Comparative Study on Various KERS

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Abstract— Conservation of natural resources has become a necessity in today’s world, especially in the new technology. In the automotive industry, maximum energy is lost during deceleration or braking. This problem has been resolved with the introduction of regenerative braking. It is an approach to recover or restore the energy lost while braking. Kinetic Energy Recovery Systems (KERS) is a type 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, batteries or super capacitors, hydraulic or hydro-electric actuators. It also gives an overview of what system is preferred where and why.

Index Terms—Batteries, Flywheel, KERS, Regenerative Braking, Super Capacitors/ Ultra Capacitors.

I. THRUST AND MOTIVATION FOR THIS STUDY

The initial stimulus for undertaking a study on hybrid vehicles and KERS was personal interest. Having learnt the importance of fuel consumption and energy saving systems in automobile industries, this paper is a study on regenerative Braking and KERS found in hybrid vehicles.

II. INTRODUCTION

Regenerative Braking

A Regenerative Brake is a Mechanism that reduces vehicle speed by converting some of its kinetic energy into some other kind of useful form of energy – electric current, compressed air [1].

The energy captured is then stored for future use or fed back into a power system for use by other vehicles. For example, electrical regenerative brakes in electric railway vehicles feed the generated electricity back into the supply system [2]. In battery electric and hybrid electric vehicles, the energy is stored in a battery or bank of twin layer compressed air (most notably the failure modes of the rotating mass and the flywheel) as the energy storage device and a variable drive transmission to control and transfer the energy to and from the driveline [4]. The transfer of vehicle kinetic energy to flywheel kinetic energy can be seen as a momentum exchange [4]. 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 [5]. At the start of braking the vehicle has a high speed and the flywheel a low speed, giving a certain gear ratio between them [6]. At the end of braking the vehicle has a low speed, and the flywheel a high speed, so the ratio of speeds has changed [6]. Examination of the energy transfer shows that the ratio between vehicle speed and flywheel speed necessarily changes continuously during the energy transfer event [5][6].

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 Stourbridge junction in England – and a powered tram from Stourbridge junction in England – and a 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.) [7][8]. It has been put into use for Formula 1 cars since the year 2009 [9][10][11][12].

dynamic braking [4].

KERS

A type of Regenerative braking is called KERS. 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 a battery or super capacitor) for later use under acceleration [4-6].

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 [7].

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
4) Hydro-electric KERS (HESS)

III. LITERATURE REVIEW

A. Mechanical storage system

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 [4]. The transfer of vehicle kinetic energy to flywheel kinetic energy can be seen as a momentum exchange [4]. 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 [5]. At the start of braking the vehicle has a high speed and the flywheel a low speed, giving a certain gear ratio between them [6]. At the end of braking the vehicle has a low speed, and the flywheel a high speed, so the ratio of speeds has changed [6]. Examination of the energy transfer shows that the ratio between vehicle speed and flywheel speed necessarily changes continuously during the energy transfer event [5][6].

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B. Electrical storage system

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 [13]. KERS components for battery storage systems are: Electric Propulsion Motor /Generator, Power Electronics – Inverter, and the Quad Flywheel Storage [13] [14] [15]. Electric Propulsion Motor and Generator in one are also known as a MGU – Motor Generator Unit [15] [16].

Capacitors are fundamental electrical circuit elements that store electrical energy in the order of microfarads and assist in filtering [16] [17] [18] [19]. The main function of a capacitor is to charge or discharge electricity [19] [20] [21]. 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 [22][23].

C. Hydraulic storage system

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 [24] [25] [26] [27] [28] [29].

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 [28] [29] [30]. The added cost, which may represent 10–15% of the total for the vehicle, is undoubtedly a deterrent [31] [32] [33].

D. Hydro-electric storage system

Hydraulic accumulator has the characteristics of higher power density and is well suited for frequent acceleration and deceleration under city traffic conditions [32-34]. It can provide high power for accelerations and can recover more efficiently power during regenerative braking [33] in comparison with electric counterparts [35]. However, the relatively lower energy density brings the packaging limit for the increasing accumulator size [35]. For example, Uzunoglu et al. [39], Rodatz et al. [40], Thounthong et al. [41] developed hybrid energy system such as battery/UC, fuel cell/UC, etc. These studies focused on the hybrid energy systems in electric forms, and publications devoted to hydraulic/electric system are relatively scarce, Ricardo [38] 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. Bozic [42] introduces hydraulic-electric synergy into hybrid transmission using the free-piston engine technology.

A hydraulic accumulator/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 [28]. Figure 1 shows operating modes transition of a hybrid with Hydro-Electric Synergy System.

### IV. Analysis

There is always scope for improvement especially in terms of technology. The analysis was done based on the different types of storage system currently in use. It is also an overview of possible alternatives to the commonly used storage devices. It also highlights the drawback of a few KERS.

Instability in voltage can lead to quick wear and tear of the energy storage device. Figure 2 shows that in...
In comparison with other storage systems, flywheels offer maximum steady voltage and power level, which is independent of load, temperature and state of charge. Second being Lithium ion (Li-ion) battery followed by Nickel metal hydride NiMH and Lead-acid batteries. Super-capacitors/ultra-capacitors being the lowest with 30% stability. Reasons being that supercapacitors have self-discharge properties. Recent research suggests that this issue might be surmounted [ref. SC a brief overview].

The charge and discharge of electrons cause temperatures to vary in storage devices. There are limitations to the temperature range that these devices can withstand. Figure 3 shows the extensive operating temperature range of these storage technologies. Flywheels again have the biggest temperature withstand range going from -40°C to 150°C as compared to the Lead-Acid batteries which have the least range (-15°C to 50°C). Super-capacitors are the second best at withstanding a large temperature range with a minimum (similar to that of a flywheel) of -40°C and maximum of 70°C could replace the flywheel.

Efficiency in storage technologies can be defined as the amount of energy stored by the system to the amount of energy given out or utilized for other use. Figure 4 shows that super-capacitors have maximum efficiency with hydraulic storage devices not being too far from it which is followed by the presently in use mechanical KERS (i.e. flywheel). Batteries have the least efficiency because their discharge rate is faster as compared to the rate at which they charge. Even though super-capacitors have high efficiency, they cannot be used in KERS yet because at constant speed, super-capacitors cannot capture the kinetic energy lost while braking.

Fuel consumption is the main aspect targeted by hybrid cars. This is to conserve and protect the non-renewable and natural resources. It is seen (from figure 5) that 40% of fuel consumption reduction takes place if super-capacitors are prioritized as storage device. Second being flywheel with 27% followed by hydraulic energy system and batteries with 18% and 15% fuel consumption reduction respectively. Batteries contribute least because they have short life and less conversion capacity as compared to other storage devices since their maximum and minimum temperature range is very small.
Cost is the main drawback of every Hybrid vehicle. Causes of high cost are the materials used in making these vehicles and their storage technologies. Figure 6 shows that flywheel system is the cheapest after batteries with 15% and 6%. However, flywheels are currently used because of the efficiency they give in this low cost. Batteries cannot store enough energy and hence charge and discharge quickly. Hydraulic systems are the most expensive of them all followed by super-capacitors with 47% and 32% respectively.

V. CONCLUSION

ERS 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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