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Design and Fabrication of a Mechanical Device which Convert High-torque Low Speed into Low–torque High Speed to Convert Muscle Energy into Electrical Energy

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Abstract: *In this paper authors, design, fabricate and experimentally studied a mechanical device which convert high-torque low speed into low-torque high speed to covert muscle energy into electrical energy. That device named as speed increaser. It has unique features of using human and animal power as prime mover for electric generator. Muscle 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 batteries of different capacity and used when required. 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: *Muscle energy, speed increaser, electric generation, dc battery.*

1. INTRODUCTION

Over 1.5 billion people rely on kerosene for light. Lack of suitable home lighting is directly linked to illiteracy, poverty and health problems. The current widespread burning of kerosene 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 animals have been using for domestic works at rural and remote areas, but the electricity generation by muscle power is a novel technology [1-9].

According to FAO [6], 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 [7] estimates there to be at least 300 million drought animals, although acknowledges that other estimates are much higher. FAOSTAT [8] 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 approximately 10% [9]. The input-output model of animal illustrates the multiple function of a working animal [10]. While this presentation indicates the generic inputs, outputs and waste products of an animal viewed as an energy conversion device, the reality is much more complex. To ‘operate’ an animal may require human inputs for task such as herding, cleaning stalls or pens, milking, harnessing and guiding.

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 [1-3]. Table shows the weights, speed and output powers of different animals. However, many factors can reduce this output significantly. These include stress, malnutrition, a poor fitting harness, difficult ground etc. The impact of poor nutrition is significant because thin, underfed or sick animals will not be able o work efficiently. Output can decline as much as 50% in oxen and buffalo, according to Pearson [9]

The device called speed increaser comprises of a mechanical link means provided with an extended pipe to transmit muscle 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 muscle 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 or human.

2. FABFRICATION DETAILS

(I) Muscle Power: The authors' main object is to use the muscle power for generating electricity for domestic and agriculture use. 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 which is made of wood and has the weight of 105 kg. Also the group of two person of 56 kg and 61 kg of age 22 year were worked as a energy source.

(II) Gears: 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 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. The 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 used for transmitting and converting low-speed high torque to high-speed low–torque. 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 gears has 68 teeth while the spur pinions 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.

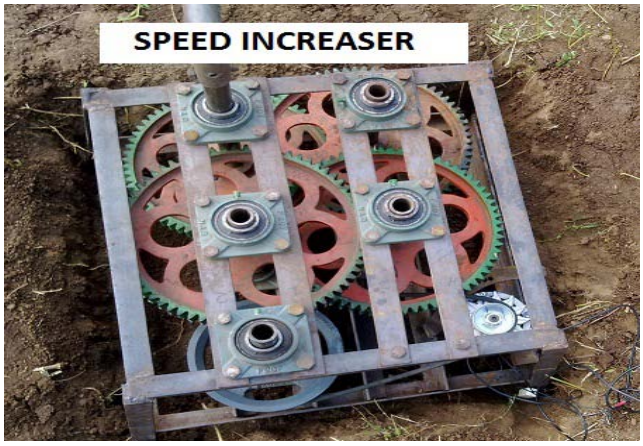

Fig. 1: Complete system of Speed Increaser.

Design of cast iron spur gear: The spur gears are made of cast iron. The Ultimate Tensile Strength of cost iron is 320 Mpa and Young's Moduls is 1.67e5 N/mm^2.

Geometric details of desired spur gear
• 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 Strength calculation for spur gear Using Lewis equation [10] Tangential load F=σb*y*Pc*b Where 'σb' is the allowable stress, 'y' is the Lewis form factor y=0.1034, 'Pc' (Circular pitch)=π * module, b' is the face width of the gears, 'd'is the pitch circle diameter of the gear. F=2*500=1000N putting in Lewis equation 1000=σb*0.1034*(π*5)*27 σb=22.81N/mm2 σall of Cast iron (high grade)=σut/3 = 320/3=106.67 N/mm2 > 22.8 N/mm2 According to [2-3] an animal (bullock) can applied the tangential force of 500N (F=2*500=1000N).

(III) 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), the A type of belt is selected which has power ranges 0.7kW–3.5 KW.

(IV) Generator: In this experimental study authors select the car alternator to generate electricity. Lucas-TVS car alternator of 12V and 95 AH 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.

(V) Storage system: In this experiment a typical 12V, 150AH Lead-acid automotive battery is used. An automotive battery is a type of rechargeable battery that supplies electric energy to an automobile. Charging time depends on the capacity of that

battery and the resting voltage of that battery when you begin to charge it.

Fig. 2: Belt and pulley unit of speed increaser.

Fig. 3: Integreted Belan, Speed Icreaser, belt&pulley, alternator and battery.

3. FABRICATION AND PROCEDURE

In 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 houses. There are four step gear transmission system. The first gear of 68 teeth was mounted on first shaft at 20mm from the color 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 mouthed 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 228.6 mm was mounted on fifth shaft at 200 mm from the bottom which drive the another pulley of 76.2 mm 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 effetely work at 3500 rpm. And animal and human have very low speed (v=1m/s) [1-9]. 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 ($2\pi \times 2.5$). And th e distance cover in one minute by bullock is 1×60=60 m. Hence the initial rpm is 3.82(60/15.7). Due to compact ability 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 rpm of output gear according to S S Ratan [11].

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

$(N_f)_g$=3.82*4.5*4.5*4.5*4.5*4.5 ≈ 1567 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 staring 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 elbow 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 shephered 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 i.e. 12V 75AH (approx as indicated by multimeter) and it took approximate 4 hours to charge fully (multimeter indicate 12.6V). Second time battery was 45% discharge and it took four hour and some minutes. The experiment done at 60%, 65%, 70%, 75%, 80% and 85% state of charge and time taken to charge fully had taken. Parallel the time required to discharge the battery at different percentage when 150 watt AC load was subjected to battery through inverter had taken. The experiment had done 9 times using same bullocks and animal had taken care regularly. At single time 360Watt DC load was subjected to fully charge battery and time taken to discharge it 50% was two hours and 7 minutes.

Fig. 4: Mechanical device for generating power using animal power.

Fig. 5: Human powered mechanical device for generating power.

4. 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 vs. RPM proves to be completely unchanging as expected and alternator generates constant voltage of 12V as specified after reaching ideal speed. State of Charge vs. Charging Time shows that battery takes more time to charge as less as state of charging is low for charging same amount. Fully charged battery shows 12.6V. Fully charged battery takes the approximately 2 hours and 7 minute to discharge 50% when 6 bulb of 60Watt DC is loaded. Since alternator takes initial current to energise the battery must not be discharge completely. Lighting Time of 6 CFL bulb of 25W AC for different state of discharge is shown in graph. Results shown that battery and inverter have more than 80% efficiency as expected. Finally result was found that at least 4 hrs (6pm–10pm) the home will be lighted using that system.

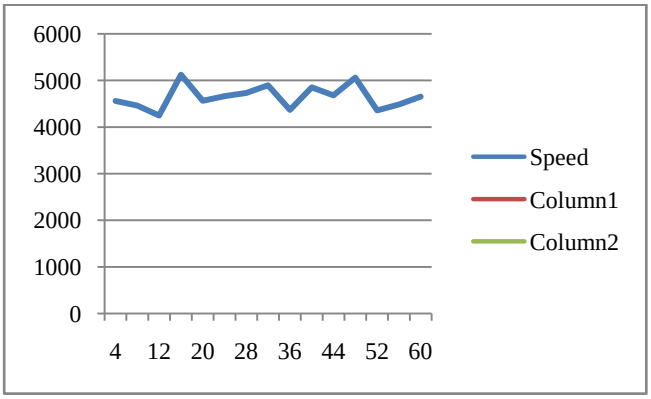

Fig. 4: Time (in minutes) vs. RPM of alternator.

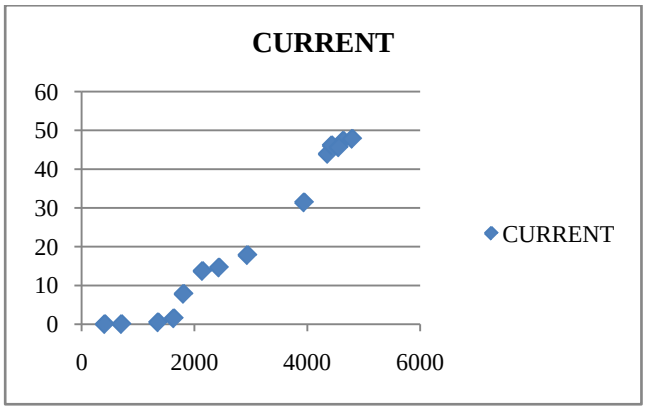

Fig. 5: Alternator RPM vs. Current in Amp.(DC)

5. CONCLUSIONS

The present work provides a mechanical device for producing electricity for home lighting using the biological energy of the muscles of animals and human. The project goal was to design, fabricate and experimentally studied of mechanical device to charge a battery array with a 12 volt DC output for1.5 billion people who rely on kerosene for light. 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. This is also concluded that fabricated mechanical device is itself a very small scale industry for charging batteries at rural and isolated areas.

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REFERENCES

[1] Fuller R. J., Aye LU,2012, "Human and animal power–The forgotten renewables" Renewable Energy 48 (2012) 326-332.

[2] Draught animals. From (http://www2.sjsu.edu/faculty/watkins/animalpower.htm) Metric conversion by Tim Lovett.

[3] Nagendra Pathak, Pushpito Kumar Ghosh, Sohan Lal Daga, Virendra J ayantilal Shah, Sanat Natubhai Patel "Animal powered mechanical device for water destination" US 7,387,728 B2. July 17, 2008.

[4] Maximo Gomez-Nacer, "Animal powered electricity generator" Patent no - US 2005/0161289 A1, July 28, 2005.

[5] Udayasankar Devanaboyina, "System for driving an animal powered vehicle" Pub. No: US 2011/0308868 A1, Des 22, 2011.

[6] FAO. Draught animal power–an owerview. UN Food and Agriculture Organisation; 2010.

[7] Wilson RT. The environmental ecology of oxen used for draught ower. Agriculture,ecosystems and environment 2003;97:211-37.

[8] FAOSTAT. Production; live animals. Available from http://faostat.fao.org/;2011 [accessed 13.12.11].

[9] Pearson A. Animal power: matching beast and burden. Appropriate Technology 1991 ; 18 (3): 11-4.

[10] Bhandari, V. B., 1994, "Design of Machine Elements," Tata McGraw-Hill.

[11] Ratan S S., "Theory of Machines," Tata McGraw-Hill