ERGONOMIC DESIGN AND DEVELOPMENT OF FLYWHEEL IN EXERCISE EQUIPMENT FOR ENERGY GENERATION

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Abstract - In this project importance of human muscle energy as an alternative energy source is investigated, since beginning to present state and its future scope. Natural fuel Use is increased due to industrial development and these sources oil, coal and Natural gas reservoirs are limited. Human power credit is more because of health benefit as a source of energy. Human power is an endless source of energy which has been wasted, Hence Power Generation Using human effort is a force for the future. In this project we pedal and drive gear trains and in this way primary flywheel and secondary flywheel also rotates and finally this rotational energy given to alternator for electricity generation. While designing this project all the ergonomics aspect has to consider which optimizing the physical contact between human and the equipment. Four important areas of bike ergonomics are considered.

Key Words: human power, economic trend, eco friendly, alternator, flywheel etc.

HISTORY:

India is the second most popular country in the world. Like many other countries agriculture is the main activity biomass and other non commercial fuels constitute around 40% of energy requirement in India. Around 85.49% of Indian villages are electrified; many will not be electrified for considerable time. The consumption of electricity in the country is increasing at the rate of 10% per year. The energy uses has been increasing through years, but there is no sufficient increase in the production.

1. INTRODUCTION

In today's modern society, most people just flip a switch or push a button, and everything we depend on is readily available. Cell phones, computers, televisions, heated water, lights, and so much more, are all the backbone of any modern Society's functionality. The electricity powering all these systems is something most people rarely think about until the power is no longer available for use. The extensive system that allows for an instant and near constant supply of Conditioned power is referred to as the grid. This grid is usually supported by government and/or private in developed countries; a government must have enough financial resources to establish and support a significant investment to provide the service of electricity. [8]

Fig -1: World marketed energy consumption by region, 1970 – 2025

1.1 Requirements

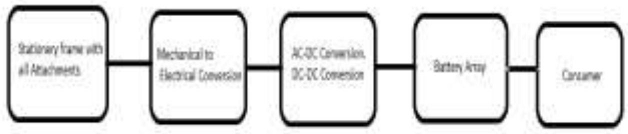


Fig -2: Block Diagram of Overall Project Design

The project's main Moto is simply to charge a battery array with a produced 24V DC from the stationery frame with all attachments design; however, for this project design to be considered successful for some objectives like primary and secondary as Low Production Cost, High Safety, High Energy efficiency Low Upkeep, High Product Durability, Use For Exercise purpose in gym etc. Project design and modifications are affordable because we used stainless steel stand, used alternator and wiring arrangement and battery etc.

2. METHODOLOGY AND DESIGN

This project has discrete design ways to complete our product while meeting the majority objectives. This means we will have to implement and correlate our different designs to assure the best product based on our set of objectives.

2.1 Design of a Frame

While designing a frame, engineers usually makes use of an older design which has proven reliable as a starting point.

The frame of the POPG created to reflect a typical Schwinn DX bike exerciser with small modifications on the materials used in order to minimize cost and considering availability of materials. Steel gives the excellent combination of performance when a steel frame dismantles, it tends to break gradually rather than suddenly and they have the capability to store and discharge energy at distinct degrees of the pedal strokes.

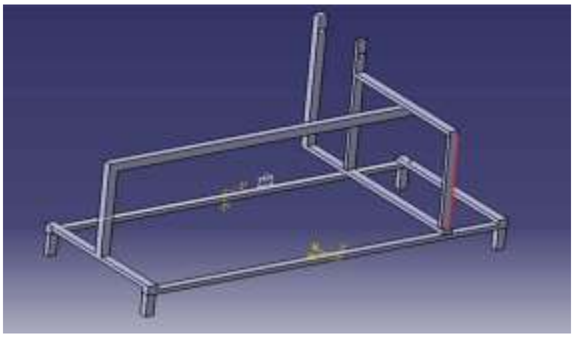


Fig -3: Design of frame arrangement in Catia

2.2 Design of pedaling Mechanism

Commonly, the bicycle pedaling mechanism converts human energy into mechanical energy for transportation purposes and with our system mechanical energy into electrical energy by alternator. The human musculature is concentrated in our legs and the pedaling mechanism set-up grant for mobilizing the maximum output. The flywheel is an ideal prime mover for electrical generation in this set up; we would need to couple an alternator and flywheel through either direct contact or a belt system. When with the help of pedaling we rotate the flywheel which stabilizes after some time and gains more speed, then the user downshift thereby increasing perceived resistance and outputs more power.

Fig -4: Standard Pair of Pedal

2.3 Design of Frame Arrangement

Fig 5: Frame Arrangement with all attachments

The first step while designing the project is the construction of the stand for the all attachments of the project, which are resting on it. As our goal behind designing this project to build a multipurpose machine for generation of electricity so, we welded all stainless steel hollow bars perfectly to form a frame like structure. By using stainless steel hollow bars we avoided the negative aspect of metal frame from the issues of heavy weight and corrosion from the user or the environment or both. For the stand to be able to handle the vertical and lateral motions of the users, a wide and solid base is necessary.

Frame dimensions as,

- Base of frame having dimension as: 167×81 cm
- Height of Frame: 107 cm
- Material used for construction of frame arrangement: Stainless Steel (S.S.) hollow rectangular bars

The frame arrangement design has made to withstand a great amount of force from the user and steel maintain its performance and form.

2.4 Alternator

The last practical option to implement for the pedaling system was to use a standard car Alternator expect Motor and Car alternator. This seems to be the most reasonable motor for the design, as car alternators are widely available worldwide for relatively low costs when purchased as a used part.

Fig 6: Standard Pair of Pedal

There are some issues while using alternator. The first issue is the power loss due to conversion from AC to DC voltage. Most alternators automatically convert AC to DC in the regulator of the part there is still the power loss in the alternator that will reduce the efficiency of the product and waste some of the energy exerted by the user. Another major issue when using an alternator occurs at the speed at which the part operated. When a car is idling, the rpm of the motor can be seen in the odometer. This value is usually around 600-700 rpms. Alternators usually run at a 3:1 rpm ratio due to the diameter difference in the motor and alternator head. This means an alternator is more efficient at speeds of 2100 rpms and higher [3]. For our testing and model design, we used a Maruti 800 TVS alternator. The rewrapping of the stator or rotor would have to be with thinner gauge wire in order to increase the number of turns by this we increase the current output at less RPMs.

The finger poles on the rotor actually bend the magnetic field of the rotor around the shaft in order to obtain the electromagnetic induction between the rotor and stator that produce the electrical power. From Faraday's equation, = - N dB/dt, we find that as N (number of turns) increases, (electromagnetic force) increases proportionally.

Alternator Mounting and Wiring should be correct to produce power it should be securely fastened to the stand and connected correctly to the flywheel rim and all other components. Alternators are very durable when connected correctly, but if connected incorrectly the alternator may be destroyed very quickly.[4]

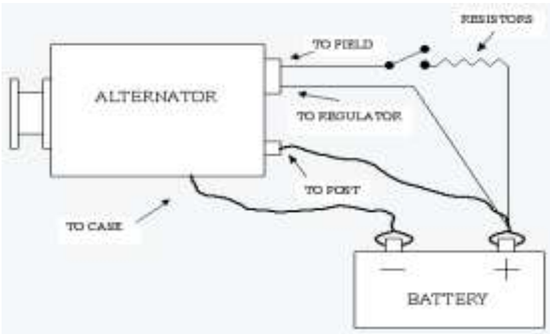


Fig.7: Battery Charging System Wiring

The three connections have made, as shown in Figures 7, are the output wire, field wire, and regulation wire. A simple battery charging connection is shown in Figure 7. 2 SMF Dry Battery is used both are 12V 7.6 Amp SMF battery, which means Sealed Maintenance Free battery, which is sealed completely because there is no need to add water. The electrolyte used is in the form of gel, which fills the cavity of plates. Just like other batteries, it also emits H_2 and O_2 gases and due to sealed batteries both these gases combine to form water. Batteries connected in Series so current are Constant and Voltage changes.

2.5 Energy Flywheel

Fig.8: Components of energy flywheel

This Energy flywheel (Primary) consist of –

- 1 Sun Gear having 30 Teeth
- 2 Planet Gear having 40 Teeth
- 2 Plates having Length-25cm, Width-7cm, Thickness2cm.
- Distance Between Two Plates are 25cm

Above assembly having 70 teeth sprocket at one side and 24 teeth sprocket at other side of energy flywheel. This Energy flywheel operation relates to the dual mass flywheel (DMF) concept.

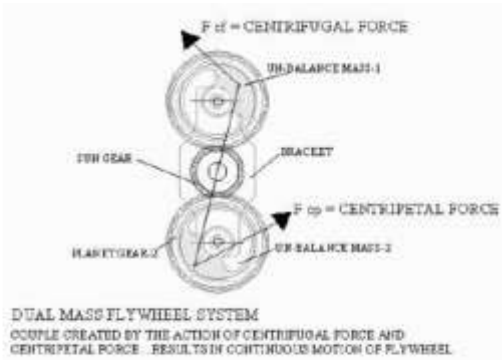


Fig.9: Dual Mass Flywheel System

From Fig. 9 it is clear that in addition to the mass of the flywheel, the couple owing to the centrifugal and centripetal forces keeps the flywheel into motion for longer time thereby increasing the work done by the system hence the output from the given system increases.[9]

The arrangement of the dual mass flywheel is best explained by the mathematical model below. The model is a two spring two mass model graphically represented as below

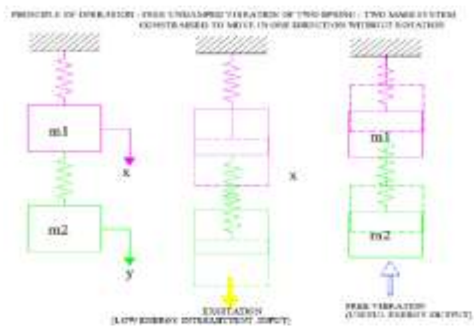


Fig.10: Graphical Model of spring mass flywheel system

The fig.10 shows free un-damped vibrations set up of two mass- two spring system. As shown in the figure the input to the system is in the form of an low energy intermittent input from any power source (excitation), this results in free undamped vibrations are set up in the system resulting in the free to and fro motion of the mass (m1) & (m2), this motion is assisted by gravity and will continue until resonance occurs, i.e. the systems will continue to work long after the input (which is intermittent) has ceased. Hence the term free energy is used. [9]

3. IMPORTANCE OF ERGONOMICS

While designing this energy generation machine, many factors considered: speed and maximum efficiency, space, ease of maintenance, cost. Ergonomic design means irrespective of the type of product and its function, evaluating it in terms of maximizing the interaction between product and user to make it more appropriate for use. [3]

- In the first level an equipment/ machinery must be safe while in contact with human beings.
- In the second level, an equipment/ machinery must not produce harmful effects in human beings over longer periods.
- The third level, an equipment/ machinery must be physically comfortable, that is, it should not require excessive efforts, both physical and mental or visual.
- In the fourth level an equipment/ machinery should provide mental satisfaction i.e. it gives a feeling of pleasure to the human being using the same.
- The fifth level is the determining the degree of modernity of an equipment/ machinery ergonomic considerations must constitute an essential factor of the social profitability of the equipment/machinery.

Fig.11: Adjustable chair

We attached a fiber material chair on the steel frame structure as shown in above figure having base dimension as 46×43 cm and height 43 cm. Therefore, the peddler may sit comfortably and pedal.

4. RESULTS AND CALCULATIONS

4.1 Previously we have designed classical model

Fig.12: Classical Model

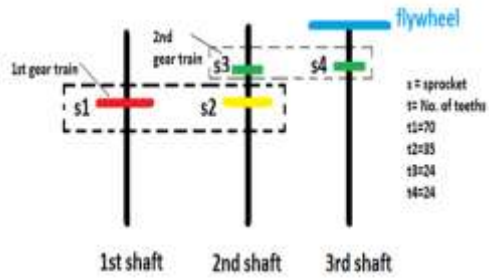


Fig. 13: Shaft, gear trains and flywheel arrangement

Where, S1, S2, S3, and S4 are the Sprockets use respectively in gear trains.

4.2 Now for first gear train between shaft 1 and 2

Therefore,

$$\frac{N_2}{N_1} = \frac{T_1}{T_2}$$

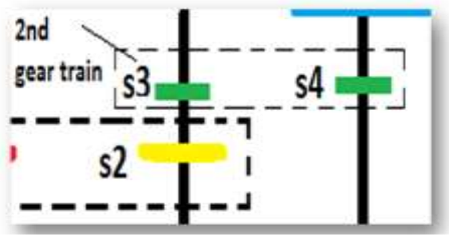
$$N_2 = \frac{T_1 \times N_1}{T_2}$$

$$N_2 = \frac{70 \times 1}{35}$$

$N_2 = 2$ rev.

Now 2nd and 3rd sprocket is on same shaft so, N2 = N3 = 2

4.3 Gear train second



Now for 2 and 3 shaft, If A=1 B=2 C=3 D=4 for respective sprockets, then

$$\frac{N_C}{N_D} = \frac{T_D}{T_C} \quad N_D = \frac{N_C \times T_C}{T_D}$$

$$N_D = \frac{2 \times 24}{24} = 2 \text{ rev.}$$

Now, Flywheel effect which can modify Revolutions by 1:1.4
NE = 2 ×1:4 = 3 Rev.

Now, DE = Diameter of Flywheel
DF = Diameter of Alternator
DE = 10 × DF

Now, Flywheel to alternator,

$$\frac{D_E}{D_F} = \frac{N_F}{N_E}$$

$$N_F = \frac{D_E N_E}{DF} = \frac{10 \times D_F \times 3}{D_F}$$

NF = 30 Rev:

Hence, Classical model gives 1:30 output, by measuring current output by voltmeter,

V=9.8V I= 2.2. Amp Now we know power,

Power =V × I

Model Power =9.8 × 2.2= 21.56 W by the Classical.

Now, If we want to charge **battery of V =12V and 7.6 Ah** time required to charge,

$$t_c = \frac{7.6}{2.2} = 3.45 \text{ hrs.}$$

And time to discharge battery if we use 5 W, 3 bulbs the power=15W, I =7.6 Ah V=12V then,

$t_d = 7.6 \times \frac{12}{15}$ = 6 hrs. Since we know, $t_d = \frac{AV}{P}$

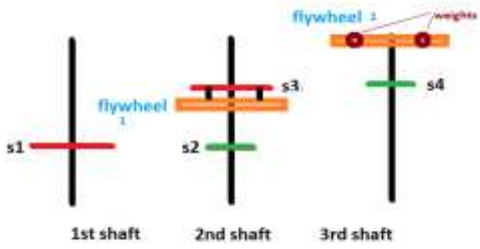
4.4 For Modified Cycle

To overcome losses and to improve system modification in system and to reduce losses we must do following modifications,

- 2nd sprocket changes
- Addition of flywheel to intermediate shaft.
- Replacement of 3rd sprocket
- Flywheel modifications

Fig 14: Modified model with all attachments

Fig15: Back View of the model



There are several purposes of Modification,

- As we seen in classical structure TC = TD so there is no use of 2nd to 3rd shaft and energy losses.
- With such a less output there is no improvement with this structure
- Free energy to flywheel to 2nd shaft
- TC = 2 × TD
- TB = 24
-

4.5 Calculation:-

Now for first gear train between shaft 1 and 2,

If NA =1

$$\frac{N_A}{N_B} = \frac{T_B}{T_A}$$

$$N_B = \frac{N_A \times T_A}{T_B}$$

$$N_B = \frac{1 \times 70}{24} = 3 \text{ rev.}$$

Now we have used free energy flywheel" on second shaft which is working on principle of free vibrations such as,

$$K_E \ \alpha \ \omega^2$$

If KERod and KEFly, Now ω α N

$$\left(\frac{K_{Erod}}{K_{Efly}}\right) = \left(\frac{N_{rod}}{N_{fly}}\right)^2$$

$$K_{Efly} = \frac{1}{2} \times I \times \omega^2$$

$$K_{Efly} = \frac{1}{2} \times (K \times m \times r^2) \times \left(\frac{2\pi N}{60}\right)^2$$

K=for wheel to adjustment=1
M=3.5. Kg
R=15 cm= 0.15 m
N=600 rpm

$$K_{Efly} = \frac{1}{2} \times (1 \times 3.5 \times 0.15^2) \times \left(\frac{2\pi \times 600}{60}\right)^2$$

$$K_{Efly} = \frac{1}{2} \times 0.07875 \times 3934.84$$

$$K_{Efly} = 155.29 \ J$$

$$K_{Efly} = 155.29 \ J$$

Now for KERod
K=for wheel to adjustment=1
M=0.25 Kg
R=10 cm= 0.10 m

N=600 rpm (assumed)

$K_{Erod} = \frac{1}{2} \times (1 \times 0.25 \times 0.10^2) \times (\frac{2\pi \times 600}{60})^2$

$K_{Erod} = \frac{1}{2} \times 0.0025 \times 3934.84$

KErod = 4.9298 J

$\frac{K_{Efly}}{K_{Erod}} = \frac{155.29}{4.9298} = \frac{155}{5} = 31$ Now,

$K_E \alpha\, N^2$

$(\frac{K_{Erod}}{K_{Efly}}) = (\frac{N_{rod}}{N_{fly}})^2$

$(31) = (\frac{N_{rod}}{N_{fly}})^2$

$\frac{N_{rod}}{N_{fly}} \sim 5$

NFly = 5 × NRod

1:5 Ratios

If NRod = NB = 3

Then NFly = 5 × 3 = 15 Rev:

NC is attached to NFly

NFly = NC = 15 Rev:

Now for 2 and 3 shaft,

$$N_D = \frac{48 \times 15}{24} = 30rev.$$

Now by general flywheel (Secondary) output 1:1.4,

NE = 30 ×1:4 = 42 Rev:

Now DE = Diameter of Flywheel

DF = Diameter of Alternator

DE = 10 ×DF

DE = 10 ×42 = 420Rev:

Now you can see the difference how our modification improves revolution rod

(Nclassical) out = 30 to (NMod) out = 420 then 14 times greater than classical model.

By Measured output,

V=15V

I=8.93 Amp

Power =V ×I

Power =15×8.93

Power =133.95W

Time of Charge to Battery of 12V battery 7.6 Ah

$tc = \frac{7.6}{8.93}$=0.85 Hrs= 51 min.

And time to discharge battery if we use 5 W, 3 bulbs the power =15W, Ah=7.6 Ah

V=12V

$t_d = 7.6 \times \frac{12}{15}$ = 6 Hrs

Table -1: Comparison between Classical Model and Modified model

	Classical Model	Modified Model
Sprocket 1	N_A = 1 when T_A=70	N_A = 1 when T_A=70
Sprocket 2	N_B = 2 when T_B=35	N_B = 3 when T_B=24
Sprocket 3	N_C = 2 when T_C=24	N_C = 15 when T_C=48
Sprocket 4	N_D = 2 when T_D=24	N_D = 30 when T_D=24
Flywheel	N_E = 3	N_E = 42
Alternator	N_F = 30	N_F = 420
Power	21.56 W	133.95 W
Time of charge , t_c	3.45 hrs	0.85 hrs
Time of Discharge for 5W, 3 bulbs	6 hrs	6 hrs

If we plot the graph for no of revolutions versus stages, the revolutions given by modified cycle are much more than that of Classical model as we see at stage 6 in the graph.

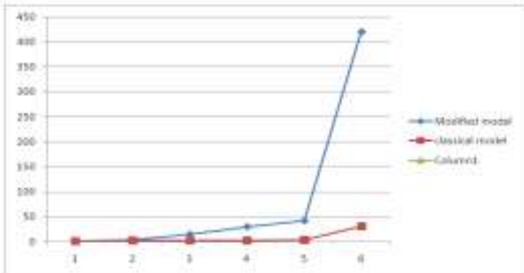


Chart -1: Revolutions Vs Stages

Voltage vs. current graph as shown in fig. rapid increase in voltage and current in case of modified model.

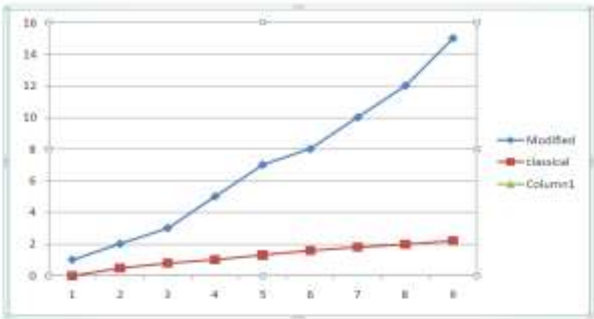


Chart -2: Voltage (v) Vs Current (I)

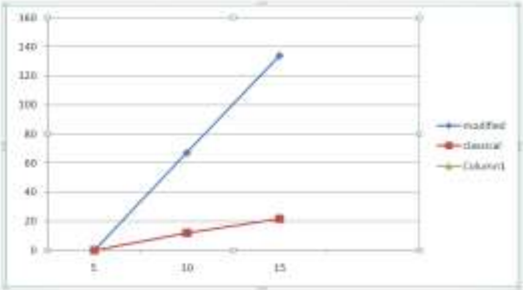


Chart -3: Power Vs Voltage

Power production is much more in case of modified cycle than that of Classical model as shown in above graph.

5. CONCLUSION

1. From classical model, we have produced power 21.56 watt and from modified model 133.95 watt which is 6.21 times more than that of classical model.

2. Charging time to charge 12V 7.6Ah battery with classical model is 207 min and where as with modified model 51 min which is 4 times lesser than Classical model.

3. Along with energy generation user can maintain his health & fitness by pedaling.

4. This energy can be stored in the battery array to facilitate various needs. As human power is used this system is very eco friendly and pollution free.

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