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Design and Development of Pedal Powered Spin Dryer Machine

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Abstract: ***In this paper, we have discussed designing and development of Pedal powered spin dryer machine. It is a low-cost dryer machine which can be fabricated with mechanical segments readily available in market. The concept behind this machine is it generates enough power by human pedalling to drive the mechanism. This process follows conversion of pedalling motion to rotatory of motion the drum. As this design follows the principle of centrifugal force hence, more the centrifugal force less will be the time elapsed to dry the clothes. This mechanism does not require the usage of electricity which makes it eco-friendly. Since, in developing countries electricity is a prevailing issue which makes the usage of electric dryer machine difficult.*** ***The key idea lies in its simple unique design, fabrication with the inexpensive mechanical parts, low repairing and maintenance cost and affordability to society. The design is eco-friendly as it does not require any chemical component that can harm the environment along with that it can be used as an alternative way of cycling as an exercise.***

Keywords: Gears, Pedal Power, Design, Dryer Machine

I. INTRODUCTION

This paper solves a lot of problems of the today's world including the usage of the electricity supply and harmful effects on nature and at the same time it also covers one of the daily house-hold activities. Most of the people face difficulties to dry their clothes in winter and rainy seasons where when there is a scarcity of the sunlight during these periods. The time taken to dry the clothes is much more and takes relatively very long time. Thus, there arises the need of the pedal powered spin dryer machine. A Pedal Powered Dryer Machine is a machine that helps to dry the clothes in any season despite of the conditions outside in the atmosphere. It contains a barrel in which clothes are placed and then rotated very quickly which helps in removing the water from the clothes and resulting in drying them up. To increase the efficiency and decrease the time taken to dry the clothes, we have added a fan with a heating system at the top which will send in the hot air in the barrel or drum to help the clothes dry. The Pedal Powered Spin Dryer Machine runs without the aid of electricity hence becoming a readily option in the rural areas and all those areas where electric supply is unavailable and expensive, powered electric drying machines becomes almost impractical. It requires more of a physical strength to run the machine which can also be result in kind of exercise to keep people fit and healthy. People ride their bicycle outside as an activity to keep themselves fit but now with the help of this machine they can work out at home meanwhile drying their household clothes too. It also helps us in saving the environment as it saves electricity. Thus, the electricity saved can be used for other purposes. As we all know that the time taken to dry the clothes in winter and rainy season is a long-time process and depends totally on the sunlight provided which is scarce in those seasons. Sometimes it takes days to dry only a handful of clothes because of the no sunlight available.

II. LITERATURE REVIEW

In the early 20th century first electric dryer was invented by J. Ross Moore who built a shed in his house for his clothes while they dried. In addition, a stove was added on the shed. The clothing would hang in front of the fire throughout the day in a series of a line. This idea was embedded as the beginning of the development of electric dryers. Moore worked to build a gas and electric unit but could not find anyone to help him get his idea manufactured. The drum-type model was built by Hamilton Manufacturing in Wisconsin.

Dharwa Chaitanya et. al. designed and developed a machine which does not require electricity for several operations like washing. This is a human powered machine which runs on gear and uses human efforts to drive. It can be used as by both human power as well as electric power. The design was ideal for use in the developing world because it does not require electricity and can be easily built using metal base, chain, bearing, foot pedal (operated by human), chain sprocket [1].

Linxu, Weinan bai et.al. designed and developed a pedal driven washing machine, the main objective of this study is to provide a product with an alternative way to wash clothes in case of no electricity. So, machine which is a pedal driven machine, it satisfies the need of rural people by giving them an alternative way of washing clothes which is quick, cost-effective, and eco-friendly [2].

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III. PROPOSED SYSTEM AND MECHANISM

For the cost effectiveness and reducing the time taken to dry the clothes, we will be designing the pedal powered spin dryer machine. The machine can be used in any atmospheric conditions hence the time taken to dry the clothes in winter and rainy season will be decreased. The machine did not require any electricity to run hence can be used in rural areas.

A. Mechanism

The mechanism of drying is based on centrifugal force of action that acts in outward direction. When we pedal, the pedalling motion is transferred to the drum and the drum is rotated at higher speeds, now the clothes present in the drum will start rotating with the drum and then centrifugal action separates the water droplets from the clothes. The faster is the speed of the rotating drum greater will be the drying efficiency. We use optional heating equipment on the top of the drum which includes a fan and a nichrome heating wire to increase the effectiveness of the machine. When we paddle, the rotation of crank rotate the chain wheel which is connected with the sprocket by chain and this sprocket is mounted on shaft on which one part of bevel gear is mounted and another part of bevel gear is mounted on vertical spindle which is connected with drum. There can be two ways of building the machine either in a horizontal axis way or in the vertical axis way but having more advantages of vertical over the horizontal, we are advancing with the idea of the vertical. Horizontal axis dryer machines are known for their naturally occurring problems associated with their design which can typically create an excess force in different plane of motion during the spin cycle. But the vertical axis dryer can have unbalances of the same order of magnitude as the horizontal axis dryer but the forces are primarily in the plane of motion, causing no major harm. As the user behaviour is not controllable, detection of unbalance in washing machines and its correction is essential to prevent the dryer from spinning up to its full speed with unbalanced load, through resonance, causing excessive noise and even some damage to the structure of the drying machine. This problem needs to be taken in attention and solved immediately as the machine is made for the residential purposes. Hence, we are using the vertical axis machine where the vibrations already at minimum comparatively due to the forces being in the plane of motion.

B. Pedal Power

Pedal power is the transfer of energy from a human source from one system to another system with the help of pedal and gears. It is a common technology which is installed mostly for transportation purposes and has been widely used to propel bicycles for more than a century. Some development projects around the world are currently transforming used bicycles into pedal powered tools and machine for sustainable development and purposes. The concept of this Drying Machine is very simple and it is that it will generate power through human pedalling to the drive mechanism which in turn converts the pedalling motion into required rotary motion of the drum for drying. With the help of compound gear system, the machine will achieve the desired speed for different purposes like rinsing and drying. Its key idea lies in its simple unique design and use of inexpensive mechanical parts. Power generated by a hand-cranking is one-fourth of the power generated by pedalling by a normal individual which is way more useful in operating this machine. Only short periods approximately of about 10 to 20 minutes of continuous pedalling can be achieved if the power rate is ¼ HP. Pedalling at half of this power (1/8 HP) can be sustained for close to 60 minutes of work.

IV. COMPONENTS

A. Seat

Seat is an arrangement provided according to the need of a person's comfortability who will sit on the machine and will carry out the operations. Seats can be made and manufactured by different materials like plastic, rubber, metal etc. The seat used here is of satisfactory softness used by keeping the comfort of a person in mind and is big enough for most users to use the machine without much fatigue. The seat has been installed just like a seat from a regular bicycle that was designed for adults. A chair can be used instead of a bicycle seat for sitting and pedalling for making of clothes more comfortable.

B. Pedal Arrangement

A bicycle pedal is a foot-operated lever like arrangement when pushed with foot is used for transmitting power to the bicycle to carry out its movement in the forward direction. It provides the connection between the cyclist's foot and the crank allowing the leg to turn the bottom bracket spindle and propel the gear to transmit pedalling motion to the gear.

C. Gear

This machine consists of the two sprocket systems or circuits. Out of two sprockets system used, one sprocket is incorporated with the pedal concluding the first circuit. The second sprocket is conjoined with the intermediate shaft, whereas both the sprockets are linked to each other with a chain which will act as a power transfer system to transfer the motion.

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This circuit is used to provide continuous rotation to the intermediate shaft in a single direction. The second circuit consists of the intermediate shaft and spindle through bevel gear that is coupled to the rotating drum.

D. Bearing

A bearing is a machine element that constrains relative motion, by guiding and supporting the components, between moving parts to only the desired motion. In this machine, we used two bearings on the drum shaft to support the drum. These bearings are placed on either side of the drum shaft resting on a support on the frame of the machine. Bearings help in smooth rotation of the shafts to ease up the pedalling effort.

E. Chain

Chain drive is an inexpensive, easy-to-install and highly efficient drive mechanism that work as a power transfer system in human powered vehicles.

F. Hub

Hub is an important part of the bicycle which involves the sprocket mounting. In this machine, we are using a Hub on to which the intermediate sprockets are mounted which helps in transferring pedalling motion of front sprocket to the drum shaft. The hub that we are using is mounted on the intermediate shaft. It carries two sprockets, one of which drives the drum and another which is connected to the pedal. It is connected and coupled to the cam plate which eventually drives the rack and pinion.

G. Drum

It is the chamber in which wet cloth is kept for drying. In this type of machine, there are two drums are used, inner & outer. Inner drum consists of the wet clothes which are to be dried & it is less in diameter as compared to outer drum. Inner drum is punched with holes throughout its body so that the water could get collected in it and dried clothes does not get wet again. It rotates with the help of gear & chain arrangement in the desired speed with respect to the purpose. Outer drum: Outer drum is used to store water which is removed from the cloth and then this water is removed from outer drum.

V. MATHEMATICAL CALCULATION

A. Design and Calculation

1) Assumptions

a) Big sprocket radius = 44 cm
b) Small Sprocket = 22 cm
c) Average rpm of cycling for a human ≈ 80 rpm
d) Average power transfer by human during cycling = 180 W
e) Assuming mass of spin dryer to be 5 kg (weight of clothes and rotating cylinder)
f) Bevel gear ratio used = 3:1
g) Radius of spin dryer = 10 cm
h) Time per drying (t) ≈ 5min ≈ 300s

2) Analytical Calculations Based On Assumptions

a) Rotational speed of shaft = Ratio of Sprocket*Ratio of Bevel gear*Avg rpm of human ≈ 2 *3*80rpm ≈ 480rpm
b) Torque ≈ 180*60/(720*2π) ≈ 3.580
c) Power of spin dryer is= $(M*r^2) * (2\pi N/60)/2*time$ = 12.633W (Assuming no friction)

B. Heating system design

1) Assumptions

a) Ambient air temperature = 30°C
b) Final temperature of air = 45°C (The Electricity Journal)
c) Density of air (ρ_{air}) = 1.225 kg/m^3
d) Radius of hot air pipe = 2 cm
e) Cp of air=1005 J/kg K
f) Battery = 100 Watt

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2) Analytical Calculations based on Assumptions

a) 100= $\dot{m}$*(C_p)air* ΔT

b) Mass flow rate of hot air ($\dot{m}$)= 0.00345kg/sec

c) M=density*area*v

d) Velocity of air = 4 m/sec

C. Shaft Calculation

1) Assumptions

a) Shaft material: low carbon steel (30C8) (from machine design book: V.B. BHANDARI)

b) Diameter of Shaft: 20 mm

c) Ambient air temperature = 30°C

2) Analytical Calculations Based on Assumptions

a) Load on shaft =Torsional Load =180/ (80*3*2) =3.58 N-m

b) D = 20 mm

c) Area = πd^2 /4 = 3.14*10-4 m^2

d) Torsional stress (shear stress) = 2.28 MPa

e) Axial load = F_t = 5*g = 49 N

f) Compressive (s)= F_t/ ($\pi * d^2$ /4) = 156.05 kPa

g) Von mises stress (net stress) = $\sqrt{(\sigma^2 + 3\tau^2)}$ = 157.21 kPa

h) Allowable = 500 MPa

i) Net stress <<< allowable stress. Hence no yielding.

D. Bevel Gear Calculation

1) Assumptions

a) Material: Steel (50C4), S_{ut} = 750 N/mm^2, BHN:400 (from machine design book: V.B. BHANDARI)

b) Rotational speed of shaft(n_p) =480 rpm

c) No. of Pinion Teeth (Z_p): 20

d) No. Of Gear Teeth (Z_g): 60, m = 2 mm, width(b) = 20 mm

2) Analytical Calculations based on assumptions

a) Pitch angle: tanΥ = Z_p/Z_g = 18.434°

b) No. of Virtual teeth = $Z_{p'}$ = Z_p/CosΥ = 21.08

c) Lewis Form Factor(Y) = 0.326

d) Bending stress = 750/3 = 250 N/mm^2

e) Diameter of pinion = 20*2 = 40 mm

f) Diameter of Gear = 60*2 = 120 mm

g) Pitch cone radius = $[(d_p/2)^2 + (d_g/2)^2]^{(1/2)}$ = 63.24 mm

h) Bending strength (S_b) = $m_b * \sigma_y$ [1- (b/a)] = 2229 N

3) Wear Strength

a) Q = ratio factor = $2Z_g/(Z_g + Z_p \tan\Upsilon)$ = 1.8

b) K = material constant = $0.16(400/100)^2$ = 2.56

c) Wear strength (S_w) = .75b$QD_pK/\cos\Upsilon$ = 2914.339 N

4) Effective Force

a) Tangential force (P_t) = 2*M_t/d_p

b) Rotational torque (M_t) = $60*10^6$*kw/2n_p = 3582 N-mm

c) P_t = 179.1 N

d) Pitch line velocity(V) = $\pi * D_p * n_p / 60*10^3$ = 1 m/sec

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e) Deformation factor(c) = 11400 N/mm^2
f) Dynamic load capacity (P_d) = $21V(c*e*b + P_t)/[21V+(c*e*b+P_t)^{1/2}]$ = 836 N
g) Where e = sum of error between two meshing teeth = 0.0125 mm
h) $P_{eff} = C_s*P_t + P_d$ = 1104.5 N
i) Where C_s = service factor = 1.5 (for moderate shock)
j) Factor of safety against bending failure
k) $F_s = S_b/P_{eff}$ = 2229/1104.5 = 2
l) The factor of safety against piting failure
m) $F_s = S_w/P_{eff}$ = 2914/1104.5 = 2.6

E. Gear Description

a) Number of teeth in pinion (N_1) = 20
b) Number of teeth in gear (N_2) = 60
c) Module of Gear (m) = 2 mm
d) Shaft Angle ($\sum$) = 90°
e) Pressure Angle (α) = 20°
f) Pinion pitch diameter (d_1) = N_1 * m = 20*2mm = 40 mm
g) Pinion pitch diameter (d_2) = N_2 * m = 60*2mm = 120 mm
h) Pitch Cone angle (δ_1) = tan—1 ($\sin\sum/((N_2/N_1) + \cos\sum)$) = tan—1 (1/3) = 18.435°
i) Pitch Cone angle (δ_2) = $\sum-\delta_1$ = 90°−18.435° = 71.565°
j) Cone distance (R_e) = $d_2/(2\sin\delta_2)$ = 120/(2sin18.435) = 63.24 mm
k) Face width (b) =10 * m = 20 mm
l) Addendum (h_a) =1.00 * m = 2.0 mm
m) Dedendum (h_f) = 1.25 * m = 2.5 mm
n) Dedendum angle (θ_f) = tan—1 (h_f / R_e) = tan—1 (2.5 /63.24) = 2.2638°
o) Addendum angle (θ_a) = tan—1 (h_a / R_e) = tan—1 (2.00 /63.24) = 1.8114°

1) Pinion

a) Pinion pitch diameter (d_1) = 40 mm
b) Pitch Cone angle (δ_1) = 18.435°
c) Outer Cone angle (δ_{a1}) = $\delta_1+\theta_a$ = 18.435°+1.8114° = 20.246°
d) Root Cone angle (δ_{f1}) = $\delta_1-\theta_f$ = 18.435°−2.2638° = 16.171°
e) Outside diameter (d_{a1}) = d_1+ 2hacos δ_1 = 40 mm + 2 * 2.0 mm * cos18.435° = 43.795 mm
f) Pitch Apex to Crown (X_1) = Recos δ_1−hasin δ_1 = 63.24 mm * cos18.435°−2.0 mm * sin18.435° = 59.362 mm
g) Axial face width (X_{b1}) = ($b\cos\delta_{a1}/\cos\theta_a$) = 18.774 mm

2) Gear

a) Pinion pitch diameter (d_2) = 120 mm
b) Pitch Cone angle (δ_2) = 71.565°
c) Outer Cone angle (δ_{a2}) = $\delta_2+\theta_a$ = 71.565°+1.8114° = 73.376°
d) Root Cone angle (δ_{f2}) = $\delta_2-\theta_f$ = 71.565°−2.2638° = 69.301°
e) Outside diameter (d_{a2}) = d_2+ 2hacos δ_2 = 120 mm + 2 x 2.0 mm * cos71.565° = 121.265 mm
f) Pitch Apex to Crown (X_2) = Recos δ_2−hasin δ_2 = 63.24 mm * cos71.565° - 2.0 mm * sin71.565° = 18.101 mm
g) Axial face width (X_{b2}) = ($b\cos\delta_{a2}/\cos\theta_a$) = 5.724 mm

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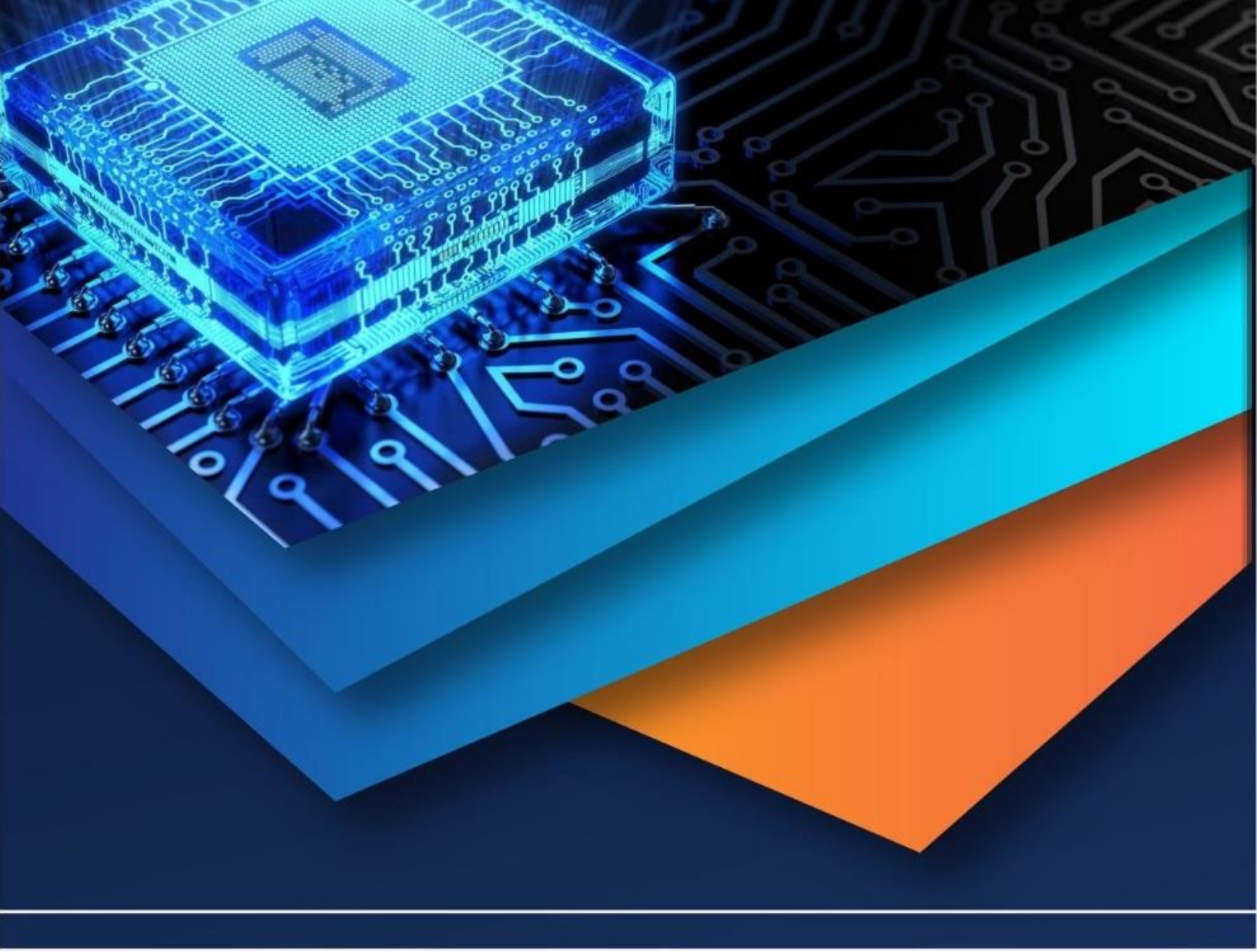
VI. CONCLUSIONS

The main objective is to provide a product with an alternative way to dry the clothes where there is no electricity and more used in winter and rainy season. It must be understood that in rural areas, it is a very time-consuming task in winter and rainy season. This machine gives an alternative way of drying clothes to rural people which is quick, cost effective and eco-friendly. The product designed has zero operating cost and is cost-effective.

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