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Design and Construction of Pedal Operated Water Pump

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ABSTRACT

This paper describes the design and construction of the pedal-operated water pump are done especially discharge rate at different speed and height. The proposed pump is a rotary pump operated by pedal power. In the rotary pump, water enters axially through the vane eyes and exits radially. In this paper, necessary dimensions are calculated for the design point of 6.096 m (20 feet) height, 0.00018 m3/sec flow rate and rotational speed 260 rpm. Pedal-operated water pump is purposed to use in small irrigation and garden irrigation and drinking water where electricity is not available.

KEYWORDS: *Flow rate, Rotary, Pump, Pedal, Speed*

1. INTRODUCTION

Pedal-operated water pump is a pump operated by pedal power. Pedal operated water pump works on mechanical energy without electricity. It is used to lift water in city when there no electricity or load shedding and also in a remote area where there is no electricity. When the pedal is done, bicycle wheel rotates, so finally it rotates a rotary pump which lifts water.

In a pedal operated water pump, a rotary water pump which is run by rotating the pedal of a cycle. The system comprises a bicycle, rim, vane, pulley and inlet and delivery pipes. A wheel is connected to another pulley with a smaller diameter the final supporting shaft is connected with a rotor through this process of paddling is used to lift water from a pipe into the form for cultivation.

This innovation is useful for pumping water from the river, ponds, wells and similar water sources thus enabling poor farmers for pumping water for irrigation and cultivation.

2. Operation of a Rotary Pump

Pump is a device, which raises or transfers liquids at the expense of power input. It is a machine and designed to elevate, deliver and move various liquids or a device that transfers the mechanical energy into potential and kinematic energy of a liquid.

Rotary pumps are positive displacement pumps that utilize rotary, rather than reciprocating, motion in their pumping action. They can be designed to pump liquids, gases, or mixtures of the two. As is the case with reciprocating pumps, their capacity per rotation is independent of driven speed. Unlike reciprocals, however, they develop a dynamic liquid seal and do not require inlet and discharge check valves. Since the rotating element of the pump directly connected to its driver via a shaft, some sort of drive shaft sealing arrangement is required. This is usually accomplished a stuffing box, lip seal, or a mechanical seal.

Figure 1.Rotary Pump

3. Specification

The hand-rotary pump is for transferring oil, water, alcohol, diesel, fuel, gasoline, alcohol, toluene and solvents. High volume delivery at low pressure makes pumping. Each part of the rotary pump shows in Figure 2 and Table I.

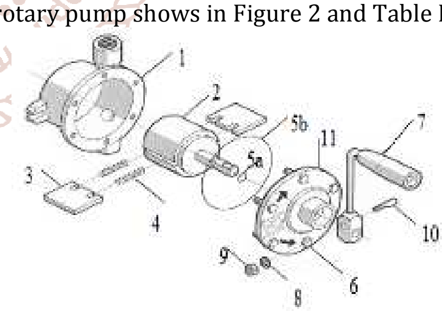

Figure 2.Parts of a Rotary Pump

Table I. Materials of Rotary Pump Component

Position	Denomination	Materials
1	Casing	Cast iron
2	Rotor	Bronze
3	Vanes	Host form
4	Spring	INOX
5a	Shaft O-Ring	Teflon
5b	Casing/ Cover O-Ring	Teflon
6	Cover-Casting Screw	Steel
7	Handle	Galvanized steel
8	Washer	Steel
9	Nut	Steel
10	Cotter	Steel
11	Cover	Cast iron

4. Process of Fabrication

The first step of making power operated water pump is the preparation of the stand. Scarp mild steel pipes are made into sufficient pieces and are welded together to get the stand. The stand is then connected with the back wheel of the bicycle. By considering the wheel and rotor shaft space the regenerative turbine pump is connected with the stand by using the nut and bolts. The suction and delivery pipes are then connected to the suction and delivery ports respectively. Manual priming of the centrifugal pump is done next. By pedaling the rpm of the rotor shaft is measured using tachometer. The flow rate of water is measured by using the measuring tank and stopwatch.

Figure 3.Process of Fabrication

5. Calculation

5.1 Pedal Operated Water Pump Calculation Formula

Sprocket,

A sprocket or sprocket-wheel is a profiled wheel with teeth, or cogs, that mesh with a chain, track or other perforated or indented material.

$$P_x = d_1 \sin\left(\frac{180}{T_1}\right) \qquad 1$$

$$P_x = d_2 \sin\left(\frac{180}{T_2}\right) \qquad 2$$

Where, P_x = Pitch (mm)

T_1= Number of teeth on the smaller sprocket or gear

T_2= Number of teeth on the larger sprocket

d_1 =Front sprocket of diameter (mm)

d_2 = Rear sprocket of diameter (mm)

Chain Design,

The chain drive assumes a special position in the large group of drive mediums for the transmission of torque and power.

$$V.R = \frac{N_1}{N_2} = \frac{T_2}{T_1} \qquad 3$$

Where,

T_1 = Numbers of teeth on big sprocket

T_2 = Numbers of teeth on small sprocket

N_1 = Speed of front sprocket (rpm)

N_2 = Speed of rear sprocket and wheel (rpm)

Centrifugal Tension in the Chain,

$$F_C = \frac{m \cdot v^2}{L} \text{ (Newton)} \qquad 4$$

Where, F_C = Centrifugal tension (N)

m/L = Total mass of the chain per length (kg/m)

v = Speed of the chain (m/s)

Length of Chain,

The length of the chain is the product of the number of chain links and the pitch.

$$L = K.\ p_x \qquad 5$$

Where, L= Length of chain (mm)

K = Chain link

P_x = Sprocket of pitch (mm)

Number of chain links,

$$K = \left(\frac{T_1 + T_2}{2}\right) + 2\left(\frac{x}{P_x}\right) + \left(\frac{T_1 - T_2}{2\pi}\right)^2 \times \left(\frac{P_x}{x}\right) \qquad 6$$

Where, x = Center distance between chain sprocket (mm)

T_1= Numbers of teeth on big sprocket

T_2 = Numbers of teeth on small sprocket

Tension in Chain due to Sagging,

$$F_S = k \cdot W \cdot x = k \cdot mg \cdot x \text{ (Newton)} \qquad 7$$

Where, m = mass of the chain in kg per meter length

x = center distance in meters

k = constant which takes into account the arrangement of the chain drive

= 2 to 6, when the centerline of the chain in inclined to the horizontal at an angle less than 40°

= 1 to 1.5, when the centerline of the chain in inclined to the horizontal at an angle greater than 40°

p_X = Sprocket of pitch (mm)

Power Transmitted,

$$P = \frac{W_B \times v}{n \times K_S} \qquad 8$$

Where, W_B= Breaking load in newton's,

V = Velocity of chain (m/s)

N = Factor of safety, and

K_S = Service factor

Tangential Driving Force,

$$F_T = \frac{\text{Power transmitted (in watts)}}{\text{Speed of chain in m/s}} = \frac{P}{v} \qquad 9$$

Design of Power,

Power is the rate at which energy is applied to a system (Watts = Joules/Second).

The power transmitted by the chain is given by:

Design power = Rated power × Service factor 10

Where,

K_1 = Load factor,

K_2 = Lubrication factor and

K_3 = Rating factor

Rated power,

$$P = \frac{2 \times \pi \times N \times T}{60} \qquad 11$$

Torque, $T = F \times R$ 15 15 15 (3.15)

Where, P = Rate Power (Watt)
T = Torque (Nm)
F = Force (N)
R = Radius (m)

Velocity Ratio of a Belt Drive,
The velocity ratio of a belt drive may be broadly defined as the ratio of the velocities of the driver and the follower or driven.

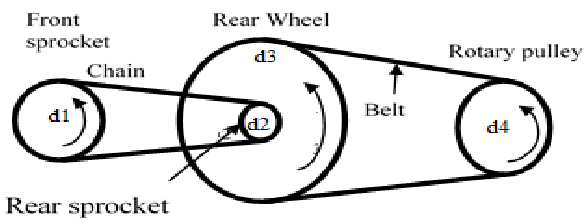

Figure4. Chain and Belt Drive

Let, d_1 = Diameter of front sprocket (mm)
d_2 = Diameter of rear sprocket (mm)
d_3 = Diameter of rear-wheel (mm)
d_4 = Diameter of pulley (mm)
N_1 = Speed of the front sprocket
N_2 = Speed of the rear sprocket
N_3 = Speed of the rear wheel
N_4 = Speed of the pulley

The velocity ratio of the sprocket 1 and 2,

$$\frac{N_1}{N_2} = \frac{T_2}{T_1} \qquad 12$$

Similarly, the velocity ratio of the pulleys 3 and 4.

$$\frac{N_3}{N_4} = \frac{d_4}{d_3} \qquad 13$$

Torque on the shaft because of power transmitted is:

$$M_t = \frac{9550}{rpm} \times kW \qquad 14$$

Torque on the shaft due to belt drive power transmission is:

$$M_t = (T_1 - T_2)\frac{d_4}{2} \qquad 15$$

$$M_t = \frac{9550}{rpm} \times kW = (T_1 - T_2)\frac{d_4}{2} \qquad 16$$

belt tension,

$$\frac{T_1}{T_2} = e^{\frac{\mu\theta}{\sin\beta}} \qquad 17$$

$$\sin\alpha = \frac{d_3 - d_4}{2C} \qquad 18$$

$$\theta = 180 \pm 2\alpha \qquad 19$$

Where,
θ_1 = angle of wrap of pulley
θ_2 = angle of wrap of rear rim
μ = coefficient of friction between pulley and belt

Length of the Belt,
Length of the belt means the total length of the belt, required to connect a driver and a follower.

$$L = 2 \times C + \left[\frac{\pi(d_3 + d_4)}{2}\right] + \left[\frac{(d_3 - d_4)^2}{4 \times C}\right] \qquad 20$$

Where,
L = Length of the belt (mm)
C = Center distance of pulley and rear wheel bicycle (mm)
D = Diameter of rear wheel bicycle (mm)
d = Diameter of pulley (mm)

Flow Rate,
In physics and engineering, in particular fluid dynamics and hydrometric, the volumetric flow rate (also known as volume flow rate, rate of fluid flow or volume velocity) is the volume of fluid which passes per unit time; usually represented by the symbol Q (sometimes $\dot{V}$).

$$Q = n \times V_s \times \eta_{vol} \qquad 21$$

Where,
Q = Flow rate, mm^3/s
n = revolution per second ,rev/s
V_s = Swept volume (mm^3)
η_{vol} = Volumetric efficiency

Output Power,
The output power is the power applied to the fluid to meet the requirement of network throughput.

$$P = \rho g Q H \qquad 22$$

Where,
Q = Fluid flow rate through the pump, m^3/s
g = Gravitational acceleration (9.81 ms^{-2})
H = Total Differential Height (m)
ρ = Density of the fluid beyond pumped (water: 1000 kg/m^3)

Input power,
Input power is always greater than output power due to the friction in the pump. Pump efficiency is the ratio of these two values.

$$\text{Pump Efficiency} = \frac{\text{Output Power}}{\text{Input Power}} = \frac{P_o}{P_i} \qquad 23$$

Table II. Rotary Pump at Tested Discharges

No.	Rotary Pump Shaft n =260 rpm, (4.33 rps)	Tested Discharge, Q(m^3/s)	Tested Height (m)
11	4.33 rps	11 liter/min or (0.00018 m^3/s)	6.096 m
22	4.33 rps	15 liter/min or (0.00025 m^3/s)	4.572 m
33	4.33 rps	27 liter/min or (0.00045 m^3/s)	3.048 m
44	4.33 rps	40 liter/min or (0.0006 m^3/s)	1.524 m

Table III. Result Data of Pump Efficiency and Power

No	Pump Efficiency	Volumetric Efficiency	Output Power (Watt)	Input power (Watt)
11	0.8	0.0219	10.76	13.45
22	.8	0.0412	11.21	14.01
33	0.8	0.0108	13.46	16.83
44	0.8	0.0289	8.97	11.21

Table IIIV. Result Data of RPM and Height of Front Sprocket and Rear Wheel

No.	Front sprocket, rev/min	Rear sprocket & wheel, rev/min	Rotary pulley, revv/min
1	50	100	260
2	66	133	346
3	84	168	437
4	88	175	455

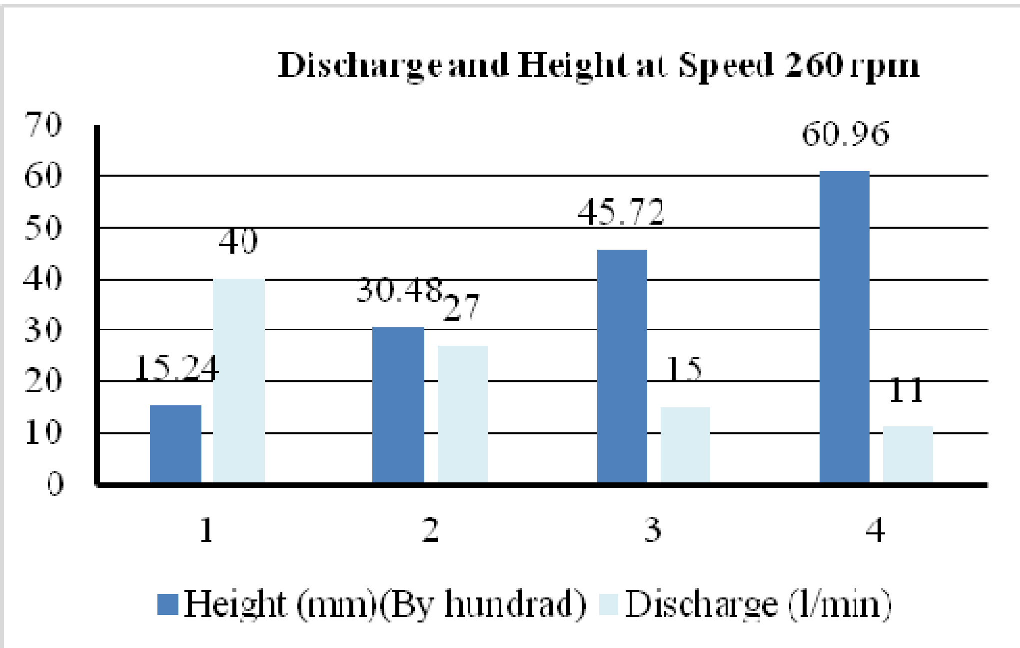

Figure5. The graph between Discharge and Height

6. Discussion and Conclusion

The pedal pump designed and constructed, so that a long time operation is possible with high efficiency. It is simple and rigid in construction, compact and portable. Manufacturing cost is lesser than the modern water pumping machine. The power saved and good exercise for all people. It uses manual power hence no fuel is required. Operation is economically and less maintenance cost. The operation is not much noisy.

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