Design and Modelling of Pedal Powered Flour Mill

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Abstract - *The paper aims at the design and modeling of a pedal-powered flour mill. This project aims to make a product that is market-ready and so efficient that the user can exercise on it as well as do a household chore i.e., flour milling. A gearbox is designed to make an option available for the user between the flour mill and the cycle. Considering a few parameters and calculating the rest with the help of pre-derived formulae and relations gears, shafts and bearings have been designed. This will make the mechanism much more efficient and at the same time will reduce the unnecessary wear and tear of the flour mill. Hence, components are designed with some boundary conditions. Components are modeled on CAD. Static Structural analysis is done of these components.*

***Key Words*: Flour mill, Pedal-powered, Gearbox, Shaft design, Gear design, Static structural analysis.**

1. INTRODUCTION

In recent times, everyone has learned the importance of fitness. Also, in these, though times of pandemic world has known what importance does a good health hold in our lives. In this project, a concept has been idealized by which people can exercise at home and along with that, providing an option to do a small house chore while doing this exercise. A gym spin bike has been used to which a flour mill is associated to grind the food grains and obtain the flour out of it. This spin bike (Gym cycle) is designed and altered in such a manner that with the help of human power which will be provided to the pedal and further it will be transferred to a shaft. This shaft will be the input shaft for the gearbox. At the output, we will be having one side for the wheel and another side for the flour mill. By the use of a gear shifting mechanism, the user can operate the wheel or the flour mill as per the user's necessity. Further, the design of gears, shafts, and bearings has been explained. CAD models are prepared for clear understanding. Kevin McGarvey *et. al* [1] have explained the formulas for finding the parameters for crushing the grains. They have sought this idea for developing entrepreneurial ideas, so this paper deals with the commercially used parameters for manufacturing the product. Yusuf *et. al* [2] have specified the formulae and calculated stresses, torsions, torques, and twisting torque that is produced on a shaft due to belt. They have also specified that an average human produces power of 22 W to 75 W. Based on this initial rpm has been calculated. Yallappa D *et. al* [3] have discussed and stated the yield recovery of the flour mill at different power inputs. The flour mill used was developed and evaluated for its performance to make flour. The performance was evaluated on different grains viz. wheat, jowar, Rawa(sooji), daal, rice, and maize. Amos Waweru [4] has given information about the chain drive, its theoretical values, and its maintenance parameters are described. This paper explains a pedal-powered flour mill that has used chain drive and operates on the rear wheel reducing the size of the hub. Dr. Kishorkumar Guru *et. al* [5] describe natural fuel, in this case, it is human energy. They have calculated pedal power, wheel design of the mill, and design of the chain, design of V belt, and power transmission capacity. Abhishek Turamandi [6] has specified the formula and calculations for the V-belt, transmission, and parameters of the mechanism. Gregory D. Williams, Kurt A. Rosentrater [7] have given a detailed explanation about the design considerations for the construction and operation of flour mills. In this paper, they have given the block diagram, fundamental formulae, structural design, and line planning of commercially used flour mills. M.S. Giripunje *et. al* [8] have done a detailed literature review on human-powered flour mills. They have designed the flour mill to address the issue of load shedding in rural areas. They have given various graphs representing human power output. They have designed a complete mechanism for power transmission. Nwogu *et. al* [9] have given an improved design of flour mill, this paper gives a complete idea of calculation of power, costing, gears, and transmission. Prasad A. Hatwalne *et. al* [10] have focused on the use of renewable energy sources, they have also designed the pedal-operated flour mill. They have kept the design simple. They have specified the human power produced and done the calculations on that basis. Prof. Dr. Tale Geramitcioski and Prof. Ljupco Trajcevski [11] have done design analysis of spur gears using computer advancements. They have explained the methodology for designing the gears, shafts, and bearings. After that, they have inferred this in a computer using C++ to simplify the tedious work of design calculations which in result expels the possibility of miscalculation while doing reiterations. Dave, Janakkumar Girjashanker [12] has written a thesis on force analysis of involute spur gears. He has explained every aspect to be considered while designing the spur gears. He has discussed involute teeth profiles on various parameters. Mr. Prasad A Hatwalne *et. al* [13] have proposed a simplistic design of the pedal-operated flour mill focusing on comfort and output. Muhammad Irfan [14] has written a thesis on gear shifting mechanism, in this paper he has given a detailed explanation about the said mechanism he has also given synchronization information. Prof. Naveen Kumar *et. al* [15] have given the modeling and analysis of a spur gear, they have optimized a spur gear to increase its performance and do its analysis which shows the results.

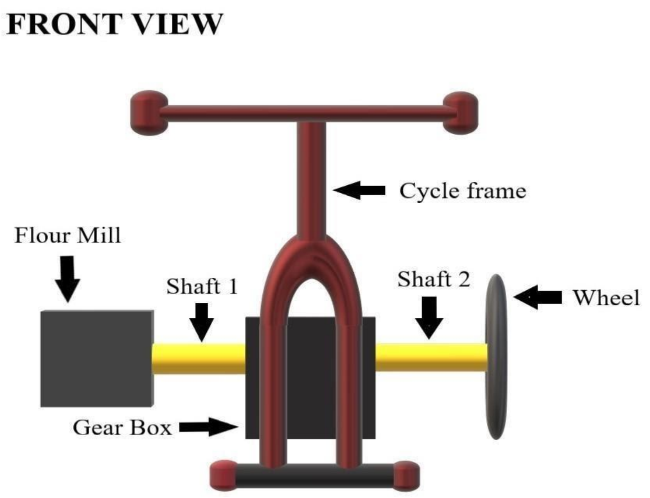

Fig 1: The 3D concept of the mechanism

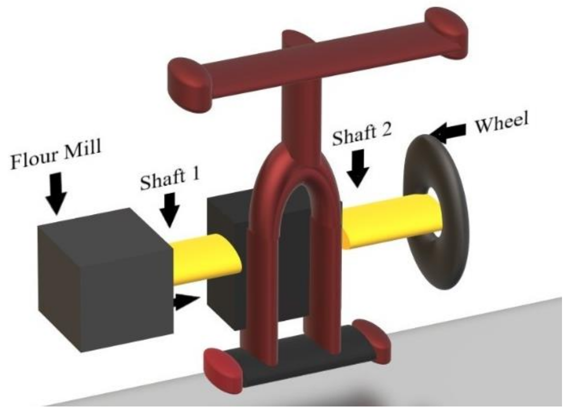

Fig 2: Isometric view

2. CONSTRUCTION AND WORKING

A gym spin bike has been used. This spin bike has an existing chain drive mechanism. A gearbox is designed for power transmission purposes. The chain is connected to the input shaft (driving shaft) of the gearbox. The gearbox has two gear pairs and a dog clutch. The dog clutch will be engaged with either one of the gear pairs, which will decide the path of power transfer. One gear pair is used for powering the wheel and the other pair is used for powering the flour mill. Further, at the end of the gearbox two outputs are given, one for the wheel and one for the flour mill. The position of the gearbox will be in the center of the spin bike.

As mentioned earlier, the basic concept is to obtain the flour out of the human power, for this, we'll use a gym spin bike. When a person will pedal the cycle, this will act as the input power which will be in the range of 22W to 100W. The input power will be given to the pedals, which will further be transferred to the input shaft of the gearbox via a chain drive. This input shaft (driving shaft) will further transfer the power to the gear pairs with the help of a dog clutch. The power will then be transferred to the desired operation of either the wheel or the flour mill. The dog clutch will have three positions, first engaged with the flour mill side, second engaged with the wheel side, and third neutral. Therefore, the engagement of the dog clutch to either one side is utterly important.

3. DESIGN CALCULATION

The Design calculation has three parts namely design of gears, design of shafts, and design of bearings.

3.1 DESIGN OF GEARS

Gear ratio (i) = 3

Input Torque (T_i)= 2.334 Nm

Input Speed (N) = 300 rpm

Tooth System: 20 degrees full depth involute.

Pressure angle (Φ) = 20^0

Spur pinion teeth (Z_p) = 18

Spur gear teeth (Z_g) = 54

Gear material selection: Mild Steel

Ultimate tensile strength (S_{ut}) = 440N/mm^2

Bending stress (σ_b) = $S_{ut}/3$ = 440/3

BHN = 130

Calculation of module:

Based on beam strength,

Service factor (C_s) = 1

Assume velocity (V) = 15m/s ……… {Pitch line velocity}

Velocity factor (C_v) = 6/(6+v) …………… (1)

C_v = 0.285

Lewis form factor (Y) = 0.308

Assume, b = 10m

Module (m) = 2.15 mm

By wear strength,

Ratio Factor (Q) = $2Z_g/(Z_g + Z_p)$ ……….. (2)

Q = 1.7142

Load stress factor (k) = 0.156 (BHN/100)^2 ………. (3)

k = 0.2636

Module (m) = 1.24 mm

Therefore, the module of the gear can be taken as 3 mm

3.2 DESIGN OF SHAFTS

Length of the shaft (l) = 0.075 m

Weight (w) = 1+0.5 = 1.5*9.81 = 14.715 N

For this condition,

Speed of Gear (N_g)

Speed of pinion (N_p)

Diameter of Gear (D_g)

Diameter of pinion (D_p)

$N_g D_g = N_p D_p$

100*20 = n*6.5

Speed (n) = 307.69 rpm

Torque (T) = 60*75/(2π*307.69)

T = 2.32 Nm

Bending Moment (M_b) = w*l/4 .... (4)

M_b = 2.759 Nm

$\sigma_{all} = 40*10^6$ .....{As per the standard conditions for MS}

Now,

$$d^3req = \frac{16}{\pi\sigma_{all}}\sqrt{(KbMb)2 + (KTT)2} \qquad \text{............ (5)}$$

d^3 = 0.0000016892

d = 0.011909 m

Diameter (d) = 11.909 mm

The minimum required diameter found by calculation is,

d = 12 mm

The diameter was chosen from the field survey and considering the factor of safety is,

d = 19 mm

3.3 DESIGN OF BEARINGS

Here, load-life relationship is used, it is given by,

$L = (C/p)^p$ .... (6)

Where,

L = Bearing life (in million revolutions)

C = Dynamic load capacity (N)

P = Equivalent bearing load (N)

p = 3 (for ball bearings)

Bearing design calculation for input (driving) shaft,

Dynamic load capacity,

$C=P(L)^{1/p}$

P = 31N

$L = (60*N_g*L_h)/10^6$

L = 144

$C = 31*(144)^{1/3}$

C = 162.48 N

C = 0.162 KN

Bearing design calculations for output (driven) shaft,

Dynamic load capacity for flour mill side,

$C = P(L)^{1/p}$

$L = (60*N_p*L_h)/10^6$

L = 432

$C = 9.81(432)^{1/3}$

C = 0.074 KN

Dynamic load capacity for wheel side,

$C = 98.1(432)^{1/3}$

C = 0.7415 KN

Hence, the bearings selected are:

1) W61904-2Z
2) 63002-2RS1
3) 61905

3.4 SPECIFICATION OF DESIGNED GEARBOX

Item	Values		Units
	Pinion	Gear	
Module	3	3	mm
Addendum	3	3	mm
Dedendum	3.75	3.75	mm

Clearance	0.75	0.75	mm
Working Depth	6	6	mm
Whole Depth	6.75	6.75	mm
Tooth Thickness	4.7124	4.7124	mm
Tooth space	4.7124	4.7124	mm
Fillet Radius	1.2	1.2	mm
Pitch circle diameter (PCD)	54	162	mm
Addendum circle diameter	46.5	154.5	mm
Dedendum circle diameter	60	168	mm

Table 1: Specification of gearbox

4. CAD MODELS

As per the above-calculated values, the CAD model has been prepared for the gearbox. This CAD model is made using Solidworks software.

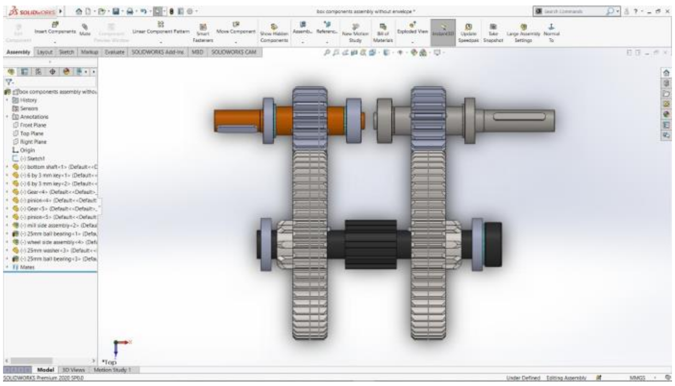

Fig 1: Gair pair mechanism.

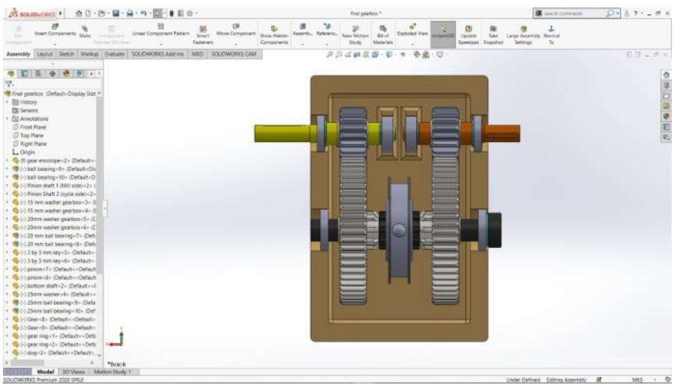

Fig 2: Top view of the gearbox

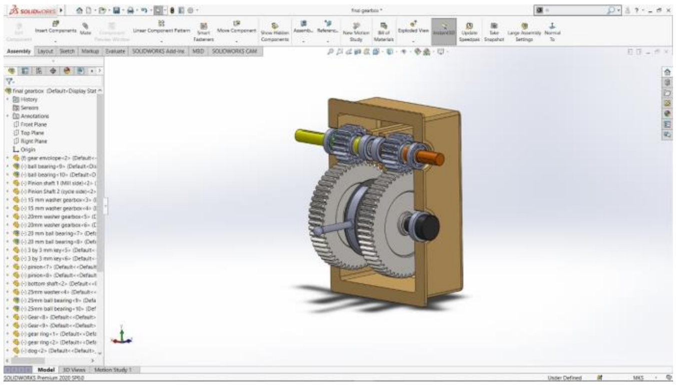

Fig 3: Isometric view of the gearbox

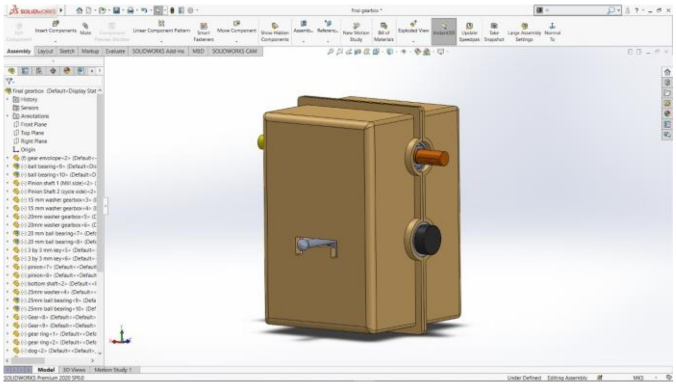

Fig 4: Isometric view of the complete gearbox assembly

As shown in fig 1, shows the mechanism of the gearbox by which power transmission will take place. The input will be given to the gears, then with the assistance of the dog clutch, the power will be transferred to either one of the paths. Further, two outputs will be connected to the flour mill and the wheel as shown in fig 2. Fig 3 shows the isometric view of the gearbox and its components. In fig 4, a complete gearbox with its envelope and dog clutch shifting lever is shown. The gear ratio here is 3, and all the components are modeled according to the values obtained out of the calculation.

5. CONCLUSION

After designing this mechanism, we are getting higher efficiency. We designed and modeled bearings, shaft & gearbox. We designed gears, shafts, pinions and modeled pulleys for the same. We achieved an option between cycling and flour milling. As we are achieving a speed of 900 rpm, we can produce 4 to 5 kg of flour. Unlike any other mechanisms available we have decreased the unnecessary wear and tear of the flour mill. This helps in reducing the effort while operating the cycle.

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