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Kinetic Energy Recovery

Alternative Propulsion Systems | ACHA5010

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1 Introduction

During braking, the kinetic energy of a vehicle is converted into heat and is normally lost through the brake pads and rotors. However, kinetic energy recovery systems (KERS) can capture some of this energy and store it for later use. This stored energy can then be used to assist with acceleration, improving the overall efficiency of the vehicle. In a hybrid electric vehicle, for example, the stored energy can be used to power an electric motor in order to drive the vehicle.



Figure 1 - Automotive Braking System (Lex Ger, n.d.)

KERS systems can also provide a power boost when needed, enhancing vehicle performance in situations like overtaking another vehicle or accelerating onto a faster stretch of road. In addition to these benefits, KERS systems can also help to reduce emissions by decreasing the workload of the internal combustion engine and thereby reducing the number of pollutants released into the atmosphere.

2 WLTP Cycle

For this task, a 1996 Honda Civic was chosen for this based on its blend of engineering excellence, power, fuel efficiency, and aerodynamics.



Figure 2 - 1996 Honda Civic 1.5 ILS Saloon

The Honda Civic model line-up has a long-standing history of being dependable and efficient on fuel consumption, and the 1996 model in specific was famous for its 3-stage VTEC lean burn engine. Which improves fuel economy by creating a swirling in the intake charge. These attributes made it an ideal choice for a base to further improve its efficiency with a kinetic energy recovery system. With a 1493cc single overhead cam 16 valve petrol engine producing 84 kW and 138 Nm of torque. The car's kerb mass, as per the manufacturer's specification, is 1000 kg. Its front surface area measures 1.99m², and it has a drag coefficient of 0.32.

$$\text{Rated power to kerb mass ratio } (W/kg) = \frac{84000}{1000} = 84$$

Its power-to-mass ratio classifies it as a Class 3b vehicle according to the Worldwide Harmonised Light Vehicle Test Procedure (WLTP), as it exceeds 34 W/kg.

For this procedure, the test mass will be the original kerb weight of the vehicle plus an additional 15%. (Volkswagen Aktiengesellschaft, 2017)

$$\text{Test mass} = 1000 + 15\% = \mathbf{1150kg}$$

The WLTP test cycle is intended to more closely reflect real-world driving conditions and to provide more accurate and representative data on vehicle emissions and fuel consumption than the previous test cycle, the NEDC (New European Driving Cycle).

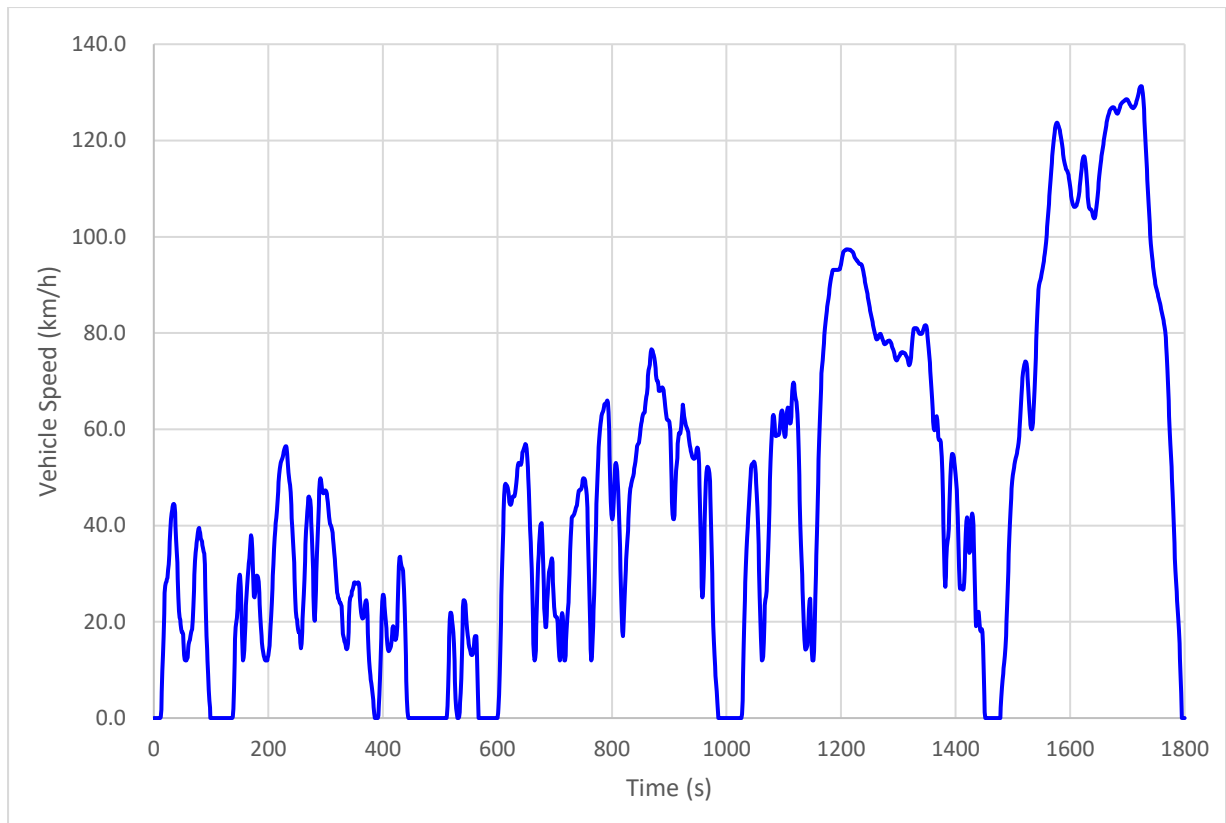


Figure 3 - WLTP Cycle Speed vs. Time Graph

The WLTP cycle is broken down into four phases: low-speed, medium-speed, high-speed, and extra-high-speed.

The low-speed phase (from $t=0s$ up to $t=589s$) simulates city driving with an average velocity of 18.9km/h and frequent stops and starts. The medium-speed phase (from $t=590s$ up to $t=1022s$) mimics suburban driving with an average speed of 39.5km/h, including longer periods of acceleration and deceleration. The high-speed phase (from $t=1023s$ up to $t=1477s$) replicates highway driving, featuring higher velocities, up to 100km/h, and an average speed of 56.6km/h. The extra-high-speed phase (from $t=1478s$ up to $t=1800s$) includes velocities up to 130km/h, the highest accelerations and decelerations and an average speed of 94km/h. (WLTPfacts.eu, n.d.)



Figure 4 - Resistive Forces vs. Time Graph

During the WLTP cycle, it can be observed that the rolling resistance, which is the force that opposes the motion of a vehicle caused by the contact of the tires with the road surface, and these factors do not change significantly during the test cycle.

On the other hand, aero resistance, which is the force that opposes the motion of a vehicle caused by the interaction of the vehicle with the air, increases drastically during the high and extra-high phases of the WLTP cycle. This is because as the vehicle's velocity increases, the amount of air resistance it encounters also increases. At high velocities, the vehicle's coefficient of drag and frontal area become more important factors in determining the amount of air resistance it experiences. KERS can only recover energy from any deceleration that exceeds natural coasting, such as braking, downshifting, or going downhill. (Ehsani et al., 2009)

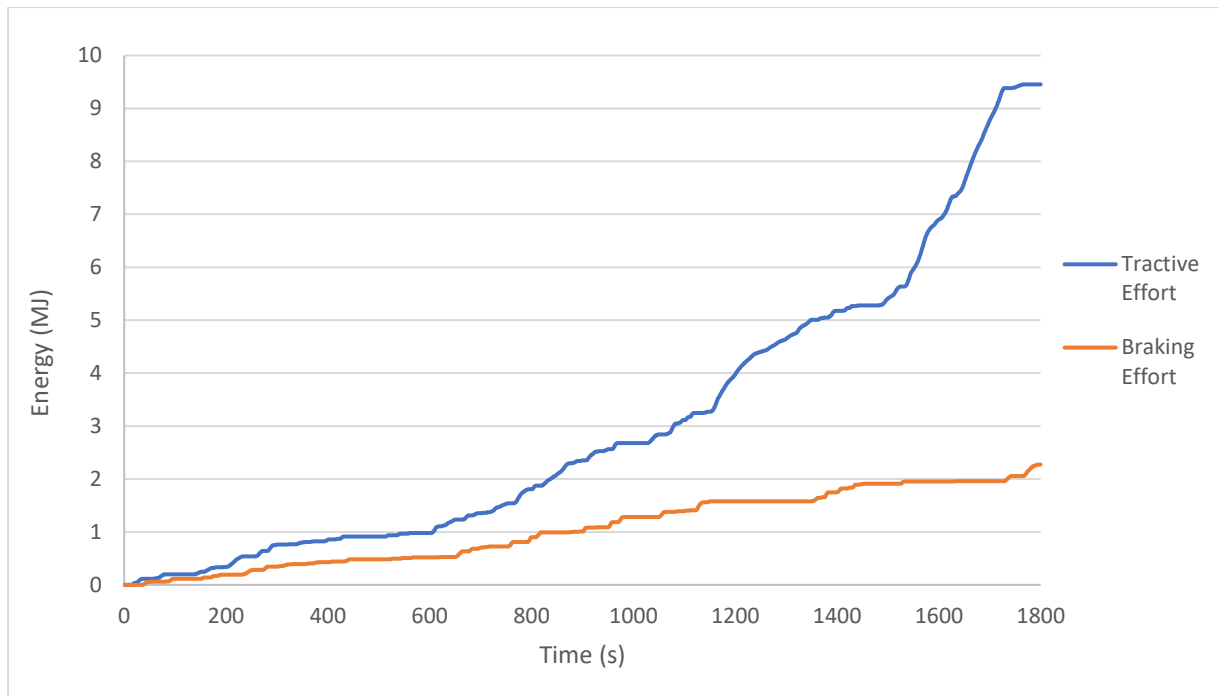


Figure 5 - Cumulative Tractive and Braking Effort Graph

The tractive effort required to propel the vehicle along the WTLP cycle was 9.45MJ

3 KERS System

One viable option to retrofit this vehicle with a kinetic energy recovery system is Hybrid Air Technology. This is a concept that aims to improve the fuel efficiency and emissions of vehicles by combining different types of power sources. The technology is developed by PSA Peugeot Citroen, now part of the Stellantis Group, the technology combines a gasoline engine, an hydraulic pump, and a compressed air energy storage system to create a hybrid powertrain. The internal combustion engine (ICE) is used for high-speed driving, while the hydraulic pump is used for low-speed, city driving or to aid acceleration in conjunction with the ICE engine. The compressed air energy storage system captures energy that would otherwise be wasted during braking and stores it for later use, increasing the vehicle's overall efficiency. The compressed air is then used to drive an hydraulic pump which generates the kinetic energy that is sent to the gearbox. (Wasbari et al., 2017)

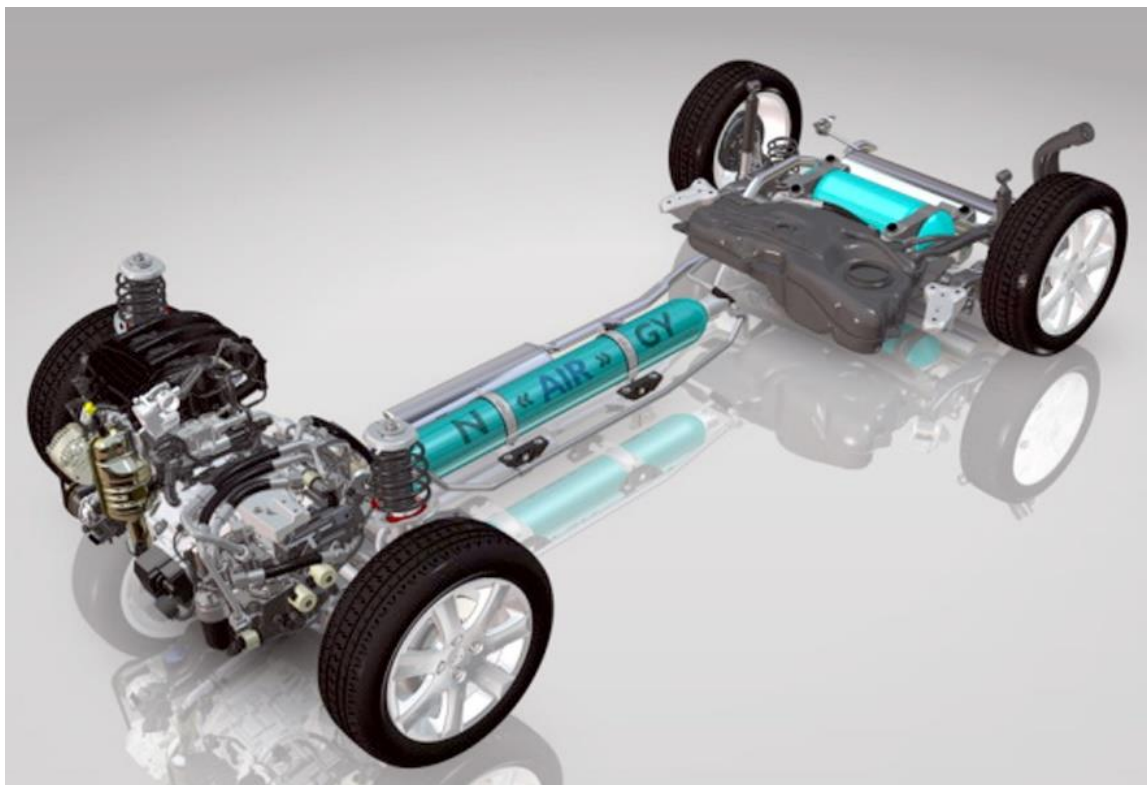


Figure 6 - PSA's Hybrid Air Technology (autoevolution, 2013)

Hybrid Air Technology is a viable alternative for retrofitting existing vehicles as it can be integrated into the existing powertrain, and it does not require any significant changes to the vehicle's design. It also offers a cost-effective solution as it uses inexpensive and readily available components. PSA Peugeot Citroen claims that the Hybrid Air drivetrain has the potential to deliver a 45% improvement in fuel economy for urban driving compared to a traditional combustion engine, while only adding 100kg to the overall vehicle weight. (Auto Express, 2013)

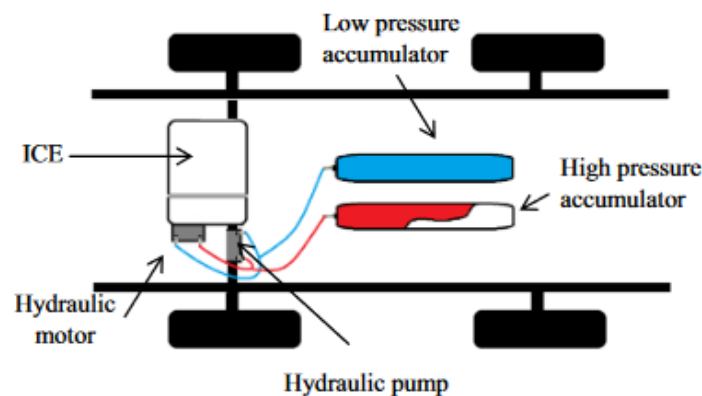


Figure 7 - Hybrid Air System Diagram (Wasbari et al., 2017)

The system chosen for retrofitting in this instance is an electric motor that acts on the rear wheels. The electric motor is integrated into the rear axle of the vehicle and is connected to a lithium-ion battery pack. The motor is powered by the battery pack and provides additional power to the rear wheels, helping the vehicle to accelerate more quickly and efficiently.

The lithium-ion battery pack is recharged using the energy that is recovered during braking and deceleration. This is done through a process called regenerative braking, where the electric motor acts as a generator and converts the kinetic energy of the vehicle into electrical energy, which is then stored in the battery pack. The battery pack also can be charged through an external power source, making this a plug-in hybrid electric vehicle.

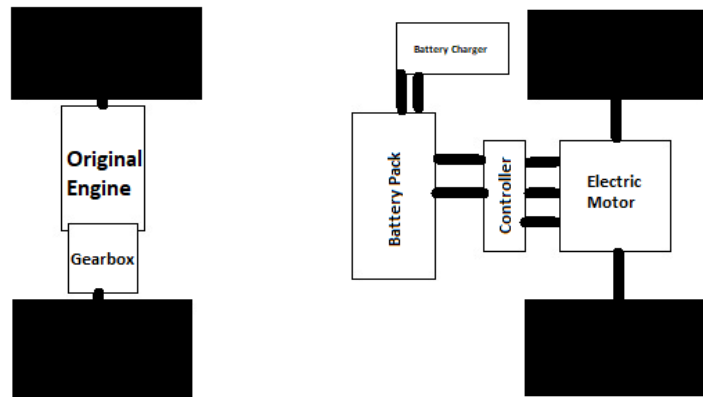


Figure 8 - KERS Proposal Diagram

As the electric motor is only connected to the rear wheels, this allows the vehicle to maintain its original powertrain driving the front axle. This system is a good option for retrofitting existing vehicles as it does not require significant changes to the vehicle's design, and it can be integrated into the existing powertrain.

Except for the additional deceleration of regenerative braking when coasting, this modification should not affect the driver's feel. With this setup, the car is rear-wheel drive when in electric mode only, front-wheel drive when propelled by the combustion engine alone, and four-wheel drive when the electric motor is assisting acceleration. Despite the heavy bias towards the driving the front wheels, this will still provide traction in harsh conditions and on loose surfaces.

4 Conclusions

In simple terms, kinetic energy recovery systems are becoming increasingly crucial for reducing fuel consumption and emissions in the automotive industry. By capturing the kinetic energy that is normally lost during braking and converting it into power, KERS can power the vehicle and lead to significant reductions in fuel consumption and emissions. This makes KERS a vital technology with the current trends of banning solely internal combustion engine cars from sale in the near future, hybrid vehicles and their recovery systems can play a vital role in the transition to sustainable transportation.

Additionally, KERS can also improve the performance of vehicles by providing extra power when needed, particularly for high-performance vehicles such as sports cars and race cars. This makes KERS an important technology for both sustainability and performance enhancement.



Figure 9 - Porsche 911 GT3 R Hybrid System (Porsche USA, 2010)

Overall, the development and implementation of KERS is essential for achieving more sustainable and efficient transportation systems. The ability to capture and reuse kinetic energy otherwise lost during braking can lead to significant reductions in fuel consumption and emissions, making KERS a key technology for a sustainable future. KERS are a solution that can help bridge the gap during the transition to electric vehicles and play a pivotal role in achieving a greener and more sustainable transportation system.

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