Sustainable Design for Water Purification in Rural Area

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Abstract

The objective of this paper is to propose a solution to overcome the scarcity of drinking water, which is one of the serious issues for many villages in India. To resolve this problem a design can be developed to provide drinkable water and produce electricity using natural means. This model is mainly aimed for the village areas, where a pure form of water is not available. The concept behind this idea is to convert kinetic energy of running water from rivers and streams. This will be harvested through a water wheel which is further connected to a scotch yoke mechanism through a gear arrangement. The Pistons will be connected to the above stated mechanism which pressurizes the water which is sent into their cylinders. This pressurized water is then used to perform reverse osmosis. On the other side of the wheel, a gear train is attached to the main shaft. This gear train is used to increase RPM of alternator to produce electricity. Due to the low economy in villages this method is very cost effective compared to other methods. Setting up of water purification plants require pumping up of water and using artificial means to purify by adding chemicals. Moreover, a huge amount of capital investment and labour is required, but in this case, once the model is perfectly setup, it can work with much less human labour. This model can even be funded by the Gramina Panchayat as its investment is low.

Keywords: Eco-friendly, Sustainable Resource, Management Development, Innovative.

I. Introduction

Scarcity of drinking water is a long-lasted problem for most of the villages in India. Government, NGOs and many major village organizations have been oriented towards finding a self-maintained and economical solution for this problem. Government has provided continuous effort towards providing drinking water, but most of the villagers deem to think that water is the basic necessity that should be provided free of cost, so very few participate in maintaining the methods implemented. The optimal solution is to be achieved which can purify water, by putting the natural forces and resources to their utmost use. This method should be easily maintainable and the basic working should be easily perceivable by a common man. To achieve a solution to the above stated issues, a mechanism is designed using the traditional water wheel, to use the kinetic energy of the flowing water to pump the water under pressure using pistons through a membrane to perform reverse osmosis and also to produce electricity using an arrangement of a rotating conductor and fixed magnetic field.

A. Importance of purification

The most important natural resource to sustain human life is water. It composes 70% of the human body. Almost three fourth of the earth's surface is covered with water. Over eight hundred thousand deaths were reported by the World Health Organization (WHO) in the year 2014 that were caused by the water borne diseases. A major number of these deaths can be avoided by having portable, clean safe water. Sanitation is one of the major concerns in remote areas and these places are deprived of clean drinking water, which does not only affect elderly but also the children and also all the living beings.

B. Role of government

Constant attempts have been made by the government to supply ample drinking water in villages such as Digging of wells for harvesting ground water or rain water, installation of hand pumps or motorized pumps, providing water through mobile tankers.

C. Methodology

Design of the product discussed in this paper is designed in Solidworks software to get the complete idea how the final product is going to be. This product contains two major systems; first one is for mass production of portable drinking water and second is for production of electricity.

D. Approach

In this approach we are using a water wheel which is conventionally used as a turbine, is now modified to purify water and also produce electricity. Water wheel is one of the best process to extract energy from the water source. Here water wheel is used to pressurize water to perform reverse osmosis. This product is capable of outputting drinkable water without any investment of artificial energy. This product can be setup at the banks of rivers or streams near the village and the purified water can be easily sent to the households. This has the added advantage of producing electricity that can also be used for other purposes. There is no continuous requirement of monitoring the product, only a timely maintenance is needed, therefore once setup not much of human interference is required. Fig 5.1 is the rendered image of the final product in Solidworks.

Fig. 1

E. Output of complete model:

The output of the complete model is in two parts. The purification of water is done by pressurisation of water to perform reverse osmosis. Production of electricity is attained by achieving high RPM. Fig 2 represents the above information.

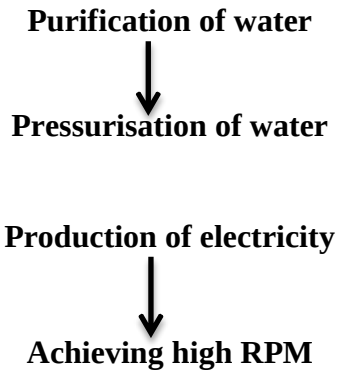

Fig. 2

For purification of water, piston pump is used as it is simple in design, suitable for high pressure and it gives a continuous rate of discharge. Fig 2 showcases the comparison between a possible alternative for the piston pump.

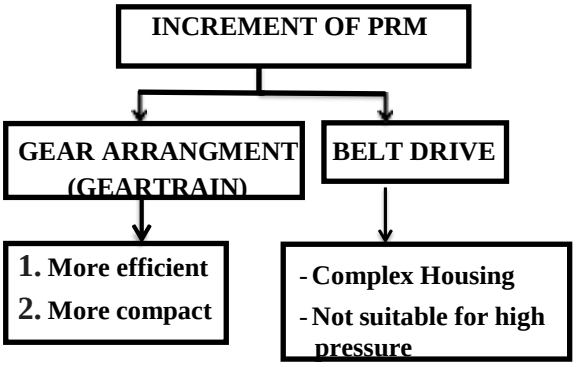

Fig 3.

For increment of RPM gear arrangement called gear train is used as it is more efficient and more compact than any other method. Fig 3 showcases the comparison between a possible alternative for the gear train.

F. Working of product:

The kinetic energy of running water is harvested through a water wheel and the wheel is connected to a scotch yoke mechanism through a gear arrangement. Pistons are connected to the above stated mechanism which pressurizes the water which is sent into their cylinders. This pressurized water is then used to perform reverse osmosis. On the other side of the wheel, a gear train is attached to the main shaft. This gear train is used to rotate a current conductor which is placed in an active magnetic field. This setup is used to produce electricity.

II. Mechanisms

A. Scotch Yoke mechanism:

A scotch yoke mechanism is a typical design that converts rotary motion into linear motion. It is achieved by connecting a slider and a crank with a rod. The given picture depicts a mechanism utilized as a system that converts the reciprocating linear motion of an automobile engine into rotary motion. Fig 4 shows the arrangement of the Scotch and yoke mechanism.

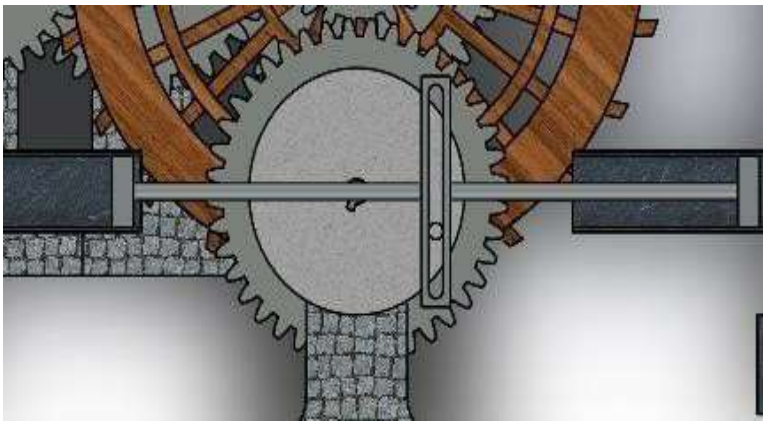

Fig 4.

B.Gear Train Mechanism:

The mechanical system that is formed by mounting the gears on frame to form a train i.e. the gears are mounted such that their teeth engage. The rolling of gears without slipping and

providing smooth transmission from one gear to another is made sure by engaging the teeth of the gears properly. Fig 8.2 shows the gear train mechanism.

Fig 5

C. Check Valves

Check valves or Non – return valve (NRV) prevent the back flow of the fluids. There are many varieties of check valves whose usage range extends very far. Day-to-day household items also contain many kinds of check valves. Check valves are mostly low cost, are small in size, and simple in design despite of being available in such a wide range of options or designs. Check valves work without supervision or do not need any other external control. The external shells of the check valves are usually made out of plastic or metal according to their design and usage. Fig 8.3 shows the check valves that are used in the product.

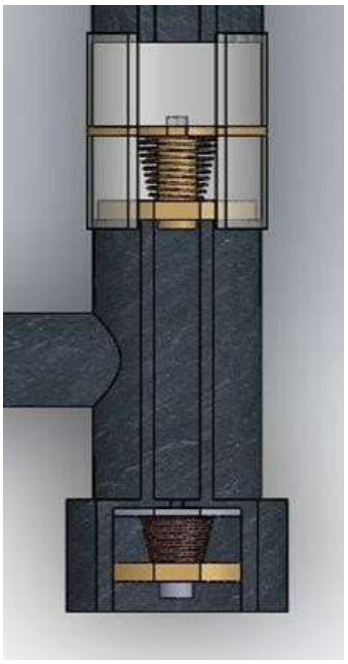

Fig 6

D. Combined Mechanism

The running water of the stream will rotate the water wheel and the axial shaft of the wheel is connected to a driver gear and this gear drives a driven gear. The shaft of the driven gear is connected to scotch yoke mechanism, and the harmonic motion of this mechanism will help piston to perform to and fro motion in cylinder to pressurize water. And the water under this pressure is sent through a membrane to perform reverse osmosis. The other end of the axial shaft of the wheel is connected to the driver of the gear train. The energy is transmitted through the gear train, and this gear train rotates a current conductor in a magnetic field. By the principle of the Fleming's right-hand rule, EMF is induced in the rotating conductor and the electricity produced is collected. The check valves are used to ensure the flow of water in the pipes and through the piston arrangement is unidirectional. The pictures given below shows the Front view (Fig 7) and the Rear view (Fig 8).

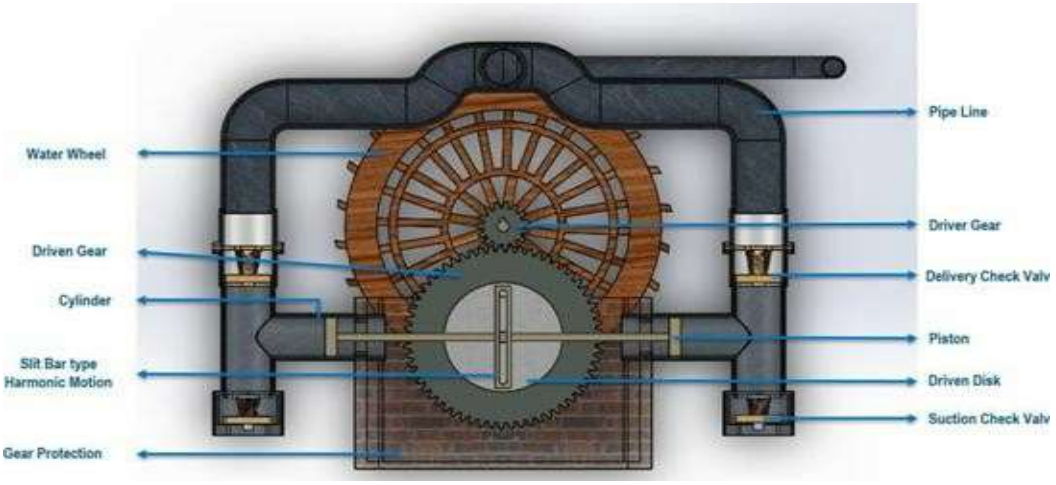

Fig 7

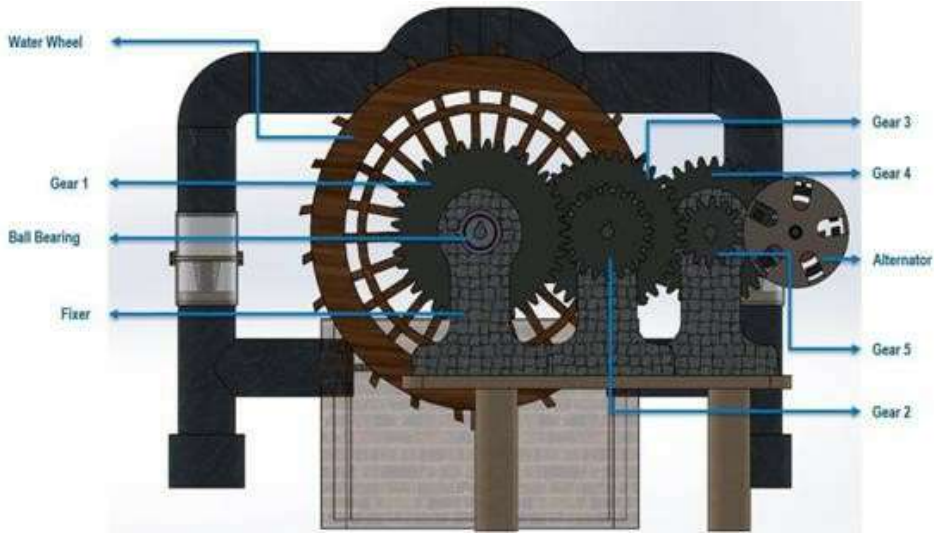

Fig 8

E.Structure of the product:

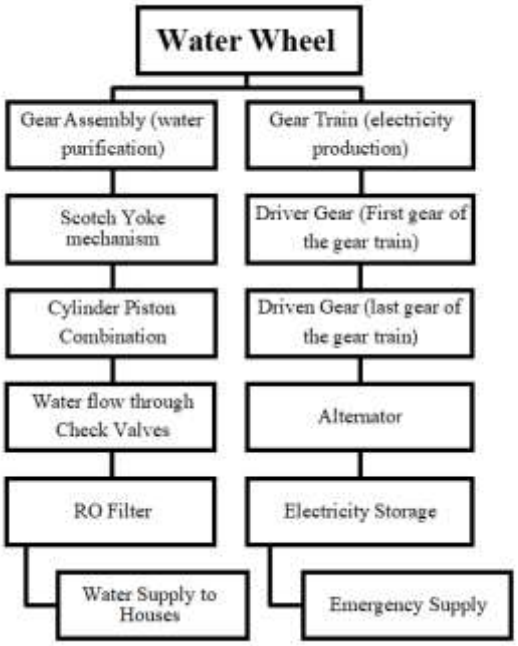

Fig 9

III. Mathematical Calculations

The purification process requires high operating pressure up to 4bar to perform reverse osmosis. Therefore, we are striving to achieve pressure about 4 bar through piston stroke.

A. Calculation for the water purification system:

Cylinder pressure = 4 bar
Radius of driver gear = 1.06 m
Average river velocity = 2 m/s Average discharge velocity of river = 200 m/s

a. For Water Wheel:

Torque = ρQ(rin Vin – rout Vout) = ρQrV = 4.06 x 105 Nm
Where,
ρ is the density of water,
Q is the flow rate of the stream water.
Since the driver gear is mounted on the same shaft as that of water wheel torque on the driver gear will be same as water wheel.

b. Driven Gear:

Torque = Fr P = 4 bar
Pr= FA Area of cylinder = 0.072965 m2 R of driver gear = 0.3048 m
F =54.82456 m2
Torque =16.71052 Nm
Where,
F is piston force,
R is radius of flange Pr is pressure

$$\text{Gear ratio} = \frac{\text{speed of driving gear}}{\text{speed of driven gear}}$$

$$= \frac{\text{torque of driven gear}}{\text{torque of driver gear}}$$

$$= \frac{\text{No. of teeth of driven gear}}{\text{No. of teeth of driver gear}}$$

$$= \frac{16.71}{4.06} = 4.12$$

c. Angular velocity of driven gear

ω_1 = v/r = 7.8474 rad/s
Where,
v is 2 m/s,
ω_1 is the angular velocity of driver gear,
V is velocity of driver gear,
r is radius of driver gear.

d. Angular Velocity for Driver gear:
ω_2 = 7.874/4.12 = 1.699 rad/s

Where,
v = 0.2589 m/s, is the angular velocity of driven gear.

e. Gear Ratio:

Driver:
Module = 1.375
Diameter= 22 inches
No. of teeth = 16

Driven Gear:
Module = 1.375
Diameter= 30 inches No. of teeth = 22

B. Calculation for Gear Train (electricity production):

For production of electricity required RPM is very large which cannot be achieved by assembly of two gears or less number of gears. Therefore, gear train is used here to achieve required RPM.

Total no. of gears = 6 Module of gear $= \frac{(\text{Diameter of gear})}{\text{number of teeth}}$

Gear	1	2	3	4	5	6
Module	1	1	1	1	1	1
Diameter	40 Inches	20 Inches	35 Inches	14 Inches	32 Inches	8 Inches
No. of teeth	40	20	35	14	32	8

$$\text{Required Speed ratio} = \frac{1}{20}$$

$$\text{Speed Ratio} = \frac{\text{product of the number of teeth of driven gears}}{\text{product of the number of teeth of driver gears}}$$

Speed ratio = (T2 x T4 x T6) / (T1 x T3 x T5)

= (30x20x10) / (60x50x40)

= 1/20

Achieved RPM is around 1500.

C. Efficiency:

Efficiency of all the parts:

a. Hydro-electric efficiency:

A basic rule that a designer uses for spur gear is 10% loss per engagement. Therefore, the power loss for the three-gear engagement will be 30%. Hence, the overall power transmission efficiency will be reduced to 70%. The final speed obtained will be around 1000 RPM.

b. Hydraulic piston efficiency:

The efficiency during the retraction process of the piston will be 95%. And during the extension process it will be 90%.

c. Water wheel efficiency:

Maximum energy that can be converted from the kinetic energy of the stream into the mechanical energy at water wheel can be attuned up to 70% as it is also depending on the blade angle.

D. Results

The end product of the project is mainly aimed at fulfilling a social purpose that is without the acceptance of any profit. Market research was done in the form of a survey before making the end product. The target audience was the educated professional to government employees who are in power to implement village reforms. The received response was positive toward implementation such design for the purpose of water purification, and production of electricity even in small amounts can be useful for many activities in the rural area. The design of the plant is made with the help of CAD software and mathematical modeling. This mathematical modeling involved research about the average velocity and average discharge velocity of Indian rivers or streams. The required torque of the water wheel is attained with the help of the velocity and discharge rate of the river hence high pressure required to perform reverse osmosis for the purification process and required RPM for electricity production is achieved.

IV. Conclusion

A design is made to overcome problems like unavailability of pure drinking water in rural sector and electricity required for irrigation purpose of small farms available in these areas. Complete design has been modelled in Solidworks software. Calculation for the working of different mechanisms is performed by finding the average river velocity of various Indian rivers and streams to achieve the rotational velocity of the waterwheel which pumps water from river by conversion of energy from one form to other form so that mechanisms can be run for purification of water and for production of electricity, also the efficiency of the product has been calculated to the nearest approximation. There are several benefits of this product as it uses only the natural means, it requires less human intervention. This product gives perennial output if the flow of water is perennial. It does not use any chemicals for purification. This is a one-time investment with less maintenance cost. It is economical and can be maintained by the villagers. It is also eco-friendly as it does not pollute water, air or land.

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