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Md. Tariqul Islam
Scientific Officer
Water Resources Planning Organization (WARPO)
Dhaka-1213, Bangladesh

Md. Abdul Kader
Assistant Director
Rural Development Academy (RDA)
Bogra-5842, Bangladesh

Correspondence:
Md. Tariqul Islam
Scientific Officer
Water Resources Planning Organization (WARPO)
Dhaka-1213, Bangladesh

Choice of Efficient Centrifugal Pump for Minor Irrigation Scheme

Md. Tariqul Islam, Md. Abdul Kader

Abstract
The exploration of centrifugal pump function is important for knowing its features viz. efficiency, discharge, specific discharge, relationship of efficiency vs. discharge and head vs. discharge. These relationships characterize the performance of pump and play an important role in selection of pump to lift water for different purposes. To address this purpose testing of two pumps such as Milton pump (4″, 1500 RPM) and KSB pump (4″, 2200 RPM) assess performance at different operating conditions at constant suction and delivery lift. The maximum efficiency and maximum specific discharge of the pumps represents the same operating condition, but specific discharge offers accurate scope of measuring discharge with respect to energy consumption in reckoned form. The difference of percent maximum efficiency of tested pumps was 0.54%, which is equivalent to the difference of highest specific discharge of 0.35 m^3/ kWh. Operation of the pump at maximum specific discharge saves specific discharge up to 22.30% for KSB pump and 29.04% for Milton pump, which is economic, and energy saving for minor irrigation scheme.

Keywords: Specific discharge, efficiency, efficient head, efficient discharge

1. Introduction

Minor irrigation scheme operated and managed by a farmer is quite impressive and popular in recent years due to the rapid return and poverty alleviation (de Fraiture, C and Giordano, M., 2013). Therefore, the numbers of small irrigation schemes are increasing rapidly in sub-Saharan Africa and South Asia (Abric *et al*., 2011, Takeshima *et al*., 2010). In India, number of privately owned well is 25 million providing 70% of all irrigated area (Shah T., 2009) and in Bangladesh area covered by small and minor irrigation is 94% of the irrigated land (Banglapedia, 2014). Same trend also prevails in sub Saharan Africa where small private irrigation dominates 55% irrigated area in Niger, 75% in Nigeria and 15% in Kenya (Abric *et al.,* 2011). With declining prices and increased local availability, small-motorized pumps, typically 1–10 hp Chinese pumps have spreaded rapidly throughout the Asia (Molle *et al.*, 2003). Centrifugal pump facilitates minor irrigation system development in those countries having available water within suction mode i.e. from lakes, rivers, creeks, or shallow wells (Islam M. T., 2013). However, the development of minor irrigation system can lead to encounter between water user groups (Shah T., 2009).

Use of fossil fuel is essential to modern production system, emits carbon di-oxide, main culprit for global temperature rise due to the greenhouse effect, but the wise use can minimize. Among the different fossil fuel user devices, centrifugal pump is remarkable in the agricultural field, which can contribute to environmental impairment but wise use can minimize. In Bangladesh, the energy used for irrigation almost 25% comes from electricity and 75% from diesel (Roy R.B., 2012).

For irrigation purposes, centrifugal pump should use in such a way that consumes less energy, increases command area, protects environmental pollution and saves the economy. Therefore, the pump should satiate the user's working conditions in terms of head, capacity, efficiency, with respect to energy consumption, which affects the operating cost. The manufacturer's shop or national authorized organization should test the pump in realistic manner to publish results in user friendly so that respective buyer can make a choice from the available information.

Features curves of Pump manufacturer, in some cases does not satiate the actual performance, given in the supplied characteristics curves and shows relationship among different parameters (head vs. discharge, head vs. efficiency etc.) not relationship of these parameters with respect to energy consumption. Again, the idea of efficiency does not convince real figure of pump size in comparing discharge with respect to energy consumption. This study reveals the discharge and energy consumption ratio for different RPM to facilitate selection of economical pump and energy saving efficient point of pump operation from test performance at constant suction and delivery lift for minor irrigation scheme.

2. Materials and Methods

This study introduces the practice of pump test approaching efficiency, head and specific discharge for lifting water within suction mode. In this work, two centrifugal pumps collected from farmers field was tested at pump testing laboratory under department of Farm Power and Machinery (FPM) in Bangladesh Agricultural University (BAU), at constant suction and delivery lift but at different RPM. The RPM was maintained using three phase induction motor of variable speed and set with RPM regulator. The constant suction and delivery lift was maintained through a proper setting of suction and delivery pipe of the pump, connected with an underground water tank via notched flume (Fig 1). Drum, Energy meter, Manometer, and Tachometer was used respectively to measure discharge, energy consumption, head and revolution per minute (RPM).

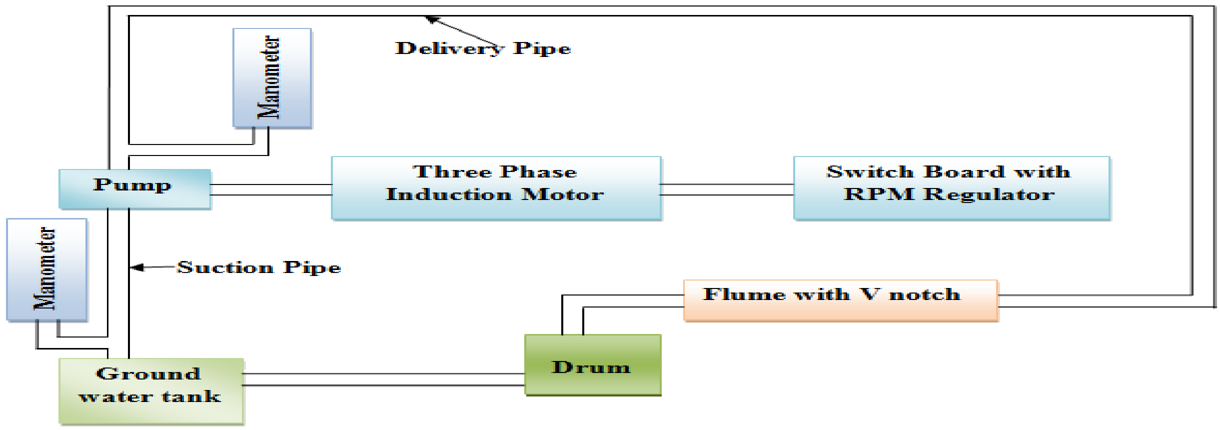

Fig 1: Experimental layout of pump test rig

2.1 Pumping head measurement

For a pump with horizontal shaft the horizontal plane containing the centreline of the shaft was considered as the reference plane. Total suction head is defined as the sum of the suction lift (l_s) and the suction loss (h_{fs}). This can be calculated from the pressure head (p_s/w) measured by pressure gauge. Measured pressure head can be related to l_s, h_{fs} and $v^2/2g$ as,

$$\frac{P_s}{W} + \frac{V^2}{2g} = l_s - h_{fs} = -h_s \qquad (1)$$

Where, V= flow velocity in the suction pipe (cm/s), l_s= vertical distance between pump centreline and water level (m), and w = unit weight of water (kg/m^3).

Total delivery head is defined as the sum of the delivery lifts l_d (m) and the head loss h_{fd} (m). Pressure head (p_d/w) in the delivery pipe was measured by manometer. Total delivery head was calculated as,

$$h_d = l_d + h_{fd} = \frac{p_d}{W} \qquad (2)$$

Where, l_d = vertical distance between pump centreline and level of discharge (m). Total pumping head can be given as,

$$H = h_s + h_d + \frac{v^2}{2g}$$

$$= l_s + h_{fs} + l_d + h_{fd} + \frac{v^2}{2g}$$

$$= l_s + l_d + h_{fs} + h_{fd} + \frac{v^2}{2g}$$

$$= l_T + h_F + \frac{v^2}{2g} \qquad (3)$$

Where, L_T = Total lift (m) and h_F = Total loss (m)

2. 2 Discharge measurement

The discharge was measured in volumetric way as,

$$Q = \frac{v}{t} \qquad (4)$$

Where, V = volume of drum, litre and t = time (s) required to fill the drum

2.3 Efficiency calculation

Electric motor was used to operate the pump. The values of kW from the energy meter was converted into horse power as,

$$\text{Input horse power} = \frac{watt}{746} \qquad (5)$$

The output horse power, also called the water horse power, indicates the horse power of pumping water (Michael. A.M., 2010) and is expressed as,

$$\text{Output horse power} = \frac{QH}{76.2} \qquad (6)$$

Where, Q = Discharge, litre per second (L/s) and H = Total pumping head, m. The efficiency (E) in percentage was calculated from the following equation-

$$E = \frac{\text{output hp}}{\text{input hp}} \times 100 \qquad (7)$$

In this work, electric horsepower supplied to the motor was taken as input horsepower and the water horsepower supplied by the pump as output horsepower. So, the efficiency calculated by the above equation corresponding to the combined efficiency of the motor and pump.

2.4 Specific discharge measurement

Discharge per unit energy consumption is termed as specific discharge for a pump, indicating discharge vs. energy consumption ratio (Samad, 2009). Depending on discharge and energy consumption, unit of specific discharge may be expressed as m^3/ kWh or m^3/ml of fuel. Where, m^3 (cubic meter) = thousand litre. In this study, energy was measured from energy meter in kWh.

3. Results and Discussion

Pumping features obtained from the test results facilitate the selection, operation, and maintenance of pump. The knowledge of operating condition of centrifugal pump also helps to realize the overall management of pump operation. Pump shows variation of head, discharge, efficiency, specific discharge, and energy consumption due to the variation of RPM. This variation helps to select economic situation, which illustrates this study for choice of different efficient conditions for economic operation of pump.

3.1 Effect of RPM change on head, discharge, and efficiency

The key feature of a pump is discharge, which depends on diverse parameter viz. suction lift, delivery lift, RPM, pipe diameter and pump size. The expectation of user is to get maximum discharge with minimum energy consumption and cost. Variation of pump RPM causes the variation of head, discharge, efficiency, and energy consumption. The normal relationship between head vs. discharge is such that discharge decreases with the increase of head but at constant suction and delivery lift, the relationship of head vs. discharge is tends to linearly increasing due to increasing of pressure and velocity head (Fig. 2)

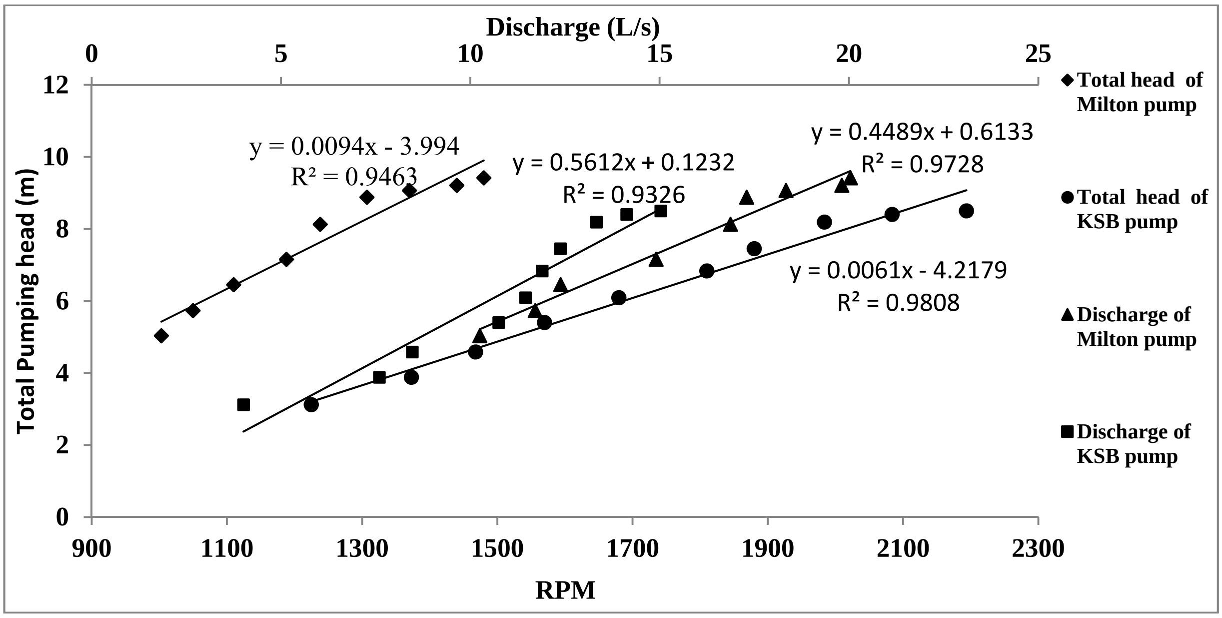

Fig 2: Total head vs. discharge and RPM at constant suction and delivery lift with RPM change

The 1480 RPM of the Milton pump offer the maximum pumping head 9.42 m but efficient head (the head that offer maximum efficiency) was 8.12 m at the 1238 RPM. For the KSB pump, the maximum head was 8.50 m at the 2194 RPM but efficient head was, 8.19 m at the 1984 RPM (Fig 2).The discharge increases with the increase of RPM due to increasing revolution of pump vane. For Milton pump, the maximum discharge was 20.04 L/s at the 1480 RPM but efficient discharge (the discharge that offer maximum efficiency is efficient discharge) was 16.8 L/s at the 1238 RPM (Fig. 3). For the KSB pump, the maximum discharge 15.3 L/s was at the 2194 RPM but efficient discharge was 13.03 L/s at the 1984 RPM (Fig. 3).

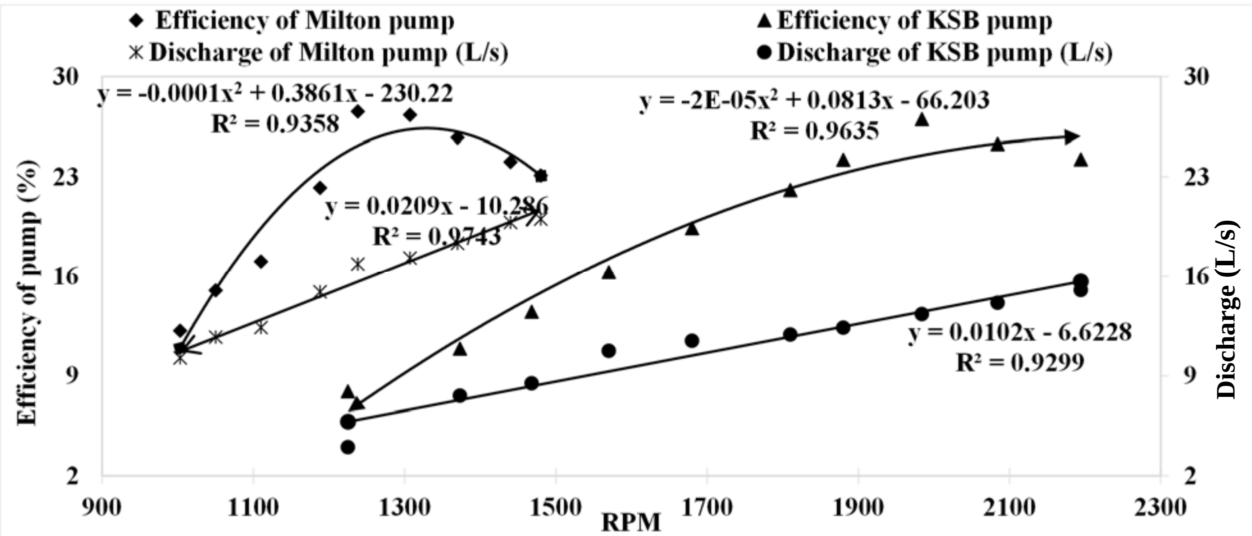

Fig 3: RPM vs. efficiency and discharge of pump

3.2 Variation of specific discharge and energy consumption with variation of RPM

The variation of pump RPM causes variation of specific discharge and energy consumption. The energy consumption increases with the increase of RPM due to encounter of more load.

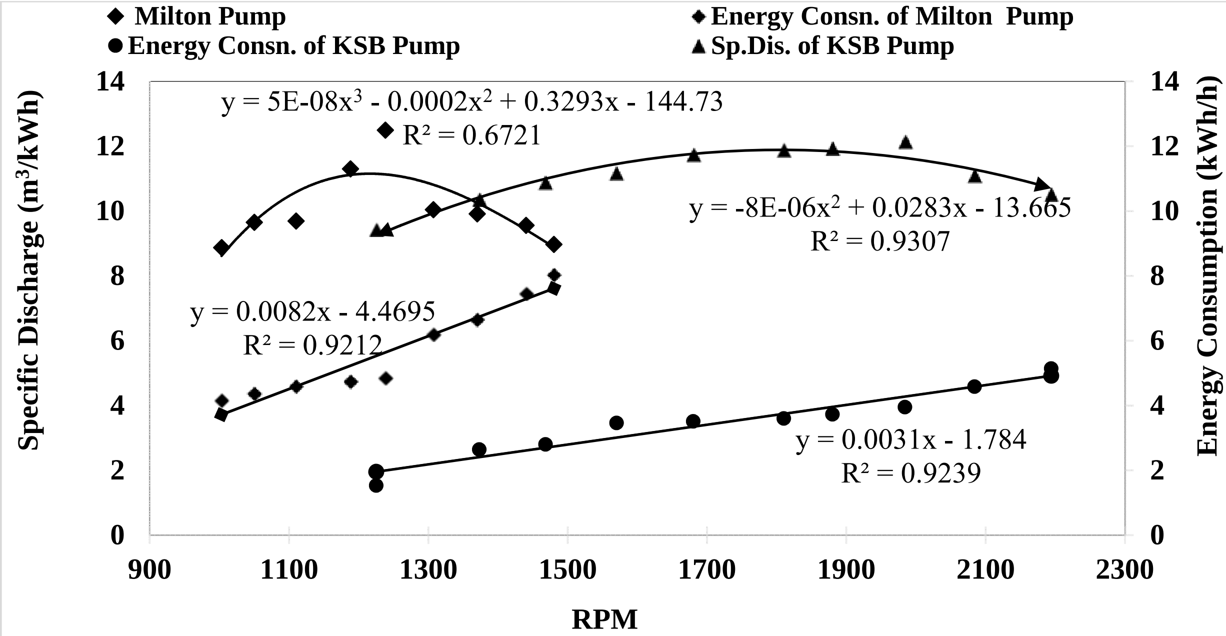

Fig 4: RPM vs. Specific discharge and energy consumption

Beyond the 1238 RPM of Milton pump, the rate of energy consumption more increases and for the KSB pump that was 1984 RPM. The discharge increases with the increase of RPM but the rate of increase reduces beyond 1238 RPM for the Milton pump and that was 1984 RPM for the KSB pump. The specific discharge of the pump increases with the increase of pump RPM, up to a certain RPM that is maximum specific discharge (Fig 4) and beyond this RPM, specific discharge decreases with the increase of RPM. The Milton pump is more economical than KSB pump. The maximum specific discharge for the Milton pump was 12.50 m^3/kWh at the 1238 RPM and for the KSB pump was 12.15 m^3/ kWh at the 1984 RPM (Fig 4). There is a relationship between specific discharge and efficiency. Both the pumps represent maximum efficiency and maximum specific discharge at the same RPM (Fig 3 and Fig 4). The impeller outlet diameter, the blade angle, and the blade number are the most critical parameters, which affect the pump performance and energy consumption. (Bacharoudis. E.C.*et al*, 2008). For the pump of 2200 RPM, energy consumption is less than the pump of 1500 RPM. Because it has one vane less than the pump of 1500 RPM. Increased number of vane increases the contact metallic wetted surface area during pumping and increases the power requirement resisting more loads.

3.3 Centrifugal pump in Minor Irrigation Scheme

About 94% of the irrigated land in Bangladesh is under small and minor irrigation. A recent survey shows, water is being lifted in this country through 26,704 deep tube wells, 4,69,226 shallow tubewells, 56,829 low lift pumps, 1,42,132 manual pumps, and more than 5,65,000 indigenous water lifting devices (Banglapedia, 2014). However, sub-optimal uses of these irrigation devices and unplanned cropping activities have resulted in low irrigation coverage. The irrigation efficiency is only about 30%. Proper utilization and improved management can irrigate 4.0 to 5.0 million ha of land easily by using the same number of irrigation devices instead of the present 3.12 million ha. (Banglapedia, 2014). Centrifugal pump is one of the important accessories of Shallow tubewell and low lift pumping plant of suction mode, efficient use of which can contribute in increasing pumping efficiency, reducing power consumption and in increasing command area. In this study, Milton pump shows specific discharge savings up to 29.04% and KSB pump shows specific discharge savings up to 22.30% with RPM change (Table 1).

Table 1: Specific discharge difference of pumps with variation of RPM

KSB Pump (2200 RPM		Milton Pump (1500 RPM)	
RPM	Sp. Dis. difference with 12.15 m^3/kWh	RPM	Sp. Dis. difference with 12.50 m^3 /kWh
1225	22.30%	1003	29.04%
1373	14.73%	1050	22.80%
1468	10.37%	1110	22.48%
1570	7.98%	1188	9.60%
1680	3.29%	1238	0.00%
1810	2.06%	1307	19.68%
1880	1.65%	1370	20.72%
1984	0.00%	1440	23.52%
2084	8.56%	1480	28.24%
2194	13.33%		

This indicates selection of pump operating point is very important for energy saving of pump operation and efficient minor irrigation system development (Table 1). Therefore, operation of pump at highest specific discharge would offer more discharge for the same energy consumption and would reduce carbon emission in environment by saving energy consumption, which is the main concern for climate change mitigation.

4. Conclusion
Diverse parameters influence the improvement of minor irrigation scheme capacity. Choice of efficient pump and efficient operating point of pump is the critical issue of minor irrigation scheme management, which characterizes the design restrictions of pump, operating conditions of the irrigation system, and required flexibility in system operation. Each brand of pump has efficient operating condition. This study reveals choice of efficient pump, efficient operating point of individual pump, efficient discharge, and maximum specific discharge from laboratory test. Features curve facilitate the design of efficient pump and operating point for the minor irrigation scheme ignoring maximum discharge concept. The maximum specific discharge and maximum efficiency coincidence with each other at the same RPM. The Milton pump represents maximum efficiency and maximum specific discharge with compare to KSB pump. Milton pump saves $0.35m^3$ discharge per kWh energy consumption. Milton pump is 0.54% more efficient than KSB Pump. At efficient RPM and discharge, Milton pump offers more discharge (3.542 L/s) than KSB pump. Therefore, pump manufacturer may supply specific discharge curve along with conventional curves to facilitate selection of economical pump, economical operating point, and annual energy consumption with respect to operating duration in eligible form for cost-effective operation of minor irrigation scheme. This study was only for two brand of pump at constant suction and delivery lift so that further study is necessitated for another brand of pump, for other operating condition like changing head, pump size, and pipe diameter.

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