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Design and Fabrication of a Hydraulic Diaphragm Pump

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ABSTRACT

Moving water creates energy that can be captured and harnessed for potential works. In order to utilize the abundant water resources of the country, the study was geared towards the development of a hydraulic diaphragm pump to alleviate the problems in areas where water is needed in higher elevations than the source. In this way, water from a spring or stream in a valley can be pumped to a village or irrigation scheme on the hillside. Initially, design considerations and criteria were determined to aid in the design calculations. With this, CAD software was used to produce a realistic image of the device which was used as a basis during the fabrication process.

The motorless pump has a total dimension of 360 mm diameter and 900 mm long. It consists of four major parts: body assembly, impulse valve, diaphragm assembly, and pump end. The pump offers an inexpensive and reliable source of irrigation water, especially for the rainfall-dependent upland farms.

Key words: *development, hydraulic diaphragm pump, motorless, energy from moving water, irrigation*

INTRODUCTION

The entire world is thinking of green energy before doing anything and everything. The hydraulic diaphragm pump uses no other external force than the kinetic energy of falling water in order to operate (Harrison 1980; Mohammed 2007). It is an effective alternative device to lift water especially in the remote highland places where electricity and fuel are not readily available.

In the Philippines, the irrigation system is among the major factors that affect crop production. Most highland farmers depend on natural rainfall to have a good cropping season. This results to limited production and farmers' low income. Commercial pumps powered by diesel or gasoline engine and electricity are widely available but require higher investment cost. Furthermore, burning of fossil fuels greatly affects the environment.

Old designs of hydraulic ram pumps exist but are very bulky (Dumaoal et al. 2014) since higher delivery head requires bigger pressure tanks. Thus, the study was conducted to design and fabricate a hydraulic diaphragm pump. The potential of using the pump is beneficial to supply water for both domestic and agricultural use.

MATERIALS AND METHODS

Design considerations and criteria

Criteria for success are the specifications a design solution must meet or the attributes it must possess to be considered successful. Selection of materials is one of the major factors to be considered in design. Among the parameters that need to be considered include the quantity of water required, quantity of flow available from the source, vertical fall, and the length of drive and delivery pipes.

Design of the device

After the determination of the basic design concepts, the use of Computer Aided Design (CAD) software facilitated the progress of the design process. The pump was constructed from good quality pipes to improve corrosion resistant properties and life span of the device. Also, machines should be designed to serve humanity, not cause danger when properly used. In accordance to the safety measures specified by the Philippine Agricultural Engineering Standard (2000), the pump was appropriately designed to prevent any user-machine contact, yet still allows for proper maintenance.

Figure 1 shows the conceptual framework of the study which follows the input-process-output method. The arrow signifies the process flow of activities. The framework was primarily based on the objective of the study.

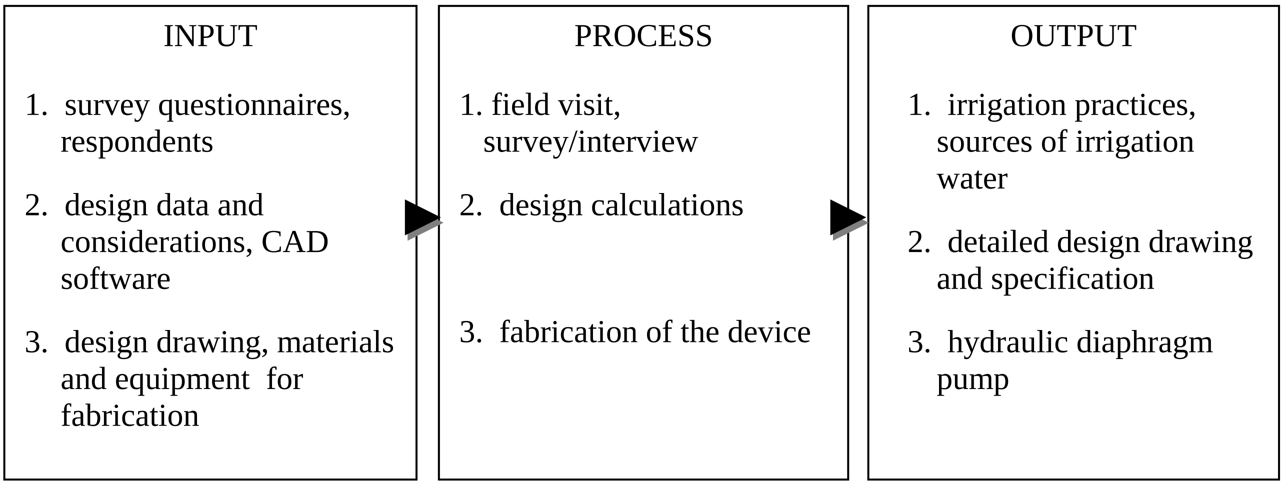

Figure 1. Conceptual framework of the study

Design calculation

The dimensions of the hydraulic diaphragm pump were essentially based on the fluid power formula equation. The power required to lift the water is given by equation 1. Equation 2 was used to estimate the force that accelerates the fluid. Furthermore, equations 3 and 4 were used to determine the available power at the drive pipe and the size of the diaphragm chamber, respectively.

$$P(r) = \rho g Q h \quad (1)$$

where: P(r) – power required, kW
ρ – density of water, kg/m^3
g – gravitational force, $9.81 m/s^2$
Q – volumetric flow rate at the drive pipe, m^3/s
h – total head, m

$$F = \rho AL\left(\frac{dv}{dt}\right) \quad (2)$$

where: F – force, N
ρ – water density, kg/m^3
A – cross-sectional area of drive pipe, m^2
L – length of drive pipe, m

$$P(a) = F/A \quad (3)$$

where: P(a) – available power, kW
F – force, N
A – cross-sectional area of drive pipe, m^2

$$A_1 * P(a) = A_2 * P(r) \quad (4)$$

where: A_1 – surface area of the diaphragm, mm^2
A2 – cross-sectional area of cylinder bore, mm^2
P(a) – available power, kW
P(r) – power required, kW

Principle of operation

The hydraulic diaphragm pump is site-specific, requiring a continuous flow of water with natural supply head of at least 0.5m. It is an automatic pumping device that works on the combined principles of hydraulic ram, diaphragm, and piston pumps. Initially, water from the supply reservoir flows through the drive pipe due to gravity. As the water velocity increases, a pressure is being built up in the diaphragm chamber which forces the impulse valve to close. When the impulse valve closes, the pressure is directed to the diaphragm; thus it pushes the plunger to force the water into the delivery valve. As the impulse valve opens, pressure at the diaphragm chamber decreases causing the diaphragm to return to its initial position and allowing water to enter the suction valve. The process is repeated.

Fabrication of the device

Prior to fabrication, the acquisition of materials, which was based on two key factors, cost, and availability, was completed. The fabrication of the device, as shown in Figure 2, was a major portion of the design process. Equipment like metal cutter, oxy acetylene cutter, drill press, ARC welding machine, and portable grinder were used during the fabrication process. From the CAD model, the machining and construction of the device was carried out following the processes: (1) measuring, marking out, and cutting the various parts of the steel pipe; (2) drilling of holes or perforations; (3) joining of machine parts through welds, nuts and bolts; and, (4) assembly, finishing, and aesthetics.

Figure 2. Fabrication of the device

RESULTS AND DISCUSSION

The hydraulic diaphragm pump works like the hydraulic ram pump powered by falling and running water. The difference is that the fabricated hydraulic diaphragm pump uses diaphragm instead of pressure tanks. The device has a total dimension of 0.90 m by 0.36 m for the length and diameter, respectively. Its primary components are the body assembly, impulse valve, diaphragm assembly, and pump end. Figure 3 illustrates the schematic diagram of the pump while Figures 4 and 5 shows the fabricated and on-site setup of the device, respectively. On the other hand, Table 1 and Table 2 present the specifications and advantages of the device, respectively.

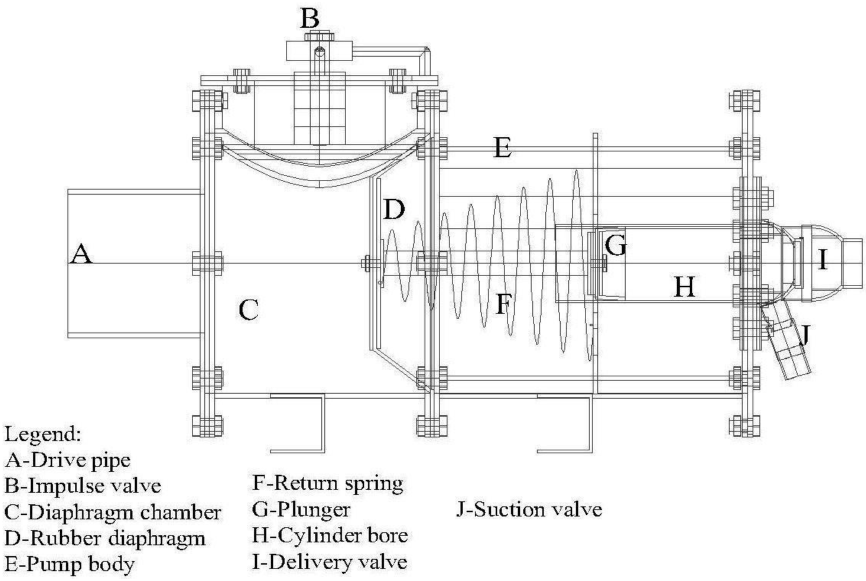

Figure 3. Schematic diagram of the hydraulic diaphragm pump

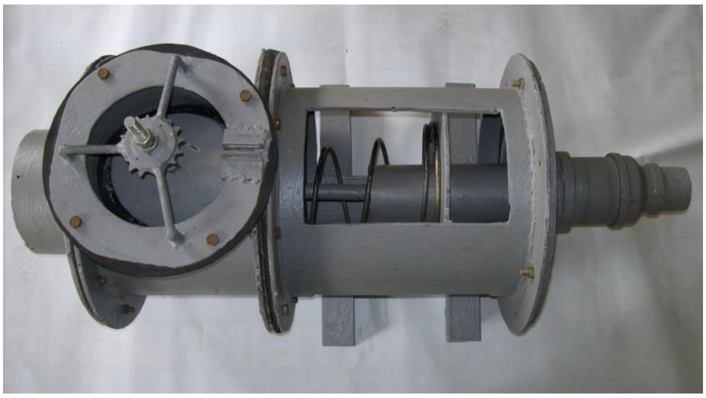

Figure 4. Fabricated hydraulic diaphragm pump

Figure 5. On-site setup of the hydraulic diaphragm pump

Table 1. Specifications of the hydraulic diaphragm pump

ITEM	SPECIFICATION
Main structure	
Overall dimension, mm	
Diameter	360
Length	914
Thickness	5
Weight, kg	50
Material	Steel pipe
Capacity @ 2 m supply head & 30m delivery head (L/min)	6
Body assembly (two joint steel pipe cylinders)	
Cylinder 1 : Diameter	178
Length	76
Cylinder 2: Diameter	152
Length	127
Impulse valve	
Surface diameter	178
Diaphragm: Diameter	300
Concavity	75
Material	Rubber
Pump end	
Cylinder bore	76
Length	178
Connecting rod: Diameter	12
Length	150
Material	Gauge 40 steel pipe
Spring capacity, kg	50
Piston gasket: Material	Rubber
One way valve: Diameter	38

The pump has a total dimension of 292 mm diameter, 914 mm long, and 5 mm thick. The body is made from high quality steel pipe to withstand the internal shock loads caused by water hammering. Two pieces of steel pipes having dimensions of 178 mm diameter and 76 mm long; and 152 mm diameter and 127 mm long are joined and used as a mounting of the impulse valve and the inlet of the drive pipe, respectively. The pump body has four flat sheet rings. The ring connecting the drive end and the pump end has a dimension of 267 mm inside diameter. The inlet of the drive pipe is mounted to a flat sheet with an inside diameter of 152 mm. The suction inlet and the discharge outlet are mounted to a 356 mm outside diameter and 102 mm inside diameter flat sheet. Bolts and nuts are used to assemble and disassemble the device.

The impulse valve is the critical part of the device because it builds a high pressure to operate the pump upon the rapid closing of the valve. It is made from 5 mm thick steel pipe with a surface diameter of 178 mm. The position of the valve is aligned with the curvature of the drive chamber. It has a valve stem guide of 17 mm diameter and 203 mm long. The stopper is equipped with three rod supports where the valve stem guide is mounted. The rubber diaphragm is made from good quality rubber that can withstand pressures built by water. It expands to push the piston to deliver water to a higher elevation than the source.

The pump end is composed of rod, spring, cylinder bore, gasket cup, and its support. The rod is made of gauge 40 steel pipe with diameter and length of 13 mm and 203 mm, respectively. The spring is responsible in returning the diaphragm to its original position when the impulse valve opens and causes the piston to move backwards to suck water from the intake valve. It is made from a coil with a capacity of 50 kg. The cylinder bore is made of steel tube to resist static pressure upon delivery of water. It is constructed from 76 mm diameter and 178 mm long steel pipe. The gasket cup pushes the confined water from the cylinder bore through a non-return valve to the delivery pipe. It has a diameter of 76 mm. Also, it is equipped with two supports, the rear, and front support.

Table 2. Advantages and limitation of the hydraulic diaphragm pump

ADVANTAGE	LIMITATION
Does not need fuel and electricity Can operate for as low as 0.5m supply head	Requires continuous moving water (at least 0.5m supply head)
Requires no big pressure tank	
Ease of repair and maintenance	
Environmentally friendly	

CONCLUSION

The study was centered towards the design and fabrication of a hydraulic diaphragm pump which could be of potential help to upland farmers to aid not only in irrigation systems but also for domestic use. Through the design analysis and use of CAD software, a prototype of the conceptualized machine design was designed and fabricated following the design considerations and criteria. The use of the device will help farmers to plant even during summer season with least cost of inputs compared to commercial pumps driven by internal combustion engines and electric motor that require the use of electricity and fossil fuels.

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