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Kinetic Energy Recovery

Alternative Propulsion Systems (ACHA5010)

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December 2024

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1 Introduction

This report will investigate the feasibility of integrating a kinetic energy recovery system (KERS) into a 1974 Mk3 MG Midget. The analysis is conducted using the Worldwide Harmonised Light Vehicle Test Procedure (WLTP) as a basis for evaluating the vehicle's performance characteristics. The study focuses on calculating key parameters such as forces, energy, and power throughout the WLTP cycle to identify the possible recoverable energy. This data will be used to choose the specification and size of a suitable KERS system.

The integration of a KERS aims to enhance the vehicle's energy efficiency by recovering kinetic energy during braking events, which is then stored and reused to assist the internal combustion engine (ICE) during acceleration.

The report includes detailed calculations, graphical analyses, and technical specifications to explore the feasibility of integrating a KERS system in a classic car. It also examines the practical implications, including its impact on driver experience and a comparison with the vehicle's original setup.

1.1 Aims

- Evaluate the feasibility of integrating a Kinetic Energy Recovery system into a classic vehicle.
- Investigate how KERS can improve the vehicle's efficiency by using the lost energy during the braking phase.

1.2 Objectives

- Research the MG Midget's characteristics such as test mass, aerodynamic drag and other properties.
- Use the WLTP cycle to calculate the tractive and braking forces as well as energy consumption and recovery potential.
- Research suitable KERS technologies to retrofit into a classic vehicle.
- Analyse the efficiency of different KERS systems.
- Evaluate the impact of KERS on driver experience and vehicle energy efficiency.

2 Vehicle selection, specifications and data

The Mk3 MG Midget is a classic British sports car known for its compact size, lightweight design, and agile handling. Powered by the 1275cc Austin A-series engine, it offers a fun, performance-oriented driving experience. Its blend of classic styling and spirited performance has cemented its place in automotive history as an iconic small sports car.



Figure 1 - My 1974 Mk3 Midget a.k.a Moriarty.

Although the Mk3 MG Midget was produced before the introduction of both the New European Driving Cycle (NEDC) and the WLTP, it is interesting to explore the efficiency of a classic car. Will highlight the technological advancements and improvements in fuel efficiency that have occurred over time, offering a perspective on how modern vehicles have evolved in terms of performance and environmental impact.

Below are all the vehicle specifications used to gather the WLTP data.

Table 1 - Table of the specs and data to complete the WLTP calculations.

1974 Mk3 MG Midget Specs		
Kerb mass	742	kg
Gross vehicle mass	950	kg
Test mass	846	kg
Max velocity	165	km/h
Width	1394	mm
Height	1235	mm
Length	3496	mm
Estimated frontal area	1.43	m ²
Estimated drag coefficient	0.5	cd
Estimated drag area	0.714	m ²
Coefficient of Rolling resistance	0.01	Car tyres on tarmac, 0.007 - 0.015 (Lukasz Wargula et al. 2019)
Density of air @ 0m @15C	1.225	kg/m ³

(Worldwide Harmonised Light Vehicle Test Procedure / VCA [no date])

The Worldwide Harmonized Light Vehicle Test Procedure uses the test mass of a vehicle to calculate all its properties. The test mass is equal to the kerb mass plus 50% of the kerb mass subtracted from the vehicle gross mass (GVM) as shown in the equation below.

Equation 1 – Test mass

$$\text{Test mass} = \text{Kerb mass} + 0.5 \times (\text{GVM} - \text{Kerb mass})$$

3 Worldwide Harmonized Light Vehicles Test Procedure (WLTP)

The WLTP is a global standard for measuring the fuel consumption, CO₂ emissions, and pollutant emissions of light vehicles. It was introduced in 2017 replacing the New European Driving Cycle to provide more accurate, real-world data on vehicle performance. The WLTP tests vehicles under conditions that better reflect actual driving behaviour, including a wider range of speeds, acceleration, and driving conditions. (United Nations 2021; Transport Policy 2024)

The MG Midget falls under the WLTP Class 3, which is based on the vehicle’s power-to-mass ratio and maximum speed.

Table 2 - WLTP class 3 requirements

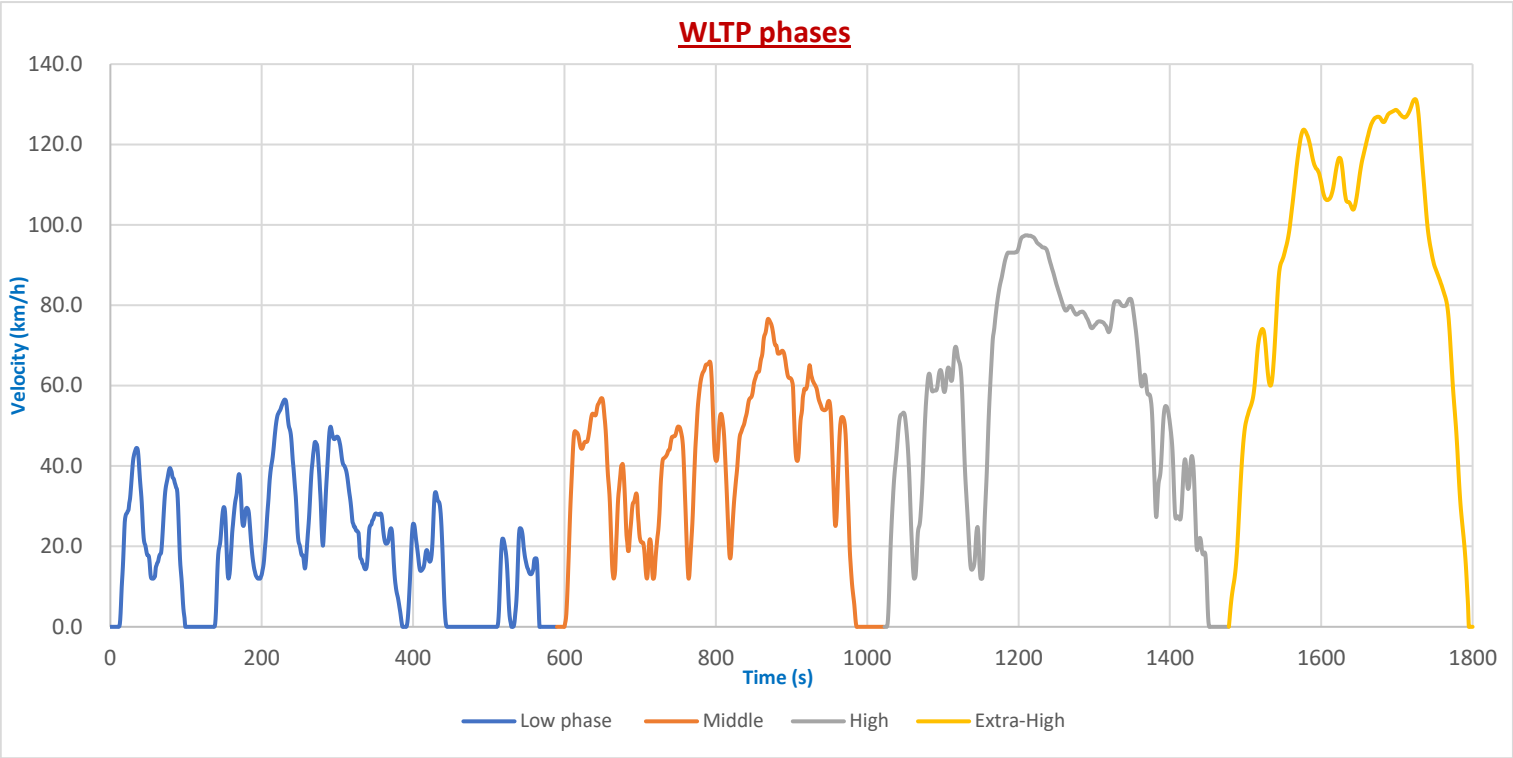
WLTP Class 3	
Required criteria	Mk3 MG Midget
PMR > 34 W/kg	PMR = 56.5 W/kg
If v max < 135 km/h, phase extra-high replaced by a repetition of low.	V max = 165km/h

Equation 2 - Power to mass ratio

$$PMR = \frac{Power\ (W)}{Test\ Mass\ (kg)}$$

$$PMR = \frac{47.800W}{846kg}$$

$$PMR \approx 56.5\ W/kg$$



Graph 1 - WLTP cycle of the MG Midget

The above graph shows the WLTP cycle of the MG Midget, the test cycle consists of four different driving phases:

- 1. **Low Speed:** Simulates urban driving with frequent stops and starts.
- 2. **Medium Speed:** Represents suburban driving with moderate acceleration and deceleration.
- 3. **High Speed:** Simulates highway driving with higher speeds.
- 4. **Extra High Speed:** Accounts for high-speed driving on roads like motorways

Table 3 - WLTP Class 3 cycle specifications

WLTP Class 3 cycle: Selected parameters									
Phase	Duration	Stop duration	Distance	p_stop	v_max	v_ave w/o stops	v_ave w/ stops	a_min	a_max
	s	s	m		km/h	km/h	km/h	m/s ²	m/s ²
Low	590	145	3095	24.6%	56.5	25.0	18.9	-1.47	1.47
Middle	433	47	4756	10.9%	76.6	44.4	39.5	-1.49	1.57
High	455	29	7162	6.4%	97.4	60.5	56.7	-1.49	1.58
Extra-High	323	6	8254	1.9%	131.3	93.7	92.0	-1.21	1.03
Total	1801	227	23266						

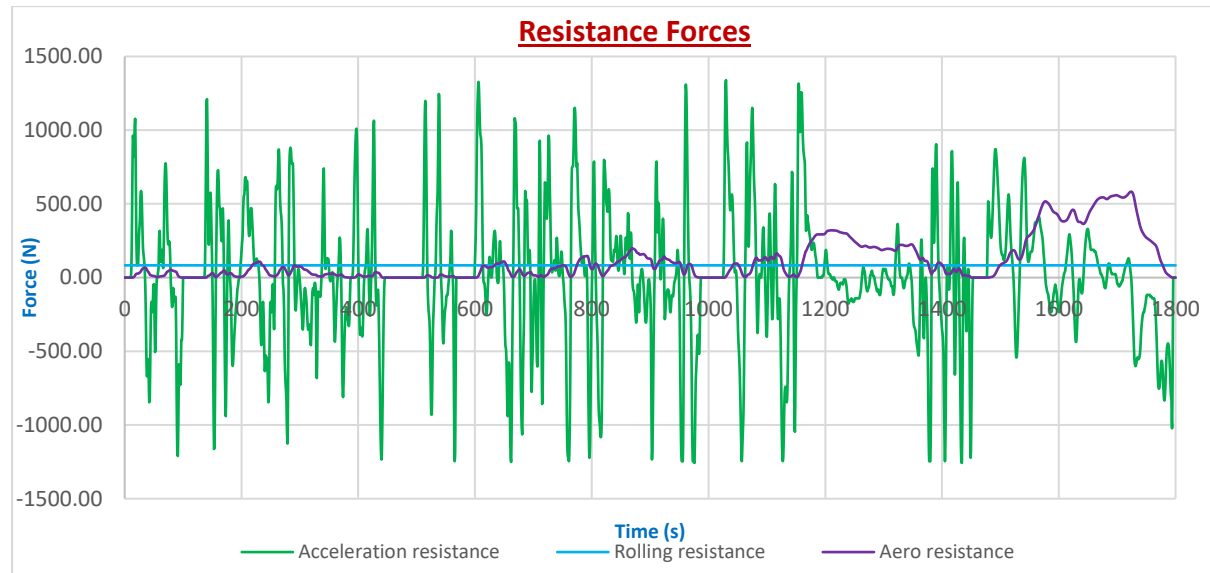
(Transport Policy 2024)

(United Nations 2021)

4 Spreadsheet Analysis

4.1 Inputs and Calculations

The graphs below were generated using data from the MG Midget and the WLTP cycle.



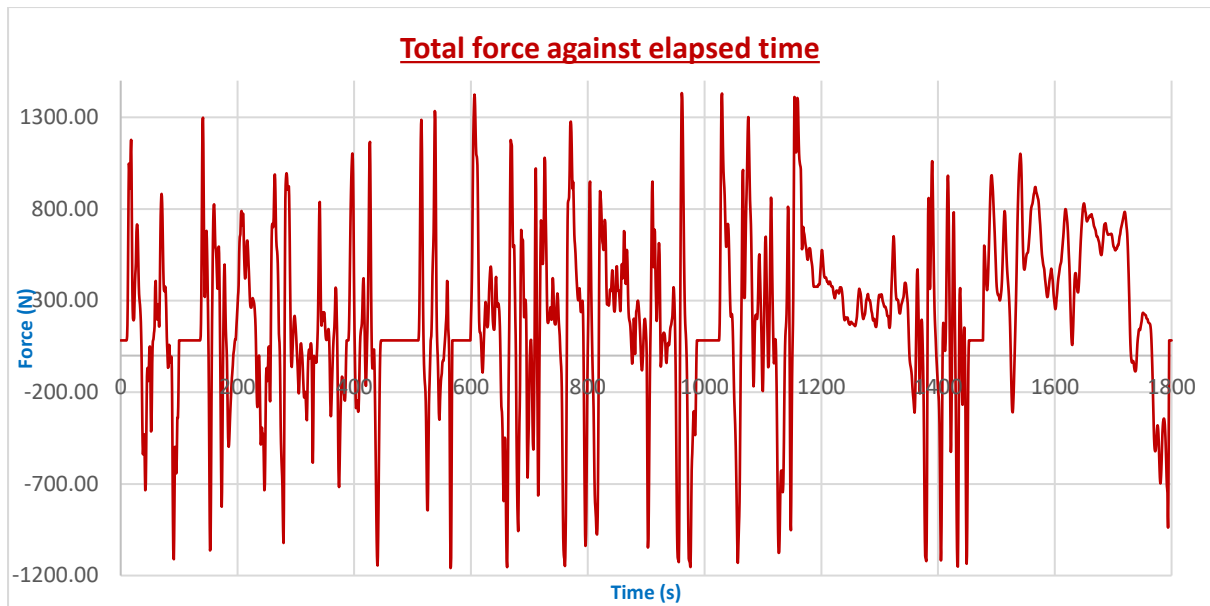
Graph 2 - Acceleration, Rolling and Aerodynamic resistance forces against time

The above graph shows the acceleration, rolling resistance, and aerodynamic resistance plotted against the time taken to complete the WLTP cycle.

The Rolling resistance is influenced by the MG Midget's test weight, with heavier vehicles requiring more energy to overcome tire friction. It directly impacts energy consumption, particularly at lower speeds.

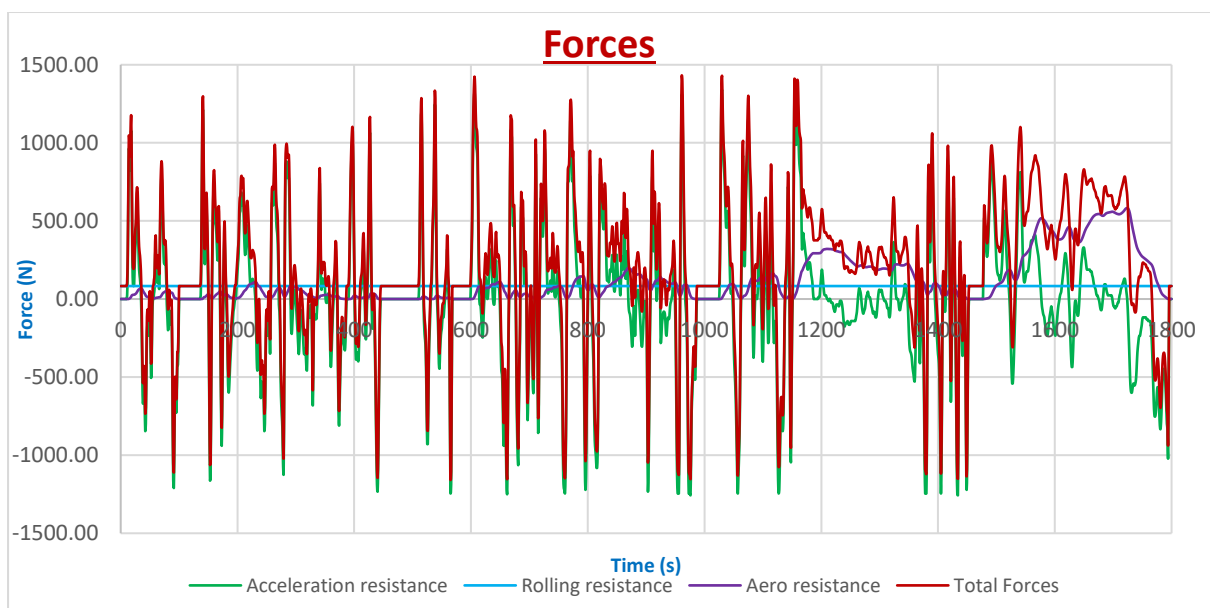
The Aerodynamic drag increases with the vehicle's speed and is a major factor at higher velocities.

The Braking resistance occurs during deceleration, converting kinetic energy into heat. While modern vehicles with KERS can recover this energy, the MG Midget dissipates it, increasing total energy consumption.



Graph 3 - The calculated total of the forces.

By combining these individual resistance forces, we can calculate the total forces acting on the vehicle, shown in the above graph.

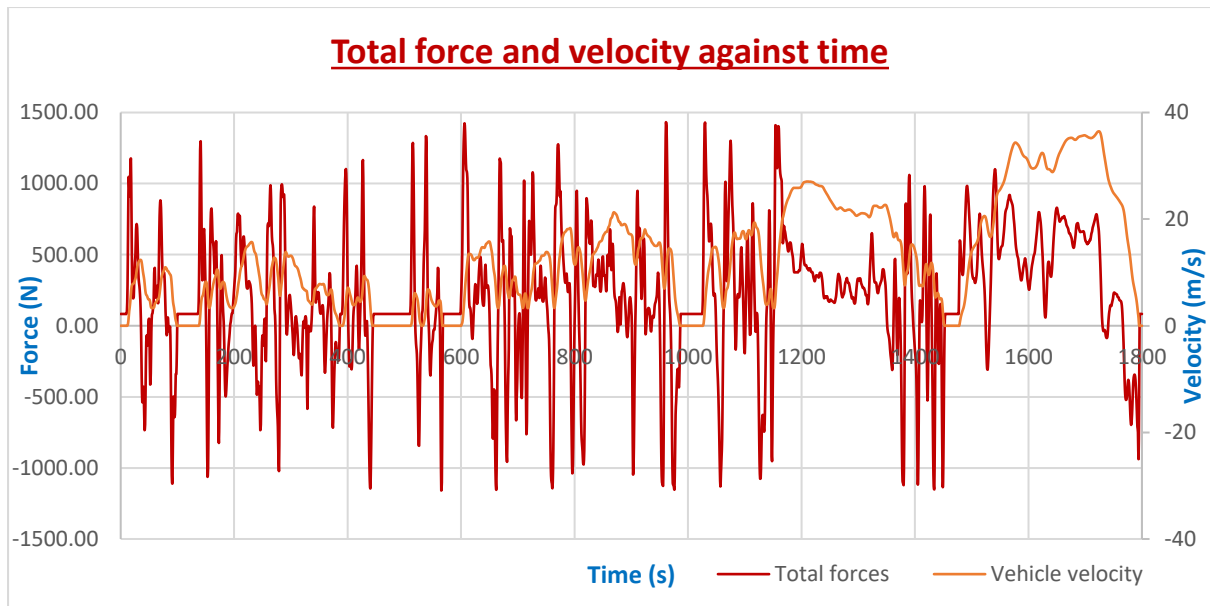


Graph 4 - All the Forces

The total forces graph is similar to that of the acceleration, highlighting the influence of the vehicle's mass on the forces acting on it. This demonstrates that the weight of the vehicle plays a crucial role in determining the overall resistance and energy required during the cycle.

Equation 3 - Acceleration resistance

$$\text{Acceleration resistance} = \text{mass} \times \text{acceleration}$$

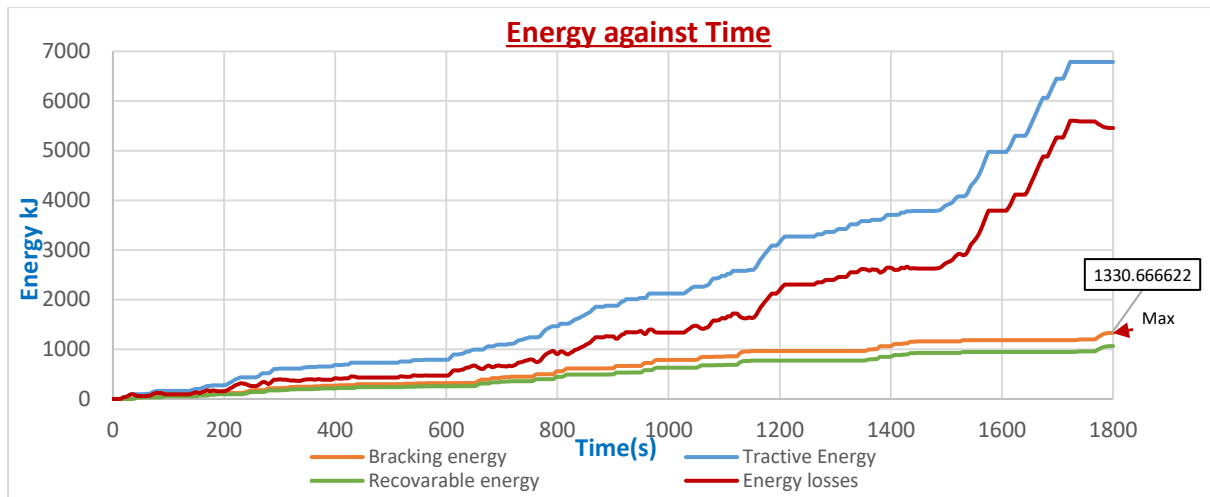


Graph 5 - Total force and Vehicle velocity against time.

Looking at the above graph that plots both force and vehicle velocity against time, velocity significantly influences the forces acting on the vehicle. This is particularly evident when comparing the total forces to the acceleration forces, as both graphs have a very similar shape. This relationship demonstrates that the energy of the vehicle is directly connected to the forces acting on it.

4.2 Outputs

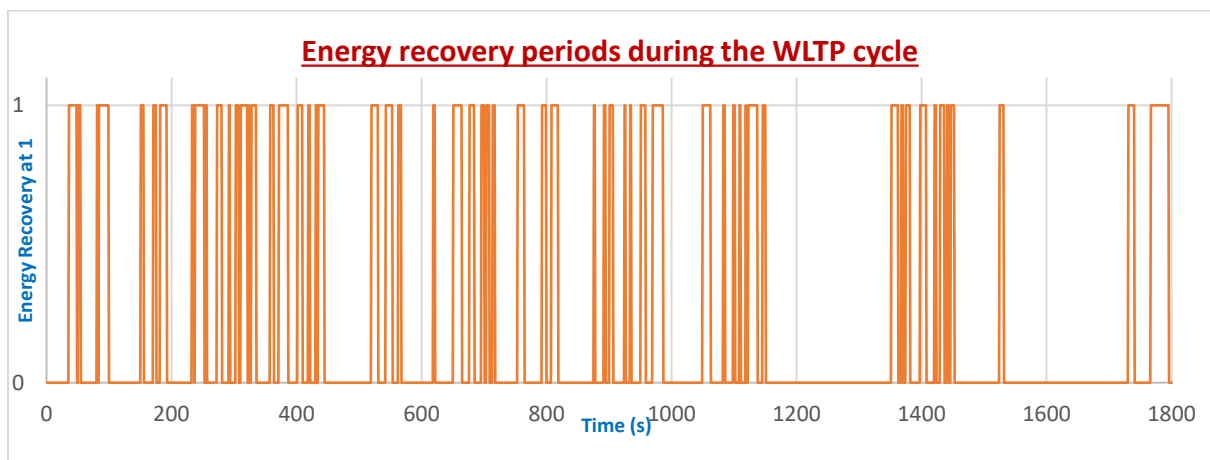
Using all the forces calculated and plotted above, the energy used during the cycle was then calculated. This included the tractive energy, which is required to move the vehicle forward, braking energy, which is generated during deceleration, the recoverable energy, which is the energy that can be recovered during braking, and the energy losses, which account for inefficiencies in the system. These energy calculations provide insight into the overall performance and potential for energy recovery within the vehicle's operational cycle.



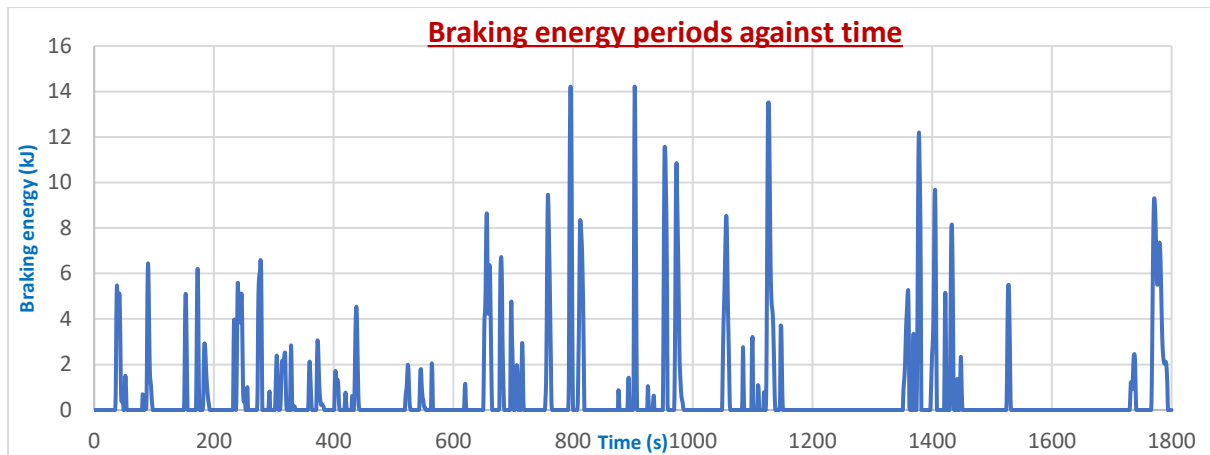
Graph 6 - The cumulative energies against the cycle time

When looking at the cumulative energies of the MG midjet during the WLTP cycle we can see that the tractive energy increases gently throughout phases one, two and three before rapidly increasing in the last phase. The final phase is when the vehicle is at its highest velocity of the test and the Internal Combustion Engine is working the hardest. All of this relates to the energy losses matching the tractive energy.

The recoverable energy has been determined using a KERS with an 80% efficiency rating.



Graph 7 - Energy recovery periods



Graph 8 - Braking Energy against time

The energy recovery periods can be determined using both the graphs above. The top one is a visualisation of when the MG is in a braking phase, this happens when the graph is equal to 1 on the y-axis and therefore when energy is being lost and can be recovered using a KERS system.

Looking at the second graph it can be determined that the maximum recoverable energy is 14.22kJ, this occurs twice during the cycle at the 796th and 903rd second.

This is important to consider when researching a suitable KERS system as if the possible regenerative power is higher than that of the system it can cause failure.

5 KERS specification

5.1 Types of KERS

There are several categories of Kinetic Energy Recovery Systems, each with unique designs and operational characteristics. These systems are designed to recover energy during braking phases, store it and then in line with the conventionally internal combustion engine use the energy during acceleration to help reduce engine usage and improve vehicle efficiency.

For the MG Midget, three systems were initially considered:

- **Mild Hybrid:** Recovers limited energy for auxiliary systems or small power boosts.
- **Full Hybrid:** Captures significant energy and utilizes it for electric-only propulsion or combined engine power.
- **Parallel Hybrid:** Combines the engine and motor outputs, with energy recovery integrated into the drivetrain.

Given the MG Midget's lightweight design and performance-oriented nature, Parallel Hybrid KERS is the most suitable configuration due to its balance of simplicity, efficiency, and ability to retrofit a system.

5.2 Comparison of KERS Options

5.2.1 Flywheel KERS

A Flywheel KERS mechanically stores kinetic energy in a high-speed flywheel during braking and releases it to assist acceleration via a transmission system.

Key Features:

Efficiency: Flywheel systems operate at ~80-90% efficiency, making them highly effective at energy recovery.

Energy Storage: Capable of storing 1-2 MJ of energy, suitable for short bursts.

Power Output: Provides a power output of 30-60 kW, enhancing performance during acceleration.

Advantages:

Lightweight and compact design.

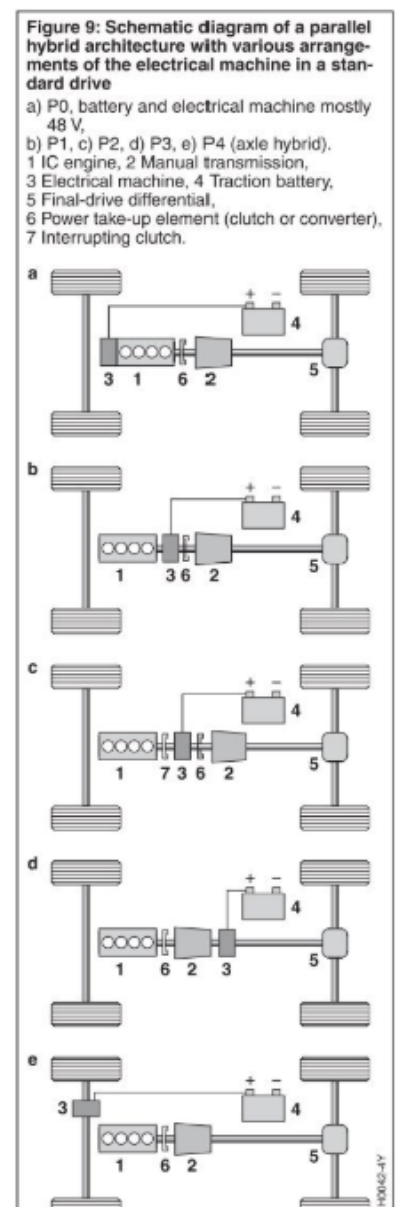


Figure 2 - Diagram of different parallel hybrid designs

Environmentally friendly, as it avoids chemical components.

Provides quick response for short energy bursts.

Disadvantages:

Limited energy storage for prolonged use.

Integration requires additional components, such as a planetary gear system or CVT, increasing complexity.

(Bosh Wiley 2022)

5.2.2 Supercapacitor-Based KERS

A Supercapacitor KERS converts braking energy into electrical energy, which is stored in supercapacitors for rapid discharge during acceleration.

Key Features:

Efficiency: Very high, at ~90-95%, due to minimal energy conversion losses.

Energy Storage: Can store up to 0.5 MJ, making it ideal for high-power demands.

Power Output: Delivers 50-100 kW, suitable for rapid energy cycles.

Advantages:

Lightweight and compact, adding minimal weight to the vehicle.

High power density allows for quick charge and discharge cycles.

Minimal maintenance, as it relies on fewer mechanical components.

Disadvantages:

Limited storage capacity for extended braking events.

Higher cost compared to flywheel systems due to advanced materials.

Table 3 - Comparison of a Flywheel KERS and Supercapacitor

Feature	Flywheel KERS	Supercapacitor KERS
Efficiency	80-90%	90-95%
Energy Storage	1-2 MJ	Up to 0.5 MJ
Power Output	30-60 kW	50-100 kW
Weight Impact	Low	Very Low
Integration Complexity	Medium	Low-Medium
Cost	Moderate	High
Best Application	Short bursts	Rapid high-power cycles

(John M. Miller 2010)

5.3 System Selection

The Parallel Hybrid Flywheel KERS was selected for its:

High efficiency and alignment with the MG Midget's lightweight, performance-driven design.

Ability to store sufficient energy for short bursts without adding significant weight or complexity.

Minimal reliance on advanced electronics, maintaining compatibility with the vehicle's classic design.

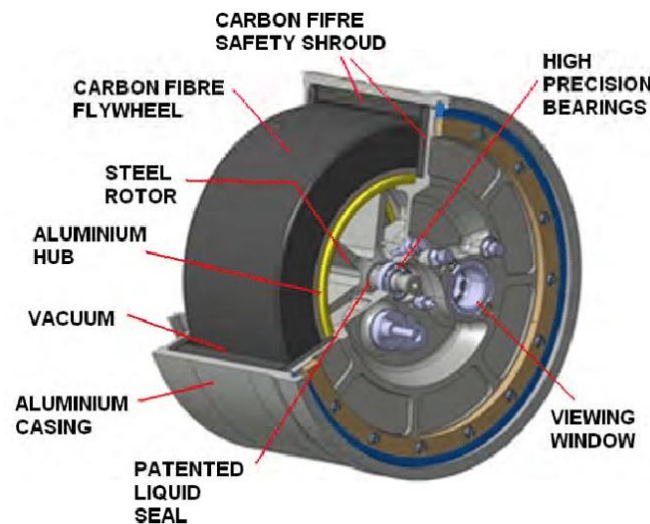


Figure 3 - A KERS flywheel

5.4 Integration of KERS into the MG Midget

The placement and configuration of the KERS system are critical for seamless integration into the vehicle. Three positioning options were considered:

Before the Gearbox:

Allows energy regeneration without engine braking by decoupling the engine via the clutch.

Simplifies energy transfer to the drivetrain.

After the Gearbox:

Directly connects to the wheels, reducing overall complexity.

However, it limits regeneration control when clutching.

On the Rear Differential:

Minimizes impact on the existing drivetrain layout.

Requires additional space and support structures.

Chosen Placement: The system will be positioned before the gearbox, with a clutch-to-engine configuration. This setup enables independent energy recovery during deceleration, improving efficiency without requiring engine braking.

5.5 Energy Analysis

Kinetic Energy Recovered: Approximately 80% of braking is recoverable.

Energy Losses: Included mechanical losses and system inefficiencies, with losses estimated at 10-15%.

Key Graphs:

Force vs. Time: Illustrates the relationship between vehicle velocity, acceleration, and resistive forces.

Cumulative Energy: Highlights energy demands across the cycle, including tractive energy increases and braking energy recovery potential.

5.6 Efficiency Analysis

The efficiency of the chosen system was evaluated with the following results:

Mechanical Losses: Estimated at 10-15%, primarily from drivetrain friction.

Energy Recovery: 70-80% of braking energy is reusable, reducing fuel consumption and emissions.

Table 4 - Efficiency analysis

Energy Metric	Value
Kinetic Energy Recovered	80% of braking energy
Mechanical Losses	10-15%
Net Energy Efficiency	70-75%

5.7 KERS conclusion

The Parallel Hybrid Flywheel KERS offers an optimal blend of efficiency, simplicity, and compatibility with the MG Midget's design. Positioned before the gearbox, it enables effective energy recovery and reuse, enhancing vehicle performance without significantly altering its classic character. This system demonstrates the feasibility of retrofitting classic cars with modern energy recovery technologies, bridging the gap between legacy design and contemporary efficiency standards.

(Iqbal Husain 2021)

(Mehrdad Ehsani et al. 2019)

(John M. Miller 2010)

6 Practical implications

The driver experience with a Flywheel KERS system fitted to the MG Midget would differ significantly from the standard internal combustion engine (ICE) setup. With the KERS in place, drivers may notice smoother deceleration as braking energy is diverted to the flywheel rather than dissipated entirely as heat. During acceleration, the flywheel system can provide additional power, offering quicker throttle response and improved performance, especially during short bursts of speed. However, the system might introduce a faster natural coast-down effect, as energy regeneration increases drag on the drivetrain during deceleration, which could feel different from the more gradual slowdown of a traditional ICE vehicle. Drivers may also hear a slight mechanical whirring sound from the flywheel at high speeds, which is absent in the standard configuration. Additionally, the system's engagement and disengagement, though typically seamless, could result in subtle changes in drivetrain behaviour that might feel unfamiliar to those accustomed to the original setup. Overall, while the KERS enhances performance and efficiency, it introduces subtle operational differences that can slightly alter the driving dynamics compared to the traditional ICE-only experience.

7 Conclusion

This report investigated the feasibility of integrating a Kinetic Energy Recovery System (KERS) into a 1974 Mk3 MG Midget, focusing on improving energy efficiency through the recovery and reuse of kinetic energy during braking. Using data derived from the WLTP cycle, key vehicle forces and energy metrics were calculated, providing a comprehensive understanding of the vehicle's performance and energy consumption.

Through the analysis of various KERS options, including Flywheel and Supercapacitor-based systems, the Parallel Hybrid Flywheel KERS was identified as the most suitable choice for the MG Midget. This system offers high efficiency, minimal weight impact, and compatibility with the vehicle's lightweight and performance-focused design. Placing the system before the gearbox with a clutch-to-engine configuration ensures effective energy recovery and reuse without significantly altering the car's original character.

The results of this study highlight the potential benefits of retrofitting classic vehicles with modern energy recovery technologies, bridging the gap between legacy design and contemporary efficiency advancements. While challenges such as integration complexity and system tuning must be addressed, the implementation of a KERS in a vehicle like the MG Midget demonstrates a practical and effective way to improve fuel efficiency and sustainability in classic automotive designs.

8 References

Bosh Wiley. 2022. *Automotive Handbook 11th Edition*. Bosh . pp. 996–1008.

Iqbal Husain. 2021. *Electric and Hybrid Vehicles*. Third. CRC Press.

John M. Miller. 2010. *Propulsion Systems for Hybrid Vehicles*. 2nd ed. The Institution of Engineering and Technology.

Lukasz Wargula, Bartosz Wieczorek and Mateusz Kukla. 2019. *The determination of the rolling resistance coefficient of objects equipped with the wheels and suspension system – results of preliminary tests* . Poznan.

Mehrdad Ehsani, Yimin Gao, Stefano Longo and Kambiz Ebrahimi. 2019. *Modern Electric, Hybrid Electric and Fuel Cell Vehicles*. Third. CRC Press.

Transport Policy. 2024. *International: Light-duty: Worldwide Harmonized Light Vehicles Test Procedure (WLTP)*.

United Nations. 2021. *Addendum 153 – UN Regulation No. 154*.

Worldwide Harmonised Light Vehicle Test Procedure / VCA. [no date]. Available at:

<https://www.vehicle-certification-agency.gov.uk/fuel-consumption-co2/the-worldwide-harmonised-light-vehicle-test-procedure/> [Accessed: 1 December 2024].

9 Appendices

Table 5 - Assumptions

Assumptions		
Drag coefficient	0.5 cd	The drag coefficient has been assumed for the MG Midget, as cars from the 1970s typically didn't have official values. Aerodynamics was not a priority then, with design focused on styling, cost, and mechanical performance, and limited access to wind tunnel testing.
Coefficient of rolling resistance	0.01	(Lukasz Wargula et al. 2019)
BSFC	280 to 320 g/kWh	It is almost impossible to find details on the brake specific fuel consumption of the MG Midget due to its age. The engine design using carburetors also makes it difficult to get accurate figures. The BSFC has therefore been assumed to be within this region with the optimal being 280 g/kWh at peak torque.
Frontal area	1.4m ²	The frontal area of the car has been calculated using the width and height dimensions. This is not an accurate result however again due to the age of the car it is very difficult to find an exact value.

Although it is stated that the maximum velocity of the MG Midget with the 1275cc A-series engine is 165km/h I would consider adding a 5th gear and removing the windscreen in order to reduce the drag to attain these speeds.