# Development of a Pedal Powered Centrifugal Pump for Rural Use



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# Development of a Pedal Powered Centrifugal Pump for Rural Use

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**A R T I C L E I N F O**

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## A B S T R A C T

*A pedal powered centrifugal water pump (PPCWP) system was developed for use in underdeveloped countries where electricity is not available for energizing a mechanical system to cause useable drives. The pumping system comprises of chain and belt drives for power transmission. The design analysis of each component was done for their specification determination. And each component material for fabrication was selected before production and assembly of the component. This was followed by performance evaluation of the developed pedal powered centrifugal water pump. The developed pump has a discharge rate of 0.0016* $m^3/s$ *at a head of 15 m using a driving torque of 8.95 Nm with estimated efficiency of 78 % considering loses and applied energy variation. This is fairly good enough result for pedal operated pumping system compared with the manually operated pump of same capacity. There is an improvement on rate of discharge due to increase in speed. The manually operated efficiency was estimated to be average of 51 %. This shows that 27 % increase in the efficiency when PPCWP is used. Areas of applications of this pump are in irrigation of farm, and drinking water pumping.*

## 1. INTRODUCTION

Water pumping technology developed in parallel with the sources of power available at the time. Indeed one can say that our first ancestors who cupped their hands and lifted water from a stream chose the ‘pumping’ technique appropriate to them (Leary, 2010). Modern devices such as centrifugal pumps which are used to transport fluids by the conversion of rotational kinetic energy to the hydrodynamic energy of the fluid flow have reached a high state of development and are widely used, particularly in developed countries, only because suitable power sources such as diesel engines and electric motors became available (Sermaraj, 2006).

The simplest pumps of all are those operated by human power. In this category come a range of hand pumps and foot pumps. The power available from human muscle depends on the individual, the environment and the duration of the task. For work of long duration, for example eight hours per day, a healthy man is estimated to produce 60-75 watts (Okuni, 2002). This value must be reduced for women, children and the aged. It also must be reduced for high temperature, and work environments with high humidity. Where the pump user and the pump are poorly matched, much of the power input is wasted, for example, when a person operates a pump from a stooped position. Tests and user evaluations help to bring out problems, such as rejection of foot pumps because pregnant women and young children could not easily operate them or the movement was not culturally acceptable (Shigley, 2006).

Pedal power is the transfer of energy from a human source through the use of a foot pedal and crank system. Since the thigh or quadriceps is the largest and most powerful muscles in the human body it makes sense to utilize it for generating as much as energy from human body. With the body on seat, the legs can provide a pedal work (Kajogbola *et al.,* 2010).

For small communities in developing countries, human and animal power is often the most readily available power for pumping water, particularly in rural areas. Under suitable conditions wind power is of relevance. Solar energy can also have potential. Diesel engines and electric motors should only be used if the necessary fuel or electricity supplies are reliably available, together with adequate maintenance and spare parts. Thus, the unavailability of electricity supply in most of the rural communities has prompted the development of a manually operated pump. The literature review brings technologies used so far in the area of water pumping. These methods are hereby stated and explained:

History reveals that, human energy has generally been applied through the use of the hands, arms, and back. With minor exceptions, it was only with the invention of the sliding-seat rowing shell, and particularly of the bicycle, that legs also began to be considered as a "normal" means of developing power from human muscles (David, 1987). Although increasing access to energy is not directly stated as one of the eight Millennium Development Goals officially formed in 2000, it is recognized as being the driver for many of the targets. Access to energy services is integral in the achievement of the Millennium Development Goals and is recognized and discussed extensively in literature (Modi *et al.,* 2005) recommended that emphasis is put on the immediate access to transitional mechanical energy devices. For the purposes of international development, this is a significant consideration; to recognize how the technology and the requirements needed from it may evolve as the users to their community.

Foot pedaling power is one of the most efficient ways to utilize human power. The efficiency of foot pedaling, the power it generates, and its ease of use are reasons foot power is used extensively for human powered transportation. Pedal power can be harnessed for countless applications which would other-wise require electricity (which may not be available) or hand power (which is far more effort). The following examples show what human power can accomplish with pumping. Biking is an effective and especially ergonomic way to deliver power to a pump (Rajesh *et al.,* 2012).

The main use of pedal power today is still for bicycling, at least in the high-power range (75 watts and above of mechanical power). In the lower-power range there are a number of uses of pedal power for agriculture, construction, water pumping, and electrical generation that seem to be potentially advantageous, at least when electrical or internal-combustion engine power is unavailable or very expensive (Ganorkar *et al.*, 1992).

There are places where wells and bore wells are very deep and to fetch water manually is cumbersome and strenuous. At such places, pedal powered pump can be used. Also at a higher level it can be used for irrigation and drinking water purposes. For pumping more water, electric pump is needed, but where electricity is not available pedal-powered water pump can be of great use (Tiwari *et al.*, 2011).

Akinwonmi *et al.,* (2012) conducted an experiment on “Pedal powered centrifugal pump” PPCP. They found out that the discharge increases uniformly with the increase in rotational speed (rpm) of the pedal powered pump. Experimental result shows that discharge of about 0.00025 $m^3$/sec can be obtained for around 140 rpm as shown in figure 1.1.

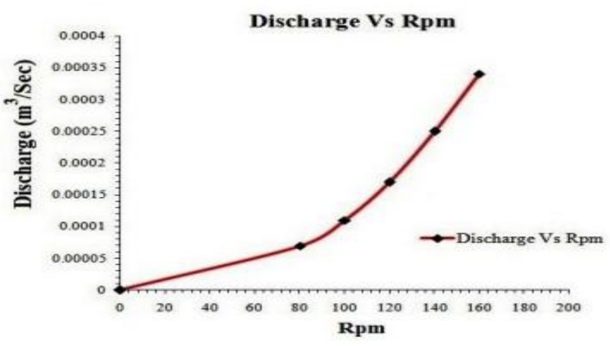


**Figure 1.1:** Variation of Discharge with rpm
(Source: Akinwonmi *et al.,* 2012)

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It is observed that the head decreases uniformly with discharge. Experimental result showed that head of 8 m can be obtained with discharge of about 0.00007 $m^3/sec$. But confirmed experienced variation in the obtained plot due to errors in observation and power transmission losses (Akinwonmi, *et al.*, 2012). This is shown in Figure 1.2.

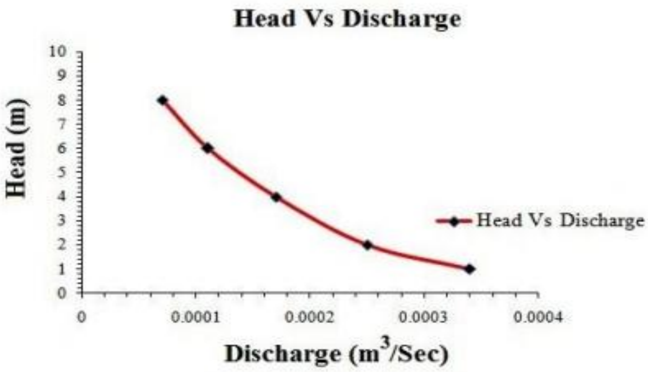
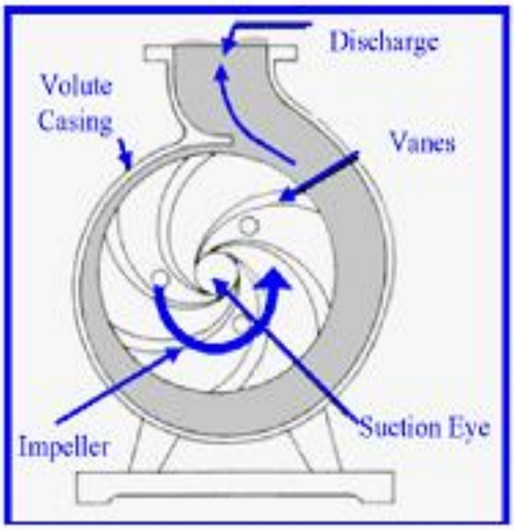



**Figure 1.2:** Variation of Head with Discharge
(Source: Akinwonmi *et al.*, 2012)

The higher delivery/discharge pressure required more the number of impellers that would be needed (Modi *et al.*, 2005). All the forms of energy involved in a fluid flow system are expressed in terms of head or height of liquid column discharged by the pumps (Serazul *et al.*, 2007). The impeller gives the liquid a relatively high velocity that can be converted into pressure in a stationary part of the pump, known as the diffuser (Sreejith *et al.*, 2013).

A centrifugal pump generally has a valve in the discharge line to control the flow and pressure (Carlos, 2010) as shown in figure 1.3a and 1.3b.



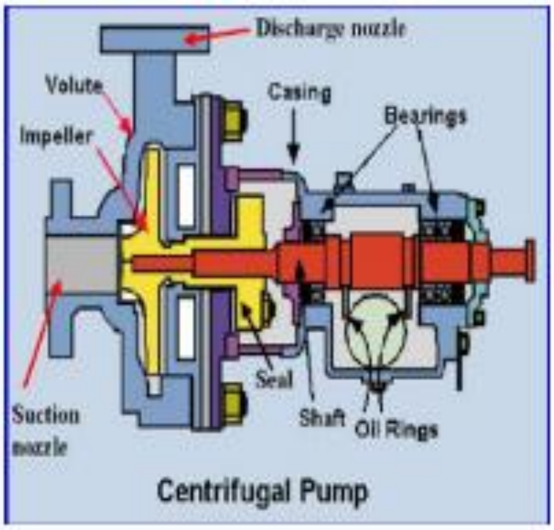




**Figure 1.3a:** Flow direction
(Source: Carlos, 2010)

**Figure 1.3b:** Dissection of the pump

Larry, 2006 developed a bicycle powered pump which allows the use of a standard bicycle to be mounted in a trainer and used to power the pump. When finished pumping, the bicycle may be quickly released from the trainer to be used in its normal transportation mode. The trainer can fit most people and be adjusted so that the bike is level during operation. A bracket was built to hold the pump to the trainer roller. The roller assembly attaches to the trainer and the rear wheel of the bicycle rides on the roller, and turns it when the bicycle is pedalled. The pump shaft is coupled to the roller shaft with flexible hose to allow for run out. A plate was attached to the left side of the roller assembly to function as a flywheel that helps smoothen the power requirements. The figure is shown in plate 1. The Larry method used in plate 1 is the most common pedal system method used. This method has its demerits which are generation of heat in between the wheel tyre of the

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bike and the rotor when it is fixed permanently. The life span of the tyre is very short because the higher the frictional effect the better is the system performance. Secondly, when partially or fully deflated, there will be a drop in the system performance or not performing due to slippage. This is the gap in literature that this study is filling.

**Plate 1:** Bicycle Powered Water Pump
(Source: Larry, 2006)

## 2. METHODOLOGY

The methods used to accomplish the objective of this research are: identification of the required components, design analysis of each component, material selection, fabrication or purchasing the components identified, assembly of the components, installation to the well or borehole site and performance evaluation of the system developed.

### 2.1 Nomenclature

V.R is velocity ratio
$N_1$ is speed of rotation of smaller sprocket in rpm
$N_2$ is speed of rotation of larger sprocket in rpm
$Z_1$ is number of teeth on the smaller sprocket
$Z_2$ is number of teeth on the larger sprocket
K is number of chain links
L is the length of chain in mm
p is the pitch
x is the centre distance
$r_1$ is radius of the driver pulley
$r_2$ is radius of the driven pulley
$\theta$ is angle of contact
P is power transmitted by the belt in Watts
$T_1$ is tension on the tight side of the belt
$T_2$ is tension on the slack side of the belt
V is peripheral velocity
$D_p$ is driver pulley diameter in mm
t is the pulley thickness in mm
$\pi$ is pie constant (3.142)
$\mu$ is coefficient of friction 0.38 (for leather)

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M is mass in "Kg"
g is acceleration due to gravity in $m/s^2$
$R_A, R_B$ are reactional resultant forces at points A and B, 'N'
$W_p$ is weight of pulley
$W_s$ is weight of sprocket
$S_{C-B}$ is shear force "N"
$M_A$,$M_B$,$M_D$ are bending moments in "Nm"
$\tau$ is torque in "Nm"
$\omega$ is angular speed in "rpm"
$I_{xx}, I_{yy}$ are moment of inertias about x-x and y-y in "$mm^4$"
E is modulus of elasticity for the material of the column
I is moment of inertia
$W_{cr}$ is maximum permissible load in N
Q is discharge in $m^3/s$
A is area of impeller in $m^3$
V is velocity of impeller in $m/s$
$\varepsilon$ is pump efficiency
$\rho$ is density of fluid in $kg/m^3$

## 2.2 Design Analysis Required for Machine Development

### *2.2.1 Design Analysis of Chain Drive*

It consists of two sprockets and one chain. The sprocket on the pedal is the driver sprocket while that on the pulley shaft is the driven.
The velocity ratio of chain drive is given by:

$$\text{V.R.} = \frac{N_1}{N_2} = \frac{T_1}{T_2} \quad \ldots (1)$$

Tiwari *et al.*, 2011, stated that the optimum cadence for pedalling is 80 rpm. Therefore, the speed of the larger sprocket for this design is taken as 80 rpm.
This speed is stepped up to 200 rpm.
Thus, $N_1 = 200$ rpm
And $N_2 = 80$ rpm
Hence, the velocity ratio is calculated from equation (1)

$$\text{V.R.} = \frac{N_1}{N_2} \quad \ldots (2)$$

$$= \frac{200}{80} = 2.5 \cong 3$$

Now, to determine the number of teeth on the larger sprocket $Z_2$, Khurmi and Gupta, 2005 stated that in order to have smooth operation, the minimum number of teeth on the smaller sprocket or pinion may be taken as 18 for moderate speeds and 21 for high speeds.
Therefore, for this design the number of teeth on the smaller sprocket is taken as 18. i.e. $Z_1 = 18$.
Thus, number of teeth on the larger sprocket or gear is given as:

$$Z_2 = Z_1 \times \frac{N_1}{N_2} \quad \ldots (3)$$

$$Z_2 = 18 \times \frac{200}{80}$$

$$Z_2 = 45$$

### *2.2.2 Length of Chain*

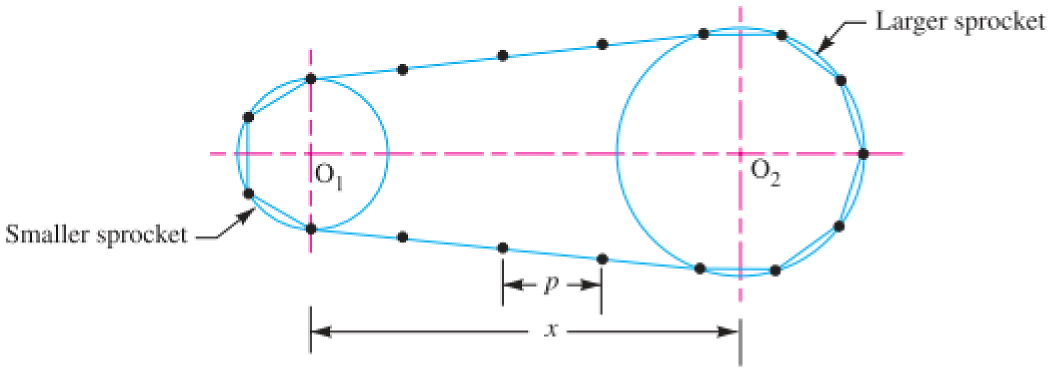


**Figure 2.1:** Length of Chain
Source: Khurmi and Gupta, 2005

The length of the chain (L) is the product of the number of chain links (K) and the pitch of the chain (p).
Mathematically, L = K.p … (4)
The number of chain links is given as:

$$K = \frac{T_1+T_2}{2} + \frac{2x}{p} + \left(\frac{T_2-T_1}{2\pi}\right)^2 \frac{p}{x} \quad \dots (5)$$

The pitch of the chain to be used for this design is obtained from the Table 2.1.
Chain number 05B was selected for this design and from Table 2.1. The pitch of the chain selected is 8mm.

**Table 2.1:** Characteristics of Roller Chains According to IS: 2403-1991

| ISO Chain No | Pitch (p) mm | Roller Diameter ($d_1$) max | Width Bet Inner Plates ($b_1$) | Transverse Pitch ($p_1$) mm | Breaking Load kN minimum | | |
|---|---|---|---|---|---|---|---|
| | | | | | Simple | Duplex | Triplex |
| 05 B | 8.00 | 5.00 | 3.00 | 5.64 | 4.4 | 7.8 | 11.1 |
| 06 B | 9.525 | 6.35 | 5.72 | 10.24 | 8.9 | 16.9 | 24.9 |
| 08 B | 12.70 | 8.51 | 7.75 | 13.92 | 17.8 | 31.1 | 44.5 |
| 10 B | 15.875 | 10.16 | 9.65 | 16.59 | 22.2 | 44.5 | 66.7 |
| 12 B | 19.05 | 12.07 | 11.68 | 19.46 | 28.9 | 57.8 | 86.7 |
| 16 B | 25.4 | 15.88 | 17.02 | 31.88 | 42.3 | 84.5 | 126.8 |

(Source: Khurmi and Gupta, 2005)

Khurmi and Gupta, (2005) stated that the minimum centre distance between the smaller and larger sprockets should be 30 to 50 times the pitch.
Taking it as 30 times the pitch
Therefore, centre distance between sprockets,

$$x = 30p \quad \dots (6)$$
$$= 30 \times 8$$
$$= 240 \text{ mm}$$

In order to accommodate initial sagging of the chain, the value of the centre distance is reduced by 2 to 5mm.
Therefore, correct centre distance,

$$x = 240 - 4$$
$$= 236 \text{ mm}$$

Now, to determine the number of chain links, from equation (5)

$K = \frac{18+45}{2} + \frac{2\times236}{8} + \left(\frac{45-18}{2\pi}\right)^2 \times \frac{8}{236}$

K = 91.13mm

Therefore, length of chain,

L = K.p

= 0.729m

**2.2.2.1** *Weight of Driven Sprocket*

Material used: mild steel

Density: $7.85 \times 10^{-3}\ Kg/mm^3$

Diameter of sprocket = 114 mm

Thickness of sprocket = 32 mm

Volume of the material used for the sprocket is given as:

$V = 0.25 \times D^2 \times \pi \times t$ … (7)

$= 72985.48\ mm^3$

Mass of sprocket = volume × density

= 0.573 Kg

Weight of sprocket $= mass \times acceleration\ due\ to\ gravity$

$= 0.573 \times 9.81$

$= 5.621\ N$

### 2.2.3 *Design Analysis of the Belt Drive*

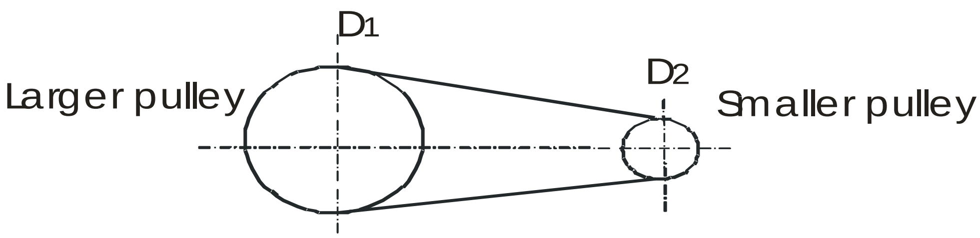


**Figure 2.2:** The Schematic Diagram of the Pulleys and Belt

**2.2.3.1** *Velocity Ratio of Belt Drive*

It is the ratio between the velocities of the driver and the follower or driven. It may be expressed mathematically as:

$V.R. = \frac{N_2}{N_1} = \frac{D_1}{D_2}$ … (8)

Now, to determine the diameter of the driven pulley when the diameter of the driver pulley is 240mm and its speed is 200rpm and the speed of the driven pulley is to be stepped up to 800rpm.

Therefore, the diameter of the driven pulley is given as:

$D_2 = \frac{D_1 N_1}{N_2}$ … (9)

= 60mm = 0.06m

The peripheral velocity:

$V_1 = \frac{D_1 \pi N_1}{60}$ … (10)

= 2.51 m/s

**2.2.3.2** *Determination of Belt Length*

The centre distance between the two pulleys would be assumed to be 360mm using the formula:

L $= \left[\frac{\pi}{2}(D_1 + D_2) + 2x + \frac{(D_1 - D_2)^2}{4x}\right]$ … (11)

= 1.21m.

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**2.2.3.3** *The Angle of Contact between Belt and Pulley*

$\sin\alpha = \frac{(r_1 - r_2)}{x}$ … (12)

$\alpha = \sin^{-1} 0.25$

$= 14.5^{o}$

**Angle of Contact$\theta$**

$\theta = 180 - 2\alpha$ … (13)

$\theta = 180 - 2(14.5) = 151^{o}$

$= 2.64 rad$

**2.2.3.4** *Power transmitted by the Belt*

The power transmitted by the belt is given as:

$P = (T_1 - T_2)\, V$ … (14)

Therefore, taking P as 300W

$T_2 = 69\ N$

$T_1 = T_2 + 119.52$

$T_1 = 69 + 119.52 = 188.52\ N$

$T_1 = 188.52\ N$

$T_2 = 69\ N$

**2.2.3.5** *Determination of Weight of Pulley (Driver)*

Driver pulley diameter $D_p$= 240mm = 0.24m

Volume of pulley = $\frac{\pi}{4} \times D_p{}^2 \times t$ … (15)

$= 9.05 \times 10^{-4} m^3$

Mass of Pulley = Density of mild steel x Volume of pulley

= 7.11Kg

Weight of Pulley = Mg

= 69.78N

**2.2.4** ***Design Analysis of Pulley and Sprocket Shaft***

The loads and the reactions acting on the shaft are illustrated in Figure 2.3 below:

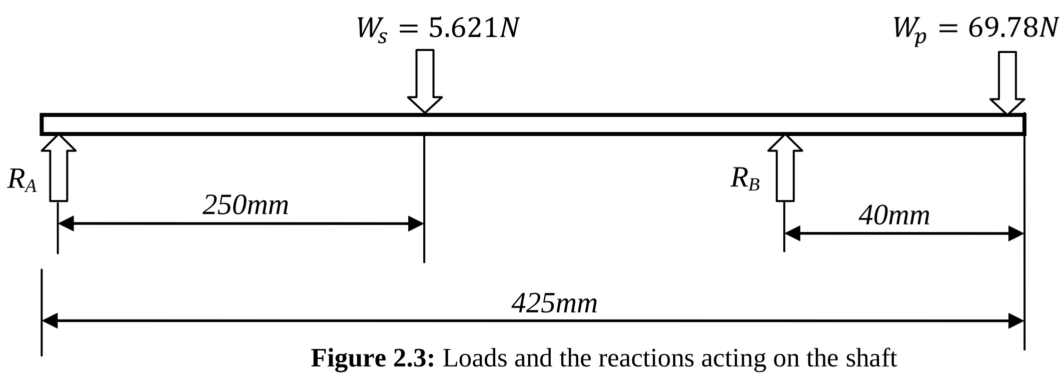


**Figure 2.3:** Loads and the reactions acting on the shaft

From the above diagram $R_A$ and $R_B$ can be obtained using the conditions for equilibrium as follows;

$R_A + R_B = W_s + W_p$ … (16)

$R_A + R_B = 75.4\ N$ … (17)

Taking moment about point $A$

$R_B = 80.69\ N$

To calculate for $R_A$ substitute for $R_B$ in equation (17)

$R_A = -5.29\ N$

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**2.2.4.1** *Shear Force Calculations*
$S_{C\text{-}B} = -69.78$ N
$S_B = -69.78 + 80.69 = 10.91$N
$S_{D\text{-}A} = 10.91 - 5.621 = 5.29\ N$
**2.2.4.2** *Bending Moment Calculations*
$M_D = 0$
$M_B = -69.78 \times 0.04 = -2.79$Nm
$M_A = 0$
$M_D = (-69.78 \times 0.04) + (80.69 \times 0.135) = 8.099N$

**2.2.4.3** *Shear Force and Bending Moment Diagram*

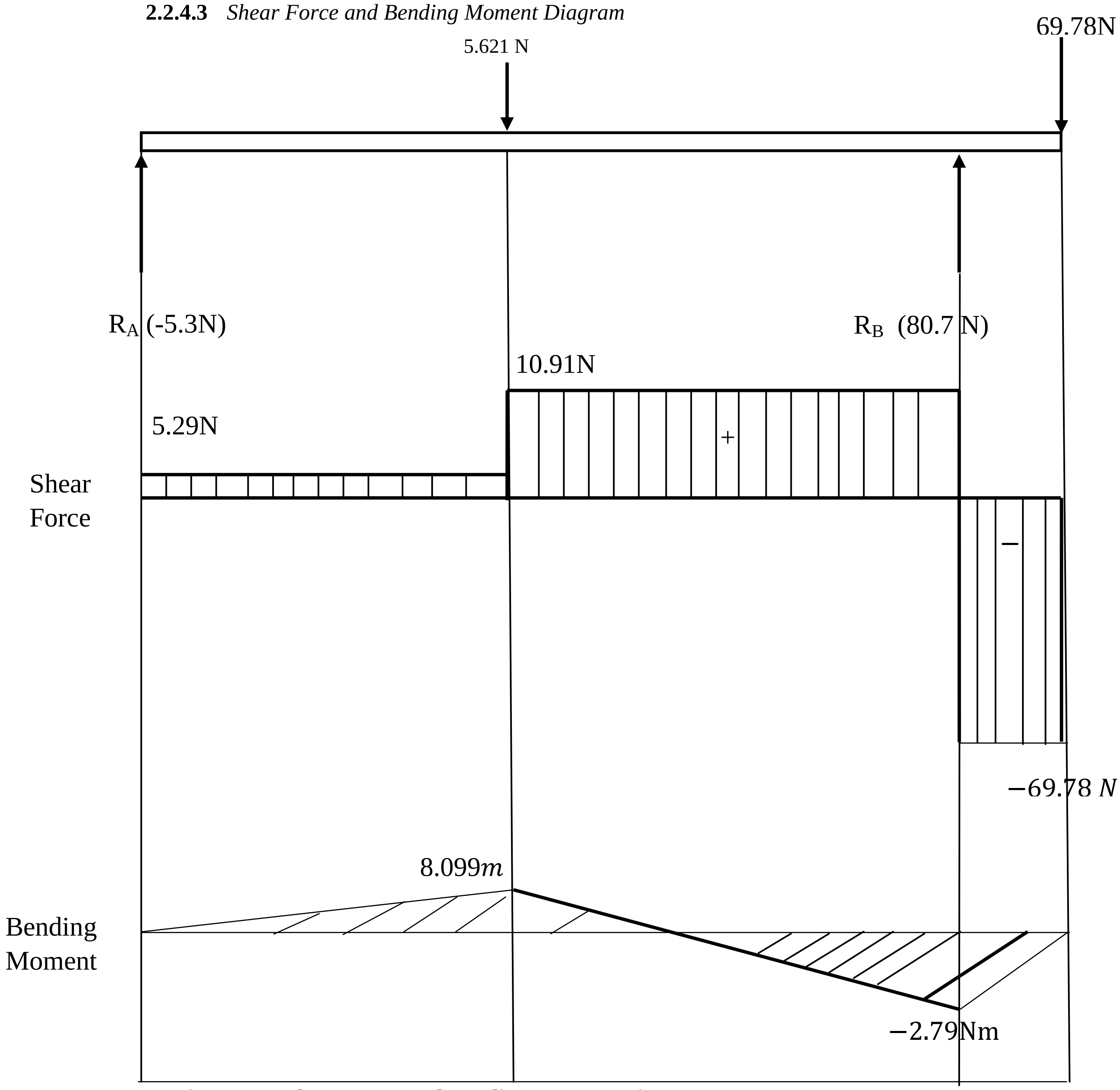


**Figure 2.4: Shear Force and Bending Moment Diagram**

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### 2.2.5 *Determination of Driving Force*

The relationship between power and torque is given as:

$P = \tau\omega$ … (18)

Taking P = 75w

And, $\omega = 80\ rpm$

$\tau = \frac{P}{\omega}$

$= \frac{75}{80 \times 0.10472}$

= 8.95Nm

### 2.2.6 *Maximum permissible Load on the Seat*

The seat is supported by a column of length 880mm and breadth of 38 mm made of mild steel and was fixed at the base to the frame of the machine. In other to analyze the buckling load of the column, the Euler's theorem for buckling is applied.

The Euler's theory for crippling load is used to determine the maximum permissible load of the seat.

The theorem is stated as:

$W_{cr} = \frac{C\pi^2 EI}{l^2}$ … (19)

Using an I-Section of the column measuring 27 mm by 12 mm by 4 mm as shown in Figure 2.5 for the analysis.

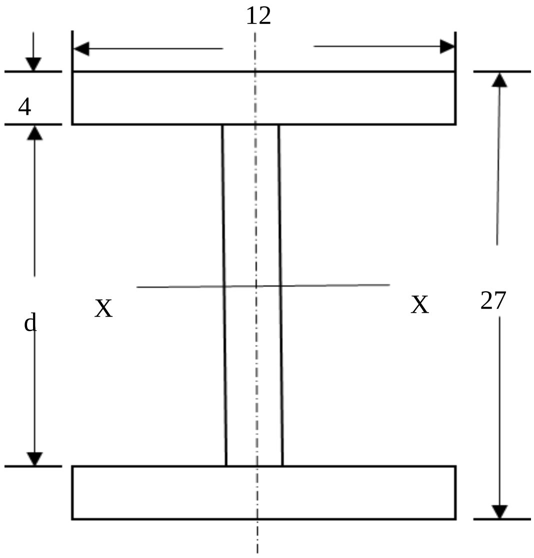


**Figure 2.5**: I-Section of the Seat Column

Using an I-Section of the column measuring 8mm by 5mm by 2 mm as shown in Figure 2.6 below for the analysis.

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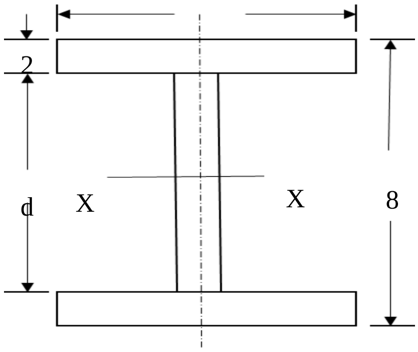


**Figure 2.6:** I-Section of the Pump Platform Column

For a column fixed at one end and the other end free, the end coefficient (C) is given as: 0.25.
The moment of inertia of the I-Section about X-X is given as:

$$I_{XX} = \frac{BD^3}{12} - \frac{bd^3}{12} \qquad \ldots (20)$$

$= 15110 \text{ m}m^4$

And the moment of inertia of the I-Section about Y-Y is given as:

$$I_{YY} = 2\left(\frac{tB^3}{12}\right) + \frac{dt^3}{12} \qquad \ldots (21)$$

$= 1232 \text{ m}m^4$

Since $I_{YY}$is less than $I_{XX}$, therefore the section will tend to buckle about Y-Y axis. Thus, the moment of inertia I of the section is taken as $I_{YY} = 1232\text{m}m^4$

Taking the Young's modulus for mild steel = 200kN/mm$^2$
From equation (19)
$W_{cr} = 785$N
Therefore, the maximum permissible load of the seat is 785N.

### 2.2.7 *Design Analysis of Pump Platform*

The pump was bolted on a square mild steel plate measuring 500mm by 500mm which is supported by four columns.
The Euler's theory for crippling load is used to determine the maximum permissible load of the supporting columns.
The theorem is stated as:

$$W_{cr} = \frac{C\pi^2 EI}{l^2} \qquad \ldots (19)$$

Using an I-Section of the column measuring 8mm by 5mm by 2 mm as shown in Figure 2.6.
For a column fixed at one end and the other end free, the end coefficient (C) is given as: 0.25.
The moment of inertia of the I-Section about X-X is given as:

$$I_{XX} = \frac{BD^3}{12} - \frac{bd^3}{12} \qquad \ldots (20)$$

$= 197.33\text{m}m^4$

And the moment of inertia of the I-Section about Y-Y is given as:

$$I_{YY} = 2\left(\frac{tB^3}{12}\right) + \frac{dt^3}{12} \qquad \ldots (21)$$

$= 72.92 \text{ mm}^4$

Since $I_{YY}$is less than $I_{XX}$, therefore the section will tend to buckle about Y-Y axis. Thus, the moment of inertia I of the section is taken as $I_{YY} = 72.92\text{m}m^4$
Taking the Young's modulus for mild steel = 200kN/mm$^2$

From equation (3.19)
$W_{cr}$ = 225N
Therefore, the maximum permissible load of each column of the support is 225N

### 2.2.8 *Pump Selection*

Leary, 2010 showed that a 300W pump when mounted to a bicycle can lift water to a head of about 30m as shown in figure 2.7.

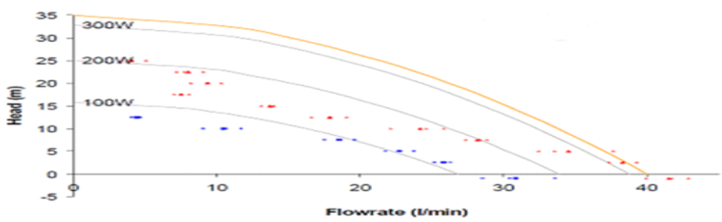


**Figure 2.7:** Experimental Results Showing the Flow Rate
(Source: Leary, 2010)

#### 2.2.8.1 *Pump Flow Rate*

The pump flow rate is given as:

$$Q = AV \qquad \dots (22)$$

For this design, the diameter of the impeller is 50mm and the operating speed is taken as 600rpm.
The area of the impeller is given as:

$$A = \frac{\pi d^2}{4} \qquad \dots (23)$$

$= 1.96 \times 10^{-3} m^2$

And, the velocity is given as:

$$V = \omega r \qquad \dots (24)$$

= 1.47 m/s

Hence, the flow rate of the pump i.e. the theoretical discharge is:

Q = $1.96 \times 10^{-3} \times 1.47$

= 0.0028 $m^3/s$

#### 2.2.8.2 *Evaluation of the Pedal Pump Performance*

The pump was operated to evaluate its performance. The pump was used to pump water from a well at a head of 15m and the discharge was 0.0016 $m^3/s$.
Thus, the pump efficiency is given as:

$$\varepsilon = \frac{\rho g Q H}{P} \qquad \dots (25)$$

= 0.78
= 78%

The pump was further operated for longer period of times and the volume of water discharged at different time intervals are shown in Table 2.2.

**Table 2.2:** Recorded discharge of the pump at different intervals

| Volume ($m^3$) | 0.48 | 0.92 | 1.39 | 1.85 | 2.14 |
|---|---|---|---|---|---|
| Time (min) | 5 | 10 | 15 | 20 | 25 |

### 2.3 Material Selection

The following factors were considered while selecting the material: availability of the materials, suitability of the materials for the working conditions in service, and the cost of the material (Khurmi and Gupta, 2005).
Table 2.3 shows the components, possible materials used, the selected material and reasons for their selection.

**Table 2.3:** Material Selection

| S/N | COMPONENT | MATERIALS | SELECTED MATERIAL | REASONS FOR SELECTION |
|---|---|---|---|---|
| 1. | Frame | Wood, mild steel, high carbon steel. | Mild steel | High resistance to twisting and shock, good load bearing capacity and readily available |
| 2. | Shaft | Medium carbon steel, mild steel, stainless steel, aluminium. | Mild steel | High load bearing capacity, readily available and affordable |
| 3. | Belt | Rubber, leather. rope. | Leather | Availability and cost |
| 4. | Pulley | Cast iron, teflon, wood, mild steel. | Mild steel | Ability to withstand high speeds |
| 5. | Chain | Alloy steel | Alloy steel | Hardness, durability and toughness |
| 6. | Sprocket | Alloy steel | Alloy Steel | Hardness, durability and toughness |
| 7. | Bearing | High speed steel, mild steel | High speed steel | Most suitable |

## 2.4 Production Cost

The cost of the materials used for the development of the machine is outlined in Table 2.4:

**Table 2.4:** Production Cost

| S/N | COMPONENT | QUANTITY | UNIT COST (₦) | TOTAL COST (₦) |
|---|---|---|---|---|
| 1 | Angle bar 2''x 2'' | 4 | 1500 | 6000 |
| 2 | Angle bar 1''x1'' | 1 | 750 | 750 |
| 3 | Big pulley | 1 | 2500 | 2500 |
| 4 | Small pulley | 1 | 250 | 250 |
| 5 | Chain | 1 | 1200 | 1200 |
| 6 | Sprocket | 2 | 450 | 900 |
| 7 | Pedal | 2 | 700 | 1400 |
| 8 | Belt | 1 | 150 | 150 |
| 9 | Metal plate | 1 | 1500 | 1500 |
| 10 | Seat | 1 | 1500 | 1500 |
| 11 | Bearing | 4 | 250 | 1000 |
| 12 | Electrode | 1 pack | 500 | 500 |
| 13 | Shaft | 1 | 500 | 500 |
| 14 | Handle | 1 | 1200 | 1200 |
| | | | TOTAL | 19,350 |

## 2.5 Description and Method of Machine Operation

The machine frame was made up of mild steel angle bars joined together by welding process. Mild steel was used for the frame in order to have the required load bearing capacity of the user and the pump. The joining process was carefully done which results in the correct fabrication of the frame. The base of the frame was designed flat to provide the required stability. A bicycle seat was fitted on the system and also arm supports were included so that the user can be stabilized while pedalling.

### 2.5.1 *Drive Unit*

The transmission of power from human to the pump is carried out in two stages namely chain drive and belt drive. The operator uses his feet and legs to rotate pedal around the crank axel. The pedals, in turn, are fixed to a chain ring (sprocket) with teeth that engages the continuous chain. The chain then transmits the pedalling action to a cog on the hub of the front wheel (driven sprocket) causing the front sprocket to rotate and then drive the shaft on which pulley is mounted. This is first stage of transmission. In second stage this power is transmitted to the pump from the pulley with the help of a belt drive.

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## 3. RESULTS and DISCUSSION

### 3.1 Results

The type of pump selected for this study is the centrifugal pump which is a roto-dynamic pump whose discharge is proportional to the speed of the impeller. The machine was designed to have suction diameter of 0.0251 m; delivery diameter of 0.0251 m; suction head of 9.0 m, total head of 15 m while it's discharge rate is 0.0016 $m^3/s$.

#### 3.1.1 *Performance Evaluation of the Pedal Pump*

The pump was operated to evaluate its performance. The pump was used to pump water from a well at a head of 15m and the discharge recorded was 0.0016 $m^3/s$.

Further test was carried out by pumping water for longer period of time at different time intervals of five minutes. And the results obtained from the test are presented in Table 3.1.

**Table 3.1:** Tests Results

| | Time/Discharge | | | | | Total | Average "Q" ($m^3/min$) |
|---|---|---|---|---|---|---|---|
| Time (mins) | 5 | 10 | 15 | 20 | 25 | 75 | 0.0904 |
| Volume ($m^3$) | 0.48 | 0.92 | 1.39 | 1.85 | 2.14 | 6.78 | |

From the results obtained, a graph of volume against time was plotted to show the relationship between the quantities of water pumped per time as shown in Figure 3.1.

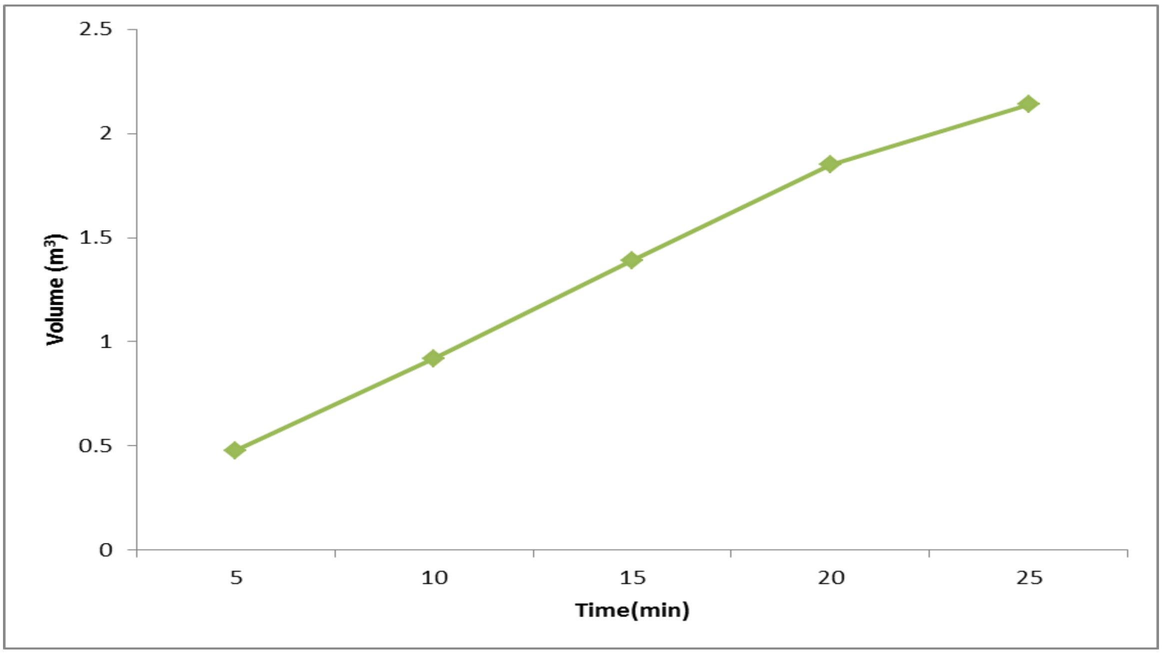


**Figure: 3.1** Discharge of Pump

The figure 3.1 shows the quantity of water pumped at an interval of five minutes. It was observed that the graph was not linear and this is due to pedalling fluctuations.

### 3.2 Discussion

The system developed was able to perform the required objective as it was able to pump water at a reasonable discharge total head. Even though, the system is energy consuming, pedalling is recommended for individuals as a form of exercise to burn calories in the body. This in turn prompts the use of treadmills and bicycles for this purpose.

From the results obtained, using pedal powered water pump at places where wells and bore wells are very deep and to fetch water manually is cumbersome and strenuous is suggested. Also at a higher level it can be used for irrigation and drinking water purposes. For pumping more water, electric pump is needed, but where electricity is not available pedal-powered water pump can be of great use.

## 4.0 Conclusion and Recommendations

### 4.1 Conclusion

The developed pedal powered centrifugal pump was aimed at producing cheap and easy to operate system which was easily fabricated by readily available material and a very simple design that can deliver efficient, productive and reliable water pump which can be used in rural as well as urban areas for irrigation and drinking purposes. The design of the machine was simple enough to facilitate easy operation. Further, this equipment can easily find its application where there is no or limited power supply.

### 4.2 Recommendation

The following recommendations are made for future adjustments or improvements of the developed pedal power centrifugal pump:

i. The driving speed of the machine can be further increased by incorporating a gear box with a high speed step up ratio in place of the pulley.
ii. Also, a flywheel can be used because of its large moment of inertia which enables it store energy and thus minimize the speed fluctuations that occurs during pedalling.

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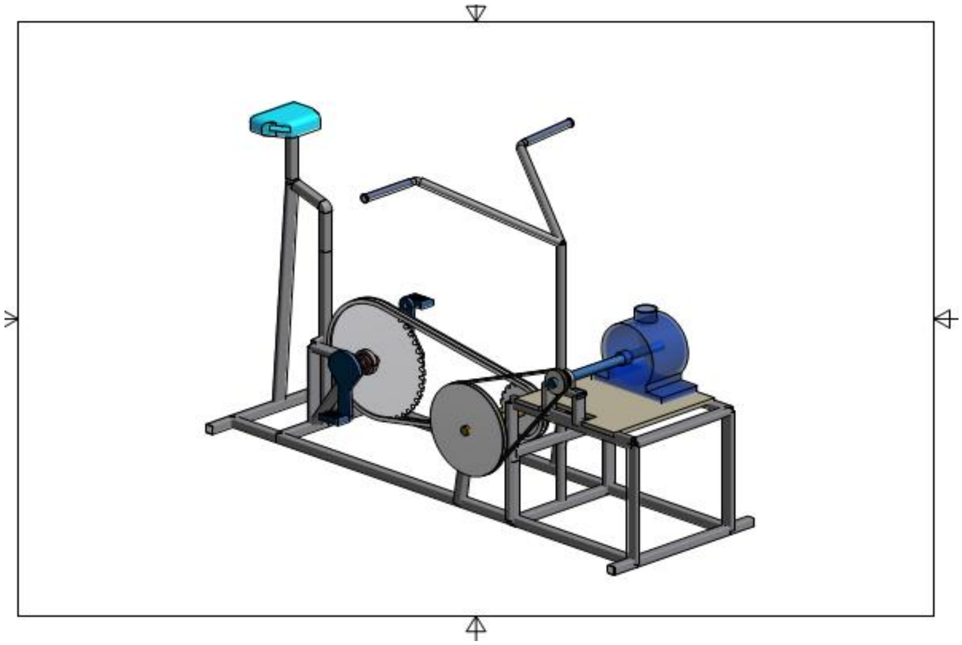
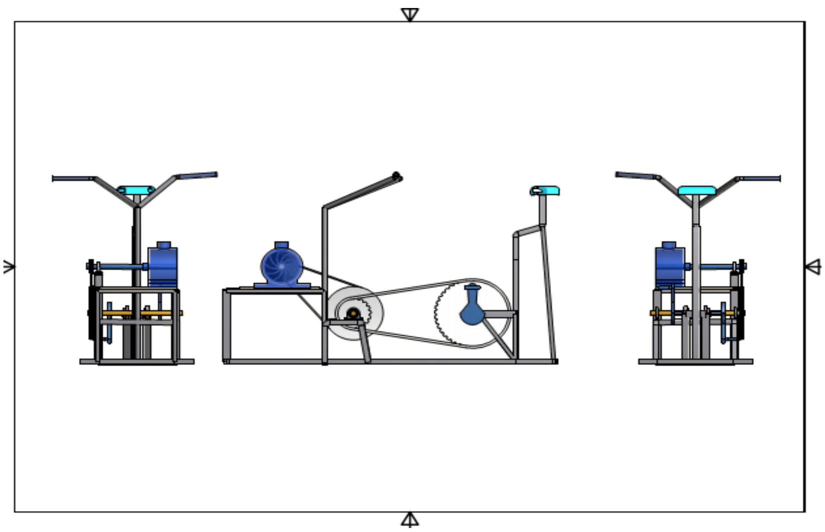
**APPENDIX**





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