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A Review on Kinetic Energy Recovery System in Motorsports and Passenger cars

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***Abstract*: Today, many hybrid electric vehicles have been developed in order to reduce the consumption of fossil fuels; unfortunately these vehicles require electrochemical batteries to store energy, with high costs as well as poor conversion efficiencies. By integrating Kinetic Energy Recovery systems, these drawbacks can be overcome and can potentially replace battery powered hybrid vehicles cost effectively. This paper will explain the engineering, mechanics of the KERS system and it's working in detail. Each component of the kinetic energy recovery system will also be described. The advantages of this technology have been elucidated carefully along with the disadvantages. The latest advancements in the field, the potential future and scope of the KERS will be assessed along with all the three types which are electronic, electro-mechanical and mechanical.**

KEYWORDS: Kinetic Energy Restoration System Types, KERS Sensors, Actuators, Data Communication, Manufacturers, Motorsports, Passenger cars

I. INTRODUCTION

With the depletion of Natural Resources worldwide there is an immediate need of more and more efficient systems without compromising with the overall performance of the vehicle. Kinetic Energy Restoration system falls under those categories of the system which is not only used to make a vehicle efficient but to increase the net performance of the vehicle as well. Although the technology itself is expensive, but gradual development in the right direction may lead to reduction in cost and improvement and also the availability. This report contains the detailed study of Kinetic Energy Restoration System and its types as well which will clarify the practicality of the technology by thoroughly analyzing the advantages and disadvantages of KERS.

A kinetic energy recovery system (KERS) is an automotive system for recovering a moving vehicle's kinetic energy under braking. The recovered energy is stored in a reservoir (for example a flywheel or high voltage batteries) for later use under acceleration.

According to W.A.D.N. Gunathilake in his paper [Reference no. 7], the Hybrid and electric vehicles are playing an important role in the energy crisis with the ongoing current development of battery technologies. Considering the amount of energy being wasted and all the recovering possibilities, kinetic energy recovering methods have a great impact on improving the fuel efficiency. Prior to the development of an electric battery, kinetic energy recovering methods were not used as there was no energy storage. Even though hybrid and electric vehicles are emerging quite faster today, still there are billions of conventional (I.C.E. Powered) vehicles and they will continue running for another few decades. The point is, they do not have any energy recovering methods as the hybrid or electric vehicles, and it is also not practical to fully convert their power trains into hybrids. So, the solution that remains is an energy recovering device with a palpable energy storage, which requires no complex installation.

There are three basic types of KERS systems:

a. Electronic

b. Electro-mechanical

c. Mechanical

The main difference between them is in the way they convert the energy and how it is stored within the vehicle.

Sensors: Boost button, brake sensor

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Actuators: Electric motor/generator unit, continuously variable transmission, flywheel, electro-hydraulic system, clutch

Data Communications: CAN Bus

Manufacturers: Bosch Motorsport, Flybrid Systems, Magneti Marelli, Williams Hybrid Power, Zytek Group

II. LITERATURE REVIEW

The law of conservation of energy states that energy can neither be created nor destroyed but instead can be continuously converted to different forms. To a Formula 1 car, that means that all the energy that the car possesses while reaching speeds of 200 mph must be transferred to other forms of energy when the car intends to go slower. When the car brakes, this energy is usually transferred to heat and sound energy that, for the purposes of the car and its driver, is lost. The job of KERS is to harvest a portion of this energy and redeploy it into the car as extra horsepower, providing a performance advantage to its driver.[5]

KERS is an accumulation of parts which takes a portion of the active vitality of a vehicle under deceleration, stores this vitality and after that discharges this put away vitality once again into the drive prepare of the vehicle, giving a power lift to vehicle. [4]

Flywheels have excellent recharge efficiencies and virtually unlimited cycle lives. When they are coupled with a mechanical transmission the conversion losses are eliminated as the mechanical braking energy is transmitted and stored in the same form. Furthermore, they operate over a wider temperature range than electrical systems. The idea of coupling a flywheel to a motor/generator to emulate a battery for use in electric vehicles is about 60 years old. It dates back to the Gyro bus, a city bus developed by Oerlikon in Switzerland that ran on electric power generated by a spinning flywheel.[6]

Invention of the internal combustion (IC) engine is a huge forward step in automobile industry. However, its inefficiencies and mass production caused depletion of crude oil and many environmental threats. In order to avoid these, researchers and engineers have been working on various methods to improve the fuel efficiency of automobiles through the analysis of waste energy recovery. Among them, methods of recovering kinetic energy have significant impact on improving the fuel efficiency. Today, both electric and hybrid vehicle are embedded with the kinetic energy recovery systems, but the reduced life cycles, disposal hazards, huge weight and high cost of batteries made them to drain their popularity.[7]

III. TYPES AND WORKING PRINCIPLE

A. Electronic KERS

In electronic KERS, braking rotational force is captured by an electric motor / generator unit (MGU) mounted to the engine's crankshaft. This MGU takes the electrical energy that it converts from kinetic energy and stores it in batteries. The boost button then summons the electrical energy in the batteries to power the MGU. The most difficult part in designing electronic KERS is how to store the electrical energy. Most racing systems use a lithium battery, which is essentially a large mobile phone battery. Batteries become hot when charging them so many of the KERS cars have more cooling ducts since charging will occur multiple times throughout a race. Super-capacitors can also be used to store electrical energy instead of batteries, they run cooler and are debatably more efficient.

B. Electro-mechanical KERS

In electro-mechanical KERS energy is not stored in batteries or super-capacitors, instead it spins a flywheel to store the energy kinetically. This system is effectively an electro-mechanical battery. There is limited space in a racecar so the unit is small and light. Therefore, the flywheel spins very fast to speeds of 50,000 - 160,000 rpm to achieve sufficient energy density. Aerodynamic losses and heat buildup are minimized by containing the spinning flywheel in a vacuum environment. The flywheel in this system is a magnetically loaded composite (MLC). The flywheel remains one piece at these high speeds because it is wound with high strength fibers. The fibers have metal particles embedded in them that allows the flywheel to be magnetized as a permanent magnet.

The flywheel will perform similarly to an MGU. As the flywheel spins, it can induce a current in the stator releasing electricity or it can spin like a motor when current flows from the stator. This flywheel is used in conjunction with an MGU attached to the gearbox which supplies electrical energy to the flywheel from the road and returns it to the gearbox for acceleration at the touch of a button. Not all flywheels used in the electro-mechanical KERS are permanent magnets. Instead, these systems use two MGUs, one near the flywheel and another at the gearbox. Some systems use flywheels and batteries together to store energy.

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C. Mechanical KERS

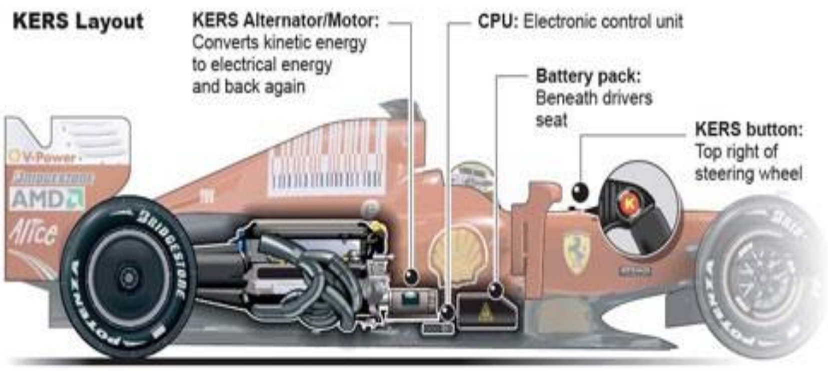
The mechanical KERS system has a flywheel as the energy storage device but it does away with MGUs by replacing them with a transmission to control and transfer the energy to and from the driveline. The kinetic energy of the vehicle ends up as kinetic energy of a rotating flywheel through the use of shafts and gears. Unlike electronic KERS, this method of storage prevents the need to transform energy from one type to another. Each energy conversion in electronic KERS brings its own losses and the overall efficiency is poor compared to mechanical storage. To cope with the continuous change in speed ratio between the flywheel and road-wheels, a continuously variable transmission (CVT) is used, which is managed by an electro-hydraulic control system. A clutch allows disengagement of the device when not in use.

IV. APPLICATION IN MOTORSPORTS

A. Formula One

Formula One has stated that they support responsible solutions to the world's environmental challenges, and the FIA allowed the use of 60 kW (82 PS; 80 bhp) KERS in the regulations for the 2009 Formula One season. Teams began testing systems in 2008: energy can either be stored as mechanical energy (as in a flywheel) or as electrical energy (as in a battery or supercapacitor).

Since 2014, the power capacity of the KERS units were increased from 60 kilowatts (80 bhp) to 120 kilowatts (160 bhp). This was introduced to balance the sport's move from 2.4 litre V8 engines to 1.6 litre V6 turbo engines.



KERS system used in Formula 1 (Source: https://medium.com/@sakshibose1/kinetic-energy-recovery-system-kers-b5fdfdac0e76)

B. World Endurance Championship

Automobile Club de l'Ouest, the organizer behind the annual 24 Hours of Le Mans event and the Le Mans Series, has promoted the use of kinetic energy recovery systems in the LMP1 class since the late 2000s.Peugeot was the first manufacturer to unveil a fully functioning LMP1 car in the form of the 908 HY at the 2008 Autosport 1000 km race at Silverstone.

The 2011 24 Hours of Le Mans saw Hope Racing enter with a Flybrid Systems mechanical KERS, to be the first car ever to compete at the event with a hybrid. The system consisted of high speed slipping clutches which transfer torque to and from the vehicle, coupled to a 60,000 rpm flywheel.

Audi and Toyota both developed LMP1 cars with kinetic energy recovery systems for the 2012 and 2013 24 Hours of Le Mans. The Audi R18 e-tron quattro uses a flywheel-based system, while the Toyota TS030 Hybrid uses a supercapacitor-based system. When Porsche announced its return to Le Mans in 2014, it also unveiled an LMP1 car with a kinetic energy recovery system. The Porsche 919 Hybrid, introduced in 2014, uses a battery system, in contrast to the previous Porsche 911 GT3 R Hybrid that used a flywheel system.

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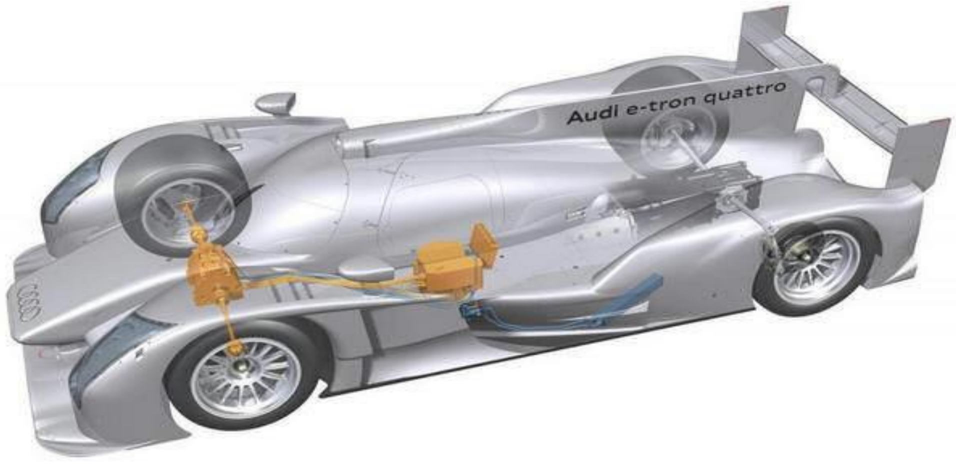

KERS used in World Endurance Championship (Source: https://newatlas.com/audi-quattro-race-car/21665/)

V. APPLICATION IN PASSENGER CARS

According to “A Feasibility Analysis of an Electric KERS for Internal Combustion Engine Vehicles”, A widely diffused passenger car, endowed of a gasoline fuelled spark ignition engines, was selected for the evaluation of the advantage connected to the implementation of the e-KERS. The attainable energy saving, together with the related fuel economy, were evaluated on the basis of standard driving cycles by means of simulation performed using MatLab Simulink employing a model properly developed by the authors. It was found that the proposed KERS could allow substantial energy savings, to which correspond important fuel economy improvement together with a reduction of CO2 emissions. The achievable fuel economy and the cost of the KERS components allowed also to estimate the economic advantage of its implementation.

This shows that KERS can help achieve greener IC Engine vehicles at lower cost as the price of Hybrid Vehicles is comparatively higher.

Volvo a renowned automobile company is also testing KERS in its passenger vehicles. The company is testing out the power boosting system in an S60, with the 'Flybrid KERS' (Kinetic Energy Recovery System) added to the rear axle. It allows the car to harness the energy created by braking, with the heat transferred to a six-kilogram fiber flywheel which can spin at up to 60,000 revs per minute. When the car moves again, the energy stored is sent back to the rear wheels for added power or a reduction of the engine load. This means the car can benefit from an additional 80hp performance, while fuel consumption is minimized by 25 per cent.

If the system is successful, it will be most beneficial when in city traffic as the energy stored from the flywheel is enough to power the car for short periods.

Derek Crabb, vice president of powertrain engineering at Volvo Car Group, said: "Our calculations indicate that it will be possible to turn off the combustion engine about half the time when driving, according to the official New European Driving Cycle." The results could be very different when compared to Indian Drive cycle, but the technology looks promising in moving towards sustainable future.

Not only passenger cars, but heavy commercial vehicle manufactures are also implementing KERS system to conserve the energy which was eventually being wasted.

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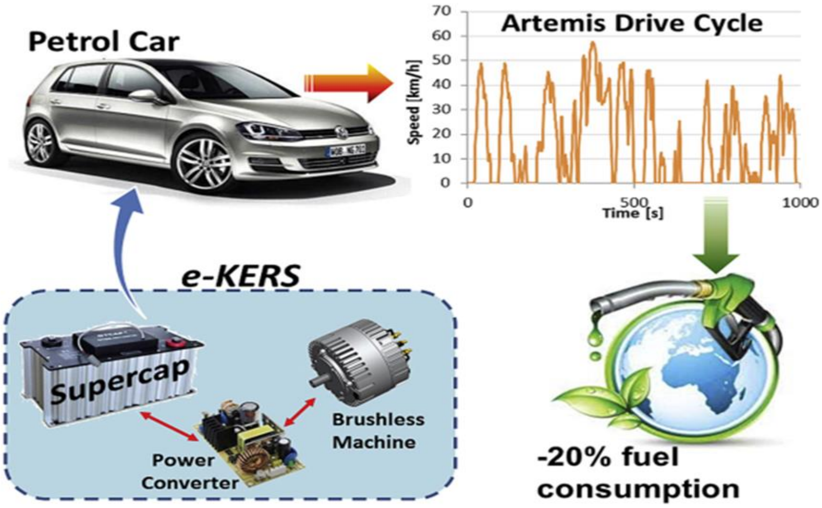
Volvo S60 KERS Prototype (https://www.youtube.com/watch?v=VP13yhEnxes)

VI. ADVANTAGES AND DISADVANTAGES OF KERS

ADVANTAGES

- High Efficiency
- Low fuel consumption
- Low cost compared to electric hybrids
- Weight
- Reduced CO2 Emissions
- Longer Life



Advantage of using KERS in Petrol Car (https://www.greencarcongress.com/2019/10/20191028-ekers.html)

VII. DISADVANTAGES

A. Electric KERS

- Lithium-ion batteries take 1-2 hours to charge completely due to low specific power (i.e rate to charge or discharge) hence in high performance F1 cars more batteries are required which increases the overall weight of the batteries.
- Chemical batteries heat up during charging process and this takes place a number of times in KERS units which if not kept under control could cause the batteries to lose energy over the cycle or worse even explode.
- The specific power is low as the energy needs to be converted at least two times both while charging or discharging causing energy losses in the process.

B. Mechanical KERS

- The specific energy capacity of flywheels is lower than some of the advanced battery models.
- Friction produced in the bearings and seals cause the flywheel to slow down and loose energy.

VIII. CONCLUSION

Cars with a Kinetic Energy Recovery System, though significantly more expensive than cars without this system, have more power and better fuel efficiency. According to www.thegreencarwebsite.co, “the system could reduce fuel consumption by as much as 20% and give a four-cylinder engine acceleration like a six-cylinder unit.” This effectively means that cars with the Flywheel KERS system have better fuel efficiency and more power than the cars without the KERS system

The flywheel KERS system promises to be a technology of the future. It makes every car more powerful and at the same time improves fuel efficiency. Better fuel efficiency directly translates to a cleaner, greener environment. It reduces the negative impact on the environment by decreasing harmful CO2 emissions.

KERS is an effective type of regenerative braking which can fulfill the main purpose of hybrid vehicles i.e., storing and re-using energy lost while braking. The various types of KERS show different ways of storing and converting energy from one form to another. As per the analysis, flywheels have proven to be the best type of KERS so far in terms of voltage stability, temperature range and efficiency. If not for the large size and high cost, super capacitors have a high chance of replacing the mechanical storage device. This paper is a brief overview of the alternate type of KERS. More in depth analysis can be done on their functions. Studies are being carried out by some of the referred authors regarding the same. Further studies can also be done to improve the quality of present in-use KERS and further research and development could help in getting even more kinds of energy recoverable systems.

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