

University of Wales Trinity Saint David

Wales Institute of Science and Art



Prifysgol Cymru

Y Drindod Dewi Sant

University of Wales

Trinity Saint David

Kinetic Energy

Recovery Systems

Alternative Propulsion Systems - ACHA4005

Oliver Gillson

2212405

September 2024

Contents

1	Introduction	1
2	Dynamic Characteristics	2
2.1	Test Mass Calculation	3
2.2	Aerodynamic Drag Calculation	3
2.3	Frontal Area Calculation	3
3	WLTP	4
4	Plots.....	5
4.1	Tractive Forces.....	5
4.2	Driving Power	6
4.3	Tractive & Braking Energy	7
4.4	Cumulative Energy.....	8
5	Kinetic Energy Recovery System	9
6	Component Specification.....	10
6.1	Supercapacitor.....	10
6.2	System Efficiencies	11
6.3	System Ratings (Safety Margin).....	11
6.4	Motor Generator	12
6.5	Invertor Unit	12
6.6	Energy Storage System	13
7	Kinetic Energy Recovered	14
8	System Operation	15
8.1	Practicality	16
9	Assumptions made.....	17
9.1	Constant Component Efficiencies:	17
9.2	Vehicle and Rider Mass	17
9.3	Energy Recovery Potential.....	17
9.4	Test Conditions	17
9.5	Losses.....	17
9.6	ESS Values.....	18
10	Conclusion.....	19
11	References	20

Table 1: Nomenclature Table.....	ii
Table 2: Ducati Panigale 1199 dynamic characteristics.....	2
Table 3: Data from low and high-speed runs.....	2
Figure 1: Frontal area in a sat-up braking position.....	3
Figure 2: WLTP cycle categorisation (DieselNet).	4
Figure 3: Class 3b cycle details (DieselNet).....	4
Figure 4: Tractive Forces vs. Time.....	5
Figure 5: Total Tractive Forces vs. Time.....	5
Figure 6: Driving Power vs. Time.....	6
Figure 7: Tractive Energy for Different Cycles vs. Time.	7
Figure 8: Braking Energy for Different Cycles vs. Time.	7
Table 4: Braking event data.	7
Table 5: Braking energy & power data.	7
Figure 9: Cumulative Tractive & Braking Energy vs. Time.	8
Table 6: Cumulative energy data.	8
Figure 10: Flow diagram of KER System.....	9
Table 7: Supercapacitor Values.....	10
Table 8: System efficiencies.....	11
Table 9: System ratings with safety margin considered.	11
Figure 11: Cumulative Energy & Energy Returned vs. Time.	14

Table 1: Nomenclature Table.

Symbol	Meaning	Unit
δ	Rotational Inertia Factor	
m	Mass	kg
T_m	Test Mass	kg
K_m	Kerb Mass	kg
C_d	Aerodynamic Drag Coefficient	
A_r	Aerodynamic Resistance	N
ρ	Air Density	Kg/m ³
A_f	Frontal Area	m
v	Velocity	m/s
F_A	Accelerating Forces	N
a	Acceleration	m/s ²
F_D	Drag Forces	N
R_R	Rolling Resistance	N
f_r	Rolling Resistance Coefficient	
g	Gravitational Acceleration	m/s ²
W_m	Wheel Mass	kg
W_r	Wheel Radius	m

1 Introduction

This report examines the application of a Kinetic Energy Recovery System (KERS) on a Ducati Panigale 1199. KERS captures kinetic energy otherwise lost during braking and converts it into usable power, improving fuel efficiency and reducing emissions. The report evaluates the feasibility of integrating KERS into the Panigale, analysing its benefits and limitations.

Key sections include an overview of the Ducati's dynamic characteristics, such as aerodynamic drag, rolling resistance, and mass distribution. Energy calculations and visualisations highlight tractive forces, braking energy, and cumulative energy losses, providing insights into recovery potential. The design and specifications of KERS components, including the motor-generator unit, supercapacitor energy storage system, and inverter, are detailed, focusing on their efficiency and safety margins.

Practical challenges, such as added weight, space constraints, and limited energy recovery during intense braking, are discussed. The report highlights trade-offs between environmental benefits and potential performance compromises.

2 Dynamic Characteristics

The dynamic characteristics of the 2013 Ducati Panigale 1199 are outlined in Table 2. According to the owner's manual (Ducati, 2012), the kerb mass includes all operational fluids, and a fuel tank filled to 90% capacity. The rolling resistance coefficient was sourced from Vitore's Motorcycle Dynamics (page 41). Table 3 provides data derived from both low-speed and high-speed tests, which were used to calculate the aerodynamic and rolling resistances.

Table 2: Ducati Panigale 1199 dynamic characteristics.

Ducati Panigale 1199	
Kerb Mass (kg)	188
Test Mass (kg)	288
Power (W)	140500
Power/Mass Ratio (W/kg)	747.34
Max Velocity (mph)	185
Max Velocity (km/h)	298
Max Velocity (m/s)	82.7
Rolling Resistance Coefficient	0.02
Coefficient of Aerodynamic Drag	0.70
Aero Resistance (N)	218.29
Frontal Area (m ²)	0.48
Mean Velocity (m/s)	32.665
Rolling Resistance	56.506
Wheel Mass (kg)	10
Wheel Radius (m)	0.323
Rotational Inertia Factor	1.043

Table 3: Data from low and high-speed runs.

Low Speed Run		High Speed Run	
dt (s)	40.99	dt (s)	20.30
dv (m/s) (deceleration)	23.94	dv (m/s) (deceleration)	27.24
Resistance (N)	168.2	Resistance (N)	386.48
V1 (km/h)	93.56	V1 (km/h)	166.63
V1 (m/s)	25.99	V1 (m/s)	46.29
V2 (Km/h)	7.38	V2 (Km/h)	68.56
V2 (m/s)	2.05	V2 (m/s)	19.04

2.1 Test Mass Calculation

Test mass can be determined using Equation 1 where K_m is the vehicle kerb mass, 75kg represents rider mass and 25kg represents baggage mass.

$$T_m = K_m + 75kg + 25kg \quad (1)$$

2.2 Aerodynamic Drag Calculation

The Aerodynamic Drag Coefficient is found using Equation 2 where A_r is aerodynamic resistance, ρ is the density of air ($1.225kg/m^3$), A_f is frontal area and v is velocity.

$$C_d = \frac{2 \cdot A_r}{\rho \cdot A_f \cdot v^2} \quad (2)$$

2.3 Frontal Area Calculation

Frontal area is gathered by obtaining a head on image of a rider in an upright position to imitate the position when in a braking moment (figure 1). The image is imported into SolidWorks and perimeter defined so a solid object can be extruded and from this the area can be determined.

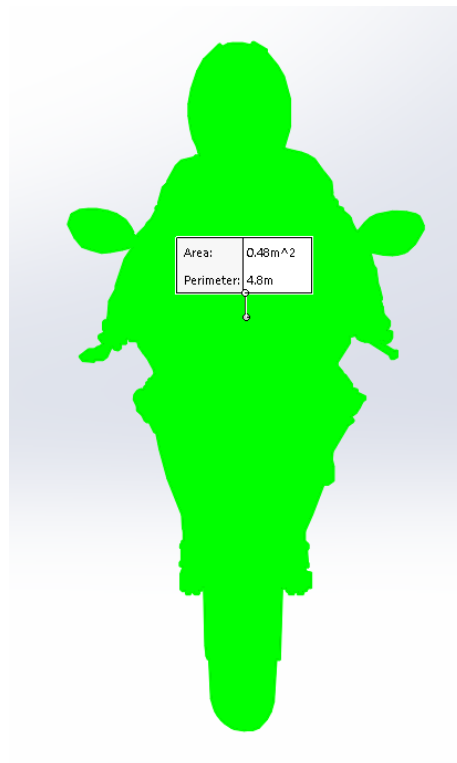


Figure 1: Frontal area in a sat-up braking position.

3 WLTP

The Ducati is categorised as a Class 3 vehicle, defined by its high power-to-mass ratio, which exceeds the threshold of 34 W/kg. Specifically, it achieves a power-to-mass ratio of 747.32 W/kg. It is further subcategorised into Class 3b due to its maximum velocity being greater than 120km/h. Figure 2 details max velocity and power-to-weight ratios, figure 3 specifics cycle details.

Category	PMR, W/kg	v_max, km/h	Speed Phase Sequence
Class 3b	PMR > 34	v_max ≥ 120	Low 3 + Medium 3-2 + High 3-2 + Extra High 3
Class 3a		v_max < 120	Low 3 + Medium 3-1 + High 3-1 + Extra High 3
Class 2	34 ≥ PMR > 22	-	Low 2 + Medium 2 + High 2 + Extra High 2
Class 1	PMR ≤ 22	-	Low 1 + Medium 1 + Low 1

Figure 2: WLTP cycle categorisation (DieselNet).

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
Class 3b (v_max ≥ 120 km/h)									
Low 3	589	156	3095	26.5%	56.5	25.7	18.9	-1.47	1.47
Medium 3-2	433	48	4756	11.1%	76.6	44.5	39.5	-1.49	1.57
High 3-2	455	31	7162	6.8%	97.4	60.8	56.7	-1.49	1.58
Extra-High 3	323	7	8254	2.2%	131.3	94.0	92.0	-1.21	1.03
Total	1800	242	23266						

Figure 3: Class 3b cycle details (DieselNet).

4 Plots

The plots detailed below help to visualise forces, power and energy data extracted from the WLTP cycle.

4.1 Tractive Forces

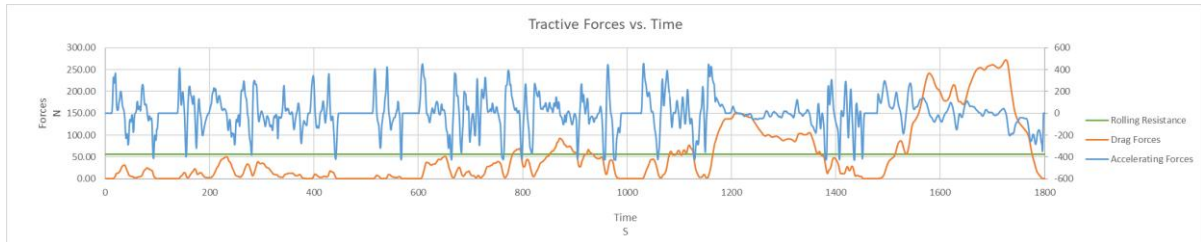


Figure 4: Tractive Forces vs. Time.

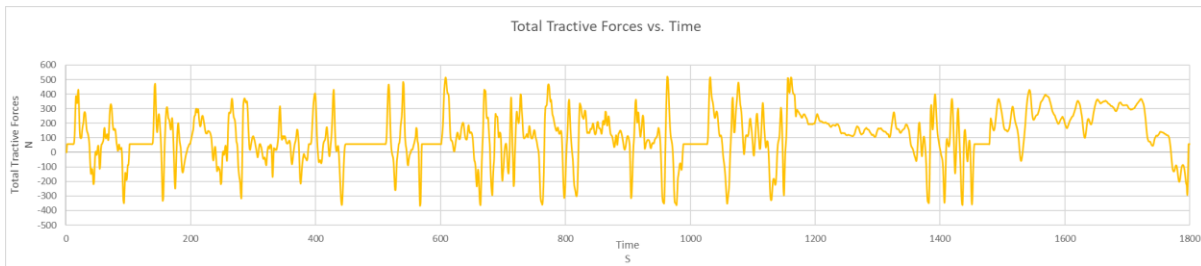


Figure 5: Total Tractive Forces vs. Time.

Figure 4 shows forces acting on the vehicle over the cycle. Accelerating forces are calculated using Equation 3, drag forces using Equation 4 and rolling resistance using Equation 5.

$$F_A = T_m \cdot a \quad (3)$$

$$F_D = \frac{1}{2} \rho C_d A_f v^2 \quad (4)$$

$$R_R = T_m \cdot R_c \cdot g \quad (5)$$

4.2 Driving Power

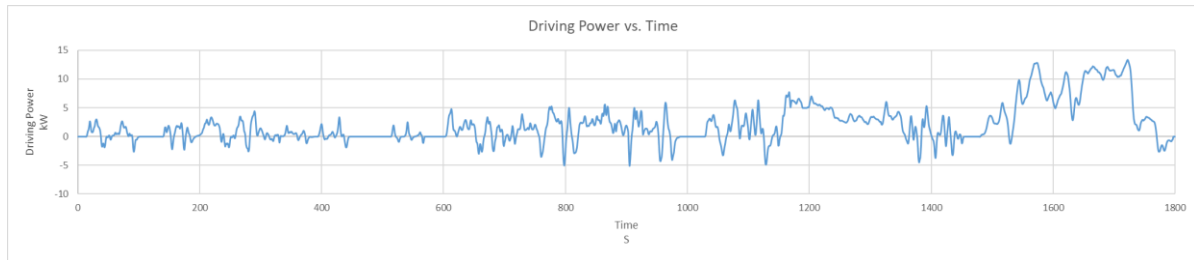


Figure 6: Driving Power vs. Time.

Driving power is calculated using Equation 6 where v is vehicle speed (m/s), m is vehicle mass (kg), g is gravity at 9.81 m/s^2 , f_r is tyre rolling resistance coefficient, ρ is air density of 1.225 kg/m^3 , C_D is the aerodynamic drag coefficient, A is the frontal area, δ is the rotational inertia factor (Equation 7) and a is the vehicle acceleration in m/s^2 .

$$P_d = \frac{v}{1000} \left(mgf_r + \frac{1}{2} \rho C_D A v^2 + m \delta a \right) \quad (6)$$

$$\delta = W_m \cdot W_r^2 \quad (7)$$

4.3 Tractive & Braking Energy

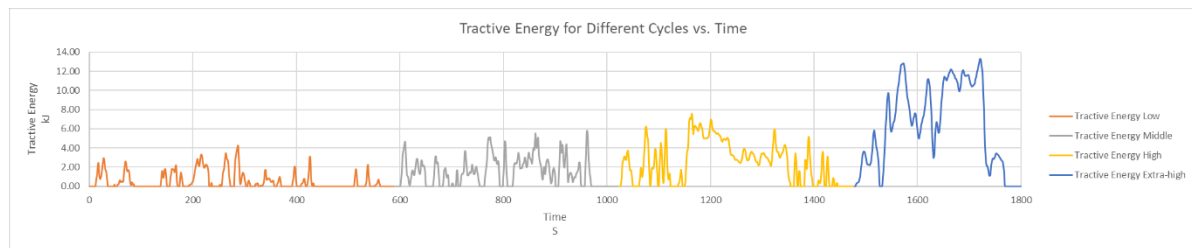


Figure 7: Tractive Energy for Different Cycles vs. Time.

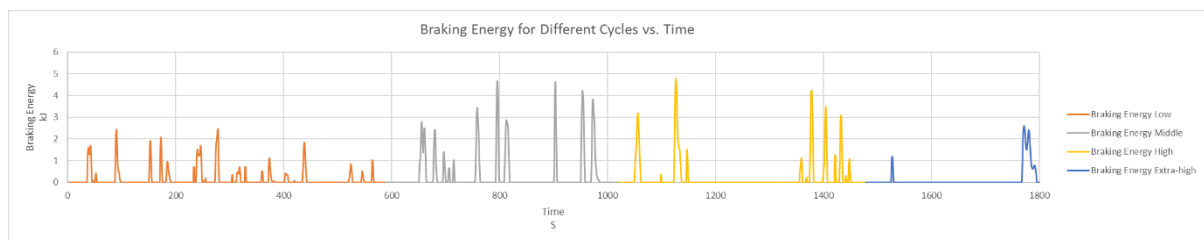


Figure 8: Braking Energy for Different Cycles vs. Time.

Tractive and braking energy are extracted from driving energy (derived from integrating driving power over time elapsed). These plots provide insight into energy expended during accelerating and braking moments.

Table 4: Braking event data.

Braking Events	
Total Braking Time (s)	342
Braking Events	47
Average Braking Event Period (s)	7.28
Maximum Braking Energy (kJ)	38.49

Table 5: Braking energy & power data.

Braking Energy & Power	
Total Braking Energy (kJ)	404.03
Maximum Braking Energy (kJ)	38.49
Average Braking Power (kW)	5.29

Using data gathered from braking event and energy calculations the average braking energy can be determined using Equation 8.

$$\text{Average Braking Energy} = \frac{\text{Maximum Braking Energy}}{\text{Average Braking Event Period}} \quad (8)$$

This figure allows for accurate sizing of KER system components.

4.4 Cumulative Energy

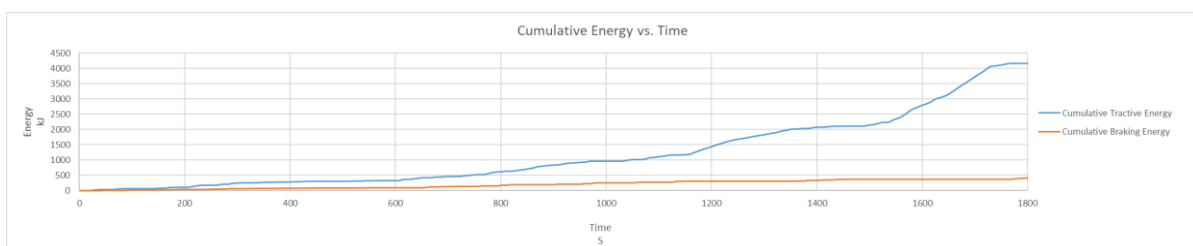


Figure 9: Cumulative Tractive & Braking Energy vs. Time.

The cumulative energy plotted above is divided into its respective components. As expected, cumulative tractive energy values are significantly higher than cumulative braking energy values. This disparity arises from the substantial energy required to accelerate the vehicle to the necessary speeds throughout the cycle. The difference between cumulative tractive and braking energy represents the losses incurred during the cycle (as shown in Table 6), emphasising the significant amount of kinetic energy dissipated.

Table 6: Cumulative energy data.

Energy (kJ)	
Total Tractive Energy	4158.52
Total Braking Energy	404.03
Total Energy Losses	3754.49

5 Kinetic Energy Recovery System

An electrical regenerative braking system has been chosen to enhance energy efficiency by converting kinetic energy into electrical energy during deceleration. This recovered energy is stored in supercapacitors, which offer high power density and rapid charge-discharge capabilities, making them ideal for capturing short bursts of energy. The stored energy is later used to assist in acceleration, reducing the load on the internal combustion engine and improving overall performance. Figure 10 illustrates a simplified schematic of the system, highlighting the flow of energy from the motor-generator unit to the energy storage system and back to the drivetrain during acceleration.

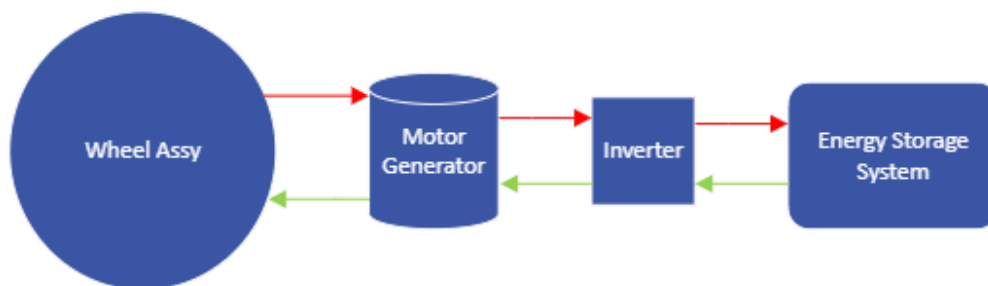


Figure 10: Flow diagram of KER System

6 Component Specification

6.1 Supercapacitor

Table 7: Supercapacitor Values

Supercapacitor Values	
Max Voltage (V)	100
Min Voltage (V)	50
Average Voltage (V)	75
System Current (I)	70.53
Capacitance (F)	10.26
Max Cell Voltage (V)	2.7
Required Cells	38
Cell Capacitance (F)	390.03
Energy Storage (kJ)	38.49

The provided supercapacitor values reflect an energy storage system tailored to the energy demands extracted from the WLTP cycle. With a total system energy storage capacity of 38.49kJ and a capacitance of 10.26F, the design ensures efficient charge and discharge cycles. The configuration of 38 cells, each rated at 2.7V and 390.03F, meets the maximum voltage requirement of 100V while maintaining optimal energy density and reliability. These values balance performance with safety and are suitable for high frequency cycling typical in regenerative braking systems.

6.2 System Efficiencies

Table 8: System efficiencies.

Motor Generator Unit (MGU)	
Max Power Rating (kW)	5.29
Average RPM Range	6000
Torque (Nm)	8.42
Efficiency (89.5%)	0.90
Invertor Unit	
Efficiency (90%)	0.9
Energy Storage System (ESS)	
Max Capacity (kJ)	38.49
Efficiency (95%)	0.95
Overall Efficiency (%)	
0.59	

6.3 System Ratings (Safety Margin)

Table 9: System ratings with safety margin considered.

MGU System Ratings	
Power (kW)	8
Torque (Nm)	10
Voltage (V)	120
Current (I)	85
Invertor System Ratings	
Power (kW)	7
Voltage (V)	120
Current (I)	85
ESS System Ratings	
Power (kW)	7
Capacitance (F)	12
Voltage (V)	120
Current (I)	85

The MGU, inverter, and ESS are designed with a 20-30% safety margin across all parameters to ensure reliable performance under varying conditions. The MGU's 8kW and 10Nm ratings, the inverter's 7kW and 85A ratings, and the ESS 12F capacitance and 120 V voltage all incorporate this margin, allowing for safe handling of transient peaks, voltage fluctuations, and thermal loads. This consistent safety margin enhances the system's resilience to electrical, thermal, and mechanical stresses, ensuring reliability and extended operational life.

6.4 Motor Generator

A brushless DC motor (BLDC) has been selected as the motor-generator for this system, chosen for its ability to efficiently provide power to the wheels while also converting kinetic energy into electrical energy during regenerative braking. According to Lu (2016), EPA efficiency standards indicate that motors producing 10 horsepower (hp) should achieve efficiencies of 89.5%. Based on these standards and the specific requirements of the system, the MGU has been designed with a maximum rating of 8kWh (10hp) to meet performance demands and to account for operational safety margins. With this configuration, and in line with EPA standards, it is reasonable to assume that the MGU will operate with an efficiency rating of approximately 89.5%. This high level of efficiency ensures that the MGU can effectively balance power delivery and energy recovery, optimising the vehicle's overall performance and energy usage.

6.5 Inverter Unit

An inverter unit will be employed to manage the conversion between DC and AC current, ensuring seamless energy flow within the system. During regenerative braking, the inverter converts the DC energy generated by the motor-generator into AC energy for storage in the energy storage system (ESS). Conversely, during acceleration, the inverter converts stored AC energy back into DC to power the motor-generator. The efficiency of the inverter unit plays a critical role in minimising energy losses during these conversions.

According to Blum and Riensche (2009), low-power inverters typically achieve efficiencies ranging from 85% to 90%, while high-power and high-input voltage inverters can achieve efficiencies as high as 96%. For this system, the inverter unit efficiency has been conservatively set at 90%, reflecting a balance between achievable performance and operational reliability. This ensures that the inverter effectively supports the energy flow between the motor-generator and the ESS while maintaining minimal energy loss, contributing to the overall efficiency of the regenerative braking and power delivery system.

6.6 Energy Storage System

A Super Capacitor Energy Storage System (SCESS) has been integrated into the design to enhance the overall energy management of the system. Super capacitors are characterised by their large effective surface area, enabling a dense and efficient energy storage solution. Their ability to handle high charge and discharge currents makes them particularly suitable for applications requiring rapid energy transfer, such as regenerative braking systems. Additionally, they offer the advantages of decreased maintenance requirements and an extended operational lifespan, making them a reliable and durable component of the energy storage infrastructure.

When paired with an inverter unit, the efficiency of the energy storage and retrieval process can exceed 95%, as highlighted by Zhong et al. (2016). This high level of efficiency ensures minimal energy loss during the conversion and transfer of energy between the MGU and the SCESS, further optimising the system's performance.

7 Kinetic Energy Recovered

Figure 10 illustrates the cumulative braking energy, and the energy returned to the wheels over time. The orange line represents the cumulative braking energy, which steadily increases as the vehicle undergoes multiple braking events throughout the measured period. The green line shows the energy returned to the wheels through energy gained via regenerative braking, which grows at a slower rate, reflecting the efficiency of energy recovery. While there is a consistent gap between the two lines, indicating energy losses during the conversion and storage processes, the upward trend of both lines demonstrates the regenerative braking system's contribution to energy recovery over time. This visualisation highlights the system's ability to reclaim a portion of the kinetic energy generated during braking, albeit with some unavoidable losses due to system limitations.

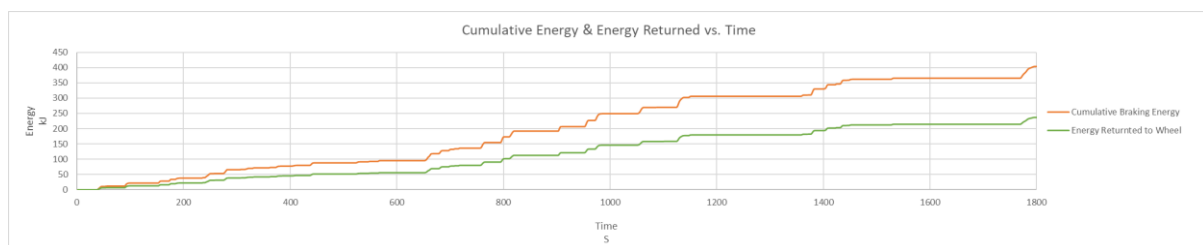


Figure 11: Cumulative Energy & Energy Returned vs. Time.

8 System Operation

The regenerative braking system operates by capturing and reusing energy that is typically wasted during braking. As illustrated in Figure 11, when the vehicle slows down, the MGU acts as a generator, converting the vehicle's kinetic energy into electrical energy. This energy is then passed through an inverter and further onto the ESS for later use. This process allows the vehicle to recover and reuse energy efficiently, contributing to improved fuel economy and reduced emissions.

One key feature of this system is the self-braking effect introduced by regenerative braking components. During deceleration, the MGU and wheel assembly work together to recover kinetic energy, resulting in a braking sensation similar to engine braking. Drivers may notice an increased resistance when coasting, as some of the vehicle's kinetic energy is being converted into usable electrical energy rather than dissipated as heat. This contrasts with the behaviour of conventional internal combustion engine vehicles, where coasting typically involves minimal resistance.

In addition to enhancing energy recovery during deceleration, the system also improves performance during acceleration. The energy stored in the ESS from previous braking events can be used by the MGU to provide a power boost, reducing the demand on the internal combustion engine. This can result in smoother and more responsive acceleration, further enhancing the driving experience.

The design of the regenerative braking system assumes seamless integration with the vehicle's traditional friction brakes to ensure safety and comfort. Energy recovery efficiency depends on various factors, such as driving patterns, vehicle speed, and road conditions. The ESS must also have sufficient capacity and reliability to store and deliver the recovered energy effectively.

8.1 Practicality

While KER systems demonstrate considerable promise in improving energy efficiency and reducing fuel consumption, their practicality in a high-performance sports bike such as the Ducati Panigale 1199 raises some valid concerns. These motorcycles are engineered with a strong emphasis on power, agility, and performance, making the integration of additional systems, like KERS, potentially counterproductive to their primary design objectives.

The first challenge is the added weight. KERS components, including the MGU, inverter, and ESS, significantly increase the bike mass. This compromises the balance required for sharp handling and rapid acceleration that define the sports bike. Even with advancements in lightweight materials, the weight penalty could adversely affect the motorcycle's dynamics, such as cornering performance and braking stability.

Additionally, the space constraints on a compact sports bike make it difficult to install a KER system without extensive design modifications. Unlike larger vehicles, motorcycles have limited room for components, and integrating KERS may require sacrificing essential design features or rider ergonomics, further detracting from its practicality.

Another factor is the energy recovery potential. High-performance motorcycles like the Ducati Panigale are designed for extreme speed and acceleration, where the benefits of KERS during braking may be marginal compared to its impact on performance. The braking events on such motorcycles are often short and intense, limiting the amount of energy that can realistically be recovered and stored. This contrasts with heavier vehicles, where longer braking periods allow for more substantial energy recovery.

Finally, there is the issue of cost and complexity. The inclusion of a KERS system would substantially increase the manufacturing cost and maintenance requirements of the motorcycle. Given that sports bike enthusiasts prioritise performance and driving experience over fuel efficiency, the added expense may not justify the limited benefits.

In summary, while KERS is a promising technology for reducing energy waste, its practicality on high-performance sports bikes like the Ducati Panigale 1199 is questionable. The trade-offs in weight, space, cost, and limited energy recovery benefits make it a less suitable choice for vehicles where performance and agility are desired.

9 Assumptions made

9.1 Constant Component Efficiencies:

The efficiencies of the Motor Generator Unit, inverter, and Supercapacitor Energy Storage System are assumed to be constant during operation.

- MGU efficiency: 89.5%
- Inverter efficiency: 90%
- SCESS efficiency: 95%

These values are based on standard benchmarks and may not reflect real-world variations under dynamic operating conditions.

9.2 Vehicle and Rider Mass

The total test mass of 288kg is derived by adding the kerb mass of the Ducati Panigale (188kg), rider mass (75kg), and baggage mass (25kg). This assumes a standardised weight for the rider and baggage, which may not always be applicable.

9.3 Energy Recovery Potential

The analysis assumes that energy recovery is feasible during all braking events, with a focus on deceleration profiles derived from specific test cycles. The variability of real-world braking patterns is not explicitly addressed.

9.4 Test Conditions

Calculations are based on predefined driving cycles (WLTP Class 3b), which assume consistent environmental conditions such as air density, gravitational acceleration and an entirely flat environment. These may differ from actual conditions experienced during on road use.

9.5 Losses

Mechanical losses in the regenerative braking system arise primarily from friction, vibrations, and inefficiencies in the drivetrain and motor-generator unit. These losses reduce the overall energy recovery efficiency, as not all the kinetic energy from deceleration is converted into electrical energy. Factors such as bearing resistance, gear friction, and misalignments contribute to energy dissipation in the form of heat and sound. While these losses are minimised through precision engineering and regular maintenance, they remain an inherent limitation in any mechanical system, affecting the total amount of energy available for storage in the supercapacitors.

9.6 ESS Values

The calculated ESS values, including capacitance, voltage, and energy storage, provide a practical estimate for system design but may not be entirely accurate due to assumptions made during analysis. Factors such as the operating voltage range, average power demands, and energy recovery efficiency were based on typical WLTP cycle data and idealised conditions. Real-world variables like dynamic braking patterns, temperature fluctuations, and supercapacitor performance degradation over time can impact these values. As such, while the ESS values serve as a reliable baseline, further refinement through testing and real-world validation is essential to ensure accuracy and optimal performance.

10 Conclusion

The analysis of Kinetic Energy Recovery Systems (KERS) within the context of high-performance sports motorcycles, such as the Ducati Panigale 1199, highlights both the strengths and challenges of this technology. KERS demonstrates significant potential for improving energy efficiency by recovering energy typically lost during braking, converting it into usable power to reduce overall fuel consumption. The integration of components like the motor generator unit, inverter unit, and supercapacitor energy storage system illustrates a well-engineered approach to energy recovery and reuse, achieving high system efficiencies.

However, the practical application of KERS in a high-performance sports bike poses several challenges. The added weight and space requirements of the system conflict with the design priorities of motorcycles like the Panigale, which emphasise agility, speed, and lightweight construction. Moreover, the limited energy recovery potential due to short and intense braking events further questions its effectiveness in this context. Increased costs and complexity add another layer of impracticality for adoption in a market driven by performance enthusiasts.

While KERS offers promising environmental benefits and technological advancements, its feasibility on high-performance motorcycles is constrained by these trade-offs. Future innovations may address these limitations, enabling a more seamless integration without compromising the performance attributes that define sports bikes. For now, KERS appears more suitable for applications where efficiency gains outweigh the constraints on weight, space, and cost.

11 References

Bai, Y., Lee, V. W., & Ipek, E. (2017). Voltage regulator efficiency aware power management. *ACM SIGPLAN Notices*, 52(4), 825–838. <https://doi.org/10.1145/3037697.3037717>

Blum, L., & Riensche, E. (2009). FUEL CELLS – SOLID OXIDE FUEL CELLS. *Systems. Encyclopedia of Electrochemical Power Sources*.

DieselNet. (n.d.). *Worldwide Harmonized Light Vehicles Test Cycle (WLTC)*. Retrieved November 28, 2024, from <https://dieselnet.com/standards/cycles/wltp.php>

Ducati. (2012). *Ducati 1199 Workshop Manual*.

Ehsani, M., Gao, Y., Longo, S., & Ebrahimi, K. (2019). *Modern Electric, Hybrid Electric and Fuel Cell Vehicles* (3rd ed.). Taylor & Francis Group.

Lu, S. M. (2016). A review of high-efficiency motors: Specification, policy, and technology. In *Renewable and Sustainable Energy Reviews* (Vol. 59, pp. 1–12). Elsevier Ltd.

Vittore Cossalter. (2006). *Motorcycle Dynamics* (2nd ed.).

WLTP R154e Feb 2021. (n.d.).

Zhong, Y., Zhang, J., Li, G., & Liu, A. (2006). *Research on Energy Efficiency of Supercapacitor Energy Storage System*. Power System Technology.

OpenAI. (2024). ChatGPT. Report readability and formatting.