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Engine Performance Characteristics Investigation

Motorsport Technology – ACHA4012

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1 Introduction

This report details an investigation into the performance characteristics of a Honda D16 1600cc four-cylinder internal combustion engine (ICE). The engine was tested using an Eddy Current dynamometer. An Eddy current dynamometer (Dyno) is suitable for this test because it can maintain lower RPMs when compared to Water Brake dyno as described by R. Lake (2006). Additionally, Eddy Current dynos have advantages over Chassis dynos for testing engine characteristics as the engine can be tested in isolation from other vehicle components in a controlled environment as well as being computer controlled enabling more accurate targeting of specific engine speeds or loads.

The aims of this investigation are to measure the peak torque and power produced by the engine, calculating to best load and engine speed to achieve the best specific fuel consumption (SFC) and collect data to suggest possible improvement to the engine's performance.

2 Equipment

The Eddy Current dynamometer used for the test is a Schenck WS230. An eddy current dynamometer functions using a drive shaft that connects the engine and the dynamometer, the dynamometer housing uses an electrical current to generate a magnetic field that applies load to the engine. As a result, a rotational reaction force is created that applies to the casing, this force is then measured by a strain gauge the result of this represents the torque applied by the engine the value of which is calculated using the load the dynamometer was calibrated for compared against the voltage of the signal from the strain gauge. The dynamometer is calibrated by placing a weight of a known mass on the end of an arm on the opposite side of the dynamometer from the strain gauge.

However as described by Boverie *et al.*, (2002) 10 to 20% of dynamometer runs need to be repeated in order to gain accurate data due to limitations of the engine control systems.

3 Methodology

This investigation was conducted using a sweep test, where the engine is moved through its RPM range at a specific load and readings are taken at each target RPM. A step test, where the engine pauses at each target RPM to allow the sensor more time to take an accurate reading, may provide more accurate results near the start of the test but as a result of the engine building up more heat during the test the data retrieved at the end of the test would be comparatively inaccurate and place more stress and wear on the engine.

The engines force (N), pressure (Bar) and fuel consumption (litres/45s) were measured at a range of engine speeds:

800, 1000, 1250, 1500, 1750, 2000, 2250, 2500, 3000, 3500, 4000, 4500, 5000, 5500, 6000, 6500 RPM

A range of loads:

2, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 54, 59, 64, 69, 74, 79, 84, 89, 94, 99, 100%

The RPM was measured when the readings were taken in order to establish true engine speed making resulting calculations more accurate.

Ambient pressures and temperatures are to be taken at the time of the test. The fuel used is 95 RON.

The Brake mean effective pressure (BMEP) and thermal efficiency of the engine will also be considered.

4 Results and Analysis

The following values were obtained.

- The length of the dyno arm is 0.815776m
- The ambient pressure was 1.024 Bar
- The ambient temperature was 297 Kelvin
- The bore of the cylinder is 0.0719m
- The stroke of the piston is 0.082m
- The specific gravity of the fuel is 0.752 (Hamje *et al.*, 2020)
- The calorific value of the fuel is 43.2 MJ/kg (Stansfield *et al.*, 2012)

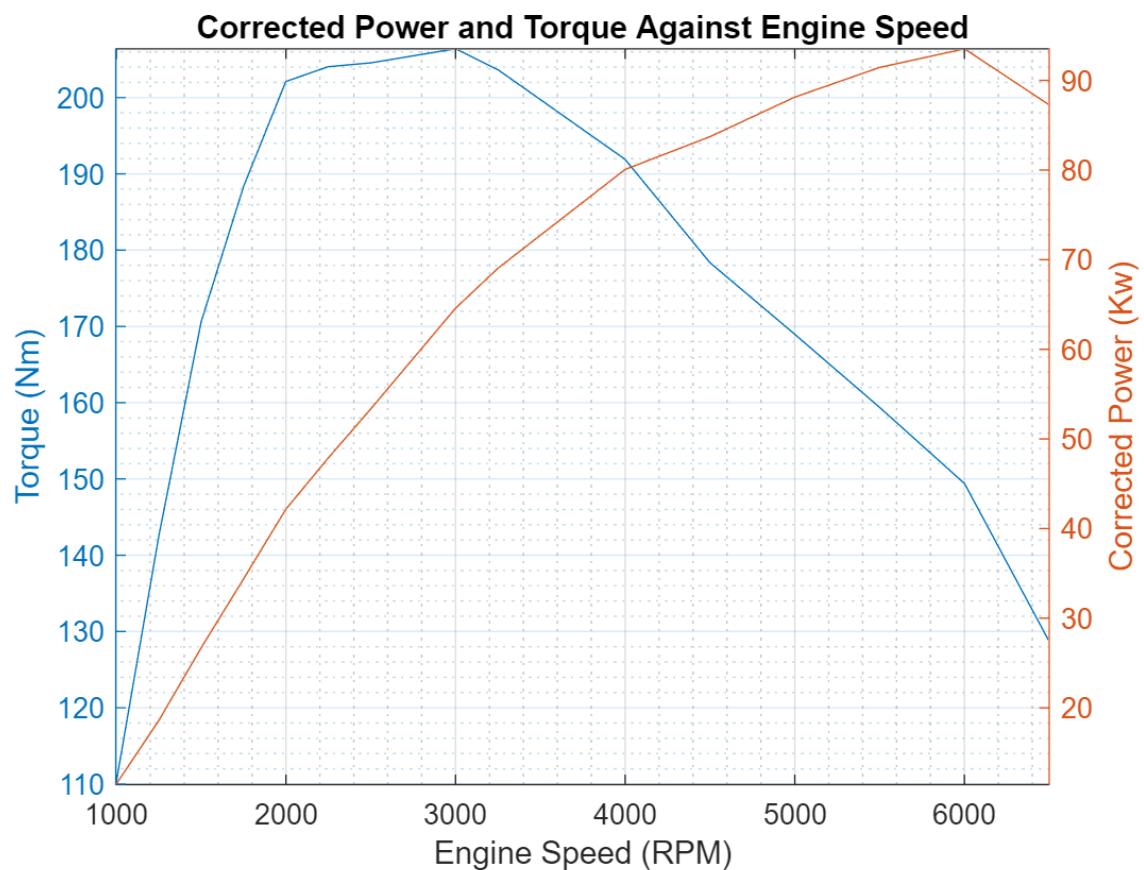


Figure 1 - Corrected Power and Torque Against Engine Speed

From figure 1 it can be observed that the peak torque (206.4Nm) occurs at 3000 RPM and peak corrected power (93.5Kw) at 6000 RPM. Power was corrected using the DIN (Deutsches Institut für Normung) standard with the standard temperature value of 25°C and standard pressure of 1.01325 Bar. The peak torque occurs relatively low in the RPM range (2000 – 3000 RPM) as after this point the volumetric efficiency of the engine decreases due to the engine being unable to intake enough air to

fully utilise the whole combustion chamber as RPM increases. A potential solution to this is the turbocharge the engine as described by Muqem, (2017) this can increase the volumetric efficiency of the engine and improve overall torque. As Gupta, Saul and Abdel-gayed, (2013) notes turbocharging increases the efficiency of an engine by partially recovering exhaust energy that would otherwise be lost. However as described by Bozza *et al.*, (2014) further work would need to be carried out on the variable valve train system (VVT) and the exhaust gas recirculation (EGR) systems in order to optimise the engine for part-load fuel economy.

Power continues to increase after the point of peak torque as power is a function of torque and engine speed. This continues until the engine speed increase can no longer account for the loss of torque and power will decrease as seen in figure 1 after 6000 RPM.

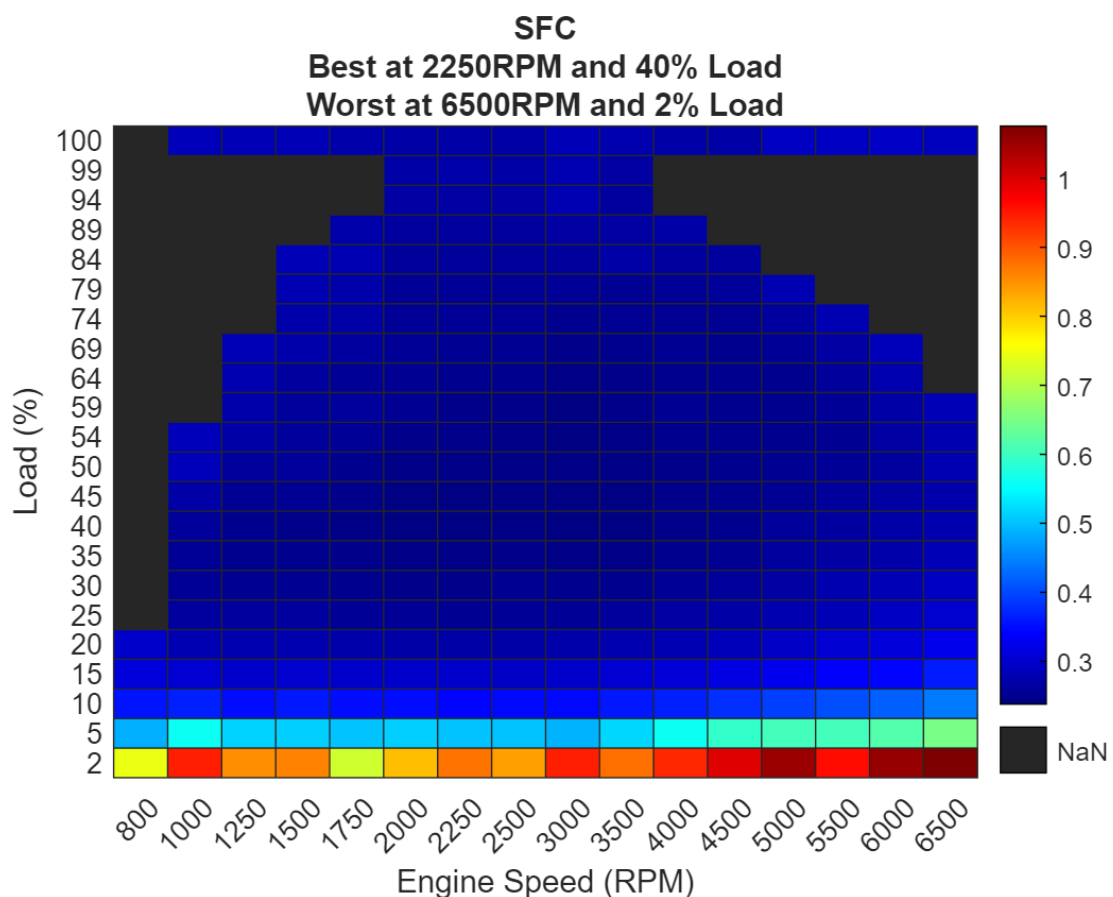


Figure 2 - Heat map showing SFC in relation to engine load and engine speed

From figure 2 we can see that the SFC of this engine is consistent across the chart (above 10% load) as this is a small displacement engine designed for fuel efficiency. The SFC is high for loads under 10% as the engine is struggling to intake air past the throttle as a result the volumetric efficiency is decreased, this effect becomes more severe at higher engine speeds as the engine requires a higher air flow rate to maintain complete combustion that cannot be achieved.

The best SFC occurs at 2250RPM as this is in the peak torque range (2000 – 3000 RPM), additionally this occurs on the lower side of this range as when engine speed increases so do frictional losses leading to a higher requirement of fuel to overcome these losses.

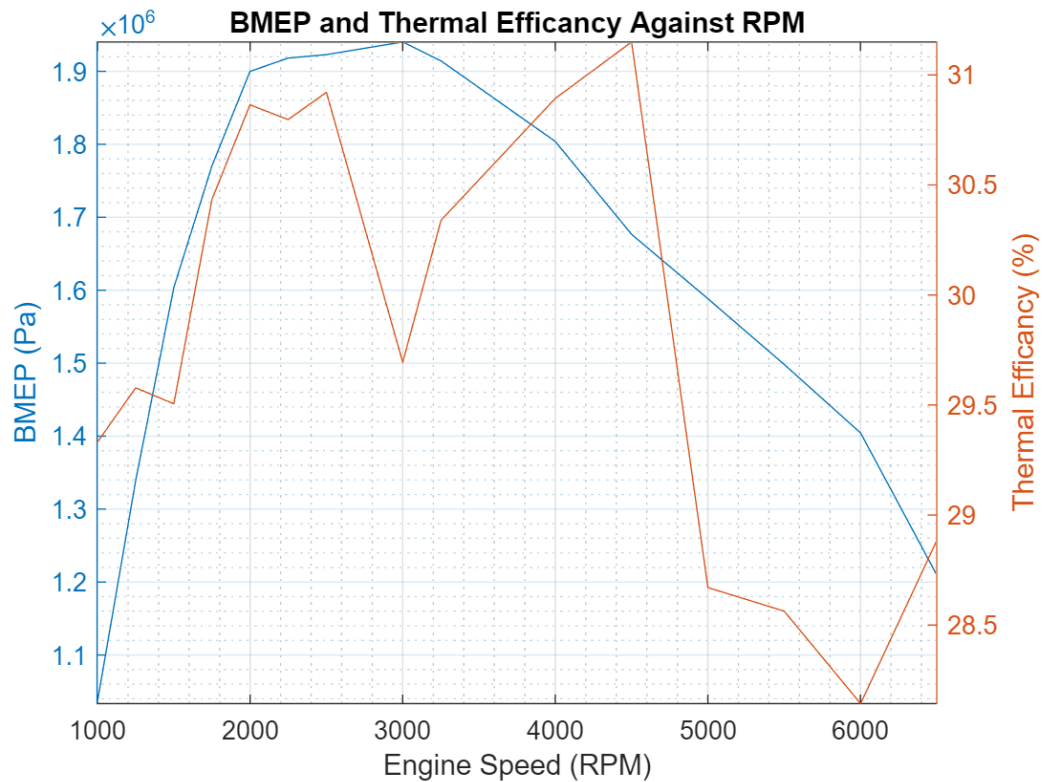


Figure 3 - Graph showing BMEP and Thermal Efficiency against RPM

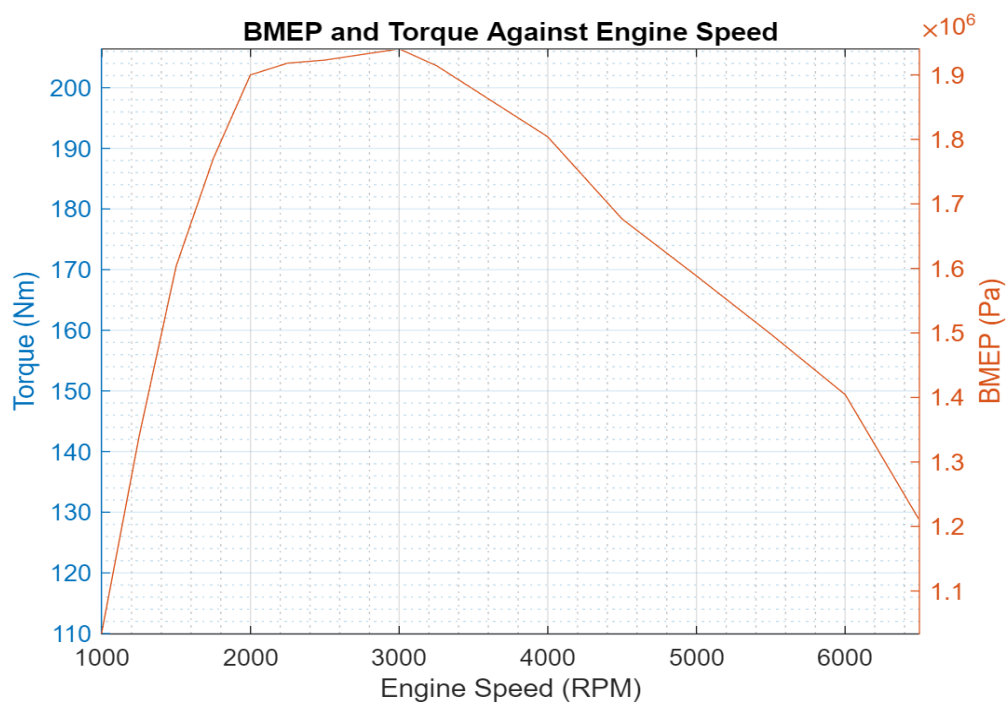


Figure 4 - BMEP and Torque Against Engine Speed

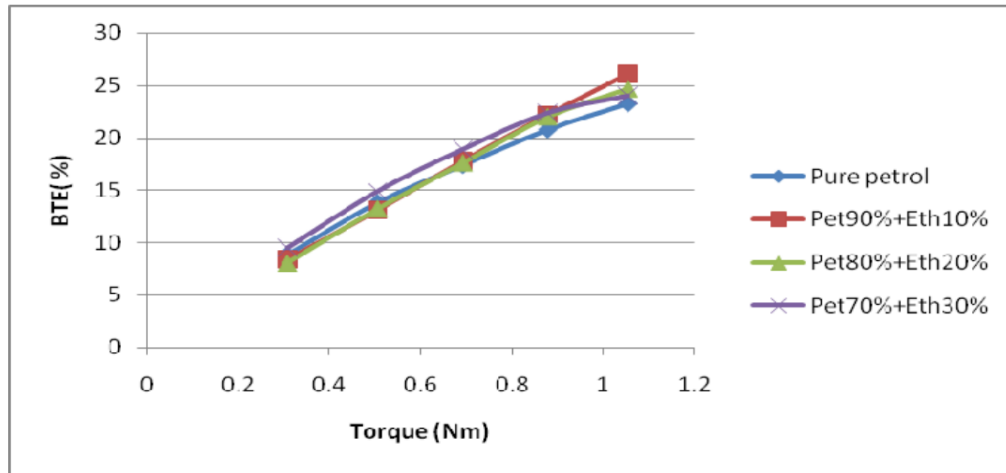


Figure 5 - Brake Thermal Efficiency Against Torque (D.BALAJI, P.GOVINDARAJAN and J.VENKATESAN, 2010)

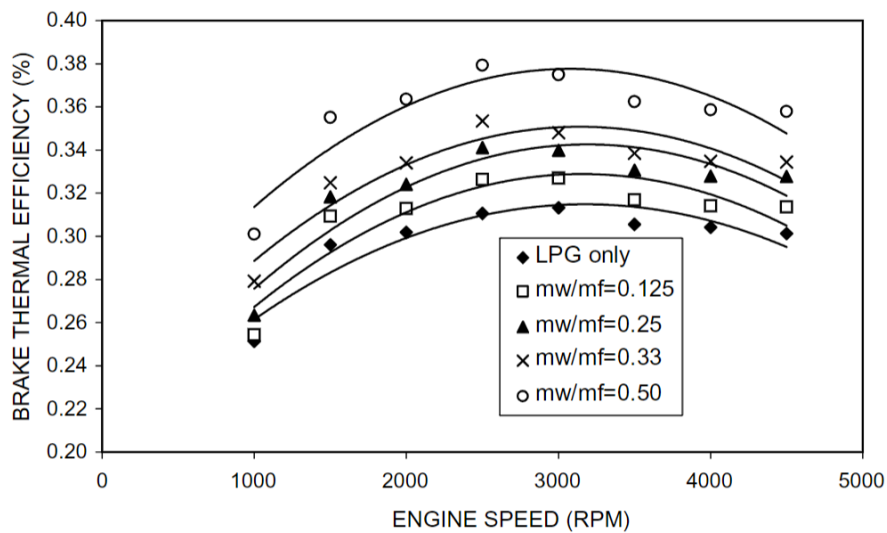


Figure 6 - Brake Thermal Efficiency Against Engine Speed (Özcan and Söylemez, 2006)

From the graph (Figure 3) it can be observed that the BMEP follows the same trend as torque, increasing as RPM increases until the point that the engine can no longer maintain its volumetric efficiency. This is further supported by Figure 4 which shows that BMEP is directly proportional to Torque, this is because the pressure acting on the piston (BMEP) equates directly to Torque generated by the engine as Torque is a function of the force on the piston.

The thermal efficiency shown in figure 3 differs from the expected result. As can be see from Figure 5, thermal efficiency show increase with torque as can be seen from Figure 3 this doesn't occur. Additionally, as can be seen in Figure 6 that the thermal efficiency data should produce a smooth curve, from this it can be assumed that there is a problem with either the sensors of the dyno or a problem with the engine itself that is causing inaccuracies in the data.

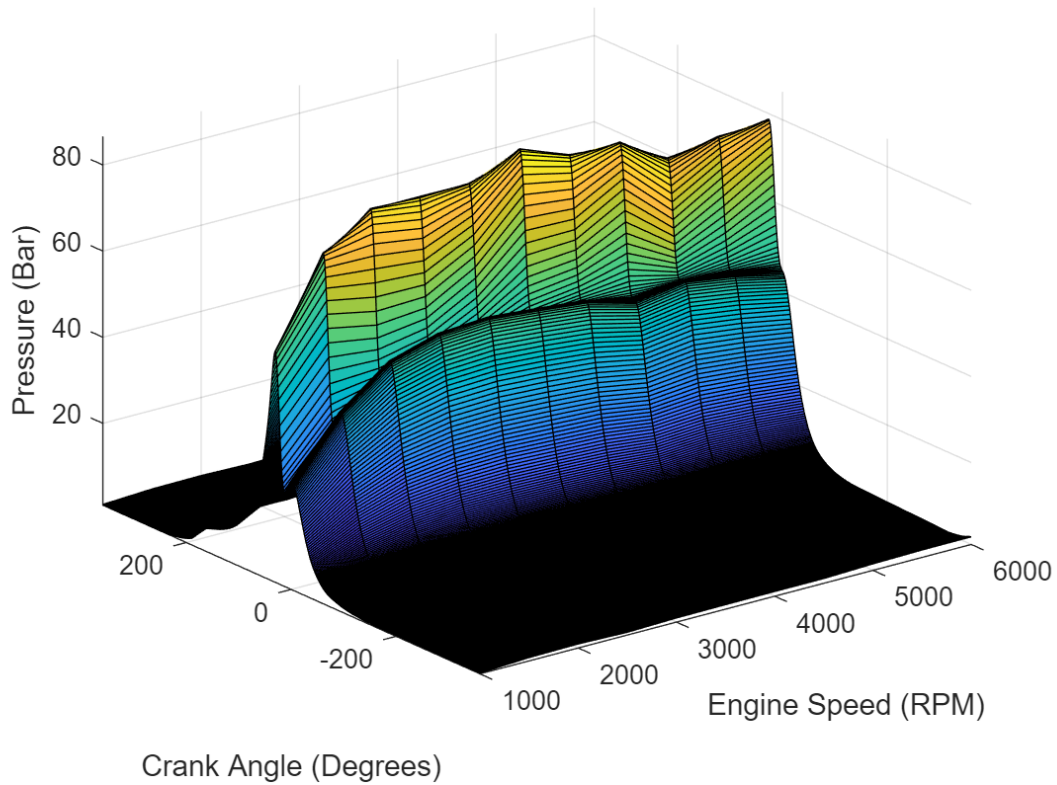


Figure 7 - 3D plot of Pressure and Crank Angle Against Engine Speed

Figure 7 shows pressures in the cylinder during the 4-stroke cycle across the RPM range. The peaks (shown in orange) represent the power stroke and as such it can be observed that pressures remain relatively constant throughout the RPM range suggesting the engine is running as intended. The secondary peaks (shown in light blue) represent the exhaust stroke and the pressure shown is a result of the piston pushing exhaust gasses out of the cylinder as it returns to TDC and as such this stroke does not achieve pressures as high as the combustion stroke.

5 Conclusion

As previously discussed, this engine performance characteristics could be improved through the use of a turbocharger, maintaining peak torque for longer, as well as the potential for an increase in part-load efficiency of the engine. Additionally, it has been discovered that the engine maintains its best SFC around the 40% load at 2000 - 3000 RPM as such the use of a turbocharger to increase the range of RPM at which this can be achieved would be beneficial to the engine.

However, due to the previously mentioned inaccuracies of the dyno and the anomalous result in Figure 7 for thermal efficiency more testing is needed to confirm results.

6 References

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