Kinetic Energy Regenerative Braking System

Shakti Mann [*], Jayesh Khatri

Department of Automotive Engineering, Delhi Technology University, New Delhi, India

Abstract

Kinetic Energy Recovery System (KERS) is a system for recovering the moving vehicle's kinetic energy under braking and also to convert the usual loss in kinetic energy into gain in kinetic energy. When riding a bicycle, a great amount of kinetic energy is lost while braking, making start up fairly strenuous. Here we used mechanical regenerative braking system by means of a flywheel to store the energy which is normally lost during braking, and reuse it to help propel the rider when starting. The rider can charge the flywheel when slowing or descending a hill and boost the bike when accelerating or climbing a hill. The flywheel increases maximum acceleration and nets 10% pedal energy savings during a ride where speeds are between 12.5 and 15 km/hr.

1. Introduction

KERS is a collection of parts which takes some of the kinetic energy of a vehicle under deceleration, stores this energy and then releases this stored energy back into the drive train of the vehicle, providing a power boost to that vehicle. For the driver, it is like having two power sources at his disposal, one of the power sources is the engine while the other is the stored kinetic energy. Kinetic energy recovery systems (KERS) store energy when the vehicle is braking and return it when accelerating. During braking, energy is wasted because kinetic energy is mostly converted into heat energy or sometimes sound energy that is dissipated into the environment. Vehicles with KERS are able to harness some of this kinetic energy and in doing so will assist in braking. By a proper mechanism, this stored energy is converted back into kinetic energy giving the vehicle extra boost of power. There are two basic types of KERS systems i.e. Electrical and Mechanical. The main difference between them is in the way they convert the energy and how that energy is stored within the vehicle. Battery-based electric KERS systems require a number of energy conversions each with corresponding efficiency losses. On reapplication of the energy to the driveline, the total energy conversion efficiency is 31–34%. The mechanical KERS system storing energy mechanically in a rotating flywheel eliminates the various energy conversions and provides a total energy conversion efficiency exceeding 70%, more than twice the efficiency of an electric system. This design of KERS bicycle was motivated by a desire to build a flywheel energy storage unit as a proof of concept.

On a flat road, the cyclist can maintain a fixed cruising speed to get from point to point. Generally all roads are flat with impediments such as intersections, cars, and turns that force the cyclist to reduce speed, then accelerate. 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.

* **Corresponding Author,**
E-mail address:

Fig: 1. Bicycle

2. Bicycle Working

A crank wheel connected to the rear wheels always rotates the clutch plate, connected in 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. 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 rides the bicycle during which we would apply clutches at this time as rear wheel rotation is lesser compared to flywheel the energy gets transmitted from the flywheel to the wheels. Now also we can reduce the overall pedalling power required in course of overrides by having clutch fully engaged. We can reduce overall pedalling power by 10 per cent. Also situation arises such as traffic jam, down climbing a hill where we do not intend to apply brake fully. For such cases we can apply our regenerative system which would allow us to decelerate and allow us to boost acceleration after this during normal riding and distance that can be covered by pedalling can also improve. During normal rides situations may arise we need to reduce the speed without braking fully such as traffic jams taking turns etc. we can store the energy that would normally be

wasted due to speed reduction by the application of clutch. When the clutch is engaged that time due to initial engage the flywheel rotation consumes energy which would result in speed reduction thus a braking effect. After some instances the energy is being stored in the flywheel this 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 then applied we can disengage the flywheel connections so that flywheel energy is not wasted and going to take ride the speed of rear wheel is null and hence engage 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 for full downhill ride and after all for some distance we need not ride the bicycle which would be done by the flywheel. This is the main advantage area of KERS bicycle. During long drive the engage can be made full time. This will help in reducing the overall pedalling effort. It has been found that the pedalling power can be reduced by 10 per cent during long drives. Also this would help in avoiding pedalling effort at some points of ride. The complete KERS bicycle is shown in figure 2 below.

3. Design Requirements

There are many requirements that need to be met to produce a product that is both feasible and optimal. There are also some constraints, both geometric and engineering that also need to be satisfied. The following list describes these requirements and constraints:

Store Energy While Braking

This is the main requirement and the overall objective of the device and must be suitable to meet the rider's needs.

Return Energy to Start Up

Once the energy is stored in the device, it is necessary to have a simple way to release this energy back to the user in positive way. This can be accomplished with an innovative chain drive system.

Must fit on a Bicycle

This is one of the most difficult constraints to achieve and most important because we are dealing with such confined spacing. The objective is to fit the flywheel and accessories in the bicycle.

Light Weight

The importance of having a light weight design is driven by the rider's desire to have a bicycle that is more manoeuvrable and more portable. This is also a direct trade off with how much energy can be stored in the flywheel.

Good Stopping Range

The stopping range is important because this product needs to be usable in real life situations. This component can be optimized to have the shortest stopping distance using dynamic analysis.

Good Stopping Force

The force required to stop is dependent on the stopping range and the comfort levels of the rider. It is also related to the possible flywheel features.

Inexpensive and Affordable

This product must be able to make a profit and be desirable.

Safe to user and Environmentally Friendly

Safety is always a very important aspect whenever there is a consumer product.

Economical

The product economical and the products for this design must be cheaply available.

Reliable

It is important to have a product that is reliable and this requirement will affect the normal bicycling process and must be easy to use.

Manufacturability

In order to make anything economical, it needs to be manufacturability, hence the important of having a product that can be made easily and cheaply.

Aesthetically Pleasing

This is not a requirement that needs to be taken heavily, but the design should always have nice look about it, because looks will persuade the rider.

Modular

Having a device that can be adapted to existing bicycles is essential to be added to the existing ones so that it's easier to adopt. This also can reduce other types of manufacturing costs.

Should not Hinder Normal Riding

To have a successful accessory for a bicycle, the ride should not feel a noticeable change in the riding performance or in the normal riding motion. A device that impedes the normal riding experience would be considered undesirable.

Controlled Release

The energy that is released back to the user must be done in a safe and manageable fashion. This can be a consideration after the prototype is completed.

4. Fabrication Process

4.1 Frame Modification

The frame modification is the first part of the fabrication that has to be done. The frame has to be modified by adding steel tube. One end has to be welded at the handle end and the other at the rear wheel centre. The frame should have enough strength so as to carry the flywheel and the additional forces that comes to play. The modification should not hinder normal riding. Also the modified frame should have enough space in order to accommodate flywheel and clutch assemblies.

Fig: 2. Frame Modification

4.2 Flywheel

The flywheel has to be bored centrally in order to place a ball bearing so that flywheel can rotate over the axle. Also flywheel has to be selected so that the selected weight does not affect the bicycle physics and riding performance of the rider. The performance of KERS system mainly depends upon the flywheel selection. For clutch accessories there should be provisions in the flywheel which is used to deliver and release energy from flywheel.

Fig: 3. Works Done on Flywheel

4.3 Clutch

A clutch has to be provided so as to control the power delivery and release from the flywheel. This can be achieved by providing a clutch plate that is linearly moved to and fro by applying a lever mechanism incorporated with a spring assembly for providing return mechanism. Linear clutch movements have to be made possible. For this purpose two cylindrical rods can be used. One end of the each rod was variably cut. This variable length is female part of another. One part of this is fixed near the frame side. This can be achieved by welding the part. Another part is made rotatory. This part can be rotated by applying force on it from lever via cable. This moves only partially over fixed one and firstly this is hold in position by a spring arrangement.

Fig: 4. Clutch Plate and Clutch Mechanism

4.4 Axle

The axle has to be made so as to carry the flywheel and clutch units. The flywheel can be inserted after bearing is added to it and if variable diameter is provided on axle within mid-point the flywheel can be made to be inserted from one end and it automatically locks in the middle of the axle over which it rotates. Also the clutch units sequentially clutch plate and the fixed and moving rods along with its mechanism can be mounted over the axle. The provision for axle placement is provided in the modified frame. The axle should withstand the forces coming to play.

4.5 Sprocket and Chain

Two sprockets have to be used. The gear ratio is to be taken in to account here. One sprocket with higher number of teeth is to be selected and other having lesser number of teeth. To store high energy in flywheel the larger sprocket is to be placed at the rear wheel end and smaller sprocket at the axle end. This is to ensure that we can provide larger flywheel rotations so that energy storage increases.

5. Analysis

5.1 Weight and Performance

Normally energy stored in the flywheel is directly proportional to the weight and radius. Hence increase in weight proves to improve the performance. But as we know that the maximum safe weight that can be used is limited due to frame properties and rider compatibility. And also after some extent the radius can't be increased and the energy storage thus seems to be limited to some particular extend. This is also because of the fact that the total running speed is being reduced due to weight. Energy storage capacity increases with increase in weight but limitation seems to be the speed driving the flywheel. And performance of system is directly linked with the energy stored

Energy stored in flywheel, $E_k = I\omega 2$

Where, "I" is the moment of inertia

"ω" is the rotational velocity (rpm)

Moment of inertia, $I = kmr2$

Where, "k" is inertial constant (depends on shape)

"m" is mass of the disc

"r" is the radius

Thus E_k is directly proportional to the mass of the disc. The flywheel and transmission add weight to the bicycle. The increased weight will add to the energy required to accelerate the bicycle and to ride it uphill. However, once the rider has provided the energy to reach a cruising speed, the flywheel reduces the energy cost of slowing down from this speed since it aids in subsequent acceleration.

6. Application and Future Scope

This technology is currently used in the Formula One Race cars to give a boost after the complex turns (like the hair-pin turn in many circuits) which slows down the car or in the cases when the driver feels a need to overtake or to gain some significant lead over the competitior. The driver have limited energy from this KERS system which he can use anytime during the lap to increase its performance and this energy is fully available to the driver at the beginning of every new lap. Formula One stated that they support responsible solutions to the world's environment

challenges, and the FIA allowed the use of 60 kW (80bhp) KERS in the regulations from the 2009 Formula One season.

An effective result of the KERS:

1. Vodafone McLaren Mercedes became the first team to win a F1 GP using a KERS equpped car when Lewis Hamilton won the Hungarian Grand Prix on July 26, 2009. Their second KERS equpped car finished fifth.

2. Kimi Raikkonen, the Finnish F1 Driver took the lead of the 2009 Belgian Grand Prix with a KERS-aided overtake and subsequently won the race with his KERS equpped Ferrari on August 30, 2009. It was the first time tha KERS contributed directly to a race victory.

In future, it has high dmand and requirement as it can provide significant amount of energy and hence can save some energy from the burning fossil fuels and hence making the car green.

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