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Dual Side Water Pumping System using Scotch Yoke Mechanism

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Abstract

The aim of the paper is to design and develop a dual side water pumping system using scotch yoke mechanism. The reciprocating motion of the plunger is utilized for the pumping action. The plunger is reciprocated with the help of a cam plate. By this action the water is pumped with very high pressure and to various heads. This can be utilized for various applications like lubrication in machines and water pumping in agriculture field. The cam plate gets the drive from the motor for its rotation and converts that rotary motion to useful dual side reciprocating motion. The motor is powered with the aid of electric power. Thus the water is pumped from source to various heads.

Keywords: Electric Power, Pumping Elements, Reciprocating Pump, Scotch Yoke

1. Introduction

Every one of us will need of some kind of water source for drinking, bathing, washing clothes, preparing food and for irrigation. We may get the water from various sources like, lake, river, ponds, open well, bore well. So we have to pump the water from the source and use the water for the various purposes.

Pumps operate by some mechanism (typically reciprocating or rotary), and consume energy to perform mechanical work by moving the fluid. Pumps operate via many energy sources, including manual operation, electricity, engines, or wind power which usually come in many sizes that vary from microscopic for use in medical applications to large industrial pumps.

Generally these mechanical pumps have numerous applications such as pumping water from wells, filtering of dust in the aquarium, filtering the ponds and aeration, also used in car industry for water-cooling and fuel injection, and finally in the energy industry for pumping oil and natural gas or for operating cooling towers.

This Scotch yoke mechanism could be used for conversion between rotational motion and linear reciprocating motion. In general this linear motion can take place in various forms depending on the shape of the slot, but mostly the basic yoke with a constant rotation speed produces a linear motion that is simple harmonic in nature.

2. Literature Review

X Wang et al.[1] have studied about the Scotch Yoke crank mechanism whose application could be used in a reciprocating internal combustion engine which will reduce the engine's size and weight in-turn generates sinusoidal piston motion that allows for complete balance of the engine. C. Gopal et al.[2] have reviewed the research developments with Renewable Energy Source Water Pumping Systems (RESWPSs). Alireza Rezae et al.[3] have studied about the technical and financial aspects of photovoltaic water pumping system for irrigation purpose in the GORGAN's farm fields (one of Northern Province of Iran) with the RET Screen software tools. Abdeen Mustafa Omer[4] has reviewed the means of using wind energy for water pumping in rural areas in Sudan. Ahmed Mohammedi et al.[5] has designed a model which will express about the water flow output (Q) that will be directly a function of

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the electrical power input (P) to the motor-pump, for various total heads. Arif Hepbasli et al.[6] has given review on HPWH systems in terms of energetic and exergetic aspects in which the technology along with its historical development was briefed and a comprehensive review of studies were subsequently conducted over them and hence they were classified and presented in the form of tables. P. Amrutesh et al.[7] has made a study to change the existing setup so that an unskilled operator could operate and maintain the lawn very fine and attain a uniform surface look with an application easier and also at reduced cost where they finally achieved in pollution control too. M. Sermaraj[8] have made a study about the foot pedal pump which is powered by our legs instead of arms to lift the water from a depth range of seven meters. In the past human energy has generally been applied through the use of the arms, hands, and back. Rizgar Baker Weli et al.[9] has made experimental investigation on a rig which is specially designed to perform the study at residential area in city of Erbil that is used to find out the amount of water which could be lifted from the ground floor to a static head of 8 meters over the roof using two modules of 50 W photovoltaic solar modules, the system contains AC centrifugal pump, inverter, charging control and a 88 Ah battery for energy saving in addition to photovoltaic panels. The electricity generation has many difficulties in our area and it is about 900 W.h/m^2.day for PV module positioned toward south at a tilt angle of 360. Oghogho Ikponmwosa et al.[10] has made a system that could be used for elimination of the cost and inefficiency of human interference that could be associated with monitoring and controlling the pump by increasing the performance and life span of the electric water pump.

The aim of this work is to design the dual side water pumping system for increased discharge and efficiency also analyse and fabricate the dual side water pumping system which works on Scotch yoke mechanism which is a mechanism used for converting the linear motion of a slider into rotational motion or vice-versa. This system is inexpensive, easy to operate and build in a small-scale size.

3. Experimental Work

The main function of this pump is entirely depends upon the reciprocating motion of the plunger. The water from the tank enters to the inlet port through PVC pipes. The water is then passed to the cylinder. Here the plunger compresses and delivers the water with very high pressure. This plunger is of one in number, which is normal loaded. These normal loaded plungers are reciprocated by a cam plate.

The cam plate is supported by ball bearing on both sides to reset on the end plates, this cam plates gets the drive from the motor. In the plunger it has a follower; it rests on the cam plate with motor shaft. When the cam plate is made to rotate the plunger is moves to the Bottom Dead Centre (BDC). When this happens the suction of the water is in action. This action is carried out by the plungers.

The water is sucked from the tank to the plunger cylinder through pipes and ports and thus the suction happens. When the cam plate rotates further the plunger is also reciprocated. The plunger forces towards the top Dead Centre (TDC). Due to this force the delivering of the water from the cylinder is carried out. The water is delivered through a one way value. The delivery action takes place on plungers alternatively.

But the flow of water will be constant. The water delivered will be of very high pressure. This high pressure water is taken through pipes and utilized for various purposes in agricultural applications.The Line Diagram, Basic Scotch Yoke Mechanism, Photography of the prototype has been shown in Figure 1, 2, 3 respectively.

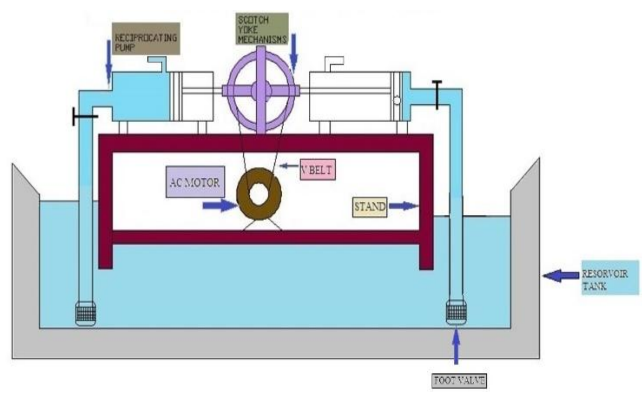

Figure 1. Line Diagram.

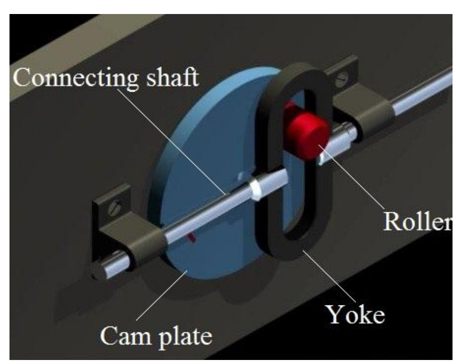

Figure 2. Basic Scotch yoke mechanism.

Figure 3. Photography of the project.

4. Important Equations and Calculations

Velocity of Water flow in pipe

$$V = \frac{Q}{A} \quad A = \frac{\pi}{4} D^2$$

Where,

Q = Discharge of the water in the pipe in (LPH)

A = Area of the pipe in (m^2)

D = Diameter of the pipe in (m)

Diameter of suction and delivery pipe will be 34 mm.

$$\text{Area of the pipe} = \frac{\pi}{4}(34)^2$$

$$A = 0.907 \text{ m}^2$$

From the standard data

The capacity of the flow = 720–3150 LPH

We are taking 3000 LPH (1000 lit = $1m^3$)

$$\text{Capacity of flow} = \frac{3000}{1000} = 3 \text{ m}^3\text{/hour.}$$

$$V = \frac{3}{0.907}$$

V = 3.30 m/sec.

So the power requirement for motor will calculated by the following calculation,

$$\text{Output power} = \frac{\rho \times g \times H \times Q}{1000}$$

$$= \frac{100 \times 9.81 \times 30 \times \frac{3}{3600}}{1000}$$

$$= 0.245 \text{ kW.}$$

$$\text{Pump Efficiency} = \frac{Output\ power}{Input\ power} \times 100$$

$$= \frac{0.245}{0.346} \times 100$$

$$= 70.8\ \%$$

$$\text{Power } (P_{\text{Motor}}) = \frac{Q \times H \times g \times \rho}{Pump\ efficiency}$$

Where,

Q = Discharge of the water

H = Head (m)

g = specific gravity of the water (9.81)

ρ = Density of the water (1000 kg/m^3)

$$\text{Power } (P_{\text{Motor}}) = \frac{\frac{3}{3600} \times 30 \times 9.81 \times 1000}{0.708}$$

$$= 346.39 \text{ kw}$$

$$P_{\text{Motor}} = 0.346 \text{ kw}$$

The calculated power requirement will be obtained by selecting the 0.5 HP motor.

This 0.5 HP motor will be enough to meet the power requirement for the system.

(1Hp = 0.746 kW) So we are going for 0.5 HP

Therefore 0.5HP = 0.373 kW

We know that the power of the motor, now we have to find the torque of the motor by using the power torque relation,

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

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

Where,

P = Power of the motor (watts)

T = Torque of the motor (Nm)

N = Speed of rotation of motor (rpm)

$$T = \frac{346.39 \times 60}{2 \times \pi \times 1440}$$

T = 2.297 Nm

Finally we are getting the following results

Discharge of the water (Q) = 3.000 $\frac{m^3}{hour}$

Speed of the motor (N) = 1440 rpm

Power (P) = 0.346 kw

Torque (T) = 2.297 Nm

5. Design Specifications

Motor Specifications

Maximum Power : 0.5HP
Maximum Voltage : 200/220 V AC
Maximum Speed : 1440rpm
Current : 3.5amps

Scotch yoke dimensions

Stroke length of the pump = 150 mm
Cam plate diameter =150 mm
Thickness of cam plate = 3mm
Inner diameter of roller = 6mm
Outer diameter of the roller = 10mm
Outside yoke length = 150mm
Inside yoke length = 10mm
Outside yoke width = 38mm
Inside yoke width = 30 mm
Bearing diameter = 28mm
Connecting rod length = 150 mm
Diameter of the pulley = 290mm
Width of belt = 12mm
Thickness of belt = 8mm
Suction and Delivery pipe diameters
Outer diameter of the pipe = 42mm
Inner diameter of the pipe = 34 mm

We design the dual side water pumping system using scotch yoke (prototype) for the above dimensions.

6. Cost Estimation

Scotch Yoke Mechanism = Rs. 2000
Pumping Elements (Pump) = Rs. 2500
Motor = Rs. 1750
Supporting elements = Rs. 1000
Machining cost = Rs. 1000
Pipes and Tubes = Rs. 500
Other expenses = Rs. 1500
Total cost = Rs. 10250

Advantages

Even if all the other pumps are similar in use the dual side water pump is more advantageous than the other pumps.

This is of compact in size.
Less Maintenance is enough.
The water pumped with a higher pressure.
Quite running and smooth operation is achieved.

Disadvantages

Leakage may be a problem if the parts are not properly machined.

High precision work is needed.

Applications

Since the dual side water pump is more efficient it is used for pumping the water mostly.

It is widely applicable in agricultural purposes.

This system is also used for lubrication purposes in machine tools like grinding machines, lathe and other machine tools.

7. Results and Discussions

We are analyze the various characteristics of the pumping system and we have to tabulate the analyze data in the following tabulation. From the analyzed data's we are solve the model calculations theoretically. We have using the general formulae's for calculation of the analyzed data's.

The following tabulation and the model calculations are made theoretically. The analysis is made by means of prototype model.

Table 1. Analysis data's

Sl. No	Pressure reading (kg/cm²)	Vacuum Pressure Ps (mm of Hg)	Time Taken Delivery of N Rev head	Head H (m)	10cm rise time S	Actual Discharge Q_{Act}(m³/s)	Input power (kw)	Output power (kw)	Efficiency In %
1.	0.5	30	28	5.39	29	1.68×10^{-4}	0.321	8.88×10^{-3}	2.77
2.	1	30	26	10.39	27	3.49×10^{-4}	0.346	0.0355	10.28
3.	1.5	30	24	15.39	25	5.58×10^{-4}	0.375	0.0843	22.50
4.	2	30	22	20.39	23	8.04×10^{-4}	0.409	0.1609	39.35
5.	2.5	30	20	25.39	21	1.09×10^{-3}	0.45	0.2714	60.33
6.	3	30	18	30.39	19	1.45×10^{-4}	0.50	0.432	86.57

Model Calculations

$$\text{Total Head} = \text{P} + \frac{V}{760} \times 10$$

$$= 0.5 + \frac{30}{760} \times 10$$

H = 5.39 m

Area of collecting tank = 9.079×10^{-4} m^2

$$\text{Actual Discharge} = \frac{A \times h}{t}$$

$$= (9.079 \times 10^{-4} \times 5.39)/(29) = 1.68 \times 10^{-4}\ m^3/sec$$

$$\text{Input Power} = (3600 \times N \times 0.8)/(E \times T)$$

$$= (3600 \times 10 \times 0.8)/(3200 \times 28)$$

$$= 0.321\ kW$$

$$\text{Output power} = (\rho \times g \times H \times Q)/(1000)$$

$$= (1000 \times 9.81 \times 1.68 \times 10^{-4} \times 5.39)/(1000)$$

$$= 8.883 \times 10^{-3}\ kW$$

$$\text{Efficiency} = (\text{output power})/(\text{input power})$$

$$= (8.88 \times 10^{-3})/(0.321) \times 100$$

$$= 2.77\ \%$$

8. Conclusion

Thus the detailed study of our paper is carried out. By the design calculations provided above, the dual side water pumping system using scotch yoke mechanism is designed and analyzed for a prototype. It is inferred that the improved discharge and efficiency is achieved by the dual side water pumping system using scotch yoke mechanism. This method of pumping water is very efficient compared to other pumping system. The implementation of the design will definitely give excellent performance to the society.

9. Future Scope

The future work will be the dual side water pumping system can run with the aid of solar power by means of using solar panel and battery system. By using the solar power the electricity expenses will be reduced and the system can work at the time of electrical source is not available.

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