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Kinetic Energy Recovery

Alternative Propulsion Systems (ACHA5010)

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1. Introduction

In the automobile sector, Kinetic Energy Recovery Systems (KERS) have become an excellent technology to reduce fuel consumption and increase energy efficiency in vehicles. KERS has attracted a lot of focus as a potential way to increase vehicle effectiveness and efficiency as concerns about alternative energy sources and environmental sustainability develop, particularly in connection with hybrid and electric drive systems. The kinetic energy produced when a car brake is essentially captured and utilized via the KERS idea, instead of wasting away as heat. By collecting and storing this energy, KERS lessens the vehicle's reliance on conventional fuel sources and cuts down on hazardous emissions. It can also be utilized later as an addition to the vehicle's power needs. The effects of kinetic energy recovery on lower vehicle usage are discussed in this report. The dynamic properties of the Audi A3, such as test mass, front end, rolling resistance coefficient, and aerodynamic drag coefficient, are specified. For the chosen vehicle, the relevant Worldwide Harmonized Light Vehicle Test Procedure (WLTP) is used to standardize emissions testing and fuel economy. In order to analyze the possible advantages of the approach and get insight into energy demands, a spreadsheet is made to plot cumulative tractive energy and brake energy required at the wheel across the WLTP cycle. The study outlines the assumptions made, how the system works, and any differences that the driver would encounter from a traditional ICE and friction brake vehicle. These variations evaluate the effect on driving enjoyment and performance. The purpose of this investigation is to determine whether using KERS in conjunction with an ICE stop-start technique can reduce fuel usage. The results aid in comprehending the advantages and difficulties associated with these tactics for improving vehicle performance and efficiency.

2. Internal Combustion Engine Cycle

Significant changes have occurred in the field of internal combustion engines as a result of increased global awareness of environmental and economic issues. These developments have prompted the invention of several systems aimed at reducing car emissions, improving fuel efficiency, and storing and recovering energy that was previously used. Amongst the numerous areas of concentration, optimizing idle moments has emerged as a significant subject since it represents an inefficient stage within the engine cycle. Because of a closed throttle and increased vacuum on the inlet side during idle, the engine experiences increased pumping losses, resulting in higher fuel consumption. Toyota developed the automated start-stop system in the middle of the 1970s as a solution to this problem, and Volkswagen and Audi followed suit in the middle of the 1980s (Varta Clarios, 2023). Compared to conventional systems, stop-start systems require five to ten times as many engine starts, which puts a substantial burden on the vehicle's battery. Additionally, the battery supports the vehicle's electrical demands during engine stoppages while continuously engaged in cycles of charging and discharging. As such, the need for a strong Stop Start battery becomes essential. In this regard, two different battery types are frequently used for cars that have stop-start systems: the absorbent glass mat (AGM) battery and the enhanced flooded battery (EFB) (R&J Batteries, 2023). One additional significant development under research is the application of kinetic energy produced during the deceleration phases. Vehicles may efficiently capture and harness this energy by using Kinetic Energy Recovery Systems (KERS), which reduces energy usage and extends the life of friction brakes and discs. However, it is crucial to stress that KERS is not intended to take the place of friction brakes. Friction brakes are essential because of things like pressure restrictions, the permissible rate of retardation, and the mechanical confidence they offer. Nonetheless, these systems show great promise for regaining energy that has been previously lost, allowing for acceleration during the deceleration phase and improving the efficiency and performance of the vehicle.

3. Vehicle selection

For this project I have selected 2014 Audi A3 3rd generation 8V sport back. The reason why I have selected this vehicle is that I have owned this car for couple of years and it stands out from my previously owned cars. The A3 is a sensible option for commuting because it provides a solid mix of performance and handling that is recognized for being responsive and fuel-efficient. Choosing this car for this project would help me to understand the potential of its performance and compare to other vehicles.



Figure 3.1 Audi A3

As per Pawel Zal and Car.info, the following information is gathered:

- Test mass – 1600kg
- Aerodynamic drag coefficient – 0.29
- Rolling resistance coefficient – 0.015
- Kerb mass – 1410kg
- Frontal area – 2.8m²

Numerous computations, including those for rolling resistance, power, and aerodynamic resistance, can be carried out by using the dynamic properties that have been identified. These computations will be used to create a Worldwide Harmonized Light Vehicle Duty Cycle (WLTP), together with the acceleration and deceleration data. Important details about tractive power, braking power, and the frictional losses that happen between the two during the cycle are provided by the WLTP. The evaluation of the vehicle's suitability for a KERS system and the selection of the best system to install depend heavily on this data.

4. Methodology

There are multiple crucial steps in the energy recovery process:

- Spreadsheet Analysis: For additional analysis, move the gathered data to a spreadsheet. This will act as a basis for figuring out energy recovery and assessing the energy dynamics of the car.
- 2. Force Calculation: Determine the forces the car must withstand when it accelerates, decelerates, and maintains a constant speed at different points in the duty cycle. In particular, take rolling resistance, aerodynamic resistance, and acceleration resistance into account to find the forces at play during the acceleration phase. These computations shed light on the force needed to accelerate a vehicle.
- 3. Analysis of the Deceleration Stage: Proceed to the stage of deceleration. Subtract the total force from the deceleration force by the sum of the rolling and aerodynamic resistances.
- 4. Power Output Differentiation: It is important to differentiate between positive power output (tractive effort) and negative power output (braking effort) throughout these computations. This distinction makes it easier to choose a suitable KERS system that meets the needs of the vehicle and permits a thorough evaluation of energy recovery capability.

This methodology makes it possible to assess the potential for energy recovery, analyze the vehicle's energy dynamics, and choose the best KERS system to put into service.

5. Results

A thorough dataset was acquired for each of the four speed cycles following computations for cumulative tractive and braking power throughout a 30-minute period. Ensuring the data plot's accuracy was the goal. A noticeable difference between the tractive power potential energy and the total kinetic energy gained during the braking process may be seen in Figure 5.1, which is shown below.

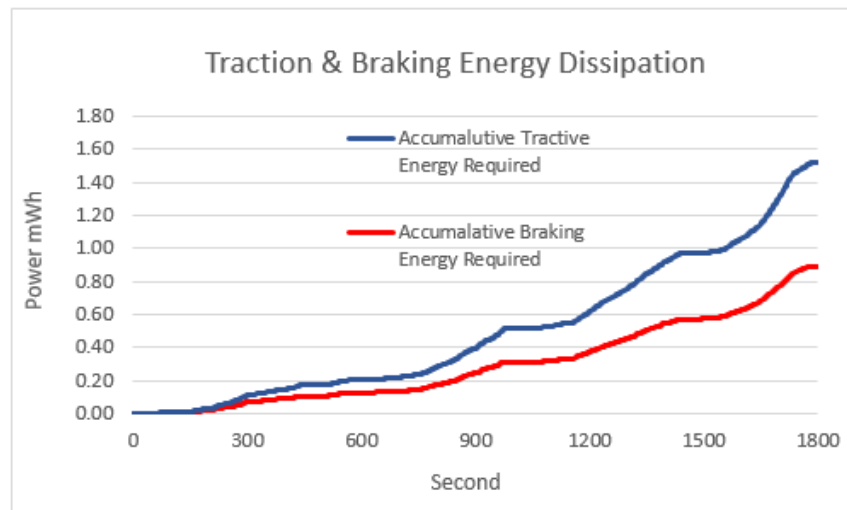


Figure 5.1: Energy dissipation graph for braking and traction

This discrepancy gets more noticeable over time, mostly as a result of heat dissipation from the brakes and losses related to the resistive forces previously mentioned. Additionally, tiny losses arising from seals and bearings contribute to the overall gap. These losses are seen more clearly in the above picture, which also emphasizes how much more of a role they play in the system's overall energy dynamics.

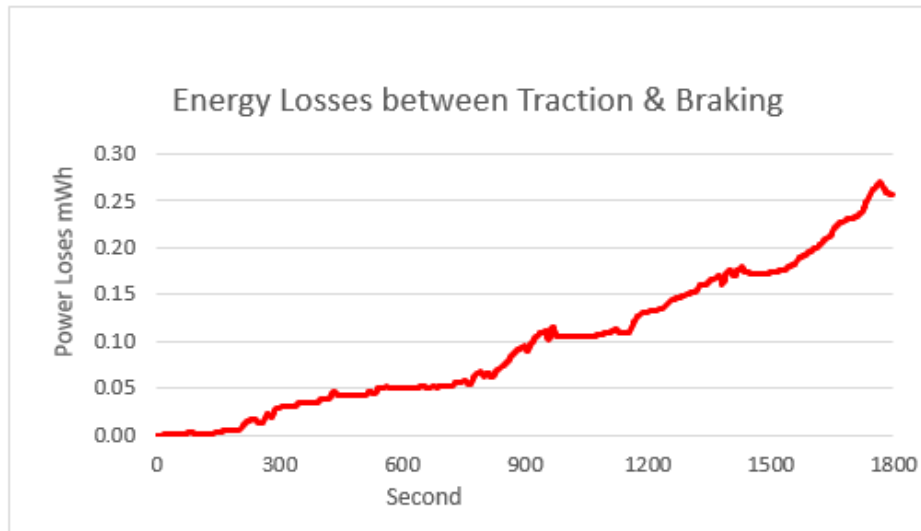


Figure 5.2 The graph shows the energy losses that occur during braking and traction.

Over the course of thirty minutes, the observations show a gradient in the losses between braking and tractive power. However, Figure 5.2 shows that there is still a significant amount of unrealized potential and a considerable quantity of kinetic energy (up to 0.8 mWh) that can be retrieved during deceleration and then used for an additional cycle of acceleration.

6. Analysis

A closer examination of the force calculations made throughout a drive cycle has shown several limitations in the findings. Firstly, the outputs for braking and tractive power at the end, which are 1.4 and 0.8 mWh, respectively, are far more than what I had anticipated for a 30-minute duty cycle. Even after doing quite a bit more research, I was unable to prove or disprove my suspicions. It is noteworthy, therefore, that these power outputs' trends and gradients match those frequently seen in normal WLTP charts for cars of a comparable make and model. As such, the advice that follows could make sense in theory, but their relevance in real life might be doubtful.

7. KERS System

Many aspects must be taken into account when selecting a suitable Kinetic Energy Recovery System (KERS), including:

- System life cycle: Does the system follow the same patterns as other vehicle powertrain components?
- Suitability of power input and output: Can the system manage the necessary power input and provide the intended output?
- System efficiency: What is the effectiveness of the system's kinetic energy conversion and storage?
- Packaging viability: Is it possible to include the system's required adjustments into the vehicle's design?
- Compatibility with present components: Does the system work with the drivetrain and power plant that are currently on the car?
- Requirements for shielding: What safeguards are required to deal with the system's electromagnetic noise?
- Noise and vibrations: In the event of a mechanical flywheel, what kind of noise and vibrations might be produced by the KERS?
- Battery storage: Does the particular KERS system under consideration have the capacity or potential to add battery storage?

7.1 Electro-mechanical KER System

An electro-mechanical system does not store recovered energy in batteries, in contrast to an electronic KERS system. Rather, it stores kinetic energy in a mechanical flywheel. According to Baba automobile, this flywheel, usually compact and capable speed of 50,000 – 160,000 rpm, acts as an electro-mechanical battery. The benefits of packaging are clear in this arrangement. The flywheel is frequently kept in a vacuum to reduce aerodynamic losses brought on by spinning. The flywheel, which is made up of metal particles and fibres, is magnetic at 50,000 to 160,000 revolutions per minute. As a result, it functions similarly to the MGU that the electronic KERS system specifies.

7.2 Mechanical KERS

The second option is a KERS system that is entirely mechanical and has a flywheel, just like the electro-mechanical system. Nevertheless, this technique lacks MGUs and instead employs a gearbox to transmit drive to and from the flywheel. Different gears and shafts are used to transfer the kinetic energy that is accumulated during deceleration. Because this system is entirely mechanical, it experiences larger losses

even if it avoids the problems with sensors and electronic noise that the other two systems have. Efficiency in energy storage is hampered by friction and heat losses. Additionally, a Constant Variable Transmission (CVT) controlled by an electro-hydraulic control system is introduced to handle the problem of constantly changing speed ratios between the road wheels and the flywheel. This kind of gearbox is typically very hefty.

7.3 Electronic KERS

An electric motor/generator unit (MGU) can be installed anywhere on the driveline to capture the rotational force produced by a decelerating vehicle in an electronic KERS system. This rotational kinetic energy is transformed into electrical energy by the generator unit and is subsequently stored in batteries. Choosing the best kind of battery for energy storage is a major obstacle when choosing this kind of KERS. For the time being, lithium-ion batteries are usually the better option, but future developments in battery technology can cause this to alter. It is mechanically challenging to package the battery packs, especially in terms of cooling, and this could mean adding cooling ducts and then changing the vehicle's body panels.

7.4 Suitable KERS for the Audi

Based on the vehicle's high potential for kinetic energy, future developments in battery technology, and existing packaging constraints, the Electro-mechanical KER System is the best option for this vehicle. The inclusion of a mechanical KERS system is not practicable due to the vehicle's relatively hefty weight. In addition, an electronic system is not practical because of the restricted space in the driveline and power units. One benefit of the electro-mechanical system is that it can accommodate a small flywheel, making packaging more manageable. Furthermore, it can easily accommodate more energy storage with the use of future battery technologies like Lithium-ion batteries without sacrificing system performance. For this reason, the best option for this vehicle is the electro-mechanical KER System. The available power in kilowatt-hours that can be recovered for use during an acceleration cycle is shown in the figure below, which was obtained by accounting for resistive forces and the distribution of power between tractive and braking forces while determining the recoverable kinetic energy. The available power in kilowatt-hours that can be recovered for use during an acceleration cycle is shown in the figure below, which was obtained by accounting for resistive forces and the distribution of power between tractive and braking forces while determining the recoverable kinetic energy.

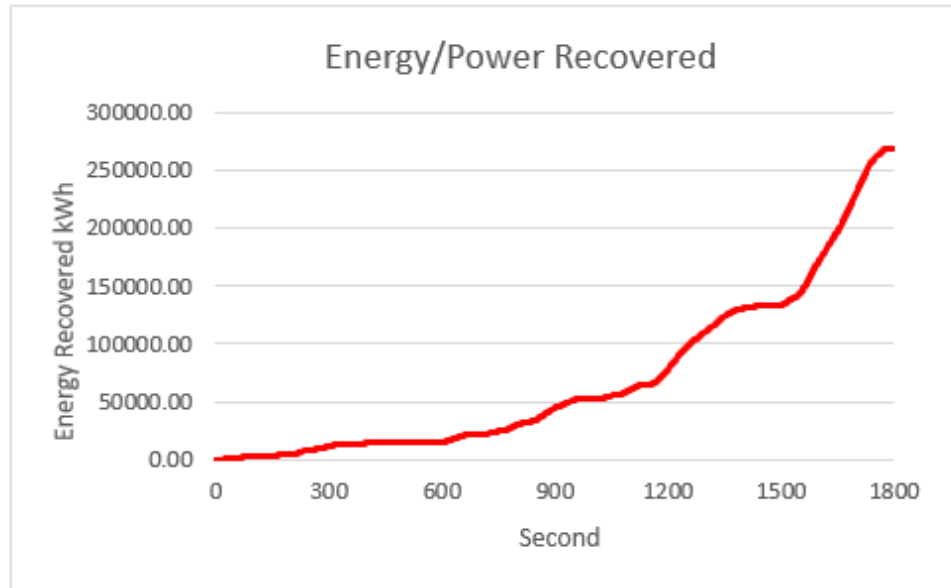


Figure 7.4 shows the electromechanical energy recovery graph for the chosen car.

It's crucial to remember that adding this KERS system will alter the car's characteristics and ease of driving, necessitating some getting used to. One of the most visible modifications will be the retardation experienced during acceleration. Every model that has a KERS system installed is meticulously configured in this regard by the producers of electronic and hybrid vehicles. Finding the ideal balance is essential because excessive retardation can cause the car to become hazardous and difficult to drive because of the large torque changes that occur as the vehicle decelerates. On the other hand, inadequate retardation would result in an ineffective system that would not be able to utilize the potential energy that could be recovered. Fuel economy would decline and energy consumption would rise as a result of this inefficiency.

8. Conclusion

In conclusion, there is a lot of room for improvement when it comes to fuel economy, energy efficiency, and overall performance when Kinetic Energy Recovery Systems (KERS) are installed in automobiles. The present report's investigation provided significant insights into the dynamic features of the chosen vehicle. The Worldwide Harmonized Light Vehicle Test Procedure (WLTP) and the vehicle data were used to assess the energy requirements and possible advantages of using KERS together with an ICE stop-start strategy. The findings show an important difference between the tractive power's potential energy and the total kinetic energy gained during braking. This indicates that there is potential kinetic energy that can be regained during deceleration and used to further cycles of acceleration. A number of criteria need to be taken into consideration when choosing an appropriate KERS system, including the system's life cycle, suitability for power input and output, efficiency, packaging feasibility, compatibility with existing components, needs for shielding, vibration and noise, and battery storage capacity. Because of its adaptability, effectiveness, and capacity to integrate extra energy storage in the form of batteries, the electro-mechanical KERS system has been determined to be the best option for the chosen vehicle. It's crucial to remember that adding a KERS system will alter the car's characteristics and ability to drive. Achieving the ideal balance is essential to guarantee efficiency and safety since too much delay can make the car hard to maneuver. With everything considered, our analysis shows how an ICE stop-start technique combined with KERS can potentially reduce fuel consumption and improve performance. Enhancing energy efficiency and minimizing environmental effects in the automotive sector will be aided by more research and development on KERS technology and its integration into automobiles.

9. References

Baba Automobile (2021) *Kinetic Energy Recovery System*. Available at: <https://babaautomobile.com/kinetic-energy-recovery-system/> (Accessed: 11 January 2024)

Batteryworld (2022) 'Why a working Start-Stop system is so important to save fuel', *Batteryworld* [blog]. 30 May. Available at: https://batteryworld.varta-automotive.com/en-be/why-a-working-start-stop-system-is-so-important-to-save-fuel?fbclid=IwAR0VycP49ogT0EK_W-7x26ndNHVvbPqI5c9691tq0Pc4ISqC_sflzGz26JA (Accessed: 11 January 2024).

RJBatt (2022) *Your guide to stop start batteries*. Available at: [https://www.rjbatt.com.au/stop-start-batteries?fbclid=IwAR1D9Mu9j0TtbGgNuTkajkv5tiVaQQ_Ilo9AWUhFRZUHSn9yo6rDPDFDQzY#:~:text=There%20are%20two%20different%20types,Glass%20Mat%20\(AGM\)%20battery](https://www.rjbatt.com.au/stop-start-batteries?fbclid=IwAR1D9Mu9j0TtbGgNuTkajkv5tiVaQQ_Ilo9AWUhFRZUHSn9yo6rDPDFDQzY#:~:text=There%20are%20two%20different%20types,Glass%20Mat%20(AGM)%20battery) (Accessed: 12 January 2024).

Wallén, J., 2004. Modelling of components for conventional car and hybrid electric vehicle in Modelica.

Zal, P. (2023) *2014 Audi A3 2WD 3-Door 3rd-gen – phase-I (8V) all versions' specifications and performance data*. Available at: https://www.automobile-catalog.com/make/audi/a3_8v/a3_8v_hatchback/2014.html#gsc.tab=0 (Accessed: 11 January 2024).

Car.info (2023) *Specifications for Audi A3 8V 2012 – 2016*. Available at: [Specifications for Audi A3 8V \(car.info\)](#) (Accessed: 12 January 2024).