



University of Wales Trinity Saint David  
Wales Institute of Science and Art

Kinetic Energy Recovery  
ACHA 5010

Jake Davies

2205290

11/2024

# Table of Contents

|                                                                    |    |
|--------------------------------------------------------------------|----|
| 1. Introduction .....                                              | 3  |
| 2. Research .....                                                  | 4  |
| 2.1 Evaluating the characteristics of the vehicle. ....            | 5  |
| 3. WLTP (Worldwide harmonised Light vehicle Test procedure) .....  | 6  |
| 3.1 What is a WLTP .....                                           | 6  |
| Total Forces against Tractive Forces.....                          | 7  |
| Cumulative Tractive Energy against Cumulative Braking Energy ..... | 8  |
| Tractive Energy (Joules) against Time (Seconds) .....              | 9  |
| All Forces against Time .....                                      | 10 |
| Identify largest possible KERS. ....                               | 11 |
| Specify a Suitable KERS .....                                      | 12 |
| Variations the driver may feel.....                                | 13 |
| Conclusion.....                                                    | 14 |
| References .....                                                   | 15 |

# 1. Introduction

The vehicle I have chosen for this test is a BMW M2 which is the highest performance vehicle from the 2 series model. The car has a twin turbocharged 3.0 litre inline six producing 453 horsepower and 406 pound-ft of torque. It has an 8-speed automatic transmission and will hit 0-60 in 3.9s. the reason I chose this vehicle is because it does not feature a KERS so doing this test on this vehicle, we will be able to see what type of KERS will be best suited to this vehicle. The BMW M2 is fitted with its own M performance features such as M compound brakes to increase the braking efficiency, adaptive M suspension to enhance the driving dynamics of the car.

## 2. Research

Test mass – 1860kg.

Frontal area = 0.85x (width x height)

$$A = 0.85(1.887 \times 1.402)$$

$$A = 2.24\text{m}^2$$

Rolling resistance coefficient –  $M = 1860 \text{ g} = 9.81\text{m/s}^2$

Assuming the tyres are on asphalt (5)

The rolling resistance force = 364.9

$$364.9 / (1860 \times 9.81) = 0.019$$

Coefficient of drag – assuming the vehicle is going 60mph also assuming air density at sea level =  $1.225 \text{ kg/m}^3$

$F_d = 350\text{N}$  at  $27.78\text{m/s}$

$$C_d = 2 \times 350 / 1.225 \times 2.24 \times (27.78)^2$$

$$= 1.225 \times 2.24 \times 771.38 = 2116.67$$

$$= 2 \times 350 / 2116.67 = 0.336$$

$$C_d = 0.34$$

## 2.1 Evaluating the characteristics of the vehicle.

**Test mass-** the test mass is the mass of the vehicle when in running conditions, this means the wet mass of the vehicle + 75kg for the mass of the driver (1). This is needed as it gives a more accurate simulation of the vehicle weight when doing day to day driving. This is required as it will make the results from the test much more accurate and give much more concise results.

**Frontal Area –** the frontal area of a vehicle refers too the cross-sectional area of an object that is perpendicular to the direction of motion (2). This is required as it is necessary to calculate the amount of drag the vehicle will face when travelling with forward motion, this leads to raising and lowering a vehicles fuel economy as a more drag efficient vehicle will be able to push through air resistance easier than a vehicle with a larger frontal area therefore a smaller frontal area will increase fuel efficiency as the engine will not need to work as hard to continue the same speed.

**Rolling Resistance –** the rolling resistance of a vehicle is the numerical amount of resistance in motion between the surface and a rolling object (3). This can also be called friction force as it is the amount of friction produced by an object when in contact with another surface. This also plays a role in fuel efficiency as the vehicle must overcome this value of rolling resistance in order to have motion, a lower rolling resistance means a lower amount of energy required to produce motion, this means that the engine will have to use less power and energy therefore increasing fuel efficiency.

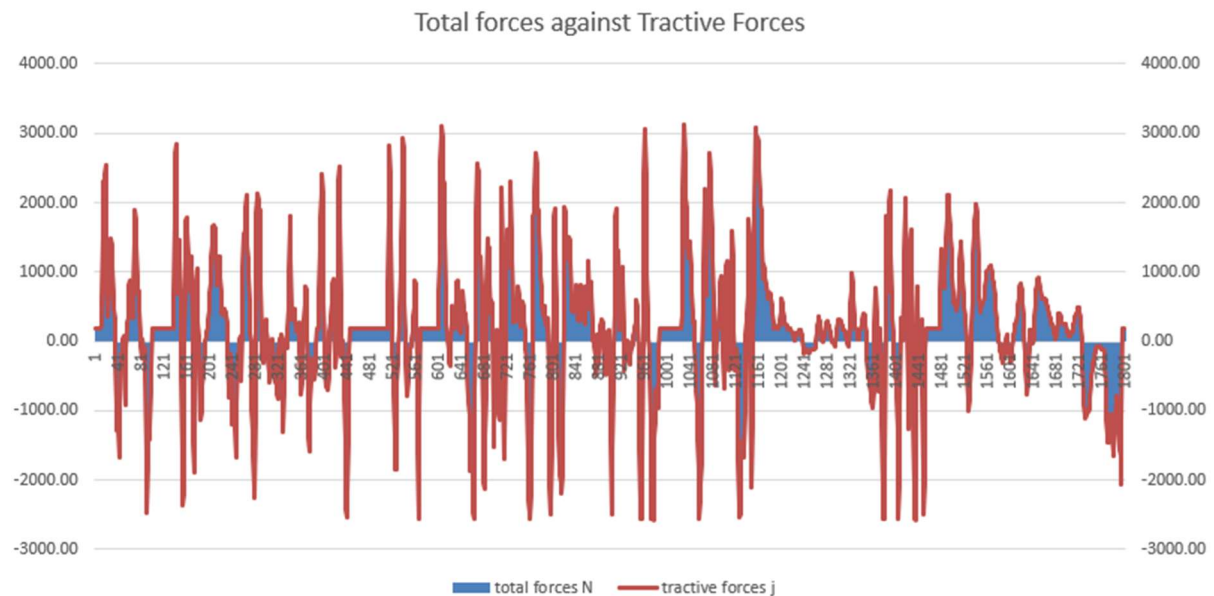
**Coefficient of drag –** the drag coefficient is how streamline a vehicle is which refers to the vehicles ability to glide through the air with least resistance possible (4). This is worked out once the vehicles frontal area is determined.

## 3. WLTP (Worldwide harmonised Light vehicle Test procedure)

### 3.1 What is a WLTP

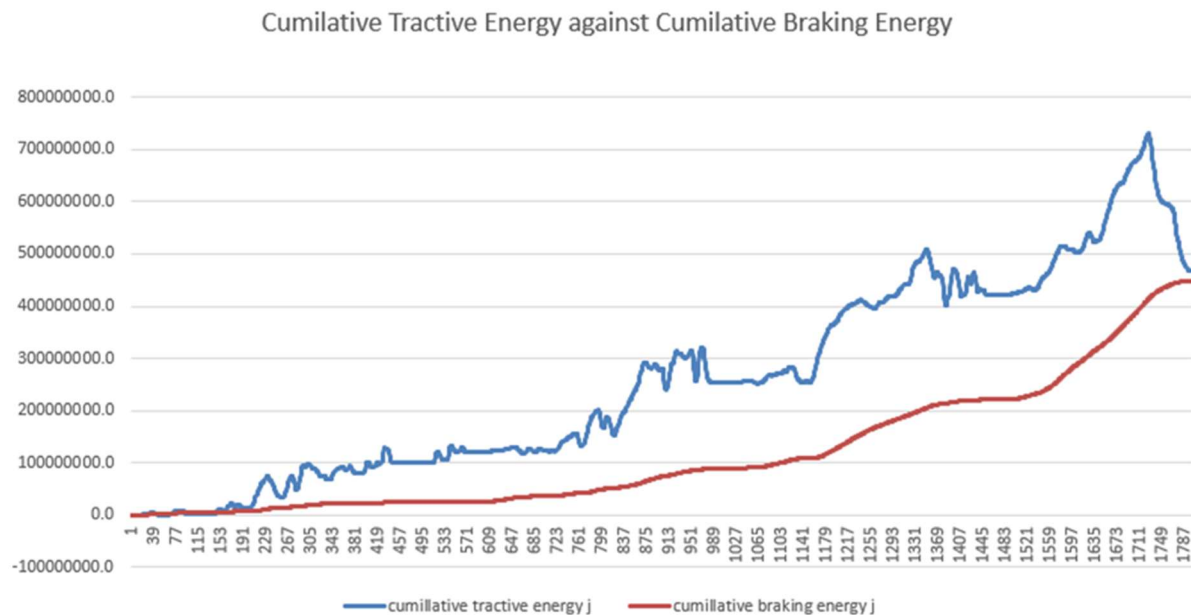
A WLTP is a global standard used to measure various factors of vehicles such as fuel efficiency, range and energy consumption. It is based on real world driving data collected from around the world and consists of 4 different phases. These phases are Low, Medium, High and extra high. Each one of these phases represents a style of real-world driving conditions including urban, suburban and motorway scenarios. The test duration is 30 minutes and measurements are made precisely at every second totalling 1800 seconds of data. The distance covered in these tests is 23.25km or 14.45 miles. These tests are performed in 23-degree Celsius air temperature, but they also include a correction factor to 14 degrees for the colder climates. This test was introduced in September 2017 for new vehicle models in the European union, this test then fully replaced the previous test called NEDC in September 2018.

## Total Forces against Tractive Forces



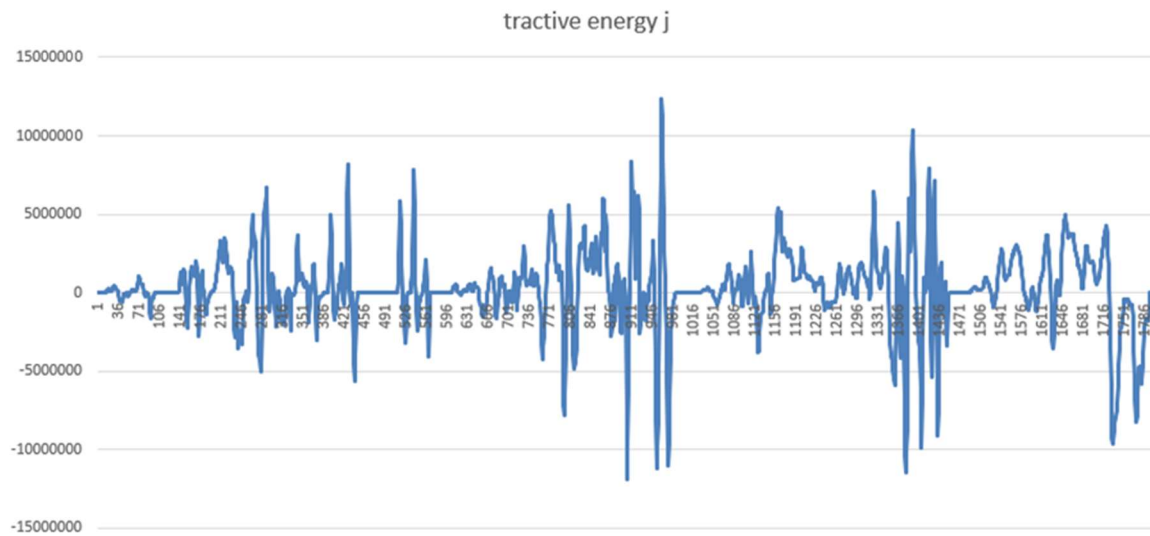
This graph shows the trends between total forces and tractive forces, the positive peaks are phases of acceleration whereas the negative peaks are from phases of deceleration. The tractive forces fluctuate much more widely than the total forces, these range from -3000 to +3000. The graph shows strong correlation between the two forces however the total forces are smaller in magnitude implying that the other forces such as aerodynamic drag and rolling resistance are acting in opposition. The large negative tractive forces are the braking events so these areas are where the potential moments for a KERS will take effect.

# Cumulative Tractive Energy against Cumulative Braking Energy



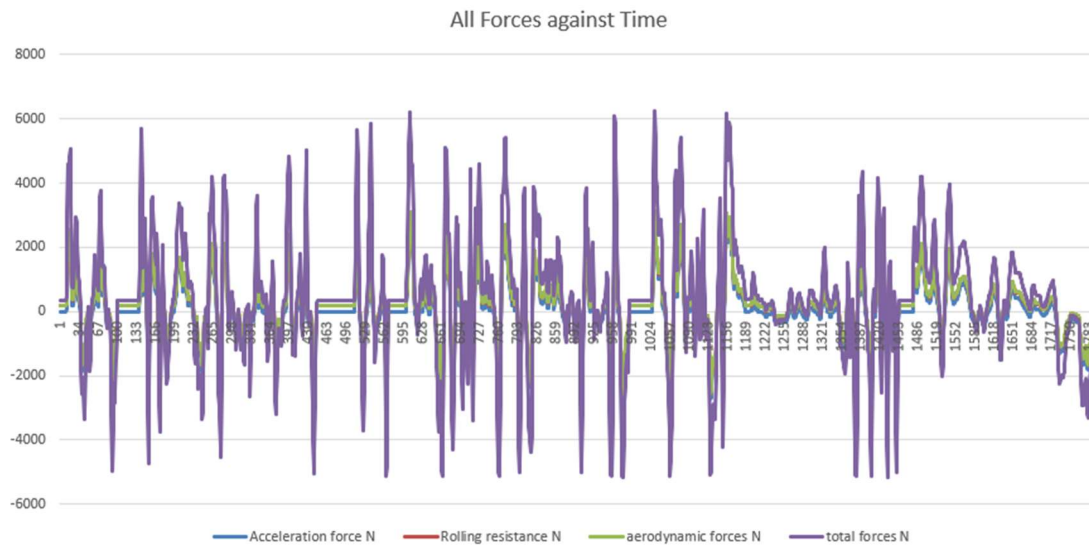
The cumulative tractive energy shows the total amount of energy generated through propulsion over time, the values increase steadily reflecting energy use during acceleration phases. The steep increase towards the end of the graph shows a large increase in energy consumption over time. The braking energy starts off very gradual but towards the end there is a very steep increase which suggests stronger braking events were taken place. The braking energy does not exceed the tractive energy which means that the braking energy recovery is used or lost due to heat dissipation. This means that a more efficient energy recovery system would benefit this vehicle to bring the tractive energy and the braking energy much more equal.

## Tractive Energy (Joules) against Time (Seconds)



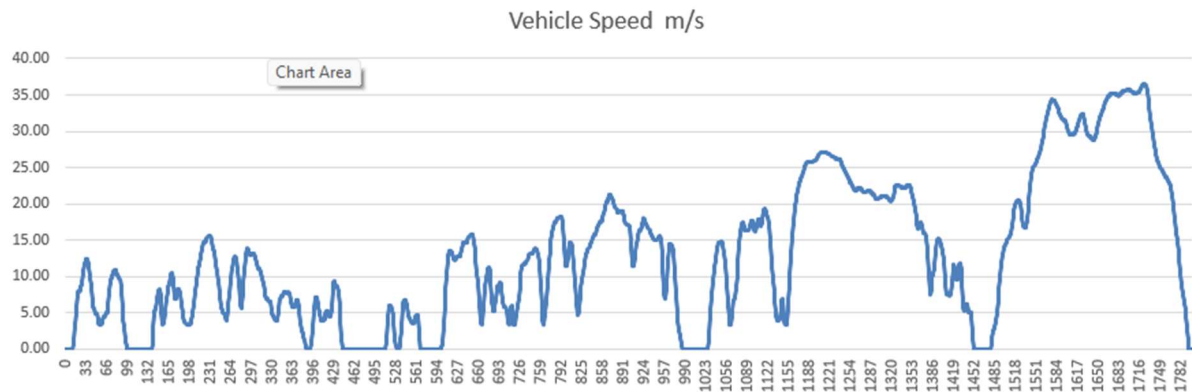
The large positive spikes show moments of high energy output likely during the acceleration phases and the negative spikes show moments of energy absorption or braking where the vehicle might be experiencing resistive forces such as drag or friction. The various oscillations throughout the graph show the different phases of the test such as stop and go traffic or aggressive acceleration and braking cycles. When implementing an efficient KERS to this vehicle we would see a significant decrease in the magnitude of the negative spikes as some of this energy will not be dissipated it will be stored for uses later. An effective KERS would also increase the positive peaks as it would provide a boost in power as the energy stored from braking can be used in acceleration.

# All Forces against Time



This graph shows all the forces from the vehicle with respect to time along the WLTP with total forces showing with the biggest peaks as it is the acceleration force + rolling resistance + aerodynamic force.

## Identify largest possible KERS.



This graph shows the speed variation during the WLTP. The sharp declines in spikes are the braking phases which is where the moment of energy recovery would take place. The largest possible KERS would take place at the end of the cycle where the highest speed recorded is reduced to 0. A largest possible KERS within the cycle before another phase starts would take place at the end of the second stage(990s) as this is where the sharpest decline of speed takes place before the next phase begins.

## Specify a Suitable KERS

Regenerative braking system is a technology used in vehicles to capture and store the energy that is typically lost in the braking phase due to heat, this technology will then convert that captured energy into usable energy to assist in acceleration whilst improving engine efficiency. This technology works when a vehicle applies the brake it decelerates, and the kinetic energy is usually converted into heat through friction of the brake pads on the rotors (6). This system will capture that energy via a generator which is usually placed in the drivetrain and store this energy in a battery or a flywheel. This energy then assists in acceleration as when the vehicle starts this phase the energy stored will then be released back into the drivetrain to provide additional power and improve fuel efficiency as this process takes stress off the engine and burns less fuel as the power is being generated from other sources not just the combustion of the engine (7).

The vehicle I chose has a pre-KERS efficiency of 35% which was calculated by taking the maximum value of cumulative braking energy and dividing it by the maximum value of cumulative tractive energy. This shows that the vehicle of choice would benefit greatly from using a KERS system as it would increase the fuel efficiency to values much greater than 35%. This type of KERS would be an electric or battery-based system as the mechanical system is more commonly used inside of motorsports not road vehicles (6). KERS also help reduce emissions as there is less reliance on the combustion engine to create performance. This will also increase the longevity of parts inside the braking system of road vehicles as less braking force is required to slow the vehicle down (7).

KERS systems are much more commonly found in hybrid or electric vehicles, this is why hybrids have much better fuel economy and produce less emissions as they rely on electric power and combustion power but adding these systems to modern day combustion vehicles would have a large benefit in improving fuel economy and emissions overall (6).

For this system to be effective on this vehicle the size of the battery would be 3 Kwh and weighing approximately 15kg as this would be able to store enough energy for high braking force applications without being too heavy where it affects the vehicles performance.

## Variations the driver may feel

The driver will feel like they don't have to switch too often and aggressively between pedals as when lifting off the accelerator the regenerative braking system will activate instantaneously which will provide a much more fluid driving experience, they will also find that to perform an emergency stop they do not need to press the brake pedal as hard as there are 2 forms of brakes being applied essentially which further increases safety of the vehicle as its stopping distance is reduced.

In a standard ICE system, the friction brakes will be much more responsive to the immediate touch of the pedal which provides a more consistent feeling for the driver.

In a regenerative braking system, the driver will feel much less vibration through the pedal and there will be a smoother transition between accelerating and decelerating.

# Conclusion

In conclusion this report has shown that a KERS will greatly increase the fuel efficiency and decrease emissions produced by a combustion engine through having a more efficient acceleration phase using stored power from heat transfer from braking. It also shows that there is a noticeable change to driving experience when using a vehicle with a KERS that can enhance the driver's feeling whilst also increasing safety. It has also shown that test mass and drag coefficient play a big part in emissions and fuel efficiency as they can increase rolling resistance of the vehicle which would increase the poor emissions as higher values of energy must be produced from the engine to provoke forward motion. These are the main factors that will change the efficiency of road vehicles, and they all inflict each other showing a positive or negative effect.

## References

- 1) WLTP DTP Lab Processes subgroup Title Vehicle test mass. (n.d.). Available at: <https://unece.org/fileadmin/DAM/trans/doc/2011/wp29grpe/WLTP-DTP-06-12e.pdf>.
- 2) Fiveable.me. (2024). Frontal Area - (College Physics I – Introduction) - Vocab, Definition, Explanations | Fiveable. [online] Available at: <https://library.fiveable.me/key-terms/intro-college-physics/frontal-area> [Accessed 1 Dec. 2024].
- 3) Anon, (2020). Coefficient Of Rolling Friction (Fully Explained) - Afrilcate. [online] Available at: <https://afrilcate.com/coefficient-of-rolling-friction/>.
- 4) Engineering Toolbox (2004). *Drag Coefficient*. [online] Engineering Toolbox. Available at: [https://www.engineeringtoolbox.com/drag-coefficient-d\\_627.html](https://www.engineeringtoolbox.com/drag-coefficient-d_627.html).
- 5) www.omnicalculator.com. (n.d.). *Rolling Resistance Calculator | Cars, Bicycles, Tires*. [online] Available at: <https://www.omnicalculator.com/physics/rolling-resistance>.
- 6) Lampton, C. (2009). *How Regenerative Braking Works*. [online] HowStuffWorks. Available at: <https://auto.howstuffworks.com/auto-parts/brakes/brake-types/regenerative-braking.htm>.
- 7) Naylor, S. (2020). *Regenerative braking: what is it and how does it work?* [online] Auto Express. Available at: <https://www.autoexpress.co.uk/tips-advice/353643/regenerative-braking-what-it-and-how-does-it-work>.

