Design and Analysis of Kinetic Energy Recovery System using Flywheel in Bicycle

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ABSTRACT:- KERS is an acronym for KINETIC ENERGY RECOVERY SYSTEM. It is used to recover energy lost during breaking as well as to transform kinetic energy loss into kinetic energy gain. When riding a bicycle, braking consumes a significant amount of energy. We employed a mechanical kinetic energy recovery system with a flywheel to store energy that is ordinarily lost while braking and then reuse it to assist the rider in driving after a rest. The engagement-disengagement mechanism transfers kinetic energy from the back wheel to the flywheel through chain drive. During the pause, the flywheel stores the available energy and powers the rear wheel back up. The recovery speed of KERS is extremely slow in theory and significantly worse in practice. The weight of the flywheel can be increased to increase the recovery speed and hence efficiency. However, putting too much weight on bike will prevent you from cycling normally. The ideal flywheel weight is between 5 and 8 kg. We will use the Fusion 360 software to create the bicycle, and then we will utilize Ansys to simulate the model. We'll also determine the speed ratio by determining the speed of a bicycle with and without a flywheel

Keywords:- Fusion 360, Ansys, KERS, Flywheel.

Chapter 1: Introduction

The flywheel has been utilized since prehistoric times. It stores energy by spinning and utilizing the moment of inertia. The energy will be stored within that cylinder disc may be used by connecting it to the medium to which we wish to transmit energy as it spins. Flywheels are frequently used in conjunction with engines to provide power to a machine or vehicle. They may also be used to gather kinetic energy while braking on bicycles; kinetic energy will be stored as potential energy and transitioned back when needed.. Their great efficiency may lead to the substitution of electrochemical cells for kinetic energy storage or rotational energy storage. In our project, we intend to put our expertise to use by constructing a flywheel that will be fitted into a bicycle.

The flywheel's most conceivable characteristic is its high power density and storage capacity. The development of materials such as carbon fiber and light anodized aluminum alloys has enhanced the power densities of flywheels while decreasing their weight and the amount of effort required to overcome their stationary inertia. The usage of such materials simplifies their application to a bicycle.

1.1 KERS Bicycle Operation:

The clutch plate linked to the flywheel axle is always moved by the crank wheel attached to the rear wheels. This is accomplished by employing a specified gear ratio chain transmission cranked to the clutch sprocket, which allows the flywheel's total speed to be raised. The clutch is engaged when deceleration is necessary, causing contact between the clutch and the flywheel. The flywheel then begins to revolve, reducing the bicycle's speed. As a result, a system of regenerative braking is developed. then accelerate while regular riding, increasing the distance we can travel by bicycling.

Chapter 2: Literature review

2.1 Previous Work

D. K. Naresh Kumar et al. devised and built a flywheel bicycle with a mobile charger that captures the kinetic energy generated by pedaling power. While pedaling the bicycle, the flywheel rotates due to the chain arrangement, which somewhat boosts the bicycle's speed. This configuration is more useful while riding a bicycle on the highway. The movement of the wheel causes the dynamo's drive wheel to revolve, producing 5V of alternating current (AC) that is converted to direct current (DC). As a result, the rear wheel of the bicycle spins while pedaling, and the kinetic energy created is recovered as extra movement of the back wheel of the bicycle by the spinning of the flywheel. According to the author, this technology has the potential to function as an alternate energy source in the near future. [1]

Nishad Kumbhojkar et al. discovered that the flywheel and gearbox increased the weight of the bicycle in their study. The increased weight increases the amount of energy required to accelerate and go uphill on the bike. However, after the rider has been given enough power to reach cruising speed, the flywheel assists in additional acceleration, lowering the energy cost of slowing down from that level. Because they are flat and provide several opportunities to lower rider speed, roads are great for flywheel cycling. Using weight scales, the author discovered that for typical riding, the optimal weight for high efficiency is 5 kg. [2}

Chapter 3: Problem Definition

3.1 Project Outline

Our design strategy is to construct a KERS flywheel energy storage unit as a proof of concept, which we intend to optimize. A system like this is viable since roads across the world include various obstructions like as junctions, automobiles, and turns that prohibit a bike from keeping a steady pace. This method will aid in the recovery of braking energy wasted due to these obstructions.

3.2 Project Objectives

Identifying the KERS potential for bicycles.

1) A summary of significant technologies for recovering kinetic energy.
2) Optimizing the present KERS design and developing a new design.
3) Testing the newly built KERS for bicycles in a variety of circumstances.
4) Identifying the external and internal factors that have boosted or diminished KERS efficiency.
5) Highlighting the limits of the intended design and recommending additional work for the KERS design.

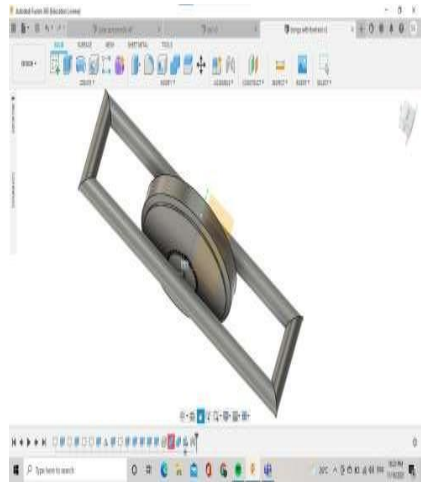


Fig:- KERS

CHAPTER:-4

Calculation for energy stored in flywheel:-

Let us assume

Load of the rider= 75 kg

Load of bicycle= 10 kg

Payloads= 10 kg

Flywheel Load= 10 kg

Total weight= 105 kg

Assume the flywheel has enough energy to propel the bicycle from a standstill to 10kmph in 5 sec

V= 10 kph= 10*5/18= 2.78 m/sec

Initial velocity= u= 0kmph

Time=5sec; $a=(v*u)/time=2.78/5=0.556\ m/sec^2$

Energy of system when it reaches 10kmph

$E= 1/2mv^2= 0.5*105*2.78^2=405.741$ joules

Total force required

$F=F_a+F_R+F_A+F_f= 58.38+7.58+6.77+2$

F= 74.73N

To get this needed power, torque is required at the centre of the wheel.

$T_w= F*r= 74.73*0.3325$

$T_w = 24.84$ N-m

Maximum diameter of flywheel= 20 cm Maximum thickness of flywheel= 3 cm m = ρ* π*r²*t m= ρ*3.1415*0.1²*0.03 m= ρ*9.4245*10⁴ kg

$I= ½*m*r^2=1/2* \rho *9.4245*10^{-4}*0.1^2$

$I= \rho*4.71225*10^{-6}$------(2)

Substitute eq (2) in eq (1) $\rho*4.71225*10^{-6}*s^2=$

$2.44\ \rho*s^2= 517799.3528$--------(3)

Initially flywheel material considered is cast iron, it's density is 7260 kg/m³

Substitute in eq (3)

$S^2=129477.3149/7850$

$S^2= 71.32$

S= 8.44

Since, it's impossible to maintain the sprocket ratio that high, For making it feasible for manufacturing let us consider the ratio as 3.

Substitute value of density in eq (2) $m= 7260*9.4245*10^{-4}$; m=6.84 kg

Therefore, Cast iron is suitable based on our considerations.

The torque needed at the midsection of the rear wheel was discovered to be quite high.

Tw = 24.84 N-m

Max gear ratio for the Cast iron fly wheel =s

Torque generated by the clutch T = 24.84/s; T= 8.28 N-m

Calculation of the Chain Length:

T1 = no.of teeth on smaller sprocket = 14

P = pitch of chain

T2 = no.of teeth on larger sprocket = 42

X = center distance = 0.5m ; K = no.of units of chain links used; L = length of the chain; p = pitch of the chain

The chain's length is calculated by multiplying the number of units by the chain's pitch.

L= K*p

The following formula can be used to calculate the number of chain links.

$K = (T1+T2) /2 + 2*X/p + (T2-T1/2*\pi)^2 * p / X$

(Standard value) p = 12.7 mm

$K = (14+42) /2 + 2*500 / 12.7 + (42 - 14/2*\pi)^2*12.7 /500$

K = 107

Then, L = 107*12.7

L = 1326.8mm

CHAPTER 5:-

FINITE ELEMENT ANALYSIS :

Each component's FEA has become a required subject in any design process. The FEA is a method of determining if a design can withstand a given load while maintaining a safe working environment. It typically aids in the detection of problems in our design. The FEA immediately aids us in determining a component's safety factor. The nicest thing is that we can modify and test the material as many times as we want without wasting the basic material. We utilized FEA to examine numerous components in our project to ensure their integrity and stability. The outcomes of all of the projects are listed below.

5.1 FLYWHEEL :-

Because the flywheel is the most rigid component of the KERS system, it is less likely to fail.

Loads acting on the fly wheel:

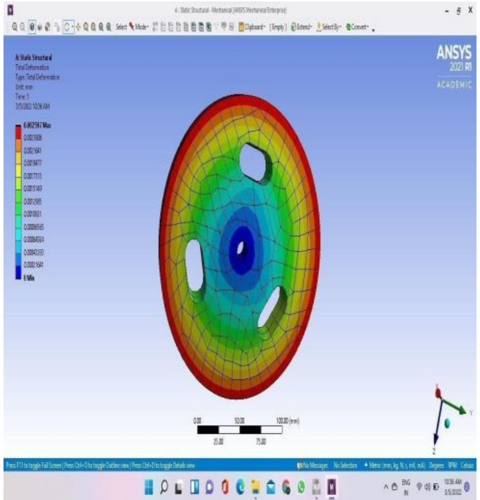
i) Gravitational force

ii) Rotational force (55.55 rad/sec)

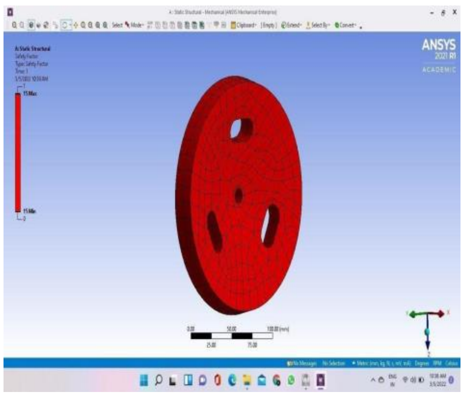
iii) Load due to engagement of clutch= 435.78N

Supports of Flywheel:

i) Bearing support
ii) Displacement support



Total deformation



Factor of safety

From FEA analysis we can see that

i) Factor of safety of flywheel= 15
ii) Maximum deformation= 0.002957 mm

The above data suggest that design of flywheel is completely safe

5.2 CLUTCH PLATE:-

The clutch plate is a critical component of KERS. During engagement and disassembly with the flywheel, it is subject to a number of restrictions.

Loads acting on the Clutch

force due to actuation of clutch= 435.78

Gravitational force

Rotational inertial force

Rotational speed when cycle runs at 25 Kmph and for ideal s (i. e= 3)

=25*5/18*2/D*s

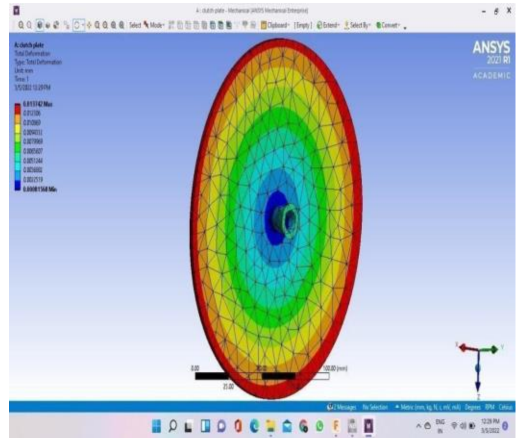
=55.55 rad/sec

Torque =8.28 N-m

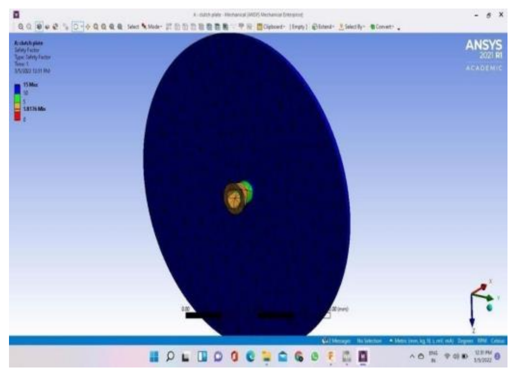
Supports,

a) Compression only support

b) Contact support



Total deformation



Factor of safety

From FEA we can assume that

1) Minimum FOS of Clutch plate= 1.8176

2) Maximum deformation= 0.013742 mm

According to the information provided above, the clutch plate design is perfectly safe.

5.3 FRONT SPROCKET:-

Because this item is constructed of cast iron, it is less likely to be damaged, but we may double-check to make sure the design is safe.

Loads acting,

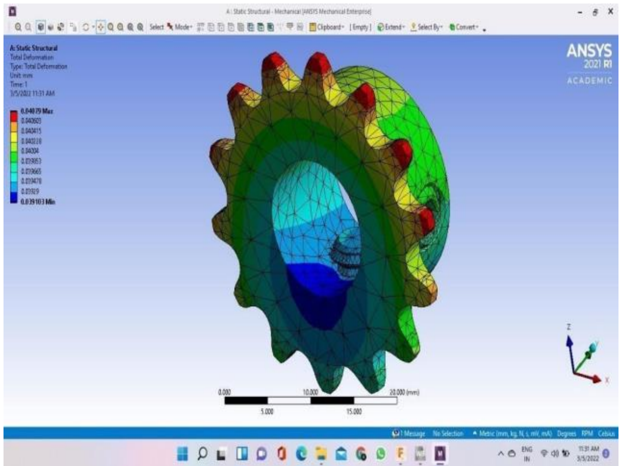
a) Gravitational force

b) Rotational inertia force = 55.55rad/sec

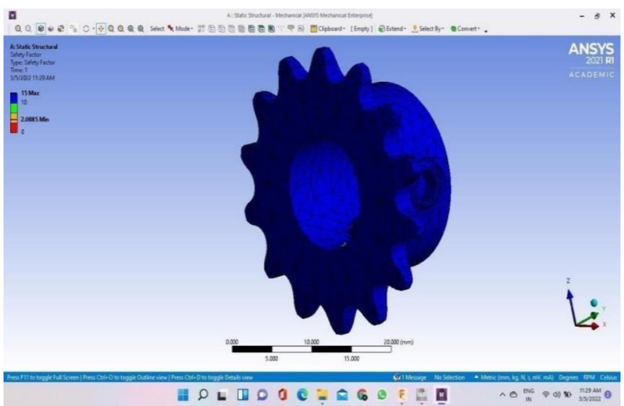
c) Torque= 8.28 N-m

Supports,

1) Compression only support



Total deformation



Factor of safety

From FEA we can assume,

i) FOS of Sprocket= 15
ii) Maximum deformation= 0.04079 mm

According to the information presented above, the sprocket design is totally safe.

CHAPTER 6:-

MANUFACTURING PROCESS:-

The following is the manufacturing procedure for each component created in this project:

The steps for each component's preparation are as follows:

i) Raw material requirement

ii) Machining

6.1 FLYWHEEL;-

1. **Raw materials :**

a) Cast iron circular sheet; outer diameter = 20cm; Disk thickness = 3.5cm

2. Machining:

a) The surface polish is achieved by performing a facing operation on both sides of the flywheel.

b) Drilling is done at the central position of the flywheel using a 12mm drill bit.

c) The outside diameter of the flywheel is then reduced to 20cm using a turning operation.

d) To prevent overheating during the turning action, the flywheel is grasped with the help of a tail-stock

e) .After the boring procedure, the hole's diameter is enlarged to 20 mm with a 0.05 mm tolerance and a depth of 0.8 mm.

f) On the other hand, the identical operations were carried out.

6.2 CLUTCH DRIVE:-

The clutch drive is manufactured in the following manner. Its copy is made in the same manner as the original.

1. Raw Materials :

1) EN8 Steel cylindrical shaft; Outer Diameter = 3cm ; Length= 5 cm

2. **Machining:**

a. Drilling in the centre using an 18 mm drill bit with a tolerance of 0.05 mm

b. The scribber is used to make the marks.

c. The purpose of the facing process is to provide a smooth surface finish.

d. A hand cutter is used to cut the material.

e. Hand grinding is done to remove unwanted material and make the surface smooth

6.3 CENTRAL SHAFT:-

1. Raw Material:

1) Stainless Steel cylindrical shaft; Outer diameter= 25 mm;

2) Length= 20.5 cm

2.Primary Machining:

a. Turning operation is done to reduce the diameter of the shaft to 20mm.

b. Grooving operation is done to make grooves of thickness 1mm.

c. The distance between grooves must be 5cm.

ASSEMBLY

CHAPTER 6:-

OBSERVATION TABLE:-

The observations are taken by using a laser tachometer. The First observation is RPM of rear wheel while energy storing in the flywheel(A). The second observation is RPM of rear wheel while energy given back to rear wheel from the flywheel(B).

(A)	(B)	EFFICIENCY =(B/A)*100 (%)
233	48	20.6
208	39	18.75
223	44	19.28

The average efficiency of the KERS is 19.54%. The RPM of rear wheel while storing energy is completely depended on the payloads that we applied.

CONCLUSIONS:-

According to the findings of various testing, the system is capable of recovering 20% of distributed energy. The KERS system offers a lot of room for improvement and energy savings. The adoption of more efficient methods will result in significant cost savings for our country's economy. We may infer that KERS offers a wide variety of technical applications for reducing energy loss. These days, conserving energy is critical.

FEA analysis is used to test and modify components to prevent failure. The flywheel has also been discovered to be a viable alternative to batteries for storing and distributing energy.

To improve efficiency, we've installed the KERS system on a bicycle with an elegant and removable clutch mechanism. Because there are so many mating components in the system, there is a lot of friction damage, which may be reduced by using a continuous variable transmission, which greatly increases power transfer.

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