Design and Fabrication of Energy Harvesting Jugaad Thread Mill

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Abstract - *The latest challenge faced with the worldwide energy situation is the growing demand for energy and its strong dependence on unsustainable fossil fuels. Another concurrent issue is the adverse health and socio-economic implication of adult obesity. Human power generation, which makes use of metabolized human energy to generate electrical power can potentially address both these challenges. The treadmill, popuraly used exercise machine, which is used at present, consumes large amounts of energy with liberation of majority of heat. The main aim of the study is to design and develop a energy harvesting human powered treadmill generator and determine its power generation potential. The developed treadmill is based on a manual flat bed using an electromagnetic dynamo generator coupled to a front axle flywheel. A rechargeable battery is used to store the generated energy with other components were used to measure the generated power. The entire setup is built under the concept of jugaad to experiment the output voltage*

Key Words: Jugaad , Thread Mill, Power, dynamo, battery

1.INTRODUCTION

With the technological advancement worldwide, demand of energy is continuously increasing. The power generation is also increasing and most of the energy generation plants are using fossil fuels [9] which bring up many adverse effects such as health issues and Global warming [5] due to climate change. In the view of the above facts there is a need for alternative methods of power generation [1] ,[2]. Researches are going on worldwide for increasing the generation of power through alternative methods. Most of the people do exercise worldwide. The electricity may be produced by using manual exercise machines integrated with electricity generators. In this way manual power may be used to generate electricity [1] during exercise and we can overcome the above mentioned problems up to some extent.
Overweight and obesity are also one of the leading challenges faced by the world, threatening the health of many people and posing significant financial burden on the developing, under developing and also for developed countries. A solution to address these two great challenges is the use of human power, use of muscular strength to power engineered applications. The important source of energy is that liberated from sugars and fat, while the output can be either extracted as direct mechanical work or convert the work to easily storable electrical energy.

1.1 LITERATURE SURVEY

Human energy has been backed up in helping solve problems since ancient times [7]. In the early days treadmill was not designed as the greatest exercise machines for all time. From its beginning purposes, start from churning butter to punishing convicts, no one predicted it can be the king of all aerobic machines
The human powered thread wheel crane was used up until the 1900s, with some designs wide enough to fit two people, doubling the effective power of the tread wheel. Some cranes even had two treadmills in one axle, making the tread wheel crane four times more powerful.
Indeed some time recently making its way into your living room, the treadmills were used in British jails as a unfeeling and abnormal form of punishment. In 1818 Englishman and engineer Sir William Cubit proposed using the convicts muscle power to simultaneously 'cure' their idleness and produce useful work.
In 1968, Mechanical engineer and fitness pioneer William Staub designed and invented the first treadmill meant for home use. Today human power has made sort of a comeback with many applications where it can be use and the reason to investigate alternative energy.

2. OBJECTIVES

The objective of the study is to design and develop a Energy harvesting human powered treadmill generator with jugaad concept and determine its power generation potential. The developed treadmill is based on a manual flat bed using an electromagnetic dynamo generator coupled to a front axle flywheel. The concept of jugaad is experimented to reuse the components. A rechargeable battery pack was used to store the generated energy.

3. COMPONENTS AND SPECIFICATIONS

The self powered treadmill consists of a frame on which an endless belt (track) is placed with the support of rollers and it is inclined at less than 10degree. Roller are attached with D.C generator .When the person walks over the track, due to the weight of the person on the track, the track rotates itself and generator produce electricity. Output voltage will be obtained in range of 12V.

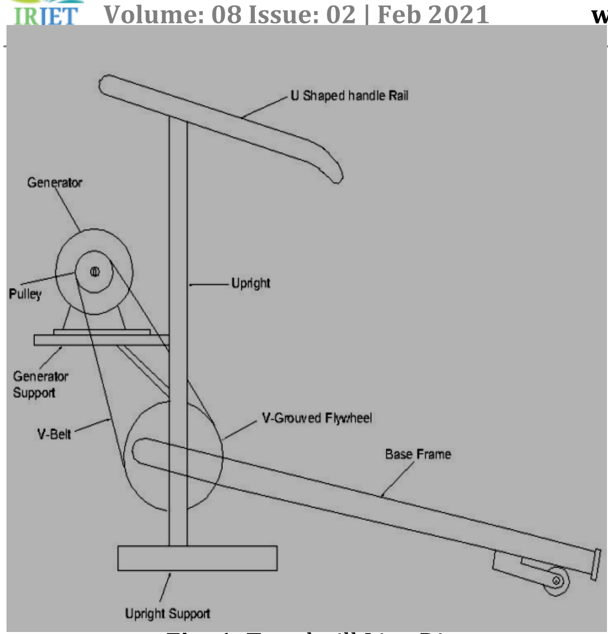

Fig -1: Treadmill Line Diagram

3.1 Base frame

The frame is the important part of the machine which can withstand the load of the motor, roller with sleeves and shaft, along with the human load. The frame and its fabrication is made of mild steel

Fig -2: Base Frame

3.2 Roller

Rollers are the important part of treadmill, as the entire job of transmitting sliding motion to the jogger belt depends on it. The material used is Hollow EN 8of length 90cm

Fig -3: Roller

3.3 Sleeves

A Solid circular rod made of mild steel having diameter 70 cm is taken. Plain turning is done for about 6mm and then it is cut into four parts of required length. For each cut sleeve centre drill is done as per shaft diameter 25.4 mm.

Fig -4: Sleeves

3.4 Pulleys

The Pulley is used to transmit the power in the system. The pulley is made up of cast iron having larger diameter of 254 mm and smaller diameter 63.5 mm.Here the pulley belt used is V-belt of standard size 'A' as per the calculations

Fig -5: Pulleys

3.5 Dynamo

The dynamo is an electrical generator that produces DC electric current

Fig -6: Dynamo

3.6 Jogger V-belt

Usually in treadmill for walking/running we use belt as track and that belt material is called as jogger belt. The belt is of length 2.7*0.4*0.02m

Fig -7: Jogger V-belt

3.7 Assembled Thread Mill

Fig -8: Assembled Thread Mill

4. Design and Calculation:

4.1 Design of shaft

The shaft is the material made up of mild steel of circular cross-section and based on the application the suitable diameter can be designed.
For the present work the shaft is the main element which will take the average human weight and will rotate on an average of 10km/hr for walking of a healthy person.
The speed calculated for 10km/hr is approximately 70rpm.
The other specifications of the shaft are

1. Length of the shaft (Ls) = 650 mm
2. Modulus of elasticity of mild steel (E) = 210kN/mm2
3. Modulus of rigidity of mild steel (G) = 80kN/mm2
4. Cross sectional area of the shaft,

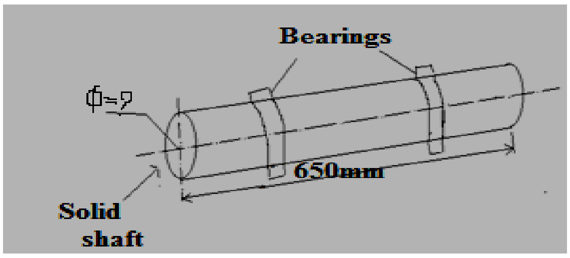

Fig -9: Shaft with Bearings

$P = \frac{2\pi NT}{60}$ (power required = 1551 W)

$1551 = \frac{2\times\pi\times70\times T}{60000}$

T = 211.689× 103 N-mm

From DDHB the yield stress and factor of safety for mild steel is

σ_y = 345 N/mm2 and n = 2.5

$\sigma_{all} = \frac{\sigma_y}{n} = \frac{345}{2.5}$ = 138 N/mm

When the shaft is subjected to torsion the shear stress will be induced and it is given by,

$\tau = \frac{\sigma_{all}}{2} = \frac{138}{2}$ = 69MPa

$\tau = \frac{T}{Z_p}$

Where, τ = tensional shear stress and Zp = polar section modulus

$69 = \frac{211.689\times10^3}{\frac{\pi d^3}{16}}$

d = 24.99 ≈ 25mm

4.2 Pulley and belt system

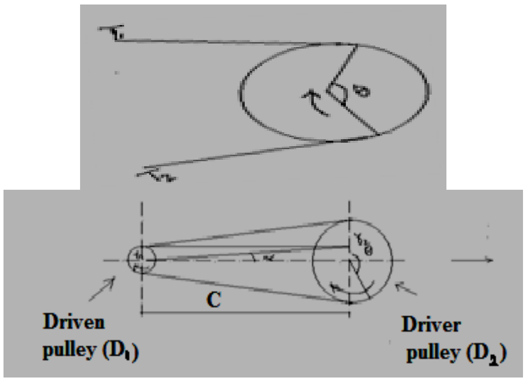

Fig -10: Pulley and Belt

The pulley and belt system component each other is achieving their purpose of usage. The pulley is made of cast iron material. The pulley used has the following dimensions.

Driver pulley diameter, D1 = 254 mm
Driven pulley diameter, D2 = 63.5 mm
Length of the conveyor belt = 2.7 m (up and down)

Any jogging speed for normal man is 10km/hr. So for full rotation of jogger belt man has to run 2.7m.

The rotation of jogger belt in one hour = $\frac{10\times10^3}{2.7}$ = 3703.7 rph

The rotation of jogger belt in one minute = $\frac{3703.7}{60}$ = 62 rpm

Diameter of each roller, Dr = 3 inch = 76.2 mm

For one rotation of jogger belt, one roller completes

$= \frac{length\ of\ the\ belt}{\pi\times D_r}$

$= \frac{2.7\times10^3}{\pi\times76.2}$ = 11.27 ≈12 full rotation

Taking the standard value as 70 rpm. As the larger pulley is connected to the shaft the speed of the jogger belt in one minute will be equal to speed of larger pulley

i.e. N1 = 70rpm.

4.2.1 The Pulley System

$\frac{D_2}{D_1} = \frac{N_1}{N_2}$

$\frac{63.5}{254} = \frac{70}{N_2}$

N2 = 280 rpm

Velocity = $\frac{\pi D_2 N_2}{60000}$

$= \frac{\pi\times254\times70}{60000}$ = 0.93 m/s

4.2.2 The Belt System

The belt used is a V – belt made of rubber material. The speed of the belt can be calculation as follows.

Belt speed (m/min) = $\frac{\pi * \text{pulley diameter(mm)} \times \text{pulley speed(rpm)}}{1000}$

For the driver pulley,

Belt speed = $\frac{\pi \times 63.5 \times 280}{1000}$ = 55.85 m/min

For the driven pulley,

Belt speed = $\frac{\pi \times 254 \times 70}{1000}$ = 55.85 m/min

This implies that the belt speed is the same at any point on either the driver pulley or the driven pulley.

4.2.3 Length of the belt:

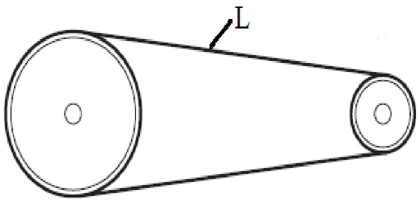

FIG 11: Belt Length

$L = 2C + \frac{\pi}{2}(D + d) + \frac{(D-d)^2}{4C}$........ (From DDHB 14.15(b))

Centre distance is not given, so an empirical formula to select the centre distance from the condition of longevity of the belt.

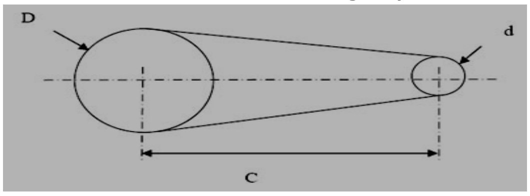

FIG 12: Centre Distance (C)

Cmax = 2(D + d) ...... (From DDHB 14.2(d))
= 2(254 + 63.5)
Cmax = 635 mm
Cmin= 0.55(D + d) + T ...... (From DDHB 14.2(d))
From table 14.14 classifications of V-belts,
For C/s A, Top width = (b) = 13 mm
Nominal thickness = 8 mm
Cmin = 0.55(254 + 63.5) + 8
Cmin = 182.625 mm
By taking the mean value of C we get
C = 408.81 ≈ 450 mm

$L = 2 * 450 + \frac{\pi}{2}(254 + 63.5) + \frac{(254-63.5)^2}{4*450}$

L = 1418.88 mm

4.2.4. Tension in the belt:

The tension in the belt as the pulley rotate can be calculated as follows.
Torque = difference in tension × radius of pulley.
Radius of driven pulley, r2 = 127 mm.
Since the shaft is connected to the driven pulley, we use the torque of the shaft in our calculation. Hence,

Torque, Ts = $\frac{T_1 - T_2}{r_2}$

Also we have,

$= e^{\mu\theta}\frac{T_1}{T_2}$

Where,
C = Centre to centre shaft distance,
r1 = Radius of driver pulley,
r2 = Radius of driven pulley,
θ = angle of contact or lap in radians,
μ = Coefficient of friction between rubber belt and dry cast iron pulley,
T1 = Tension in the belt on tight side,
T2 = Tension in the belt on slack side,
Take μ = 0.3, and also r1 = 31.75 mm, r2 = 127 mm,
C = 450 mm
For open belt,

$\sin\alpha = \frac{r_2 - r_1}{C}$

$= \sin^{-1}\left(\frac{127-31.75}{450}\right)$

$\alpha = 12.22°$

Angle of contact,

$\theta = (180° - 2\alpha) \times \frac{\pi}{180}$ .... (From DDHB 14.1(a))

$= (180 - 2\times12.22) \times \frac{\pi}{180}$

θ = 2.715 radians

$\frac{T_1}{T_2} = e^{\mu\theta} = e^{(0.3\times2.715)} = 2.258$

T1 = 2.258 T2
Recall that T = 211.689kN – mm and
Ts = (T1 – T2) × r2
211.689×103 = (T1 – T2) × 127
(T1 – T2) = 1666.84
T1 = 1666.84 + 0.4428×T1
T1 = 2991.45 N
T1 = 2.258 T2
2991.45 = 2.258 ×T2
T2 = 1324.82 N

4.2.5. Calculations for dynamo:

The EMF induced in the armature of an alternator is similar to that of DC Generator.
EMF induced / Ph,

$e = \frac{ZN\emptyset P}{60}$ Volts.

Where,

Z = No. of conductor in series / phase.

N = Rotation of armature in revolution / min (rpm) i.e. N/60 rps.

$\emptyset$ = Flux produced per pole.

P = No. of poles.

According to specification of Dynamo,

No. of turns = 1000.

Winding material = copper.

Current produced = DC.

Winding = 2.

Z = 2 Conductors in series / phase.

Assuming when,

N = 25 rpm of magnet.

Assume $\emptyset$ = 3.6 web/ Second per pole

P = 2 no. of poles.

EMF induced = $e = \frac{ZN\emptyset P}{60}$

$= \frac{2\times25\times3.6\times2}{60}$,

e= 6 Volts.

5. Results and Discussions

Table -1: The changes in the values of voltage in response to change in different speeds

Large pulley speed (rpm)	Belt speed (km/h)	Dynamo Speed(rpm)	Voltage (volts)
7.5	1.46	30	0.3
12.5	2.0	50	0.579
25	5.36	100	1.15
50	10.72	200	2.36
75	16.08	300	3.54
100	21.4	400	4.72
125	26.8	500	5.9
150	32.4	600	7.1
175	37.8	700	8.26
200	43.2	800	9.44
225	-----n/a-----	900	10.62
250	-----n/a------	1000	11.8

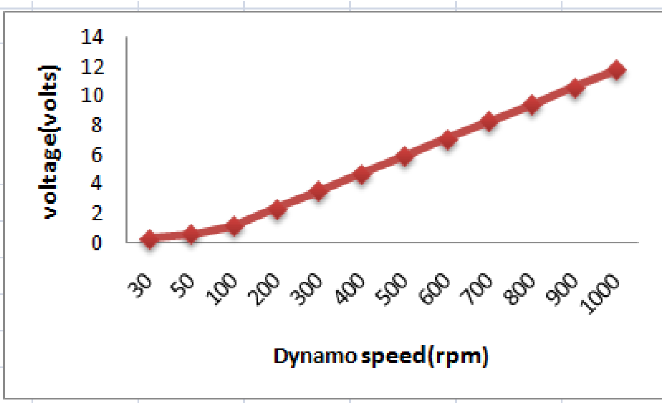

Chart -1: Dynamo speed v/s voltage

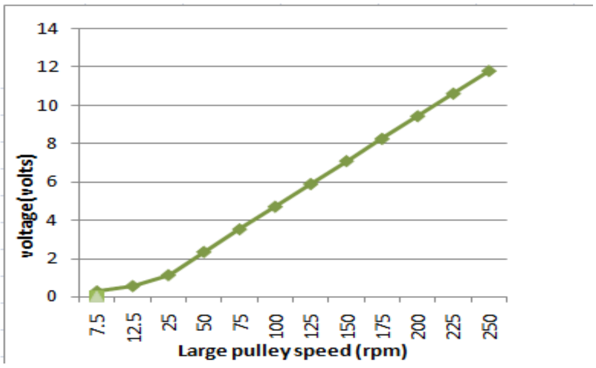

Chart -2: Large Pulley Speed v/s voltage

As the individual steps over the platform with the support of side rails and grips his foot over the curved jogger belt which will partially rest over curved frame. As the person tries to keep his foot on Jogger belt with force applied to walk or run, will cause the belt to rotate in the roller which will result in turning of rollers which are rested over the bearing. As the roller rotates the central shaft will rotate which causes the larger pulley to rotate. The larger pulley is connected to the dynamo with the help of V- belt drive, which will turn the dynamo. As the dynamo tries to rotate it will produce power, which will be then transferred to secondary circuit to amplify to the desired voltage output, so that it can be used for any particular application.

6. CONCLUSIONS

The concept of Treadmill Power Generation opens up a new level of fitness equipment which will be able to produce the power by human effort. This will result in low power consumption in Gyms and will help in producing a green environment.

The treadmill which is used for walking helps to keep us fit as exercise is also one of the important task for a person to be fit and healthy for day to day life. This equipment could produce voltage up to 12 volts which could charge 12 volt, 3 amps battery in 6 hours.

From the Enterpernual point of view, this project has a strong potential so that it could be commercially fabricated as it is a low cost machine and everyone can afford the equipment.

The treadmill is built using the concept of jugaad in which many of the components were reused from the earlier existed projects which pays the way for the new experiment.

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