

“Experimental study on animal powered mechanical device for minor irrigation system”

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ABSTRACT: *In this paper authors experimentally studied the animal powered mechanical device for minor irrigation system. Although animals have been using for domestic works at rural and remote areas, but the electricity generation by Animal power is a novel technology. This invention provides animal powered mechanical device for minor irrigation system. It has unique features of using animal power as prime mover for electric generator. Animal energy in form of high-torque low-speed can be converted into low-torque high-speed through speed increaser to energize the electric generator. The electricity generated is stored in the battery and 0.5 hp motor pump has run using inverter and take 26 second to deliver 15 liters. 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 power, electric generator, minor irrigation, prime mover, speed increaser.*

I. INTRODUCTION

In developing countries like India who depends on agriculture need continuing power supply for different processes like crop dryer, harvesting, paddy dryer, food storage, hot water for germination, suction of wet air, irrigation etc. It is very costly and very difficult to availability of grid power at the remote areas but it is necessary of continuing energy supply. To achieve this goal consists of using renewable energy sources, not only for large-scale energy production, but also for stand-alone systems.

In this paper authors introducing the animal power as a new renewable energy resource. According to FAO [1], animal power is still “persistent and widespread in Asia and Latin America” and its use in even “expanding in Africa”. In terms of numbers of working animals, estimates vary. Wilson [2] estimates there to be at least 300 million draught animals, although acknowledges that other estimates are much higher. FAOSTAT [3] indicates that there are 110 million equines alone. In terms of net efficiency, animals are comparable with the tractor with efficiencies above 30%, but walking and maintenance reduces their efficiency significantly to 10%. The force exerted by a working animal is approximately equal to 10-12% of its live weight, and this means for example, that a buffalo has a power output of about 300 W, or 5.4 MJ/d, if it is assumed that the animal works for 5 h per day. The impact of poor nutrition is significant because thin, underfed or sick animals will not be able to work efficiently. Output can decline as much as 50% in oxen and buffalo, according to Pearson [4-6].

The device called belan comprises of a mechanical link means provided with an extended pipe to transmit animal power in form of high-torque low-speed to a speed increaser; a speed increaser provided with an input shaft mounted with 68 teeth gear and an output shaft mounted with 15 teeth gear for converting animal power received from a mechanical link in the form of a high-torque low-speed to low-torque high-speed in four stages; a belt and pulley system which is connected to the output shaft of the speed increaser for transmitting mechanical energy in form of low-torque high-speed received from the speed increaser to generator; generator to convert mechanical energy into electrical energy; and a storage system. The prime mover is preferably at least one draught animal such as a bullock. More preferably, the prime mover comprises of a pair of bullocks.

II. EXPERIMENTAL 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 456 kg and 478 kg. The mechanical link is fitted with a device pulled by pair of bullocks called bellan (Dhauri) which is made of wood and has the weight of 105 kg.

2.2 Speed increaser: Speed increaser is a four 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 4 numbers of stages with gear ratio of 1:4.5. Input shaft of the speed increaser having 50 mm diameter and 1500 mm length of mild steel material is in vertical position whereas output shaft having 50 mm diameter and 1000 mm length of mild steel material of

the same is also in vertical position. The vertical shafts are supported with taper roller bearings at top and bottom. Bearings are fastened on tie-bars which are welded on frame. Speed increaser is specially designed for transmitting and converting low-speed high torque to high-speed low-torque.

2.3 Gears: Four sets of spur gears transmit the power among parallel shafts. The spur gears are made of cast iron having module 5 mm. The spur gear has 68 teeth while the spur pinion has 15 teeth. The pressure angle is 20 degree and outside diameters are 350mm and 85mm respectively. The speed ratio of 1:4.5 is obtained in single stage.

Table 1: Shows the geometric detailed and strength calculation for cast iron spur gear.

Geometric details of desired spur gear [7]	Strength calculation for spur gear [7]
<ul style="list-style-type: none"> • Module (m) = 5 mm, Addendum = 1 module, Dedendum = 1.157*module Pressure angle (α) = 20 degrees Tooth thickness (t) = 1.571 * module = 1.571*5 = 7.855mm Whole depth = 2.25 * module • Face width (b) = 5.4 * module = b = 5.4*5 = 27mm. • Fillet radius = 3.9 * module • No of teeth (z) = 68 and 15 Pitch circle diameter (pcd) = z*m = 68*5 = 340mm and 15*5 = 75mm Outside diameter = (z+2)*m = 350mm and 85mm 	Using Lewis equation [1] Tangential load $F = \sigma_b * y * P_c * b$ Where ‘ σ_b ’ is the allowable stress, ‘y’ is the Lewis form factor $y=0.1034$, ‘ P_c ’ (Circular pitch) = $\pi * \text{module}$, b’ is the face width of the gears, ‘d’ is the pitch circle diameter of the gear. $F = 2 * 500 = 1000\text{N}$ putting in Lewis equation $1000 = \sigma_b * 0.1034 * (\pi * 5) * 27$ $\sigma_b = 22.81\text{N/mm}^2$ σ_{all} of Cast iron (high grade) = $\sigma_{\text{ut}}/3$ $= 320/3 = 106.67\text{ N/mm}^2 > 22.8\text{ N/mm}^2$

According to [4-6] an animal (bullock) can apply the tangential force of 500N ($F=2*500=1000\text{N}$). And the ultimate strength of cast iron is 320 N/mm^2 [7].

2.4 Belt and Pulley transmission unit: The final speed increasing is done by using belt and pulley system. One pulley of 228.6mm (9 inch) was mounted on the output shaft of the speed riser and counter pulley was mounted on car alternator having 76.2mm(3 inch) thereby stepping up the speed in the ratio 1:3 when connected with belt. According to Indian Standard Code (IS: 2494-1974), “A” type of belt is selected which has power ranges(0.7–3.5)kW.

2.5 Generator: In this experimental study authors select the car alternator to generate electricity. Lucas-TVS car alternator of 12V 95AH is used. Car alternator needs high rpm to work efficiently. It produces constant voltage but current depends on rpm and produce high as rpm is high. The direction in which the alternator is oriented to spin does not affect its output power. The alternators rotor can be rotated either clockwise or counter clockwise and achieve the same output values. Once the pulley belt is connected between the output gear shaft and alternator head the alternator must be wired to output DC power.

2.6 Storage system: A typical 12 V, 150 Ah Lead-acid automotive battery is selected. An automotive battery is a type of rechargeable battery that supplies electric energy to an automobile. It shows 12.6 volt at full charge and at fully discharged: 11.8V. Charging time depends on the capacity of that battery and the resting voltage of that battery when you begin to charge it. If battery is 50% or more full, it takes less time to charge. The 12V 180AH tubular batteries are also used with sine wave inverter in series to get more power to deliver water for long time.

2.7 Minor irrigation system: The 0.5 hp/0.37 kwatt centrifugal water pump of RC Energy metering (P) Ltd is used in experiment. Suction head is 8 MTRS, Discharge head is 27 MTRS, Discharge is 33 LPM.

III. FABRICATION AND PROCEDURE

The fabrication of speed increaser was done very carefully because there are five vertical shafts which are supported by taper roller bearing. The bearing covers were 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 hubs.

There are four step gear transmission system. The first gear of 68 teeth was mounted on first shaft at 20mm from the collar which meshes with the second gear having 15 teeth mounted on second shaft at 20mm above from the collar. The third having 68 teeth was mounted on second shaft 50mm above the second gear and meshes with the fourth gear having 15 teeth which was mounted on third shaft at the same height. The fifth gear having 68 teeth was mounted on third shaft 50mm above the fourth gear and meshes with the sixth gear having 15 teeth which was mounted on the fourth shaft at the same height. The seventh gear having 68 teeth was mounted on fourth shaft 50mm above the sixth gear and meshes with the eighth gear having 15 teeth which was mounted on fifth shaft at same height. The pulley of 228.6mm (9 inch) was mounted on fifth shaft at 200mm from the bottom which drive the another pulley of 76.2mm(3 inch) mounted on alternator and alternator was fabricated on the frame with the help of mechanical linkage.

Authors select the car alternator for generating electricity which has the ideal speed of 2000rpm – 6000rpm but effectly work at 3500 rpm. And animal has very low speed ($v = 1\text{m/s}$). 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 $1 \times 60 = 60$ m. Hence the initial rpm is 3.82(60/15.7). Due to compactibility and resources available author select the gears used in sugarcane juice machine of speed ratio 4.5. Four stage gear system is used. Output rpm is increased by using pulley and belt which has speed ratio 3. So that the output rpm of gear according to SS Ratan [8]

$$\frac{N_8}{N_1} = \frac{Z_1}{Z_2} \times \frac{Z_3}{Z_4} \times \frac{Z_5}{Z_6} \times \frac{Z_7}{Z_8} \tag{1}$$

$$(N_i)_g = 3.82 * 4.5 * 4.5 * 4.5 * 4.5 * 4.5 \approx 1567 \text{ rpm.}$$

The system was tested by means of human power for three times and it was recognized that the initial force (torque) to rotate alternator at idle speed was very low, it can easily operated by using single hand. Before starting the experiment the alternator was connected with battery and ampere meter was jointed in series. The mechanical link GI pipe was fitted with the first shaft of speed increaser by means of elbo and nut-bolt at one end and another end was coupled on belan with the help of GI wire such that the center of belan coincide at 2500mm of mechanical link. The speed increaser was fixed into the pit of 780mm×780mm×300mm. The bullock pair was harnessed with traditional means. When shepherded applied force the bullocks started moving into the circular path and also the belan along with mechanical link rotate the first shaft of the speed increaser. At the starting the rpm was very low hence the alternator was not responding but as well as speed was increasing the alternator start to generating power. Bullocks were need to applied force time to time to maintain average speed. The rpm and generated volt & current were taken after every four minutes. First time the battery was 50% discharge and it took approximate 2 hours to charge fully (hydrometer indicate 12.6V).



Fig 1: Animal powered mechanical device for minor irrigation system.

IV. RESULTS AND DISCUSSION

The animals' effort and speed depend on the load subjected and force applied by shepherd. Animal speed is change very quickly and abruptly. It is very difficult to taking speed reading continuously because animals got puzzled. The readings are taken after every four minutes within one hour and results are shown in graphs. Speed vs. Time graph shows that average speed of alternator is mostly changes, but it is within the ideal working range of alternator. Speed vs. Current shows that at low rpm at starting of animal motion it is not generating current, but as well as rpm is increasing and reaches to ideal working rang alternator producing high value of current. Experimental result shows that animals take very little time to get their average speed of 0.8

m/s to 1 m/s. But still alternator is not generating current as expected and specified by company due to very quick and abrupt changes in animal speed. Voltage was completely unchanging as expected and alternator generates constant voltage of 12V as specified after reaching ideal speed. In first four experiments the automotive battery of 12V 150AH was charged with animal power system and the 0.5 hp water pump run using inverter. The suction head was 4.7 meter and it took 26 second to deliver 15 litter water and worked for 2 hours and 35 minutes. So that it delivered 5200 litter of water upto 75% discharge. Same time tubular battery delivers 15 litters in 24 second and worked for 2 hour and 50 minutes. So that it delivered 6300 litter of water upto 75% discharge. Finally both charged batteries were connected to the MRO-TEK's DSP based sine wave inverter in parallelly and 0.5 hp water pump run very efficiently and delivered water continuously for long time up to 75% discharge. Combine system takes 22 second (average) to deliver 15 litter and worked for 5 hours and 45 minute and delivered 13000 litters of water. Experiment also done during the charging of battery with animal power and result found that 0.5 hp pump run very efficiently when battery was charged 75%.

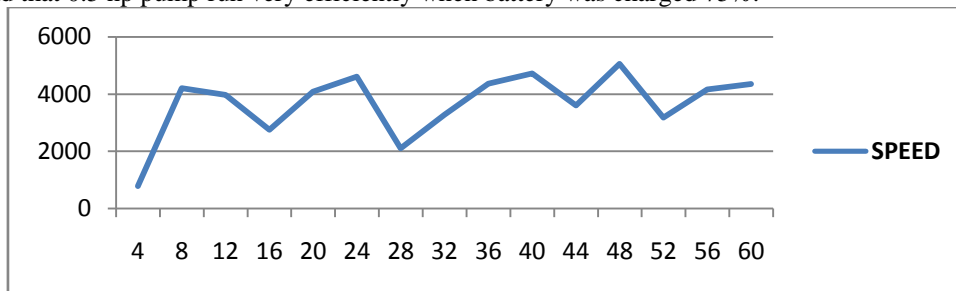


Fig 2: Time (in minutes) vs. RPM of alternator.

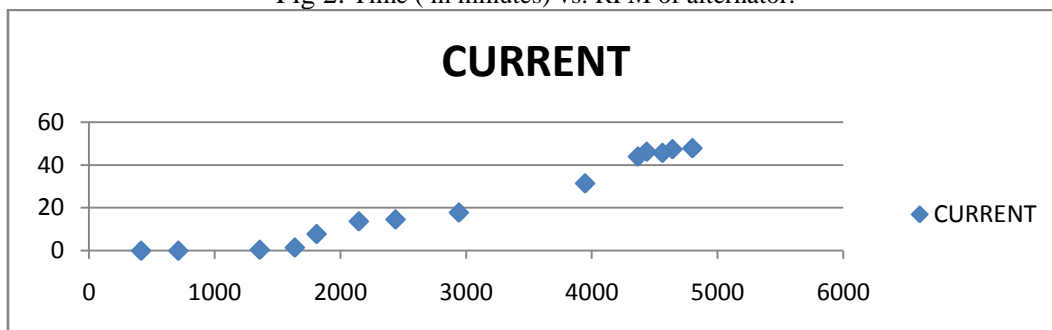


Fig 3: Alternator RPM vs. Current in Amp.(DC)



Fig 4: The animal powered water pump to deliver water from well.

V. CONCLUSION

The present work provides a system and method for producing electricity for minor irrigation using the biological energy of the muscles of animals like bullock by means of a mechanical device. The project goal was

to supply a battery array with a 12 volt DC output for billions of people who rely on nature and diesel pump 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. Authors believe authors accomplished this goal. This is also concluded that Animals are the great energy source for generating power even running at low speed for domestic and agriculture uses at rural and isolated areas.

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