | Discharge per stroke | The number of strokes t(stroke per minute) |
|---|---|---|---|---|
| IHP | 0.34 | 4 m | 0.77 | 27 |
| IHP | 0.30 | 4 m | 0.80 | 23 |
| IHP | 0.33 | 4 m | 0.59 | 33 |
| IHP | 0.32 | 4 m | 0.72 | 26 |
| IHP | 0.40 | 4 m | 0.53 | 45 |
| **IHP** | **0.34** | **4 m** | **0.68** | **31** |

**Table 7.** Summary of discharge for both pumps at different heads

| Type of Hip pump | Discharge (lit/sec) | The static head (m) | | The number of strokes (stroke per minute) |
|---|---|---|---|---|
| | Q | Hs (m) | Hd (m) | |
| MHP | 0.37 | 2.00 | 0.70 | 40 |
| MHP | 0.24 | 2.00 | 3.20 | 35 |
| MHP | 0.27 | 2.30 | 0.70 | 59 |
| MHP | 0.23 | 2.30 | 2.00 | 25 |
| MHP | 0.34 | 3.00 | 0.70 | 37 |
| MHP | 0.22 | 3.00 | 3.20 | 37 |
| MHP | 0.29 | 4.00 | 0.70 | 37 |
| MHP | 0.17 | 4.00 | 3.20 | 49 |
| MHP | 0.17 | 5.00 | 2.20 | 34 |
| IHP | 0.41 | 2m | 0.7m | 39 |
| IHP | 0.38 | 3m | 0.7m | 34 |
| IHP | 0.34 | 4m | 0.7m | 31 |

**Table 8.** Summary of discharge for two pump at 2.3 m suction and 0.7 m delivery head

| Operator | Discharge (l/s) IHP | Discharge (l/s) MHP | P-Value |
|---|---|---|---|
| ADR | 0.51 | 0.32 | |
| KSR | 0.46 | 0.24 | |
| DMT | 0.27 | 0.27 | |
| TAR | 0.27 | 0.29 | |
| mean | 0.38 | 0.28 | |
| | | | **0.2201** |

**Table 9.** Summary of discharge for two pump at 2 m suction and 0.7 m delivery head

| Operator code | Discharge (l/s) MHP | Discharge (l/s) IMP | P-Value |
|---|---|---|---|
| AD | 0.31 | 0.40 | |
| ADU | 0.36 | 0.43 | |
| AAQ | 0.37 | 0.41 | |
| DAD | 0.40 | 0.40 | |
| KS | 0.42 | 0.43 | |
| **Mean** | **0.37** | **0.41** | **0.04177** |

**Table 10.** Summary of discharge for two pump at 3 m suction and 0.7 m delivery head

| Operator code | Discharge (l/s) MHP | Discharge (l/s) IHP | P-Value |
|---|---|---|---|
| AD | 0.34 | 0.44 | |
| ADU | 0.38 | 0.33 | |
| AAQ | 0.26 | 0.33 | |
| DAD | 0.36 | 0.40 | |
| KS | 0.34 | 0.41 | |
| **Mean** | **0.34** | **0.38** | **0.1661** |

**Table 11.** Summary of discharge for two pump at 4 m suction and 0.7 m delivery head

| Operator code | Discharge (l/s) MHP | Discharge (l/s) IHP | P-Value |
|---|---|---|---|
| AD | 0.30 | 0.34 | |
| ADU | 0.24 | 0.30 | |
| AAQ | 0.32 | 0.33 | |
| DAD | 0.28 | 0.32 | |
| KS | 0.29 | 0.40 | |
| **Mean** | 0.29 | 0.34 | **0.01541** |

From the result above, there was no significant difference in discharge between modified hip pump and imported hip pump at the 2.3 m suction head and 3 m. while there is significant difference in at 4 m suction head. In other aspect like pump parts were modified to locally available material. So the modified hip pump can replace the imported one and save foreign currency. The modified hip pump can pump water from the depth up to 6m suction head and delivery head is up 4m. The pump total head is about 10 m. The modified pump can pump the water up 50 m through horizontal hose.

The modified hip pump mean discharge is 0.33 l/s and 38 stroke/min. The mean discharge per stroke is 0.58 l/stroke. The imported hip pump mean discharge is 0.38 l/s and 35 stroke/min. The mean discharge per stroke is 0.69 Lit/stroke.

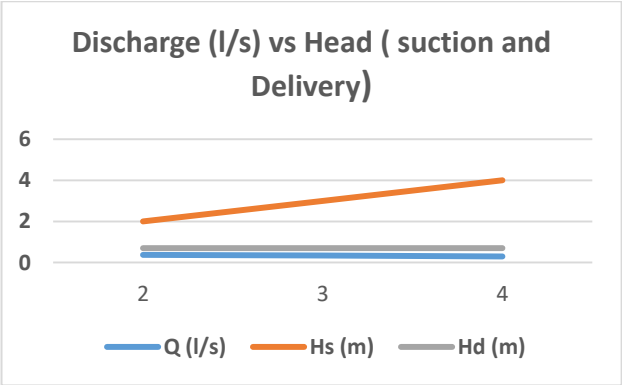


**Figure. 1** Discharge versus suction and delivery head 0.7m

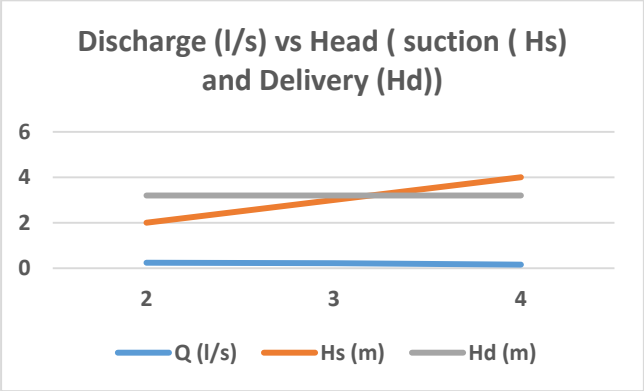


**Figure.2** Discharge versus suction and delivery head 3.2m

The result shows, that discharge and suction or static head are inversely proportional. As the suction head increase the discharge decrease. Also as the delivery head increase the discharge decreases.

## IV. Conclusion and Recommendation

### A. *Conclusion*

The operation of the modified hip pump is simple and one adult man or woman can operate the pump easily. The modified pumps are affordable, easy to maintain, and culturally appropriate could be accepted by the farmers. Modified hip pump can be maintainable with available raw material, and reduce cost.

The design constituted a major success and it could be easily manufactured from locally available materials and it could be possible to manufacture in the microenterprise level.

The modified hip pump can pump water from the depth up to 6m suction head and delivery head is up 4m. The pump total head is about 10 m. The modified hip pump mean discharge is 0.33 l/s and 38 stroke/min. The mean discharge per stroke is 0.58 Lit/stroke. The imported hip pump mean discharge is 0.38 l/s and 35 stroke/min. The mean discharge per stroke is 0.69 lit/stroke. It was concluded that, discharge and suction or static head are inversely proportional.

### B. Recommendation

As recommendation, although the modified hip pump is simple and one adult man or woman can operate the pump easily also it is better to simplify it more.

Modified hip pump can be able and maintainable with available raw material, and reduce cost, its need some modification to use the durable material to improve the frequent changing of seal or rubber parts that used with piston.

It is recommended to undertake on farm evaluation with farmers to collect farmer's feedback.

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