Designing a pedal-operated diaphragm pump and assessing its performance

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Abstract:

This research study presents the design and construction of a pedal-operated water pump that may be put to use in a variety of contexts, including garden irrigation, small-scale agriculture, and the removal of water from a reservoir. The pump that is controlled by pedalling may be constructed using just the resources and know-how available locally. The water pumping apparatus consists of a centrifugal pump that may be powered by foot pedals. The housing that the foot pedal and the rotating drive shaft will be linked to on the pump stand is included in the pump stand. It works according to the idea of compressing a tube and then suddenly releasing it. This creates a negative pressure within the tube, which in turn creates a vacuum that sucks water from the sump. This pump, which is controlled by a bicycle's pedals, can extract water from wells and boreholes that are up to 23 feet deep at a rate of 25 to 30 litres per minute. Irrigation and drinking water are provided by it in areas where there is no access to power. It is possible to construct it using materials that are readily accessible in the area, and it is easy to modify it so that it meets the requirements of the people living there. The user saves money on ever-increasing energy expenses, it can be used anywhere, it does not cause pollution, and it provides a good kind of exercise.

Keywords: *Pedal-operated, Diaphragm pump, Performance*

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Introduction:

An engineering endeavour as complicated as the design of a pedal-operated diaphragm pump may be difficult to do, basic overview of the design considerations and an evaluation of the pump's performance (1)

Design Considerations for Pedal-Operated Diaphragm Pump:

Pump Type: Select a diaphragm pump design suited for your application. Positive displacement pumps that use a flexible diaphragm to generate suction and discharge pressure are referred to as diaphragm pumps (2).

Power Source: Pedal power will be used to run the pump, thus you will need to develop a mechanism that can effectively transform the action of pedalling into the reciprocating motion that the diaphragm requires (3).

Diaphragm Material: Choose a diaphragm material that is both long-lasting and chemically robust, since this will ensure that it can tolerate the medium that will be pumped (4).

Valves: Incorporate check valves or other types of valves to control the direction of flow and prevent backflow (5).

Pedal Mechanism: Create a pedal mechanism that enables smooth and consistent pumping action, allowing for pleasant and efficient pedalling, and meets all of these criteria (6).

Frame and Housing: Create a robust structure that will support the components of the pump and offer stability when the pump is in operation. The housing has to be able to facilitate simple maintenance while also providing enough protection for the interior components (7).

Performance Assessment:

Flow Rate: Measure the flow rate of the pump, which indicates the volume of fluid it can transfer per unit time (8).

Pumping Efficiency: Calculate the pumping efficiency by comparing the output power (fluid power) with the input power (pedal power). Efficiency can be affected by factors such as friction losses, valve design, and diaphragm characteristics (9).

Suction Lift and Discharge Head: Evaluate the maximum suction lift and discharge head that the pump can handle effectively. These factors determine the pump's ability to move fluid from a lower to a higher level (10).

Pressure Capability: Assess the pump's maximum operating pressure, which determines the pump's ability to overcome resistance in the system and deliver fluid under pressure (11).

Reliability and Durability: Evaluate the pump's reliability and durability under different operating conditions. Consider factors such as diaphragm life, wear and tear of components, and resistance to clogging or damage from solids (12).

Maintenance and Ease of Use: Assess the ease of maintenance, including the accessibility of components for inspection and replacement. Consider ergonomic factors to ensure comfortable and user-friendly operation (13).

Remember that the design and performance assessment of a pedal-operated diaphragm pump should be tailored to the specific application and requirements. Detailed engineering analysis, prototyping, and testing are crucial steps to ensure optimal performance and efficiency (14).

Material and Methods:

Survey work was conducted in the selected villages of Orissa during 2000 to collect the information on different mechanical and ergonomical problems related to the two most popularly used manual pumps i.e. low lift hand pump (LLH pump) and Krishak Bandhu pump (KB pump). The two pumps were tested and based on the test result analysis, feedback from users and other factors; a pedal operated diaphragm pump was designed and fabricated.

For the purpose of decision making regarding pump study 19 numbers of villages (varying from 2 to 5) in the districts of Khurda, Puri, Bhadrak, Balasore, Dhenkanal and Bolangir were selected. In selection of village, population of manual pumps in the village and its' use was considered as the main criteria. Preference was given for village selection where the numbers of manual pumps being actually used by the farmers was more. In selecting the villages, the help of officers of Agriculture Departments and Block officers was taken.

Treadle pumps provide one of the best ways of using human power to lift water. Ergonomic is the science of matching people with machines- in this case matching operators with pedal operated diaphragm pump (PD pump)/ treadle pump. In this way, the pump component sizes and dimensions are chosen to get the best out of the human power input and ensure that the pumps are comfortable to operate. Therefore sizing ofthe components and careful design are essential to ensure that this is done in the most efficient manner. Pump output requirements of discharge and pressure must be matched with the mechanical components, such as the diameter of the cylinder, stroke length, mechanical advantage and the cadence- the frequency with which the treadles are pushed up and down. This process of design is complicated by the wide variations of possible pumping needs of different sites and the wide range and adoptability of operators. The design must also be as simple as possible in terms of its manufacturing and maintenance. Design of pump based on observations is discussed in the following articles.

The PDP was developed in the workshop of Implement Factory of Depth of Agriculture, Govt, of Orissa as per the design specification. The process of development for the pump has been mentioned in the following paragraphs. It essentially consists of three parts i.e. pumping unit, base frame and operating system.

Result and Discussion:

Testing of the developed pedal operated diaphragm pump

The cadence that was created by both male and female operators was shown to have a polynomial connection with the suction head, as can be seen in Figure 1. For male and female operators, respectively, the values dropped from 41.2 to 29.6 and 37.6 to 26.2 for the LLH pump, whereas the values dropped from 50.0 to 34.6 and 45.4 to 31.2 for the KB pump. The drop is because a greater pumping power is needed to overcome the higher head at which it is operating.

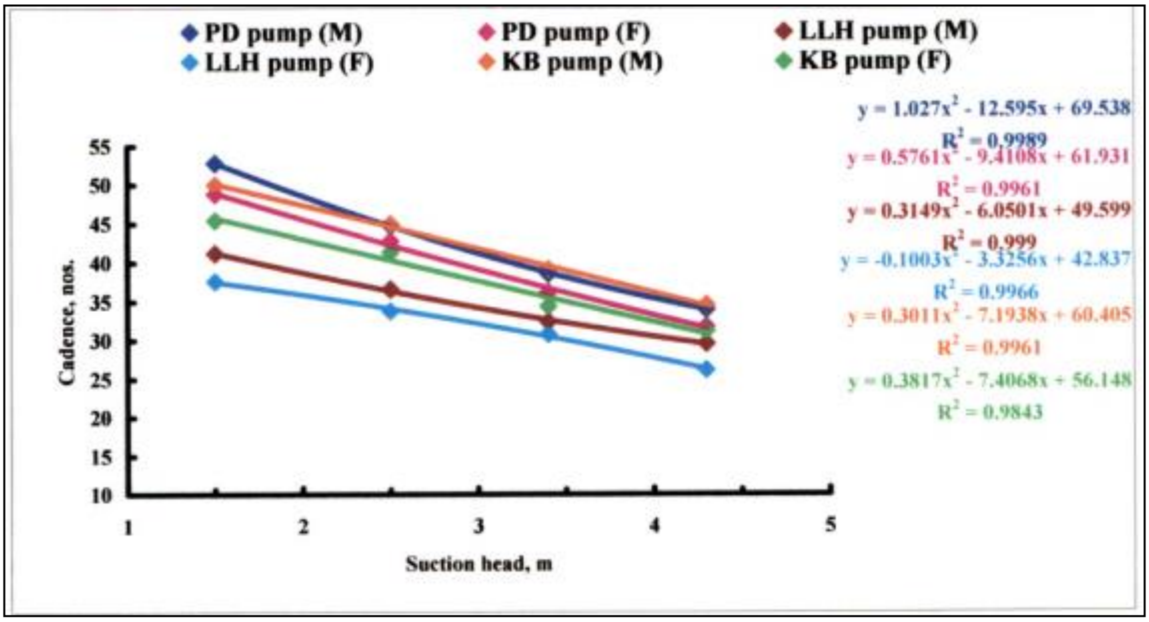

Figure 1: Suction head Effect of operators on cadence for three manual pumps

The discharge was lower in female operators than that of male operators owing to the natural fact that among operators, women are less strong than the male person and they were able to operate at comparably lower cadence. This is the reason why the discharge was lower in female operators than that of male operators. According to ergonomists, the maximal aerobic power of a woman is around seventy to seventy-five percent of that of a man (15).Figure 2 displays the head capacity curves for each of the three pumps.

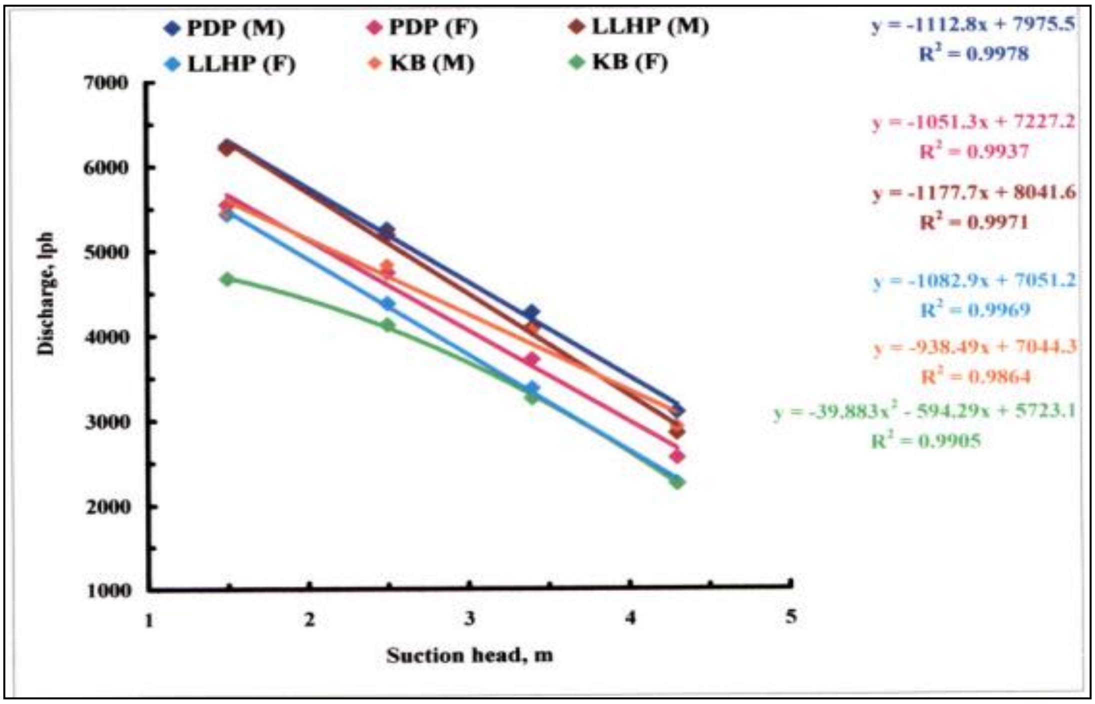

Figure 2: Suction head Effect for three manual pumps on discharge

Performance characteristics of pedal operated diaphragm pump in field condition

According to the results of the tests that were carried out, a pedal-operated diaphragm pump has superior performance characteristics, especially those pertaining to the human aspect. The experiment was carried out at the hydraulic laboratory of the Department of Soil and Water Conservation Engineering at CAET, which had a maximum suction head of up to 4.3 metres. However, the environmental conditions in the laboratory are not an accurate reflection of the conditions seen in the field. As a result, the pump was put through rigorous testing in the environment it would normally be used in. At five different suction heads of 1.5 (Hi), 2.5 (H2), 3.4 (H3), 4.3 (H4) and 5.2m (H5), the pump was tested for its various performance parameters, such as its head-discharge relationship, cadence, foot force requirement, volumetric efficiency, and overall efficiency, with operators of both sexes and ages ranging from 20 to 26 years old (Ai), 27 to 33 years old (A2), and 34 to 40 years old (A3). In addition, the pump underwent an ergonomic analysis to determine the working heart rate (WHR), the average heart rate (AHR), the oxygen consumption rate (V02), the energy expenditure rate (EER), the mean arterial pressure (MAP), and the overall discomfort rating (ODR) for the agricultural operators. Under the most ideal operating circumstances for the pump, a study was conducted to analyse the work and rest cycles for the operators. All of the aforementioned examinations were conducted at the Central Farm of the OUAT in Bhubaneswar during the months of October 2003 and March 2004. The tests were carried out according to the concept of RBD, which stands for two factors, and the findings were assessed statistically.

Figure 3 displays the average cadence that was achieved by a variety of male and female operators across three age groups while operating the designed pump at five distinct suction heads.

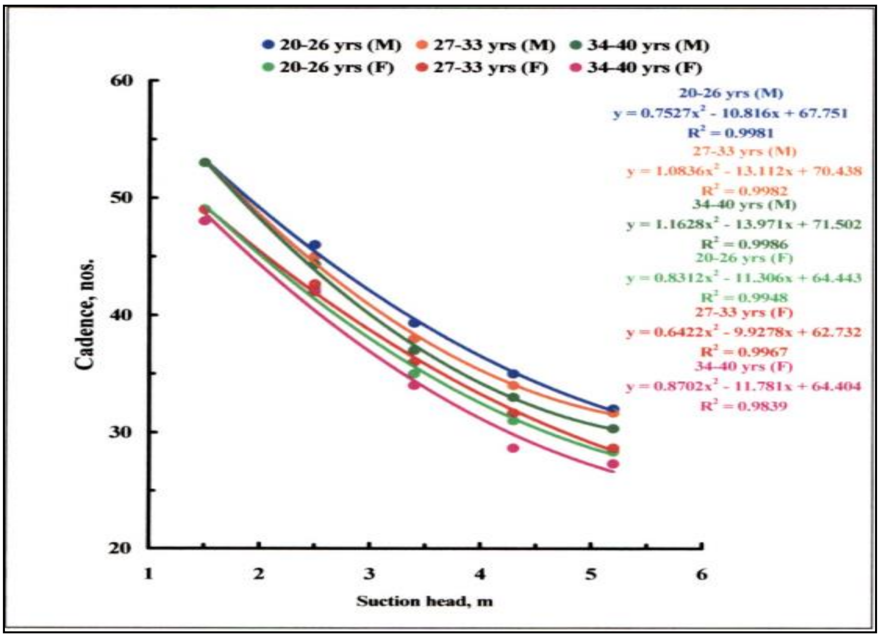

Figure 3: Suction head Effect of different operators on cadence for PD pump

The effect of head on foot force at the pump treadles was noticed to be highly significant for both gender operators. The effect of age of operators on foot force requirement was found to be highly significant (16). The interaction effect of head and age on the foot force was highly significant for male operators but it was significant at 5 per cent level for female operators.

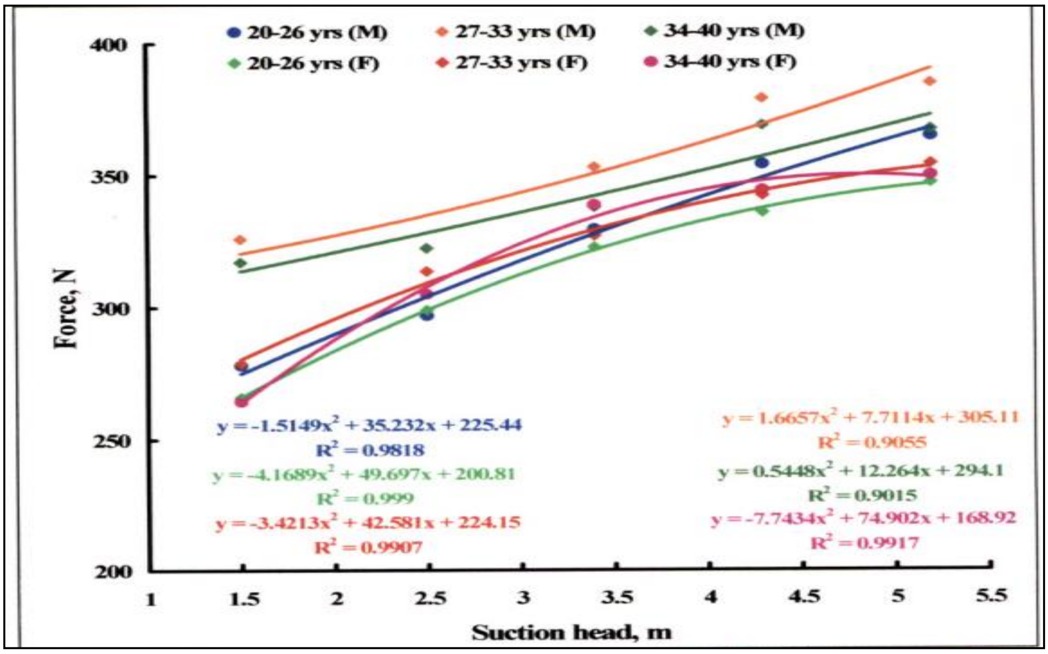

Figure 4: Suction head Effect for PD pump on foot force for operators

Work rest cycle

In the field, the work rest cycle of the chosen operators for continuous operation of the pedal-operated diaphragm pump was investigated at three different suction head heights: 2.5 metres, 3.4 metres, and 4.3 metres. Based on the results of the preliminary tests that were carried out, it was determined that the average endurance limit (EL) for the operators was somewhere in the range of 37 to 42 minutes for male operators and 30 to 35 minutes for female operators when operating at 3.4 metres of suction head. The work rest cycle was analysed by doing continuous work for 15 to 40 minutes at a time, breaking it up into five-minute chunks, and monitoring the operator's heart rate and oxygen consumption rate during the duration. There were three separate iterations of each battle.

It was discovered that the amount of time spent resting grew proportionally with both the number of hours an operator worked and their age. This was the case for workers of both sexes. When comparing the work and rest cycles of male and female operators, it was found that the resting time of female operators was always longer than that of male operators for the same amount of working time. This was true regardless of whether the operators were male or female. This might be because it takes much longer for female operators' WHR and OCR to return to their resting levels than it does for male operators, as was observed (17). It was discovered that the amount of time spent resting by operators working at a suction head of 2.5 metres has an exponential connection with the amount of time spent working (Figure 5 and 6).

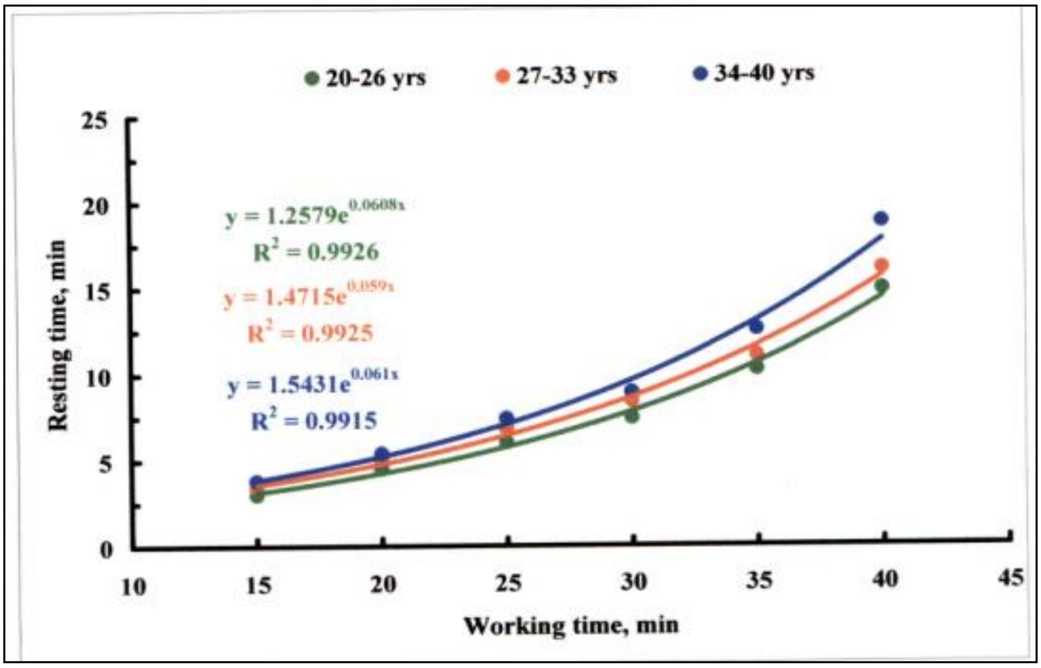

Figure 5: Working time effect for male operators on resting period at 2.5 m suction head

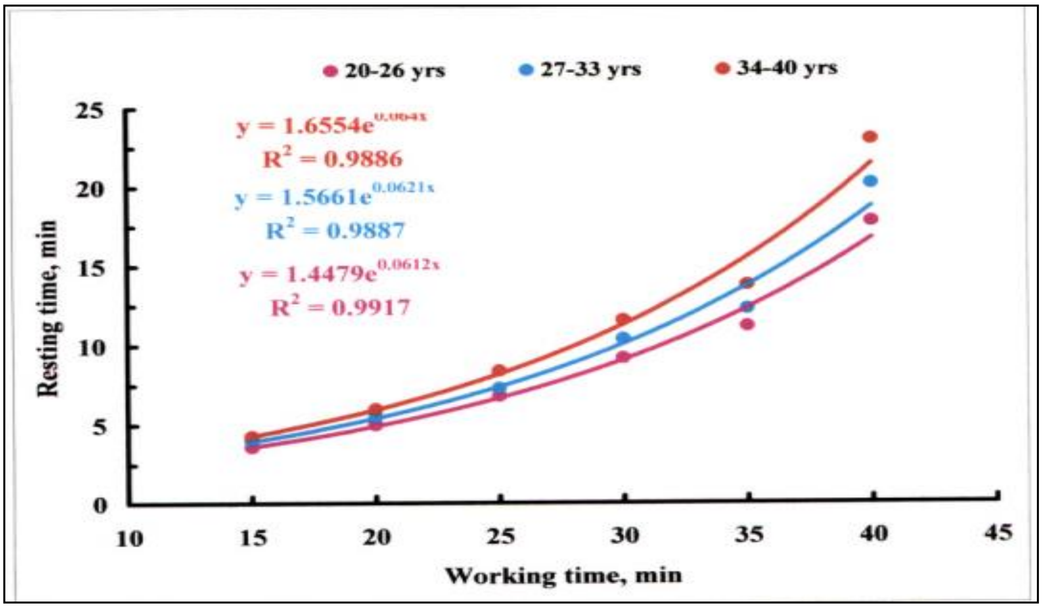

Figure 6: Working time effect for female operators on resting period at 2.5 m suction head

Conclusion:

In order to overcome flow difficulties and transfer liquids from one point to another, whether it be against a larger pressure or to a higher height, energy must be delivered to the liquid. This is true whether the liquid is being transported against a greater pressure or to a higher elevation.

Pumps are used in order to transfer the required quantity of energy from one location to another using fluid. Because of this, the dictionary describes a pump as "A machine used to add energy to a liquid." Pumps have a vast range of potential uses in many different domains. There is a vast selection of both types and dimensions of pumps on the market today. The kind of pump is determined by the function that it is meant to carry out, while the size (and speed) of the pump is determined by the volume of liquid that has to be pushed in a specific amount of time.

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