FLYWHEEL HYBRID KINETIC ENERGY RECOVERY SYSTEM

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ABSTRACT

This paper presents a theoretical study and scope of implementing mechanical Kinetic Energy Recovery System (KERS) in commercial vehicles on Indian roads. In recent studies and experimentation, KERS which was initially introduced in Formula 1 Racing has been found to benefit commercial vehicles in terms of better fuel efficiency and lower emissions. It has higher efficiency than other recovery systems like TERS and Electric Hybrid System. A thorough study of the usage of KERS in commercial and passenger vehicles globally was conducted. The proposed KERS is capable of supplying power of around 100kW in each braking-accelerating cycle. In Indian cities, owing to traffic conditions, frequent braking is involved which increases the scope of KERS in city vehicles. Thus the target of this study is mainly city vehicles. Basic assumptions were made regarding the daily commute distance to evaluate cost recovery time. A standard of 25% fuel saving was considered with the implemented KERS. The payback period for commercial buses and passenger cars was found to be of 1.25 and 5 years respectively.

MOTIVATION

The motivation behind this study is the need to develop a hybrid system which can improve the fuel efficiency of the vehicle while keeping the cost factor into account, and most importantly which can be used in road transport vehicles. Most fully hybrid vehicles today utilise a rechargeable electric battery running alongside an Internal Combustion Engine (ICE). In terms of satisfying changes needed to combat climate change, electric hybrid vehicles are arguably a step in the right direction but they have received poor reviews for their real world economy. Although electric hybrid vehicles offer fuel savings on certain drive cycles, there are considerable issues with the technology such as increased weight, poor efficiency, performance deterioration with life, and availability of raw materials, issues with recycling and high cost. These issues have so far restricted its applications to high priced niche vehicles and therefore, we need to explore a possible alternative for the electric hybrid.

The traffic in India is very haphazard. The speed of the vehicle makes the inertia the main source of energy recovery. When deceleration is needed, a force has to be applied to overcome the inertia of the vehicle which reduces the speed of the vehicle by converting part of its KE into waste heat in the brakes. The aim is to recuperate and store that energy that can be used again, normally under acceleration, thus reducing high demands on the engine and consequently lowering fuel consumption. HEVs often result in the use of rare earth metals and battery acids being released to environment. On the other hand, KERS is highly recyclable, and thus environment friendly.
INTRODUCTION

Energy Recovery Systems based on vehicle inertia are termed as **Kinetic Energy Recovery System (KERS)**. The device recovers the kinetic energy that is present in the waste heat created by the car’s braking process, stores that energy and converts it into usable power.

**Mechanical KERS System** has a flywheel as an energy storage device and transmission to control and transfer the energy to and from the driveline. To cope with the continuously changing speed ratio between road wheels and flywheel, a continuously variable transmission is used. Fig 1. Represents the schematic arrangement of KERS in a vehicle. The transfer of vehicle kinetic energy to flywheel reduces the speed of the vehicle and increases the speed of the flywheel. The energy thus stored can be harnessed by connecting it to the car’s rear wheels. For a driver it is like having two sources of energy at his disposal, one being the engine and the other being the stored kinetic energy. It can be stored by converting to electric energy or used immediately, either along with the engine or in one great big lump. As the energy stored in the flywheel is delivered back to the wheels, the energy that is required from the engine to accelerate the bus is reduced which consequently reduces the fuel consumption of the vehicle.

![Figure 1. Schematic Layout of KERS](image)

**FUNCTIONAL REQUIREMENTS**

Detailed view of the KERS system is depicted in Fig 2. The components and methodologies employed are due to the following reasons.

1. To create sufficient power storage density, a small enough and light enough unit has to be used. To achieve this the speed of the flywheel has to be increased massively which allows a smaller & lighter flywheel.
2. It has to be contained in a very robust structure in case of failure.
3. It has to be run in a vacuum otherwise high flywheel speed will create windage losses that will sap power and produce enormous amounts of heat.
4. To get power in and out without air leaking in, totally hermetic shaft seal can be used as the power loss in energy transfer in electrical solutions would be too great. The flywheel is made from carbon filament wrapped around a steel hub. High tensile strength of carbon prevents the hub from shattering under the forces acting at such high speeds and steel hub also provides ample mass [1].
5. The flywheel made from carbon fibre wrapped on steel hub has a life of almost 8,00,000 charge-discharge cycles [2].

WHY MECHANICAL KERS?

- By recovering and re-using energy, KERS reduces fuel consumption thereby saves money and lowers CO2 and other pollutants emission.
- Significantly lighter and smaller packaging than battery electric hybridization systems, reducing the impact on Gross Vehicle Weight and overall capacity.
- No infrastructure investment required for charging or safety equipment.
- Reduces wear and tear on vehicle brakes and retarders by providing up to 70% of the required braking capacity.
- Long system life & low maintenance requirement
- Effective across a range of drive cycles, returning best economy improvements in urban driving.
- KERS can be used to “torque-fill” during phases when the engine is producing low torque output. This can be useful to overcome turbo lag in turbo-charged vehicles.[3]
- Have the highest efficiency among other recovery systems i.e. 70% in mechanical KERS as compared to 25% in TERS (thermal energy recovering system) & 30% in the electric hybrid system.

Figure 2. Detailed view of KERS System [4]
ONGOING RESEARCH

1. The KERS which was originally developed for Formula 1 applications was later modified by Flybrid Systems for commercial vehicles, particularly urban delivery trucks and buses that need to stop and start repeatedly, and passenger cars.
2. Arriva (one of the largest bus and train transport services organisations in Europe) is trying the system on its buses, manufactured by Wright buses.
3. Volvo Cars have developed KERS equipped S60-TS. The system is capable of collecting 150-watt hours in a braking time of eight seconds. This energy can cut fuel consumption by up to 25% and also bring down 0-60mph from 7.68 to 6.07 seconds. [5]

CALCULATIONS

The top allowable speed of flywheel=60,000 rpm [6]. The change of angular speed with the motion of the vehicle is represented in Figure 3. The flywheel accelerates while the braking period and decelerates during the accelerating period, thus transferring its energy to the vehicle.

Maximum allowable speed is kept high so as to reduce the mass of the flywheel and keep the system compact.

Mass of flywheel=6-8kg

\[ K.E = \frac{1}{2} (I \omega^2) \]
For a vehicle with a kerb weight of 1600kg moving at a speed of 100kmph, following results were obtained [7].

<table>
<thead>
<tr>
<th>Braking Period (s)</th>
<th>Power (kW)</th>
<th>Energy (kJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>108</td>
<td>432</td>
</tr>
<tr>
<td>6</td>
<td>72</td>
<td>432</td>
</tr>
<tr>
<td>8</td>
<td>54</td>
<td>432</td>
</tr>
<tr>
<td>10</td>
<td>43.2</td>
<td>432</td>
</tr>
<tr>
<td>12</td>
<td>36</td>
<td>432</td>
</tr>
</tbody>
</table>

The kinetic energy stored in the flywheel is independent of the braking period as long as the initial and final speed of the vehicle remains same. Power available is inversely proportional to the braking period.

**CUSTOMER BASE**

Energy recovery systems work best in urban traffic as there is a lot of braking involved in driving. Hence the primarily targeted customer would be the city buses involved in transportation. Our secondary target would be the passenger cars. In big cities like Delhi (which is the targeted area for this study), there are a lot of traffic lights and hence continuous braking and acceleration is involved.

**SELLING AND MARKETING STRATEGY**

**Cost Recovery Time**

Values assumed for calculating cost recovery time are-
For city driving conditions it was assumed that Car travels - 15 km/day during weekdays State Transport Buses – 80km/day

<table>
<thead>
<tr>
<th>Type</th>
<th>Avg. Mileage (km/l)</th>
<th>Distance travelled (km/6 months)</th>
<th>Diesel Price (INR)</th>
<th>KERS Efficiency[6] (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BUSES</td>
<td>4</td>
<td>15600</td>
<td>55.19</td>
<td>25</td>
</tr>
<tr>
<td>CARS</td>
<td>12</td>
<td>2000</td>
<td>55.19</td>
<td>25</td>
</tr>
</tbody>
</table>

Initially expected cost (as per flybrid KERS used in motorsports) is taken as 1.5 Lac. Break-even time, as shown in the Fig 4, has come out to be 1.25 years for commercial buses and 5 years for passenger cars. **Clearly, KERS has a significantly shorter Payback Period.** Electric systems of equivalent in a bus will require the entire vehicle lifespan for payback, while KERS can provide a return on investment in under 5 years [8].
Environmentally Sound –

KERS is readily recycled and has a low embedded CO2 content, with no rare earth metals or highly processed battery acids as often found in HEVs. For the same distance travelled 25% [6] lesser fuel is used and hence reduced the quantity of air pollutant.

Government Funding - IREDA finances the end user energy efficiency retrofit projects which contribute to energy saving like Electric hybrids & hence KERS can be pitched for funding reducing further initial costs.

REFERENCES

[4] Volvo S60 KERS System