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Pedal Operated Washing Machine using 4-bar Crank Mechanism

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Abstract: Washing clothes is one of the important parts of our daily lives and it helps a lot to save energy and time.[1] The main objective of pedal powered washing machine is to wash clothes efficiently without use of electricity. As electricity is not accessible by everyone especially in the rural areas, this is of great benefit for the people living there. We have used 4-bar mechanism as our driving mechanism for washing and drying the clothes.

Keywords: ***pedal power, washing, drying, washing machine, 4-bar mechanism, clothes.***

I. INTRODUCTION

A washing machine (laundry machine, clothes washer, or washer) is a home appliance used to wash laundry.[2]

Our main aim is to generate energy for washing clothes through human pedaling with a proper driving mechanism that will convert the pedaling into the required rotary motion. Considering the electricity crisis in the rural areas, an electric washing machine is not suitable for the use. Also washing clothes manually is time consuming and a tedious job. Hence, pedal operated washing machine is a convenient option.

A. Objectives

- Design a washing machine that does not require electric to operate.
- Can perform washing, drying and rinsing within a single machine.
- Easy in operation and can wash all types of clothes.

II. METHODOLOGY

The pedal operated washing machine is completely mechanical and hence there is no need of external energy such as fuel or electricity.

The surveys of the literature are as follows

Dharwa Chaitanya, Kirtikumar [3] designed and developed a multipurpose machine which does not require electricity for several operation like cutting and grinding. The design is ideal for use in the developing world because it doesn't require electricity and can be built using simple mechanical products.

S.G.bahaley, Dr. Ague Awate, S.V. Saharkar [4], Designed and fabricated a pedal powered multipurpose machine. The system is also useful for the work out purpose because pedaling will act as a health exercise and also doing a useful work.

Linxu, Weinan bai, Jingyu rue, and Qiang li [5], Designed and developed a pedal driven washing machine. The method is Eco-Friendly & cost-effective, obtaining a less effort uniform washing.

Rajat Thakur, Rajesh Ranjan, Saurabh Bhat, Shubham Thakur, Mohit Chauhan [6], developed the pedal powered washing machine using a chain drive mechanism. It was effective in washing clothes and help save time compared to the manual hand washing.

III. GAP ANALYSIS

This table explains the comparison between already existing model of washing machine and the one we have designed.

CURRENT CASE	DESIRED CASE	DIFFERENCE
Electricity required for the conventional washing machine.	Using human pedaling power to perform the washing process.	No electricity required
Chain or belt drive used to transmit pedaling power.[6]	4 bar linkage mechanism used to transmit the pedaling power.	360 rotation as well as to and fro rotary motion can be used
Front load type washing machine	Top load type washing machine	Efficient washing of clothes using impeller, ergonomically better to input clothes.
Costlier due to drive mechanism and high maintenance	Maintenance is comparatively lesser.	Cost effective as well as low maintenance

Table 1: **Gap Analysis**

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IV. MATERIAL SELECTION

The following table contains the list of materials of various components that are taken into consideration while calculating and designing the machine.

Sr. No	Components	Material used
1.	Base Frame	440C Stainless Steel
2.	Bicycle	6061 Aluminum
3.	Mechanism	1022 Plain Carbon Steel
4.	Shafts	C-48 Mild Steel
5.	Bevel Pinion	$40Ni_2Cr_1Mo_{28}$ Alloy Steel
6.	Bevel Gear	$15Ni_2Cr_1Mo_{15}$ Alloy Steel
7.	Inner drum, Impeller	Polypropylene (PP) Plastic
8.	Outer Drum	Stainless Steel

Table 2**: Material Selection**

V. CALCULATIONS

A. Bar Mechanism

a. Washing mechanism

For Washing Condition,

The pedal diameter is approximately 300 mm so the 'x' length selected is 150 mm. The lengths

'a' and 'b' selected from the iterations is 400 mm. The 'y' length is 175 mm and the travel span

of 'y' length should be less than 180 degrees in order to avoid blocking of the mechanism.

Hence, the actual span is 142 mm.

For Crank Rocker Mechanism to be achieved, the condition is sum of smallest & largest

links<sum of other two links and in order to achieve to and fro mechanism, this mechanism is selected.[7]

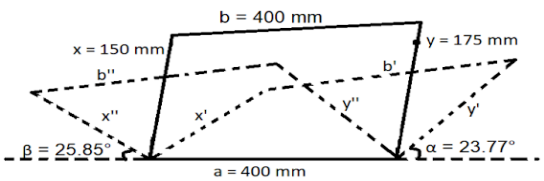

Figure 1: **Crank Rocker Mechanism.**

Input link x=150mm
Output link y=175mm
Fixed link a=400mm
Floating link b=400mm

- Minimum transmission angle

$$(a-x)^2=y^2+b^2-2ybcos\mu$$

- Maximum transmission angle

$$(x+a)^2=y^2+b^2-2ybcos\mu$$

Span of washing mechanism= 130.38°

b. Drying Mechanism

For Drying Condition,

Input link x=150mm

Output link y=150mm

Fixed link a=400mm

Floating link b=400mm

Double Crank Mechanism has been selected in which x, y lengths are kept equal so that 360 degrees rotation can be achieved and the desired motion can be obtained.[7]

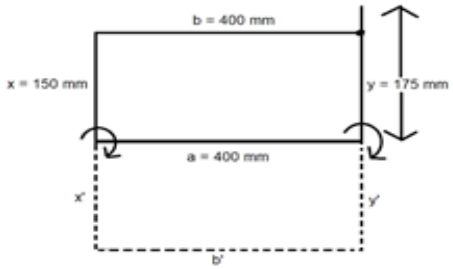

Figure 2: **Crank-Crank Mechanism**

B. Power Calculations

Assumptions

- N = 70 rpm (max rpm a human can provide for longer time by pedaling)
- F = 180 N (max force a human can apply)
- d = 0.3 m (Assuming diameter of pedal arm)

By using the relation,

$P = 2\pi NT/60$

We get

Power P= 400W

After comparing our calculations with the available data [8], we can conclude that the washing time required is 30 mins at 48 RPM and drying time is 10 mins at 400 RPM.

Sr. No	Operation	Time	RPM
1	Washing	30 min	48
2	Drying	10 min	400

Table 3: **RPM Requirement**

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C. Drum Calculations

Max Weight of Clothes = 3 kg
Water for 1 kg of clothes = 5 liters.
Hence, for 3 kg of clothes water required = 15 liters.
1 liter of water = 1 kg by weight
Total Tub Load = 18kg
Volume required= 18L
From the above data,

- Inner drum
  Radius= 156mm
  Height=312mm
- Outer Drum
  Radius=165mm
  Height=320mm

D. Gear Calculations

We require a bevel gear in order to transfer motion from pedal to the inner drum through the mechanism.

The equations and method of finding the solution was taken from book of Theory of Machines. [9]

The calculation of bevel gear is as follows

	Pinion	**Gear**
No of teeth	18	45
Face width	10 mm	10 mm
Module	1.2 mm	1.2 mm
PCD	24 mm	54 mm
Shaft Diameter	12 mm	12 mm

Table 4: **Gear Calculations**

VI. CAD MODEL

All the models are developed by using Solidworks v2019.

A. Pedal with 4-bar mechanism

This is the CAD model of the 4-bar mechanism attached to the bicycle on the bicycle pedal.

Figure 3**: 4-bar Mechanism on bicycle pedal**

B. Drum Assembly

The drum assembly consist of the outer drum, inner drum and the impeller. It also has a flange for mounting it on the chassis.

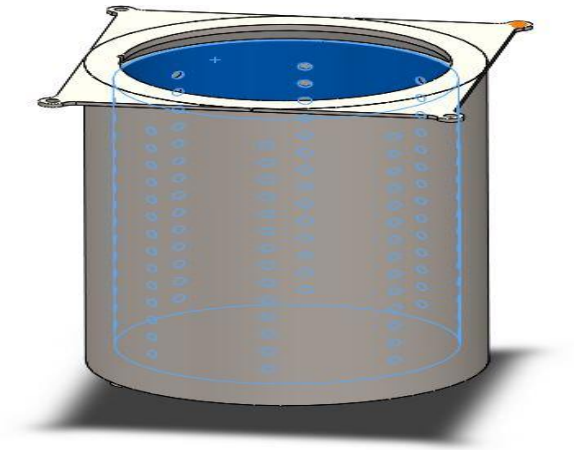

Figure 4: **Drum**

C. Bevel Gear

It consists of a straight bevel gear and a pinion in meshing. It is used to supply motion from pedal to the machine drum.

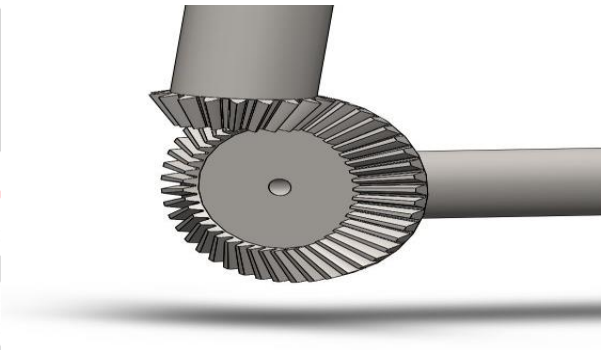

Figure 5**: Bevel Gear**

D. Full CAD Assembly

This is the complete assembly of the CAD model. It includes all the sub-assemblies and is supported by the base frame and the wheels for the mobility

Figure 6**: Assembly**

VII. STRUCTURAL ANALYSIS

The structural analysis of the components was done in ANSYS v18.1.

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A. Inner Drum

The following is the analysis of the inner drum. Analysis was done by applying the centrifugal forces as well as hydrostatic forces on the drum. We get the Equivalent stresses and the Total Deformation.

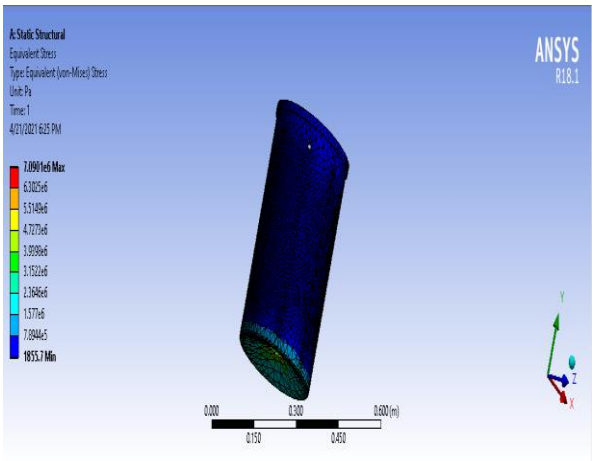

Figure 7**: Equivalent Stresses**

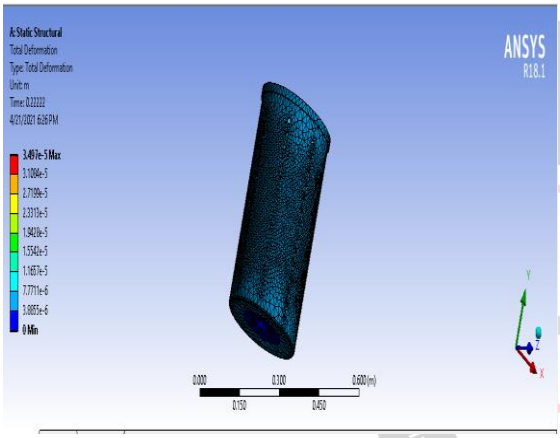

Figure 8: **Total Deformation**

B. Bevel Gear

The gear is the most significant component. The forces were applied on the teeth of the gear. By applying the forces and the moments from the gear calculations we can get the results for Equivalent stresses and Total Deformation.

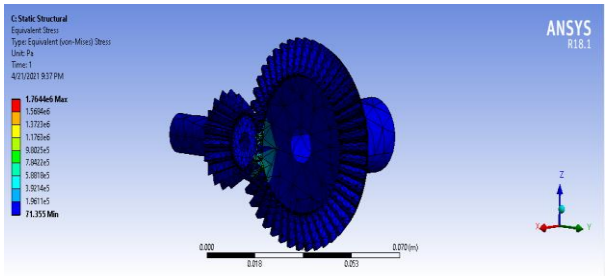

Figure 9**: Equivalent stresses**

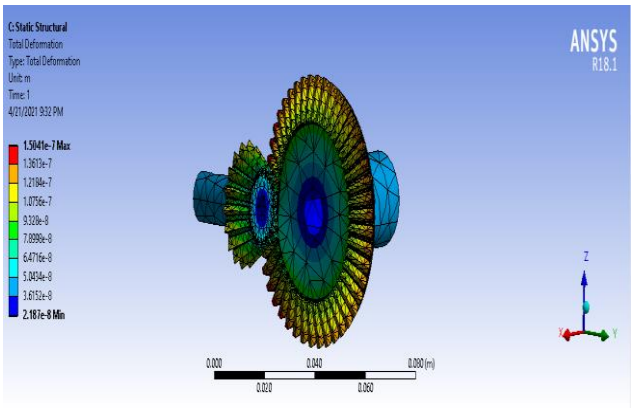

Figure 10: **Total Deformation**

C Results

From the analysis we can conclude that the Equivalent stresses in the inner drum was more at the bottom of the drum while minimum on the circumference. The total deformation was almost same at all points on the drum body.

In the case of drum, we can observe that maximum stresses are at the contact point. Also, the total deformation the gear tooth is maximum compared to the other points. The following table shows the minimum and the maximum values we obtained from the analysis.

Component	Equivalent Stresses (Pa)	Total Deformation (m)
Inner Drum	Min-1855.7Pa Max- 7.0901×10^{6} Pa	Min- 0 m Max- 3.497×10^{-5} m
Bevel Gear	Min-71.355Pa Max- 1.764x10e6 Pa	Min- 2.187×10^{-8} m Max- 1.5041×10^{-7} m

Table 5**: Analysis**

VIII. ADVANTAGES

There are various advantages of using pedal operated washing machine. Some of the advantages are listed below.

- Consumption of electricity reduces because of pedal power.
- Ideal for people living in rural parts as there are electricity crisis.
- Less time consuming and convenient as compared to washing clothes with hands.
- Maintenance is low as less complicated parts are involved.
- Low manufacturing cost as it is mostly made from scrap.
- It also has health benefits, as the operator does some effort in operating the machine.

IX. FUTURE SCOPE OF WORK

Even though the machine is well designed and analyzed, there is some more scope of development. Some of the things which can be implemented are given below.

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A. Increasing Drum Volume

Further modifications can be done by increasing the capacity of machine. By doing so the effect of load and change in rpm can be observed.

B. Automatic Mechanism for Inlet Water

In case of our washing machine the water while washing needs to be supplied manually. A mechanism can be developed for automatic supply of water.

C. Water heating

In our machine only cold water can be provided. A

X. CONCLUSION

By using the 4-bar mechanism we have designed a pedal operated washing machine. Based on the calculations, the CAD modelling and the analysis done, it works smoothly and effectively.

A pedal operated washing machine would allow to wash clothes faster with less effort and also effective washing is achieved. In small villages where there is shortage of electricity, this can be a beneficial thing. Through our research we have tried to explain the concept of pedal operated washing machine and the purpose of designing it.

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