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"Design, Fabrication and Experimental Study of Animal Muscle Powered Mechanical Device to Run Centrifugal Pump for Irrigation"

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Abstract—*In this research work I, design, fabricated and experimentally studied an animal muscle powered mechanical device to run centrifugal pump for irrigation. It has unique features of using animal power as prime mover for centrifugal water pump of 0.5 hp. Animal Muscle energy in the form of high-torque low-speed can be converted into low-torque high-speed through speed increaser to run centrifugal pump of 0.5 hp. It discharges 10 litre of water in 39.5 seconds. The finite element analysis also shows the safe design of the gear system. Static analysis of a 3-D model of gears has been performed using ANSYS 14.0. This is also concluded that fabricated mechanical device is itself a very small scale industry at rural and isolated areas. This equipment is emission free, low cost and has long life. Also this equipment needs less maintenance and any person can run either skilled or unskilled.*

Keywords*: Animal Muscle Energy, Speed increaser, Centrifugal pump, Ansys.*

1. INTRODUCTION

Motor-driven water abstraction and conveyance requires a reliable energy source – or a reliable combination of energy sources. The vast majority of water pumping for irrigation purposes is to date done by diesel or petrol motors as well as by electric motors that fed from the grid or are run by diesel generators. The current widespread burning of fossils also results in environmental pollution. It is very difficult and very costly to available grid power everywhere specially at remote isolated communities in developing countries. There are many renewable power sources like solar power, wind power, hydropower, bio-energy, geo-thermal power, tidal energy etc, but all have their limitations. Although from beginning of mankind human have been doing for domestic works, but the irrigation using animal muscle power is a novel technology [1-5].

Animal power is a work or energy that is produced from the animal body. It can also refer to the power (rate of work per time) of an animal. Power comes primarily from muscles, but body heat is also used to do work like warming shelters, food, or other animal. An animal of good average fitness works average between 400 and 450 watts for an hour of use. A healthy well-fed animal over the course of an 8-hour work shift can sustain an average output of about 450 watts.[1-5]

The device called animal powered speed increaser comprises of a mechanical link means provided with an extended MS pipe to transmit muscle power in form of high-torque low-speed; a four step gear system (with an input shaft mounted with 68 teeth gear and an output shaft mounted with 18 teeth gear in three step vertically and single step bevel gear system of 64 and 8 teeth to change vertical motion into horizontal motion) for converting muscle power received from a mechanical link in the form of a high-torque low-speed to low-torque high-speed; mechanical coupling systems which is connected to the output shaft of the gear system for transmitting mechanical energy to run centrifugal pump; centrifugal pump to draw water. The prime mover is preferably at least one animal.

2. FABFRICATION DETAILS

2.1 DRAUGHT ANIMAL: The authors' main object is to use the animal power for generating electricity for domestic and agriculture use. And bullocks are mainly used in Indian agriculture for different purposes. For this experimental study authors use the pair of bullocks. The weights of bullocks are 356 kg and 375 kg.

2.2 MECHANICAL LINK : Mechanical link of mild steel pipe with elbow having 38.1 mm diameter and 200 mm length with extended extra strong MS pipe of 3000 mm length and 4.5 mm wall thickness, capable of transmitting power in form of high torque low speed is attached to speed increaser. Mechanical link starts moving in a circular path of 5 meter diameter when animal pulled belan attached to mechanical link with the help of nut bolt assemblly.

2.3 WOODEN BELAN: Wooden-Belan is a pulling device. In this project use the animal pulled Belan and its weight is 105 kg. The vehicle is driven in circles over the paddy bunches as these are thrown on to the threshing area (5m to 10m in diameter around the stack) in India (Chhattisgarh) it calls "Belan". The mechanical link MS pipe was fitted with the first shaft of speed increaser by means of elbow and nut-bolt at one end and another end was coupled on Belan with the help of nut bolt assemblly such that the centre of Belan coincide at 2500 mm of mechanical link. The animal started moving into the circular path and also the Belan along with mechanical link rotate the first shaft of the speed increaser.

Fig. 2.2: Wooden Belan.

2.4 SPEED INCREASER: Speed increaser is a three set of spur gears housed in a frame of mild steel angles having 690 mm × 690 mm at the top and 780 mm × 780 mm at bottom. It is having 3 numbers of stages with gear ratio of 1:3.78. Input shaft of the speed increaser having 50 mm diameter and 600 mm length of mild steel material is in vertical position whereas output shaft having 50 mm diameter and 450 mm length of mild steel material of the same is also in vertical position in fourth stage there is one set of bevel gears having teeth 64 and 8. The Centrifugal pump of 0.5 hp is coupled with the other end of small bevel gear with mechanical couple. The shafts are supported with taper roller bearings at top and bottom. Bearings are fastened on tie-bars which are welded on frame.

Fig. 2.3 Complete system of speed increaser.

2.5 WATER PUMP SYSTEM: The 0.5 hp/0.37 KW centrifugal water pump of RC Energy metering (P) Ltd is used for experiment. The specification of water pump is shown in table:

Drive	0.5HP/0.37KWatt
Voltage (V)	220 ±5%
Frequency (Hz)	50
Suction head (meter)	8 MTRS
Discharge head (meter)	27 MTRS
Discharge (L/min)	33 LPM

Fig. 2.4: Speed increaser with centrifugal pump.

3. FABRICATION AND PROCEDURE

In the fabrication of speed increaser is done very carefully because there are four vertical shafts which are supported by taper roller bearings. The bearing covers are fitted with the help of nut and bolt on the mild steel ties, which are welded on the frame at top and bottom. Collars are provided at bottoms of shaft to support the load on bearings. Gears are fitted by means of nuts by drilling two holes on the shafts and on gear houses. There are four step gear transmission system. The first gear of 68 teeth is mounted on first shaft at 20 mm from the color which meshes with the second gear having 18 teeth mounted on second shaft at 20 mm above from the collar. The third having 68 teeth is mounted on second shaft 50 mm above the second gear and meshes with the fourth gear having 18 teeth which is mounted on third shaft at the same height. The fifth gear having 68 teeth is mounted on third shaft 50 mm above the fourth gear and meshes with the sixth gear having 18 teeth which is mounted on the fourth shaft at the same height. The seventh gear is a bevel gear having 64 teeth is mounted on fourth shaft 50 mm above the sixth gear and meshes with the eighth gear having 8 teeth which is mounted on fifth shaft fixed horizontally on extended frame. The Centrifugal pump of 0.5 hp is coupled with the other end of horizontal shaft with mechanical couple. The shafts are supported with taper roller bearings at top and bottom. Bearings are fastened on tie-bars which are welded on frame.

Author selects the centrifugal pump of 0.5 hp for irrigation which are work efficiently on and above speed of 600 rpm. And animal have very low speed (v = 1m/s). If bullock rotates at radial distance (r) of 2.5 m from the main shaft (first gear) then the distance at one revolution is 15.7 m ($2\times \pi \times 2.5$). And the distance cover in one minute by bullock is 1×60=60 m. Hence the initial rpm is 3.82(60/15.7). Three stage of spur gear system and single stage of bevel gear are used. So that the rpm of output gear according to S S Ratan.

$$\frac{N_8}{N_1} = \frac{Z_1}{Z_2} \times \frac{Z_3}{Z_4} \times \frac{Z_5}{Z_6} \times \frac{Z_7}{Z_8}$$

$(N_f)_g$ = 3.82*3.78*3.78*3.78*8 ≈ 1771 rpm.

The system is tested by means of animal power and it is recognized that the initial force (torque) to rotate centrifugal pump at idle speed is very low, it can easily have operated by using single hand. Before starting the experiment, the pump is connected with suction pipe which is subjected to inlet water source. The mechanical link GI pipe was fitted with the first shaft of speed increaser by means of elbow and nut-bolt at one end and another end was pulled by animal power. When animal started moving into the circular path the mechanical link rotate the first shaft of the speed increaser. At the starting the rpm is very low hence the pump was not responding but as well as speed is increasing the centrifugal pump start to discharge water. Animal are need to applied force to maintain average speed.

Fig. 3.1: Animal powered Centrifugal pump.

4. RESULTS AND DISCUSSION

4.1 EXPERIMENTAL RESULT

The animals' effort and speed depend on the load subjected. The experiment had done 15 times. Experimental result shows that animal take very little time to get working speed. The readings are taken after discharging 10 liters. Figure No of Experiments Vs. RPM of Centrifugal Pump shows that rpm is almost constant in every experiments. The force applied by animal power is varying so that the discharge from centrifugal pump is varying during experiment. The average rpm of animal muscle powered irrigation system is 800-900 rpm. Figure between No of Experiments Vs Time for 10 Ltr. (in seconds) shows that the time taken to discharge 10-liter water is almost constant and the average time to discharge 10 liters is 39.5 seconds for 0.5 hp centrifugal water pump.

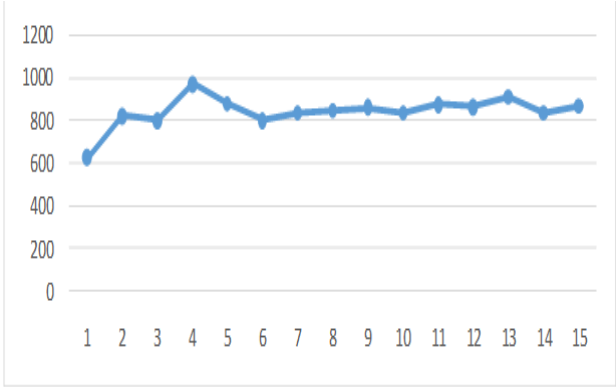

Fig. 4.1.No of Experiments Vs. RPM of Pump.

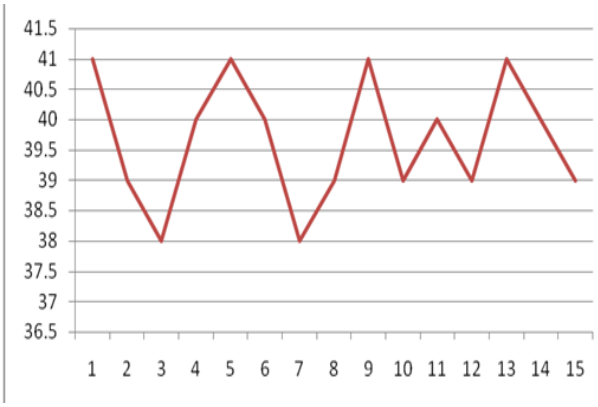

Fig. 4.2: No of Experiments Vs Time for 10 Ltr (sec).

4.2 Results of FEA ANALYSIS

The finite element analysis has done for tangential load or torques applied on the smaller spur gear because when both gears are made of same material then smaller gear is weaker and has to design. Result of bending analysis using ANSYS 14.0, The Deflections and Vonmises stress value for the ductile cast iron spur gear is tabulated below which show that the stress and deformation generated are within the safe zone.

Table 4.1: Bending stresses on Ductile Cast Iron Spur Gear

Vonmises Stress(N/mm2)	Deflection (mm)
153.032	0.0269

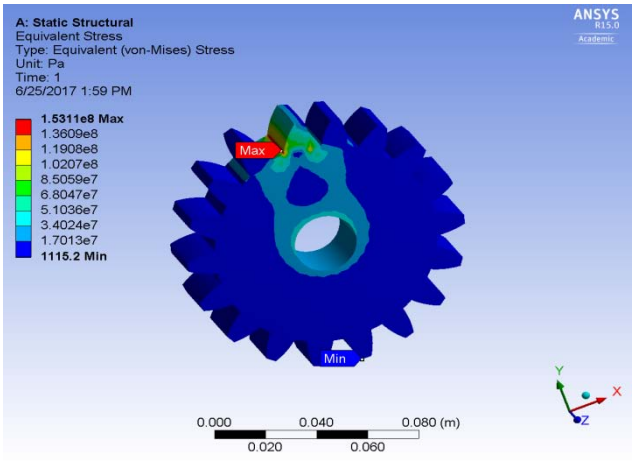

Fig. 4.3: Vonmises stress in Ductile Cast Iron Spur Gear

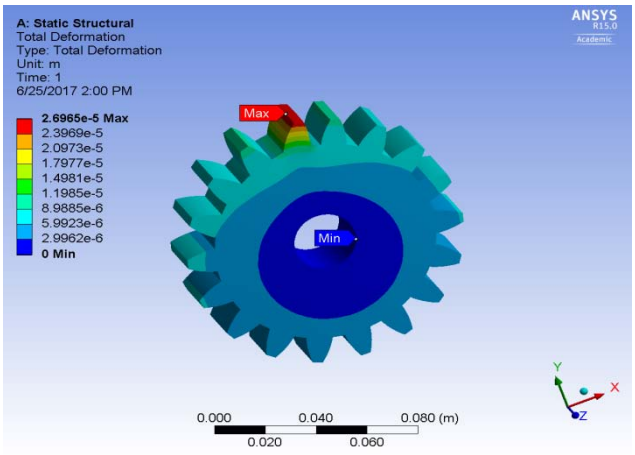

Fig. 4.4: Deflection in Ductile Cast Iron spur gear.

5. CONCLUSIONS

The present work demonstrated a mechanical device to run centrifugal pump for irrigation using the biological energy of the muscles of animal. The project goal was to design, fabricate and experimentally study of animal muscle power to run 0.5 hp centrifugal pump for the billion people who rely on fossil and natural source for irrigation. This goal had to be met within the constraints of a low production cost and high safety. The project has to offer a durable product with relatively good efficiency. The finite element analysis also shows the safe design of the gear system. Static analysis of a 3-D model of gears has been performed using ANSYS 14.0. This is also concluded that fabricated mechanical device is itself a very small scale industry for irrigation system at rural and isolated areas.

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