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Kinetic Energy Recovery

Alternative Propulsion Systems

ACHA5010

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1 Introduction

1.1 Justification

In this report, the effects of introducing a kinetic energy recovery system to a 2002 Peugeot 206 in order to reduce fuel consumption will be analysed. The car will be put through the Worldwide harmonised Light vehicle Test Procedure (WLTP) to determine factors such as acceleration resistance, aerodynamic resistance, tractive forces and energy to see what the best Kinetic Energy Recovery System (KERS) is best suited for the Peugeot 206. This will be done to help this small hatchback car to further improve fuel economy.

1.2 Aims

The aim of this report is to calculate where the largest possible areas of Kinetic Energy deployment as well as how much energy can be recovered and stored. The aim will be to recover the maximum amount of energy that is available to make the system as efficient as possible to increase fuel economy.

1.3 Objectives

The objective of this report will be to find a suitable Kinetic Energy Recovery System for the Peugeot 206. The size of the components will need to be specified as well as the efficiency of the system. From here, the amount of Kinetic Energy that is returned to the wheel will be calculated, and the differences between driving with the implemented system compared to driving a conventional Internal Combustion Engine (ICE) will be compared.

2 Dynamic Vehicle Characteristics

2.1 Vehicle dimensions

The Peugeot 206 that will be analysed in this report is a 2002 1.1 litre small hatchback car. The car has a kerb mass of 985kg and produces 60 horsepower, which is the equivalent of 44.74kW. The car has a height of 1433mm and a width of 1652mm, giving an estimated frontal area of 2.37m^2 (Peugeot 206 Hatchback 1.1 Style 3d specs & dimensions [no date]).



Figure 2-1 - A 2002 Peugeot 206 1.1

2.2 WLTP Class Calculation

To calculate what class of vehicle the Peugeot 206 falls into for the Worldwide harmonised Light vehicle Test Procedure (WLTP), the power rating in Watts needs to be divided by the kerb mass:

$$44742/985 = 45.42$$

As $45.42 > 34$, this leads to the 206 being classified in class 3.

2.3 Test Mass

The test mass of a vehicle is the mass of the vehicle used for road load determination, which includes the kerb mass of the vehicle, passengers, fuel and luggage (Brussels et al. 2011). The test mass of the vehicle will be 1100kg, assuming that one person will be driving the car with a nearly full tank of fuel.

2.4 Rolling Resistance, Drag Coefficient and Aero Resistance

The rolling resistance for car tyres on concrete or asphalt is equal to around 0.013 (Eshani et al, 2004). To calculate the total rolling resistance the following equation is used:

$$\text{Rolling Resistance} = \text{Mass} \times \text{Gravity} \times \text{Coefficient of Rolling Resistance}$$

$$\text{Therefore, Rolling Resistance} = 985 \times 9.81 \times 0.013 = 125.62\text{N}$$

The coefficient of drag for the Peugeot 206 is around 0.3 (Eshani et al, 2004). The aerodynamic resistance at any speed can be calculated with this equation:

$$\text{Aero Resistance} = 0.5 \times \text{Density of Air} \times \text{Coefficient of Drag} \times \text{Frontal Area} \times \text{Velocity}^2$$

This will give the drag force for each velocity during the WLTP.

3 Worldwide harmonised Light vehicle Test Procedure Results

3.1 Acceleration Resistance

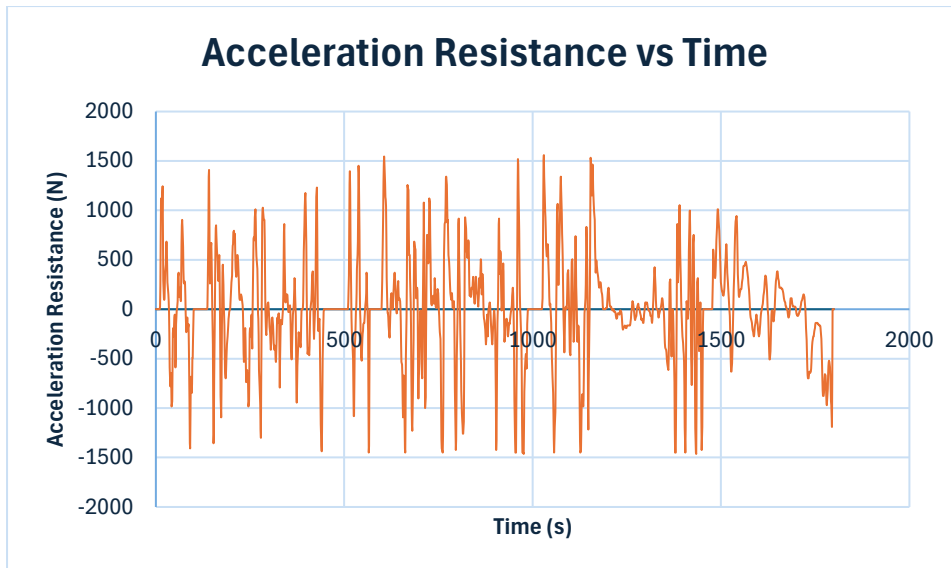


Figure 3-1 - Graph of Acceleration Resistance vs Time

The acceleration resistance of the Peugeot 206 is calculated by the following equation:

$$\text{Force} = \text{Mass} \times \text{Acceleration}$$

As seen in figure 3-1, the maximum acceleration resistance is around 1500N, with the minimum being around -1500N, which will be the braking force.

3.2 Aero Resistance

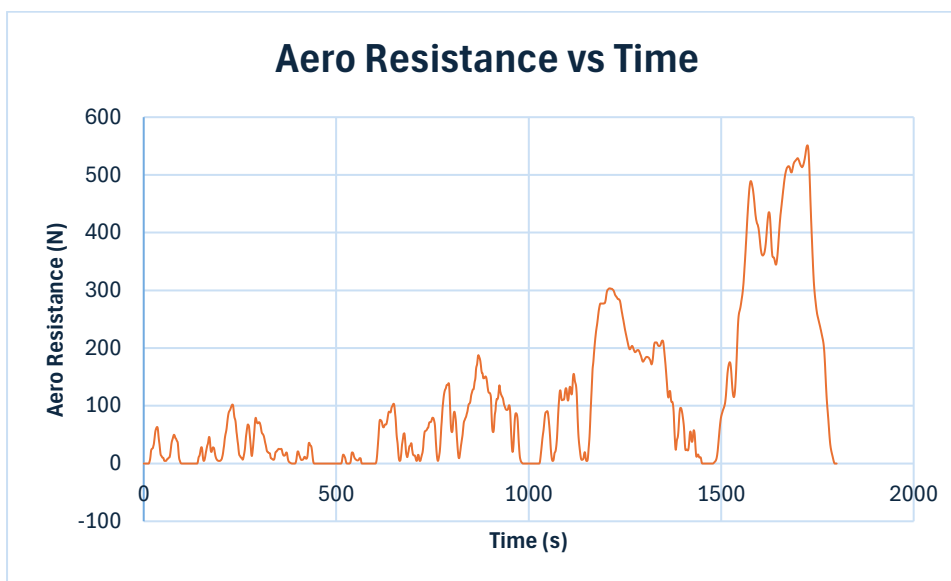


Figure 3-2 -Graph of Aero Resistance vs Time

There WLTP consists of four speed stages – low, medium, high and extra high. As seen in figure 3-2, the aero resistance increases through each phase of the WLTP as it goes from low to high. The aero drag is highest in the extra high phase, with it being around 550N.

3.3 Total Tractive Force

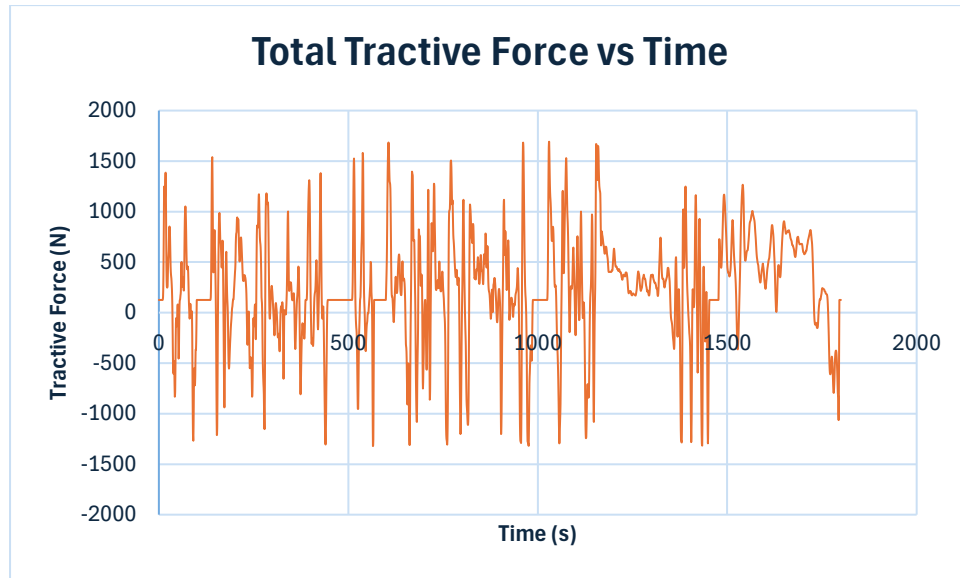


Figure 3-3 – Graph of Total Tractive Force vs Time

The total Tractive force is the cumulation of all the forces. This includes the rolling resistance, the aero drag force and the acceleration force. This total force can then be used to calculate the power requirement needed for the Peugeot 206.

3.4 Tractive Power

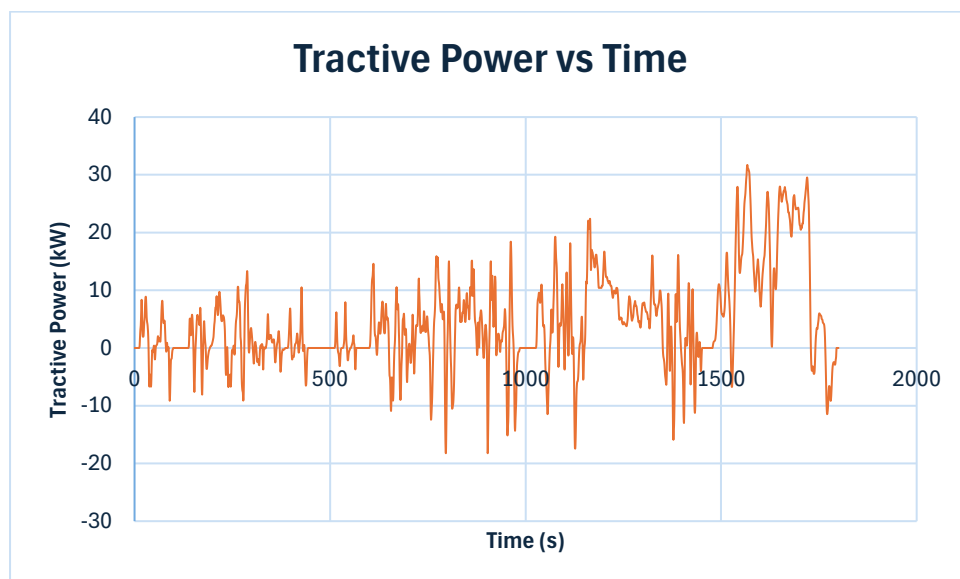


Figure 3-4 - Graph of Tractive Power vs Time

The tractive power is the power requirement needed for each second of the WLTP. As seen in figure 3-4, the highest power requirement is just over 30kW, with the largest power requirement under braking just under -20kW. Now the power has been calculated, the energy required can be calculated.

3.5 Traction Energy

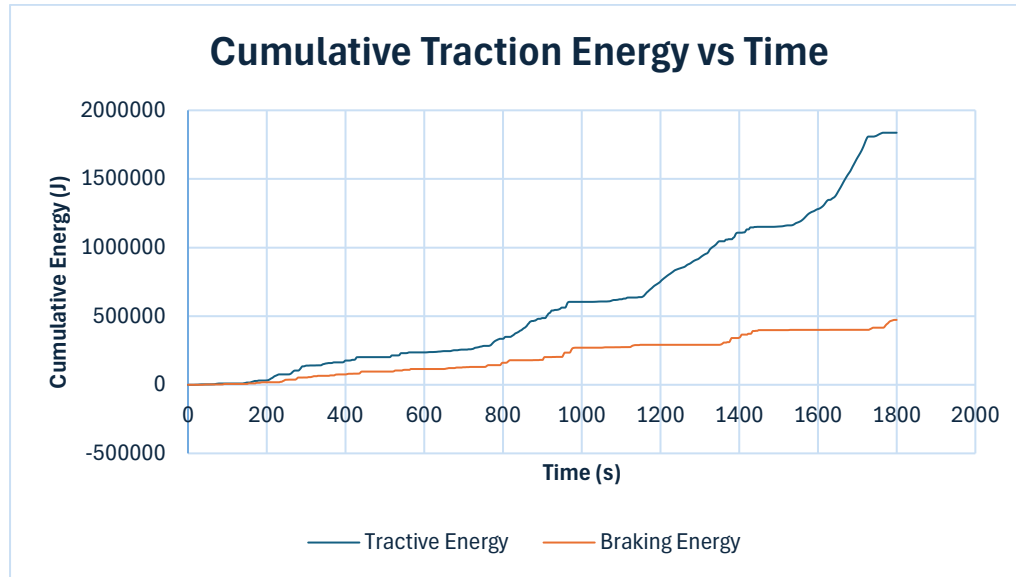


Figure 3-5 - Graph of Cumulative traction energy

As seen in figure 3-5, the cumulative tractive energy and braking energy has been plotted. With this graph, the total losses incurred during the cycle can be calculated. From the graph, it's seen that around 13MJ of energy is lost during the 1800 second test. From this point, the largest areas of loss during the WLTP can be found and the amount of energy that can be recovered will be calculated to reduce the loss.

4 Suitable Kinetic Energy Recovery System

4.1 Largest KERS Power Input and Energy Storage

One area where a lot of energy storage is needed followed by a large power input is between 792 seconds and 869 seconds of the WLTP. At the start of this period, the Peugeot 206 is travelling at 66km/h, or 18.33m/s, and at the end of the deceleration period is travelling at 17km/h, or 4.72m/s. At any stage of this phase, the Peugeot's Kinetic Energy can be calculated using this equation:

$$\text{Kinetic Energy} = \frac{1}{2} \times \text{Mass} \times \text{Velocity}^2$$

This gives Kinetic Energy = $\frac{1}{2} \times 1100\text{kg} \times 18.33^2$, which equals 184.79kJ.

At the end of the deceleration phase the Kinetic Energy = $\frac{1}{2} \times 1100\text{kg} \times 4.72^2$, which equals 12.25kJ. This is a loss of 172.54kJ over 27 seconds.

4.2 Selection of KERS

The selected Kinetic Energy Recovery System will be a 12 Volt lead acid battery linked with a regenerative braking system. There are a few positives to lead acid batteries. These include that there is a low initial cost to the batteries and that they have high power density, meaning it can absorb power quickly and means energy can also be delivered at a fast rate (*Energy density vs power density - Energy Education* [no date]). This will work well with the Peugeot 206 over the WLTP, especially within the timeframe stated in 4.1 as it means the Kinetic Energy can be absorbed at a fast rate and deploy at a quick rate before the next recovery period. A lead acid battery has around 80% efficiency, meaning 80% of the energy can be recovered, and the other 20% is lost to other factors such as heat (*Lead Acid, Lithium & LiFePO4 Battery Run Time Calculator* [no date]).



Figure 4-1 - Example of a 12 Volt lead acid battery

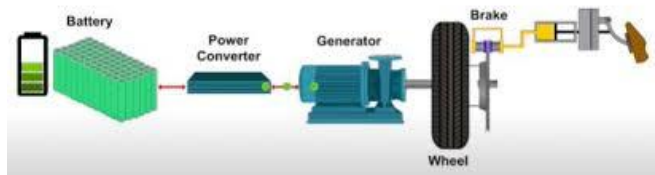


Figure 4-2 - An example of a regenerative braking system

4.3 System Requirements

The Peugeot 206 loses 172.54kJ of energy during this time period. To calculate the force that the car experiences, the same equation as 3.1 is used:

$$\text{Force} = \text{Mass} \times \text{Acceleration}$$

Using this equation, the force comes out as $1100/9.81$, which equals 112.13N. From here the power needed can be calculated using the following equation:

$$\text{Power} = \text{Force} \times \text{Velocity}$$

This gives $\text{Power} = 112.13\text{N} \times 18.33\text{m/s}$, which equals 2.06kW. From here, the time the deployment stage takes can be calculated from this equation:

$$\text{Time} = \text{Energy}/\text{Power}$$

From this, the time taken for deployment = $172.54 \times 10^3 / 2.06 \times 10^3$, which is equal to 83 seconds. However, this duration is longer than needed, so extra energy can be stored in the next recovery period. Once the deployment time was calculated, it was plotted on a graph.

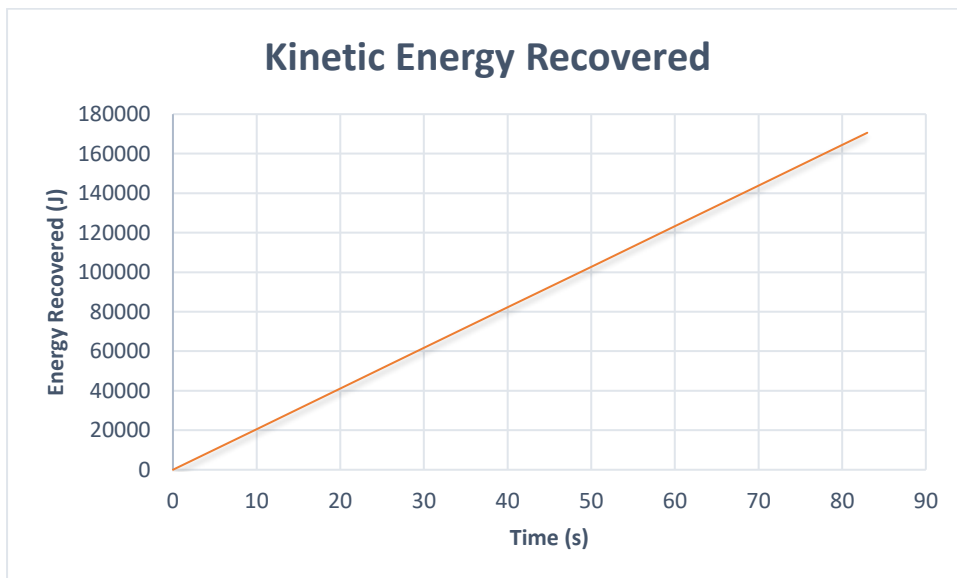


Figure 4-3 - Kinetic Energy Recovered over the deployment time

5 System Operation and Driving Variations

5.1 Operation

The Lead Acid battery has several cells each with two plates, one plate is lead whilst the other is lead dioxide. It also contains sulphuric acid electrolyte, and they typically have two volts per cell. When the battery is charging, in the deceleration phase, the sulphuric acid electrolyte goes from the negative to the positive plate of the cell. When the battery is discharging in the acceleration stage, the sulphuric acid electrolyte does the opposite and goes from the positive to the negative plate. Depending on the current flowing through the battery is how quickly the battery discharges and how quickly the Kinetic Energy is released to the wheel.

The battery will normally charge and discharge between 30% and 70% as this is the best use area. It means the most cycles can be done by the battery as this depth of discharge does not damage the battery as much as it will if it goes out of this range. As the battery is charging and storing energy in the deceleration stage, the efficiency of the battery decreases, whereas when the battery increases in efficiency as the Kinetic Energy is released.

With the regenerative braking system, the system will be in series. This is combined with the friction brakes. This system captures all available energy up to around 20% of the braking effort. This is then sent through a generator which then charges the Lead Acid battery.

5.2 Driving Variations

There are a few variations the driver will feel using the Kinetic Energy Recovery System when using the regenerative brakes. For example, there is an extra engine brake effect that the driver will feel when lifting off of the throttle. Sometimes it's enough of a deceleration that the driver will not feel the need to use the friction brakes (*How does regenerative braking work?* | Foray Motor Group [no date]). The driver will also notice a power boost on acceleration as the battery discharges.

5.3 Wheel Lock Speed

There are several steps to calculate the wheel lock speed. The first step is to calculate the force on the car under braking. The mass of the car is 1100 Kilograms and the highest rate of acceleration is 1.6 m/s^2 . The same equation is used as 3.1:

$$\text{Force} = \text{Mass} \times \text{Acceleration}$$

This gives the force as 1100×1.6 which equals 1760 Newtons. With the power of the system being stated in 4.3 as 2.06kW, the same equation used in 4.3 can be rearranged:

$$\text{Velocity} = \text{Power} / \text{Force}$$

This gives the velocity as $2.06 \times 10^3 / 1760$ which means the wheel lock speed is equal to 1.17m/s.

6 Conclusion

In conclusion, the Lead Acid battery combined with the regenerative braking system should be implemented successfully on the Peugeot 206. The system itself will add some weight to the vehicle however the operation of the Kinetic Energy Recovery System will increase fuel economy and reduce emissions.

The introduction of the system should decrease forces such as the acceleration force on the engine as the energy is deployed to the wheels. However, the overall tractive forces will increase with the added mass. The system itself should help improve the driveability, as the driver does not have to input as much under braking.

While the Lead Acid battery has high power density, the number of cycles the battery can do is quite low. However, if the depth of discharge is managed well, this should increase the systems lifetime. It is also more effective than other systems such as capacitors as they have a higher power density. The other advantage to having high power density means that it performs well in short bursts, which will be very effective in urban driving environments.

One other advantage of introducing the system is that as the Peugeot 206 is a low power car producing only 44kW, this system should increase the tractive power the car can produce when the battery is discharging and the deploying the recovery system.

7 References

Brussels, W., Francisco, S. and Mock, P. 2011. Development of a Worldwide Harmonized Light Vehicles Test Procedure (WLTP) ICCT contribution No. 4 (combined solution for vehicle test mass definition and inertia mass step-less approach). Available at: www.theicct.org [Accessed: 25 November 2025].

Energy density vs power density - Energy Education. [no date]. Available at: https://energyeducation.ca/encyclopedia/Energy_density_vs_power_density [Accessed: 26 November 2025].

How does regenerative braking work? | Foray Motor Group. [no date]. Available at: <https://www.foraymotorgroup.co.uk/news/how-does-regenerative-braking-work/> [Accessed: 27 November 2025].

Lead Acid, Lithium & LiFePO4 Battery Run Time Calculator. [no date]. Available at: <https://manlybattery.com/battery-tools-and-resources/lead-acid-lithium-lifepo4-battery-run-time-calculator/> [Accessed: 26 November 2025].

Modern Electric, Hybrid Electric, and Fuel Cell Vehicles Third Edition. [no date]

Peugeot 206 Hatchback 1.1 Style 3d specs & dimensions. [no date]. Available at: <https://www.parkers.co.uk/peugeot/206/hatchback-1998/11-style-3d/specs/> [Accessed: 27 October 2025].