

# Analysis and Application of Various Kers (Kinetic Energy Recovery System) On Bicycle Considering Weight Limitations for Maximum Performance

Shaik Himam Saheb, Ch.Dora Deepak, A.Vidya Sagar

**Abstract—**“ENERGY NEITHER BE CREATED NOR BE DESTROYED BUT IT TRANSFORMS FROM ONE FORM TO OTHER.” In this transformation it may convert to either one form or different depending upon the forces acting, properties, type of materials and time etc.in many industrial applications this converted form of energy is also utilized to improve plant efficiency but major problem arises in recovery of this transformed energy. In automotive industry maximum amount of energy is wasted during braking. This problem is solved by the introduction of regenerative braking. Kinetic energy recovery system is a kind of regenerative braking system which has different approaches to store and reuse the lost energy. This paper mainly highlights the different ways of recovering energy using flywheel, super capacitors, batteries, hydraulic, hydroelectric actuators and influence of weight parameters for maximum performance of vehicle.

**Index Terms—** Regenerative braking, KERS (kinetic energy recovery system), flywheel, bicycle, weight

## I. INTRODUCTION

### REGENERATIVE BRAKING

In coming years the effective utilization of vehicle is a challenging task. Regenerative systems help to continue lower consumption in vehicles and to reduce their carbon foot print. They can also develop electric vehicles which make them suitable for everyday use .A type of Regenerative braking is called KERS. KERS is an automotive system for recovering a moving vehicle ‘kinetic energy under braking. The recovered energy is stored in a reservoir (for example a flywheel or a battery or super capacitor) for later use under acceleration .Electrical systems use a motor-generator incorporated in the car’s transmission which converts mechanical energy into electrical energy and vice versa. Once the energy has been harnessed, it is stored in a battery and released when required

*Types of storage devices*

There are different type of devices and forms in which the Kinetic Energy lost while braking can be stored. They are:

- 1) Mechanical KERS
- 2) Electric KERS
- 3) Hydraulic KERS

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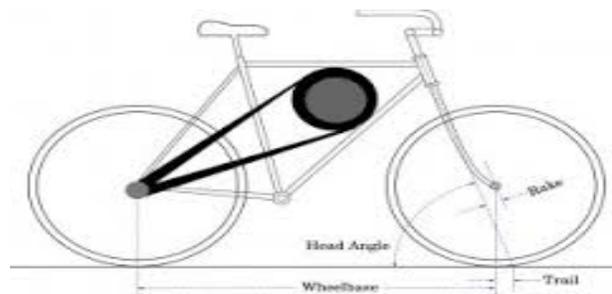
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- 4) Hydro-electric KERS (HESS)

## II. LITERATURE REVIEW

### MECHANICAL KERS

The mechanical hybrid utilizes a rotating mass (or flywheel) as the energy storage device and a variable drive transmission to control and transfer the energy to and from the driveline. The transfer of vehicle kinetic energy to flywheel kinetic energy can be seen as a momentum exchange. Energy is drawn from the vehicle and supplied to the flywheel. In doing this, the speed of the vehicle reduces, (effectively this is braking), whilst the speed of the flywheel increases. At the start of braking the vehicle has a high speed and the flywheel a low speed, giving a certain gear ratio between them. At the end of braking the vehicle has a low speed, and the flywheel a high speed, so the ratio of speeds has changed .Examination of the energy transfer shows that the ratio between vehicle speed and flywheel speed necessarily changes continuously during the energy transfer event .Flywheel based mechanical hybrid systems are not new –systems have previously been developed by the Technical University of Eindhoven and Leyland Trucks amongst others and indeed it is possible to ride on a Flywheel powered tram from Stour bridge junction in England – and flywheel based system is not without areas requiring focus (most notably the failure modes of the rotating mass and the method of control and transmission of the energy to and from the flywheel.) It has been put into use for Formula 1 cars since the year 2009.



### ELECTRICAL KERS

The well documented electrical hybrid systems utilize chemical batteries as the storage medium and electric motor/generator systems as the energy transfer and control media. KERS components for battery storage systems are: Electric Propulsion Motor /Generator, Power Electronics –Inverter, and the Quad Flywheel Storage .Electric Propulsion Motor and Generator in one are also known as a MGU – Motor Generator Unit .Capacitors are fundamental electrical circuit elements that store electrical energy in the order of microfarads and assist in filtering. The main function of a

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capacitor is to charge or discharge electricity. Super-capacitors have special features such as long life, rapid charging, low internal resistance, high power density, and simple charging method as compared to capacitors and batteries.

## MOTOR AND GENERATOR SET



## HYDRAULIC KERS

Regenerative braking in vehicles using a variable displacement hydraulic pump/motor together with a hydro pneumatic accumulator has attracted considerable interest during the last 20–25 years. Such a system is particularly suitable for application in city buses. Despite the significant gains in the efficient use of energy that can be brought about by hydro-pneumatic regenerative braking, its use has not attained great popularity. The added cost, which may represent 10–15% of the total for the vehicle, is undoubtedly a deterrent.



## HYDRO-ELECTRIC KERS (HESS)

Hydraulic accumulator has the characteristics of higher power density and is well suited for frequent acceleration and deceleration under city traffic conditions. It can provide high power for accelerations and can recover more efficiently power during regenerative braking in comparison with electric counterparts. However, the relatively lower energy density brings the packaging limit for the increasing accumulator size. These studies focused on the hybrid energy systems in electric forms, and publications devoted to hydraulic/electric system are relatively scarce, Ricardo proposed a combined regenerative-dissipative brake system for a city bus. The regenerative component consists of a fixed displacement hydraulic pump/ motor and a hydro pneumatic accumulator. A hydraulic accumulator or battery hybrid energy system, called hydraulic/electric synergy system (HESS), is designed to overcome the drawbacks of existing single energy storage sources used in heavy hybrid vehicles, which adopts hybrid energy structure to combine high power

hydraulic accumulator and high specific energy battery together.

This paper looks at other aspects which have not yet been dealt with while considering storage systems for KERS and their future scope. Further studies can be done to improve upon these storage systems.

## III. ANALYSIS OF VARIOUS KERS

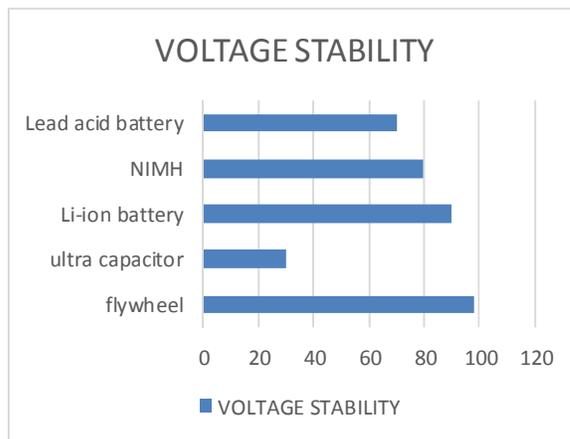
To perform various analysis on KERS a detailed study of requirements need to be done those include

- Energy storage while braking
- Return energy to start up
- Must fit on bicycle
- Light weight
- Good stopping range
- Good stopping force
- Inexpensive and affordable
- Environmental friendly
- Safe to user
- Reliable
- Economical
- Manufacturability
- Aesthetically pleasing
- Shouldn't hinder normal riding
- Modular
- Controlled release

By considering above requirements following analysis is made on different KERS they include

## VOLTAGE STABILITY

Voltage stability plays a crucial role in supply and storage systems, the voltage maintained by mechanical KERS using flywheel maintains a maximum part while ultra and super capacitors stand in least with 30% while Li-ion battery, nickel metal hydride, lead acid battery follows each other covering a minimum of 60% voltage stability



## EFFICIENCY

The cost obtained by usage of components required for application of various KERS is shown in which hydraulic occupies a highest of 47%,super capacitors occupies 32%,mechanical flywheel occupies 15%,batteries occupy 6%,super conductors

**IV. IMPORTANCE**

The above basic analysis reveals the importance to study the mechanical based KERS. In mechanical based KERS the components which to be mounted on vehicle should be of simple in design and functioning. The major part of problem arises in selection will be based on Energy storage system, various mechanical elements could be used out of which the following suits best for any vehicle

**COILED SPRING**



**FLYWHEEL**



**V. COMPARISON**

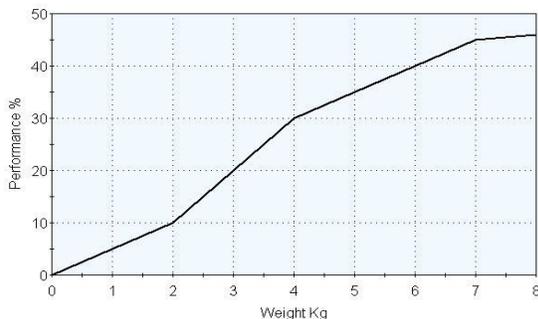
<b>FLYWHEEL</b>	<b>COILED SPRING</b>
Energy storage depends on number of rotations made	Energy storage depends on stiffness Of material
Temperature effects are less	Temperature effects are more
Constant torque is produced	Constant torque is not produced
Life span is more	Life span is less
Weight is high	Weight is low
Less scope for mechanical failure	Mechanical failure easily occurs
no limitations in storing energy	Limitates up to maximum coiling
Uses chain mechanism in storing	Uses sun gear mechanism in storing
Simple in design	Little complex in designing
Cost is more	Cost is less

The above comparisons reveal the importance of flywheel type of Mechanical KERS

**VI. PERFORMANCE**

Weight of the flywheel plays a crucial role in evaluating the performance of mechanical KERS based bicycle.

**Performance versus Weight**



The energy stored in flywheel mainly depends upon factors like weight of flywheel, pedal power input and its angular velocity. The performance curve is obtained by applying optimal conditions on a bicycle and by changing the weight of respective flywheel the 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. Thus a graph can be plotted between performance and weight. Optimum value lies between 5 and 8 kg. Energy stored in flywheel,  $E_k = \frac{1}{2} \omega^2$

Where, "I" is the moment of inertia

" $\omega$ " is the rotational velocity (rpm)

Moment of inertia,  $I = kmr^2$

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. Roads are optimal environment for the flywheel bicycle because it's flat and there are lots of reasons for the cyclist to slow.

From the graph it is clear that the weight of flywheel effects performance of vehicle if it is less than 5kg less amount of energy is stored in it but where as if it crosses 8kg weight of vehicle increases there by lowering its efficiency. Optimal conditions for performance evaluation are considered as

(I) Minimum weight of flywheel: 5kg

Flywheel material: Cast iron

Radius of flywheel: 122mm

Thickness: 16mm

Inertial constant  $k=0.5$ (generally considered)

Maximum torque: 6900NM@3500 rpm

Angular velocity=  $\omega = 2\pi \times 3500 / 60 = 366.33 \text{ rad s}^{-1}$

(ii) maximum weight of flywheel: 8kg

Flywheel material: Cast iron

Radius of flywheel: 122mm

Thickness: 16mm

maximum torque: 6900@3500rpm

inertial constant  $k=0.5$

Angular velocity=  $366.33 \text{ rad s}^{-1}$

$$\begin{aligned}
 E &= \frac{1}{2} \omega^2 \\
 &= kmr^2 \omega^2 \\
 &= 0.5 \times 5 \times 0.16^2 \times 366.33^2 \\
 &= 858.86 \text{ NM}
 \end{aligned}$$

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$$\begin{aligned}
 E &= \frac{1}{2} \omega^2 \\
 &= kmr^2 \omega^2 \\
 &= 0.5 \times 8 \times 0.16^2 \times 366.33^2 \\
 &= 13741.84 \text{ NM}
 \end{aligned}$$

We know that one NM is equal to one joule. So 13741.84 joules of energy can be stored in the flywheel and same amount of torque can be produced from the flywheel.

$$\begin{aligned}
 \text{Power produced by the flywheel} &= 2 \times 3.14 \times N \times T / 60 \\
 &= 2 \times 3.14 \times 3500 \times 13741.84 / 60 &= 2 \times 3.14 \times 3500 \times 858.86 / 60 \\
 &= 5034.09 \text{ KW (max)} &= 314.629 \text{ KW (min)}
 \end{aligned}$$

**Overdrive Test:**

This test was carried out to find out how much pedaling power can be saved by having KERS bicycle. This was done by riding the bicycle on a slope and initial pedaling was given same and noted down the distance at which the bicycle stops when flywheel is not being connected. Then taken 10 m back point from the stopping distance. The experiment was again done by riding cycle with flywheel coupled from 10 m side and noted down the extra distance that was covered by the bicycle. The result was tabulated. The values reveal a total gain in energy of about nearly 10 per cent.

Thus flywheel bicycles can help in reducing the overall pedaling power by 10 per cent used in overdrives

**CONCLUSION**

KERS system used in the vehicles satisfies the purpose of saving a part of the energy lost during braking. Also it can be operated at high temperature range and are efficient as compared to conventional braking system. The results from some of the test conducted show that around 30% of the energy delivered can be recovered by the system (automobiles). 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 got a wide scope in engineering field to minimize the energy loss. As many mating parts are present large amount of friction loss is found in this system and in this paper a study on weight limitations is made. The major distractions for any design is friction but frictional contact for above clutch engagement and disengagement process to continue is mandatory. Further study is expected in reducing this frictional contact and to obtain maximum performance as loss couldn't be completely avoided.

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S.NO	NUMBER OF TRAILS	DISTANCE COVERED(m)	
		FLYWHEEL ENGAGED	FLYWHEEL DISENGAGED
1.	1	10.60	10
2.	2	20.76	20
3.	3	30.72	30
4.	4	40.86	40
5.	5	50.78	50

Mechanical department for supporting us in every aspect

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