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Impact of Regenerative Braking System Using Flywheel

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Abstract:- **In today's world energy crisis and depletion of resources has become major concern. So, there is need for a technology that recovers energy which usually gets wasted. In the case of automobiles one of these useful technologies is the regenerative braking system. Generally in automobiles whenever the brakes are applied the vehicle comes to a halt and the kinetic energy gets wasted due to friction in the form of heat energy. Using regenerative braking system in automobiles enables us to recover kinetic energy of the vehicle to some extent that is lost during braking process. The present work utilizes flywheel to store the energy which was actually being wasted during braking process. The kinetic energy of a vehicle which is lost during deceleration is used to accelerate a flywheel, this flywheel is subsequently coupled to transmission to assist in starting the vehicle from rest thus conserving the energy. The shape of the flywheel is important and must be designed such that stress in the material is the same throughout. Since regenerative braking results in an increase in energy output for a given energy input to a vehicle thus efficiency is improved. Therefore amount of work done by the person in pedalling the bicycle is reduced.**

KEYWORDS **- Flywheel, Kinetic Energy , Regenerative Braking ,**

I. INTRODUCTION

The Regenerative braking system delivers a number of significant advantages over a car that only has friction brakes. In low speed, stop and go traffic where little deceleration is required, the regenerative braking system can provide majority of the braking force. This vastly improves fuel economy of the vehicle and further enhances the attractiveness of vehicles using Regenerative braking for city driving. At higher speeds, Regenerative braking has been shown to contribute to improved fuel economy by as much as 20%. Consider a heavy loaded truck having few stops on the road, it is operated maximum engine efficiency. The 80% of the energy produced is utilised to overcome the rolling and aerodynamic road force. The energy wasted in applying brake is 2% and also its brake specific fuel consumption is 5% . But a vehicle operated in the main city where traffic is a major problem where brake has to be applied frequently, in such cases the wastage of energy in the applying brake is nearly about 60-65 percentage

II. MECHANISM AND WORKING

A flywheel can temporarily store the kinetic energy from the bicycle when the rider needs to slow down. The energy stored in the flywheel can be used to bring the cyclist back up to cruising speed. In this way the cyclist recovers the energy normally lost during braking. Every mechanical system that needs to control the power it outputs requires a transmission. The transmission accepts the power input to the system and outputs it in whatever fashion is necessary for the system. In the case of the bicycle chains and sprockets are used to deliver the power from the crank to the back wheel. The relative size of the sprockets will determine how quickly the wheels spin relative to the crank. Chain drive is also used to transmit power between the flywheel and the bicycle. For a bike flywheel, the size and speed are not likely to even approach a higher enough value to create a stress above the tensile strength of a material, so this consideration is not so important. But the flywheel should have as large of a radius as possible, and spin as fast as possible, to be able to propel the bicycle.

For the cam action to be possible, a separate brake lever and a wire need to be used. It could be fitted either on the right or the left handle. When the lever is pressed, the

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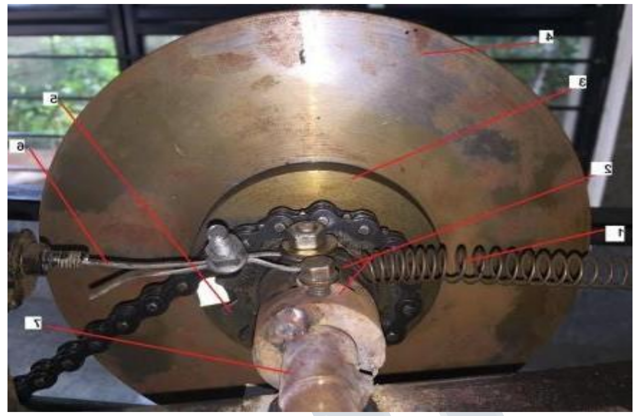
right cam is actuated and it further actuates the clutch. Hence the clutch comes in contact with the flywheel.

Working

A crank wheel connected to the rear wheels always rotates the clutch plate, connected to the flywheel axle. This is being achieved by using chain transmission at a specified gear ratio, crank to clutch sprocket helps us to increase the overall speed of flywheel. Now at a time when a speed reduction is required, clutch is applied which makes the contact between the clutch and flywheel. Then the flywheel starts rotating. Also the speed of bicycle is decreased since the kinetic energy of the bicycle will be absorbed by the flywheel.

Thus a regenerative braking system is achieved. On course, energy is stored in flywheel. In case the brake has to be applied fully then after flywheel rotations clutch is disengaged and the brake is applied. Now when we again want to ride the bicycle, we could apply the clutch at this time as rear wheel rotation is lesser compared to flywheel the energy gets transmitted from the flywheel to the wheels.

During normal riding, situations may arise when we need to reduce the speed without braking fully such as traffic jams, taking turn etc. during which we can store the energy that would normally be wasted due to speed reduction by the application of clutch. When the clutch is engaged then the clutch engages with the flywheel; the rotation consumes energy which would result in speed reduction thus a braking effect. After some instance the energy that is stored in the flywheel can be reused by the engage of clutch plate and energy transfer from the flywheel occurs whenever the rotation is high enough to rotate rear wheel. Thus if sudden braking is applied we can disengage the flywheel connections so that flywheel energy is not wasted and hence engaging would help in returning the energy from the flywheel to rear wheel. While riding downhill we always use braking for allowing slowdown. This is the best case where we can store maximum amount of energy in our flywheel. The flywheel can be engaged throughout our downhill ride and for some distance we need not ride the bicycle which would be done by the flywheel. This is the main advantage of a KERS bicycle. During long drive the engage can be made full time. This will help in reducing the overall pedalling effort.



The flywheel along with other components

1. Spring used to bring the cam to its initial position
2. Cams
3. Clutch plate
4. Flywheel
5. Front sprocket with 16 teeth
6. Brake wire
7. Shaft

USE OF MATLAB

The regenerative Brakes utilizes flywheel to store the energy during the retardation of the vehicle so current study needs the energy evaluation stored in the fly wheel for various speeds of the vehicle. Since calculation of energy storage in flywheel is complicated and time consuming task, hence Mat lab was utilised to calculate the energy stored in the fly wheel for various speeds

MATLAB Codes for the Energy evaluation of the flywheel

```
function [N1,N2,N2E,PThe,PExp,EThe,EExp]=RegenerativeBrake(V)

%%Parameters and Constants for Energy Evalution
D=0.6;
v=V.*1000/3600;
N1=60.*v./(pi*D);
N2=2.75.*N1;
I=0.0195;

%% Calculation of theoritical Energy and Power
w1=(2*pi.*N2)./60;
EThe=0.5*I*w1.^2;
PThe=(2*pi.*N2.*EThe)/60;

%% Calculation of   Experimental Energy and Power
N2E=[101  141  222  263  303  375  485  502  550]
w2=(2*pi.*N2E)./60;
EExp=0.5*I*w2.^2;
PExp=(2*pi.*N2E.*EExp)/60;

%%Plotting
figure(1)
plot(N2,EThe,'r')
grid on

figure(2)
plot(N2,EExp)
grid on
end
```

MATLAB codes used to calculate energy stored in flywheel

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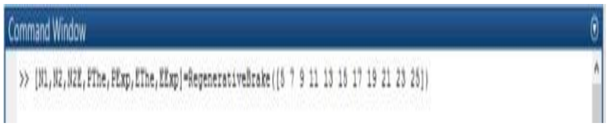
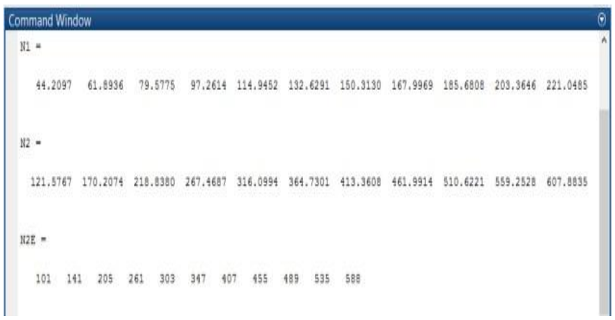
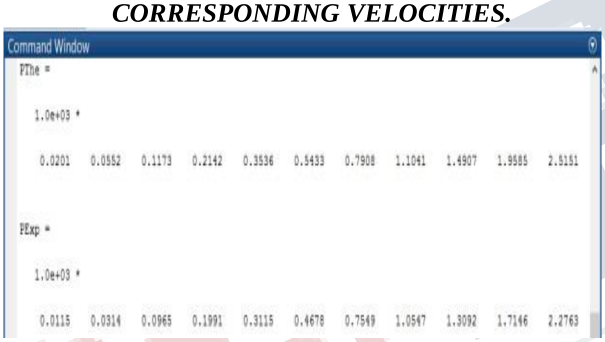
INPUT TO FUNCTION FILE REGENERATIVEBRAKE



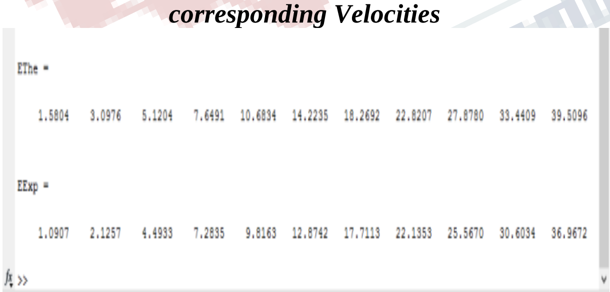
OUTPUTS TO FUNCTION FILE "REGENERATIVEBRAKE.M"



DIFFERENT SPEEDS OBTAINED FOR CORRESPONDING VELOCITIES.



Theoretical and Experimental Power obtained for corresponding Velocities



Theoretical and Experimental Energy obtained for corresponding Velocities

Table Showing the Energy Stored and Power Output for Different Velocities

SL. NO	VELOCITY (Km/hr)	N1 (rpm)	N2THE (rpm)	N2EXP (rpm)	ETHE (Joules)	EEXP (Joules)	PTHE *103 (Watts)	PEXP *103 (Watts)
1	5	44.2	121.5	101	1.58	1.09	0.02	0.01
2	7	61.8	170.2	141	3.09	2.12	.005	0.03
3	9	79.5	218.8.	205	5.12	4.49	0.117	0.096
4	11	97.2	267.4	261	7.64	7.28	0.214	0.199
5	13	114.9	316.0	303	10.69	9.81	0.353	0.311
6	15	132.6	364.7	347	14.22	12.87	0.543	0.467
7	17	150.3	413.3	407	18.26	17.71	0.790	0.754
8	19	167.9	461.9	455	22.82	22.13	1.104	1.054
9	21	185.6	510.6	489	27.87	25.56	1.490	1.309
10	23	203.3	559.2	535	33.44	30.6	1.985	1.714
11	25	221	607.8	588	39.50	36.96	2.515	2.276

EQUATIONS

Experimental Calculation of Energy Stored In Flywheel.By using the tachometer the speed of the rear wheel sprocket is set to n1=132rpmFor the above value of n1 the front sprockets speed is found to be n2= 347rpm. 132rpm speed is selected because that the revolution of the rear sprocket can be obtained for the velocity of 15m/s which is the average velocity for a normal person can pedal. By using the equation 2 ω = 2πn2/60 ,angular velocity is found to be ω = 36.33 rad/sec and moment of inertia I = k m r 2 , k = 0.3 (for

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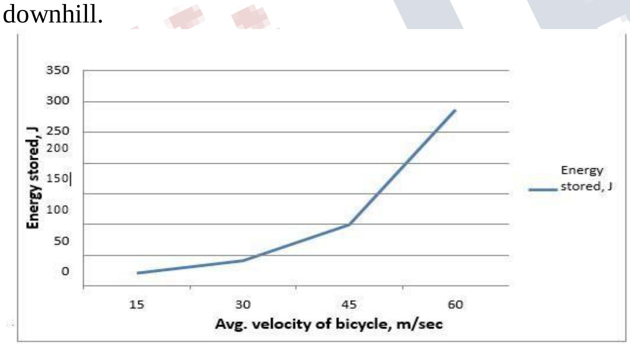
solid disc flywheel with a center hole), m = 6.5kg r = 0.1, m I = 0.3*6.5*0.12 ,

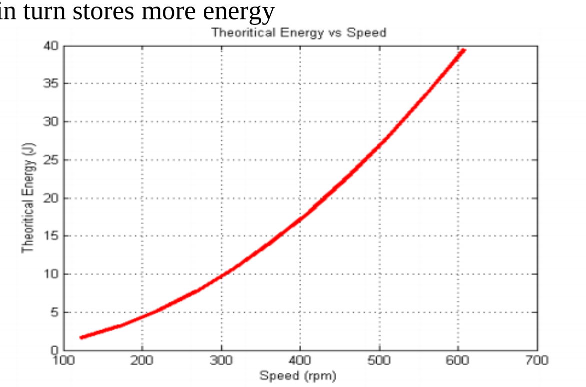
Therefore I = 0.0195kgm by substituting the value of ω and I) in equation by E = ½ I ω² , we get E= 12.87 Joules Here same amount
of torque is transmitted therefore E = T (torque transmitted)
Therefore from equation , P = 2n2T/60 power is calculated And P = 0.467 KW.

III. RESULTS

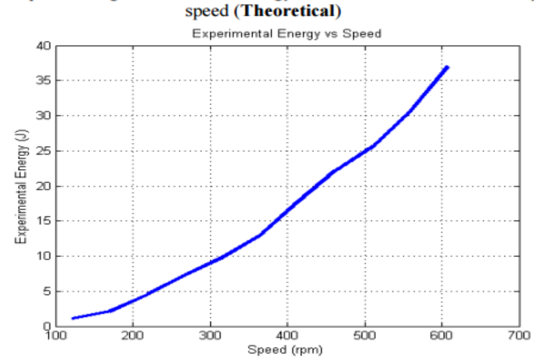
The flywheel is the most important
component in this project. Hence all other considerations are done based on the flywheel. Here, the energy stored in the flywheel during braking is evaluated. The energy stored in the flywheel greatly depends upon the mass and the speed of the flywheel. The speed of the flywheel in turn depends upon the average velocity of the bicycle. Hence for calculation purpose, we assumed the average velocity of the bicycle as 15m/s. In actual practice it may vary according to the rider, bicycle and the surface on which the bicycle is travelling, whether it is uphill or downhill.



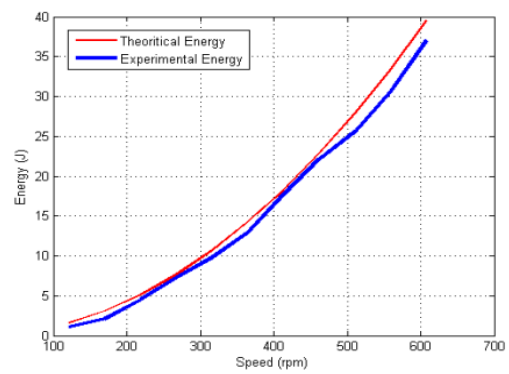
Graph showing the increase in energy stored in the flywheel when the average velocity of the bicycle is increased (Theoretical) From the graph, it can be understood that energy stored in the flywheel greatly depends upon the average velocity of the bicycle. This means that, in conditions where we need to frequently brake or decelerate the bicycle, the effect of regenerative braking is not that pronounced. But it will work in instances where the rider is travelling at a constant speed and suddenly brakes the bicycle. The effect will be more pronounced if the velocity of the bicycle is more. In that case, if the rider applies the brakes, the kinetic energy of the bicycle will get transferred to the flywheel and hence the speed of the flywheel will increase, which in turn stores more energy



Graph showing the increase in energy stored due to increase in the flywheel speed (**Theoretical**)



Graph showing the increase in energy stored due to increase in the flywheel speed (**Experimental**)



Graph showing the increase in energy stored due to increase in the flywheel speed (**Comparative graph**)

From the above graph we can infer that there is a small variation in the experimental values and the theoretical values of the energy stored in the flywheel. The speed measured using tachometer is plotted against the energy calculated. Due to some losses during the energy transfer the energy stored in the flywheel is comparatively less to the theoretically calculated values. The above comparative graph shows the deviation from the actual graph to the experimental graph.

Another important parameter which influences the energy stored is the speed of the flywheel. In formula one cars, the flywheels are revolved to very high speeds, in the range of 40000-60000 rpm. The flywheels there are rotated by motor/generators. But since this is a bicycle, the speed of the flywheel is less. It depends upon the rider and the velocity of the bicycle, as discussed in the previous paragraph. The energy storage will be higher when the bicycle is moving downhill, because of higher velocity of the bicycle. The energy storage also depends upon the mass of the flywheel. But greater the mass of the flywheel, greater will be the torque required to rotate the flywheel. Also, since the vehicle is a bicycle, very large flywheels cannot be fitted which may cause stability problems. So an optimum mass need to be considered for best results.

IV. CONCLUSION

Conclusion Flywheel technology is on the rise across many kinds of technology and rightly so. It is a pollution free method of storing energy that has many current and potential applications. In the case of road vehicles there is much to be desired in terms of energy efficiency, especially when considering pollution per unit of energy. Any system of brake regeneration can help that, but flywheels have the potential to increase the efficiency of road vehicles without direct or indirect negative effects on the environment. The batteries used in hybrids do not last the cars lifetime and can have costly environmental effects. A flywheel has environmental impact only at its time of production, and has the potential to heavily outweigh those costs through its use. Bikes do not have the pollution problems cars and other modes of transportation have, but they can serve as a good analogy for how a kinetic energy recovery system can increase the efficiency of a vehicle.

KERS system has a wide scope for further development and the energy savings. The use of more efficient systems could lead to huge savings in the economy of any country. Here we are concluding that the topic KERS has a wide scope in engineering field with respect to minimizing the energy loss. As of now a day‟s energy conservation is a necessary thing. Here we implemented KERS system in a bicycle with an engaging and disengaging clutch mechanism for storing the energy normally lost during braking, hence converting energy loss into energy gain.

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NOTATIONS USED

1) E =Kinetic energy stored in the fly wheel
2) I = Mass moment inertia of the fly wheel
3) ω = Angular velocity of the fly wheel
4) m = Mass of the fly wheel, kg
5) r =radius of the fly wheel, m
6) k = inertial constant of flywheel
7) n =Speed of the rear wheel/bicycle, rpm
8) v =Average velocity of bicycle, m/sec
9) c=Circumference of the rear wheel, m
10) D =Dia. Of rear wheel, m
11) n1=Speed of the rear sprocket rpm
12) n2=Speed of the front sprocket rpm
13) z1 =Number of teeth on rear sprocket = 44
14) z2 =Number of teeth on front sprocket = 10
15) T =Torque,Nm
16) P=N =Power, kW
17) Mt=Torque transmitted by the clutch plate
18) D2=Outer dia. of clutch plate, m
19) D1=Inner dia. of clutch plate, m
20) Dm =Mean dia., m
21) P=Maximum pressure for clutch
22) Fa=Axial force of clutch plate, N