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A Review on Ergonomic Design and Development of Flywheel in Exercise Equipment for Energy Generation

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***Abstract*: In this present paper the ergonomic design and development of flywheel in exercise equipment is studied. Nowadays in developing countries like India lots of energy crisis are there thus we should be aware about new methods of generating energy to overcome these problems. Here we are mainly focusing on electricity generation through human power. Properly designed mechanisms are useful to convert these human efforts into electrical energy using ergonomic and tribological considerations. Flywheel is also added in the design so as to minimize human efforts for continuous constant power output..**

Index terms *– Human power machine, process unit, flywheel, alternator*

I. INTRODUCTION

Humans are much accommodated and can produce a power over a wide range by peddling mechanism. This power production depends upon pedaling rate and it varies from person to person and also on environmental conditions. In pedaling, muscular work of a human is converted into electricity by running alternator and finally stored in battery to run various equipment's like to charge laptops, mobile phones, batteries etc. Ergonomics is the study of to design equipment's and devices that fit the human body and its cognitive abilities and also comfort design, functional design and systems. There is iteration between user and machine. Ergonomic design fulfills occupational health and safety and productivity. Human pedals the system with rate suitable to it. Flywheel is an initial energy storage device. When supply of energy is more than the requirement, it stores that energy and releases that energy during a period of requirement. Flywheel smoothens the variation in speed of shaft caused by torque fluctuations[10].

A. Flywheel

Flywheel is an energy storage device that uses moment of inertia to store energy by rotation of it. It ingests mechanical energy and act as a reservoir. It stores energy when amount of energy is more than the need and releases that energy at a time of requirement[12]. Flywheel are directly proportional to loading on flywheel. The amount of energy stored in flywheel is directly proportional to the square of its rotational speed[2].

Figure 1: Key elements of flywheel wheel energy storage system

B. Principle of Application of Flywheel

Flywheel stores energy in spinning mass. The amount of kinetic energy reserved as a rotational energy in flywheel directly proportional to inertia and speed of rotating mass. The main concept is that the flywheel is placed inside the vacuum regulation to eliminate the obstacle due to air because which causes friction. Kinetic energy transmission from the flywheel which is connected to the machine, works as a generator or motor. In generator mode the kinetic energy is saved in flywheel. This kinetic energy applies the torque and then converted into required electric energy. In Motor mode electrical energy given to stator winding and is reformed into torque and due to it flywheel rotates in faster speed [8].

The kinetic energy reserved in flywheel is directly proportional to the mass and square of its whirling speed, the following equation as,

$$Ek = (1/2)\, I\omega^2$$

Where,
Ek = Kinetic Energy
I = Moment of Inertia
ω = Angular Velocity of Flywheel

As stated in above equation, the biggest capable procedure of increasing stored energy is to step up the flywheel for Steel rotors; the eminent shape is a solid cylinder giving the following expression for I,

$$I = (1/2)\, mr^2 = (1/2)\, \pi.a.\rho.r^4$$

Where,
a = Length of radius
m = mass of cylinder
ρ= density of cylinder material

The Other important shape is Hollow circular cylinder, almost a composite or steel rim attached to the shaft with a web, which advance to the next equation,

$$I = (1/4)\, m.\, (r02 + r12) = (1/4)\, \pi.a.\rho.(r04\text{-}r14)$$

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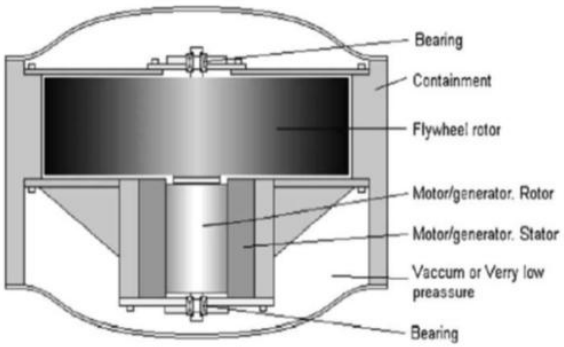

Figure 2: Basic scheme of the FES system

Below table shows technical characteristics for the most familiar raw materials used in designing the flywheel energy units.

TABLE I
TECHNICAL CHARACTERISTICS OF RAW MATERIALS

Material	Density (kg/m^3)	Tensile Strength (MPa)	Max Energy Density (for 1 kg) kWh/kg	Cost ($/kg)
Monolithic material	7700	1520	0.05	1
E-glass	2000	100	0.014	11.0
S2-glass	1920	1470	0.21	24.6
Carbon T1000	1520	1950	0.35	101.8
Carbon AS4C	1510	1650	0.30	31.3

C. Human Power Products

Nowadays we are observing large number of portable electric devices or instruments which mainly run on battery. Examples are Various IT products, audio-visual devices, communicating devices in which electronics play`s very important role and number of devices which gives mechanical work at their output. By keeping in mind the advantages of rechargeable batteries like wide availability, high energy density and international standardization etc. From this discussion batteries are the main source of energy in future but batteries are bulky as well. So the personal energy system (PES) group at DUT aims at searching options for the increased use of batteries like human power [1].

C. Power Stages

The power stages depend on rate of pedaling of a healthy peddler. This power limit maximum of 75 watts for healthy no-athlete if he pedals for several hours and healthy peddler may double this power production. The graph shows various record limits pedaling below optimum condition. Power levels related to atmospheric conditions and surrounding too [2].

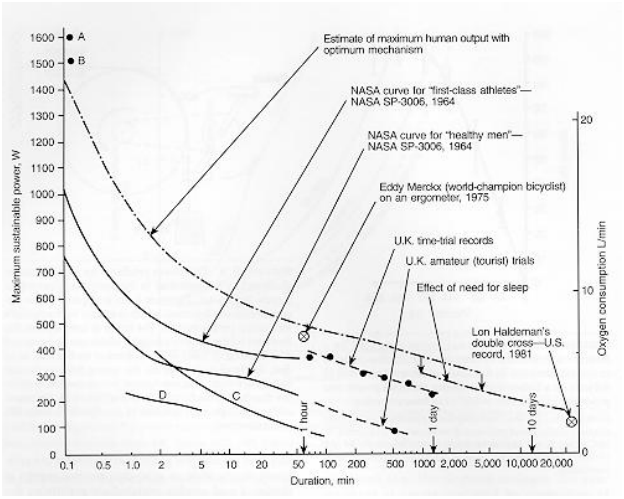

Figure 3: Human Power Output Pedalling

II. TRANSMISSION MECHANISM

A. Chain Drive

In order to avoid sleeping, chain drives with steel chains are used. Chains are comprises of rigid link which are used together in order to keep the necessary resilience for twist around driving and driven wheels. The wheels have projecting teeth and feet into the corresponding slots. It gives perfect velocity ratio. The toothed wheels are well known as sprocket wheels or simply sprockets [12].

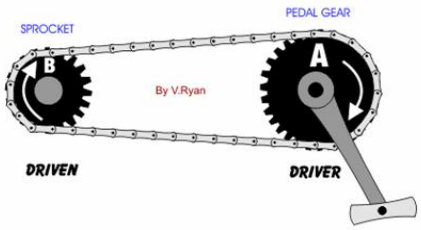

Figure 4: Chain Drive used for generation

B. Gear Drive

Gears are mechanical elements which are used to transfer synchronous motion between two shafts which maybe parallel or skew axis. Gears are used to transmit high power with high efficiency up to 99% in case of parallel shafts whenever definite velocity ratio is required. As in watch mechanism the only positive drive that is gear drive is used. Gear drive is also implemented when distance between driver and follower is very small. According to the shaft alignment gears are classified as spur, helical, bevel and worm and worm gear. [4]

When two gears mesh, if one gear is bigger than other gear, a mechanical advantage is produced with whirling speeds and the torques of the two gears differs as per their diameters. It is advantageous if this drive used for mechanism of transmission for designing a flywheel operated electric generator because it has maximum efficiency. [2]

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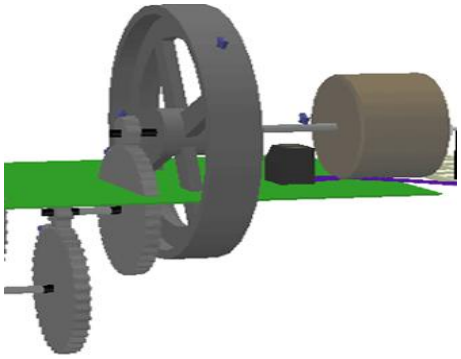

Figure 5: Gear drive in Flywheel generator

C. Belt Drive

Belt drives used to transfer power from driving shaft to driven with the help of pulleys which rotate at the equal speed or different speeds. Belt is made up of flexible material. Belts run evenly and with little noise. Belts are looped over pulleys and there is no need of shaft to be parallel as the source of motion. Conveyor belt is one of the utilizations where the belt is fitted to carry a load continuously among two points. If we use belt drive for flywheel operated electric generator, it is cheaper as compare to chain and gear drive but slippage take place and hence perfect velocity ratio is not obtained and hence we prefer chain drive while designing flywheel operated electricity generator [4].

Figure 6: Belt Drive in Flywheel energy generation

TABLE II
COMPARISON BETWEEN DRIVES [5]

Factor	Chain	Belt	Gear
Required Alignment Accuracy	Medium	Medium	High
Positive drive	Yes	No (except toothed)	Yes
Efficiency	High	Medium	Variable
Stiffness	High	Low	High
Strength	High	Low-medium	High
Ability to span large distances	Medium	Medium	Low
Maintenance	High	Medium	Medium
Cost	Low	Low	Medium

III. HUMAN POWERED MACHINES

A. Pedal operated flour machine

The design and Fabrication of flour machine is done by simple sprocket chain mechanism and fabrication carried out by locally available materials and devices as belt, pulleys, shaft, ball bearing, grain container and millstones. Result of it is as follows,

TABLE III
RESULTS OF PEDAL OPERATED FLOOR MACHINE [15]

Sr. No.	Product	30-50 rpm	50-70 rpm	70-90 rpm
1	Dalia (min/kg)	25	20	10-15
2	Flour(min/kg)	40	25	15-20
3	Maida	55	30	20-25

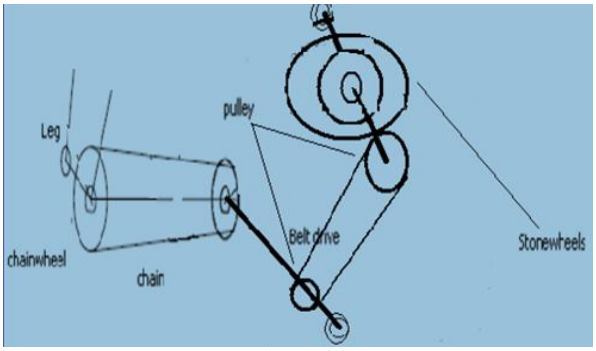

Figure 7: Design of Pedal Operated Floor Mill

B. Flywheel Motor Operated Forge Cutter

The improvement and performance of a Human Powered Flywheel Motor (HPFM) operated forge Cutter is carried out. This installation is nearly new to cut crop parts which are in excess amount. The Operator pedals and energy is stored in flywheel. Speed rising gear pair is also there. [15]

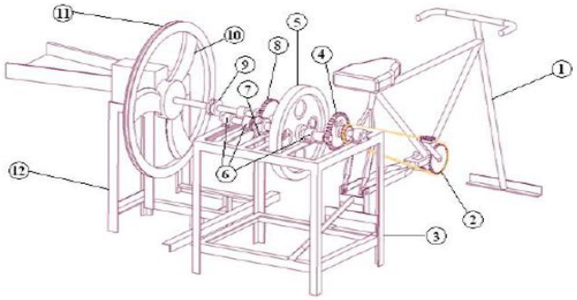

Figure 8: Developed experimental setup

C. Pedal Powered Hacksaw

The design development and performance evaluation with the help of model is carried out by using basic principle of slider crank mechanism. The materials like wood, plastic and metals are cut. The hacksaw reciprocates because its one end is connected to big sprocket of bicycle and other end connected to the connecting rod. We know that leg muscles are stronger than hand. The device is limited for local manufacturing competence. Eco-friendly and fuel free device, it helps to obtain less effort uniform cutting [16].

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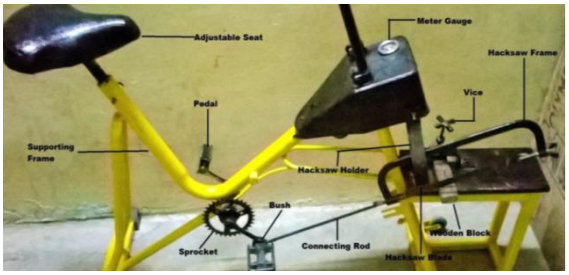

Figure 9: Complete Assembly and Final Presentation of PDH

D. Human Powered Electric Generation Machine

With a proper methodology the design of bicycle and bike stand is carried out. When we pedal bicycle the rotating motion of rear ring is utilized to rotate the alternator to produce DC voltage. For AC to DC conversion rectifier is used and energy is stored in battery array [3].

Figure 10: Actual view of bicycle and bike stand

IV. Tribological Considerations In Design

The general point of view of this is to examine the crucial theory of tribology and to examine the nature of machine elements with tribology. This paper was accredited by HAMK University of Applied Sciences with the direction to provide extra studying material for this science field. The initial backdrop was based on machine elements theory and the work results give us important knowledge for machinery related design [18].

The purpose of this task is to define theory and results afterwards friction phenomena. Also, to determine different wear types and reasons for wear failure. This work also targeted on different facets of lubrication and effective viscosity and lubrication establishment on machine elements performance. An additional target of this work was to present tribological behavior of gears and sliding elements.

The starting theory in this work was depends on machine elements and durability of material studies but it require a supplementary knowledge of other fields such fluid and solids mechanics, thermodynamics, physics and material science. The work aims only on tribological applications of gears and sliding elements and requirement of previous knowledge of these members [19].

The studies represented in this work granted analysis of different phenomena causing friction and the definition of different formulas to check friction. The work also gave methods of calculations to anticipate wear losses under non-lubricated and lubricated conditions. Moreover lubrication facilitates for operating machine elements and viscosity response for different operating conditions was represented. Finally, equations quantifying bearing and gears tribological behavior are calculated.

If all these concern of friction and lubrication are taken into consideration then we can design electric generator which will give a maximum efficiency. This maximum efficiency is achieved as in terms of reducing human efforts. The properly lubricated system will ensure low loss of energy and thus maximum utilization of human power [4].

V. Conclusion

Simplified ergonomic design of a pedaling mechanism with flywheel reduces human efforts. Thus all age level users find this machine very helpful for generating maximum constant electricity. The use of tribological aspects reduces the power transmission and thus overall efficiency increases. It is also beneficial for physical fitness as well as good health of users. As human efforts are used as source to operate this machine so it is Eco-friendly.

VI. Acknowledgement

The Quality is never an accident…. it is always the result of an intelligent effect. There must be a will to produce a superior thing. Success is not a one man phenomenon but it is the result of working together I take this opportunity to express my gratitude towards Prof. Pravin D. Patil, Prof. Dr. D.S. Deshmukh, Prof. M. P. Mohurule for their valuable guidance at each and every step of my work.

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