



Prifysgol Cymru
Y Drindod Dewi Sant
University of Wales
Trinity Saint David

Engine Performance Characteristics

Powertrain Technology

Grace Robinson

2500220

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Abbreviations

RPM- Revolutions per Minute

BMEP- Brake Mean Effective Pressure

SFC- Specific Fuel Consumption

OTE- Overall Thermal Efficiency

Chapter 1 – Introduction

This report will outline engine performance characteristics of a Honda 1.6 VTEC (2000/2001), D16 model. This engine is known for smooth torque delivery, high reliability, and everyday usage, originally used in Honda Civics. This report will outline the process taken to collect data from an engine dynamometer in a controlled environment using a sweep test. The data obtained from the experiment was then used to calculate further important values such as torque and brake power. This report will include analysis of graphical results and will discuss the conclusion of the results effect on overall performance across the engines operating range.

Chapter 2 - Methodology

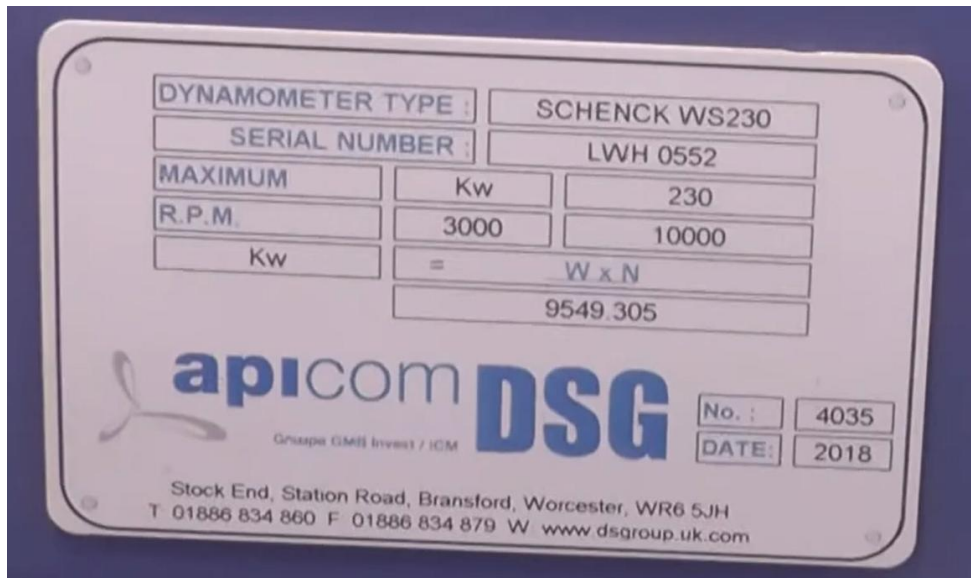


Figure 1 Dynamometer Type Specification (UWTSD WISA Workshops, 2020)

The specification of the dynamometer used in the collection of results has been shown above. The Schenck WS230 was used, it is an eddy current dyno, this means that the inner core is powered by the engine and spins freely, the outer casing is then fed by current which produces an electromagnetic field which in turn produced a resistive load on the engine, which slowed it down, simulating real world engine loading.



Figure 2 Calibration Arm Length (UWTSD WISA Workshops, 2020)

The length of the calibration arm was needed to calculate the torque on the engine. The length was the distance from the perpendicular length of the mass hook to the central axis of the dynamometer.



Figure 3 Calibration Arm and Load Hook (UWTSD WISA Workshops, 2020)



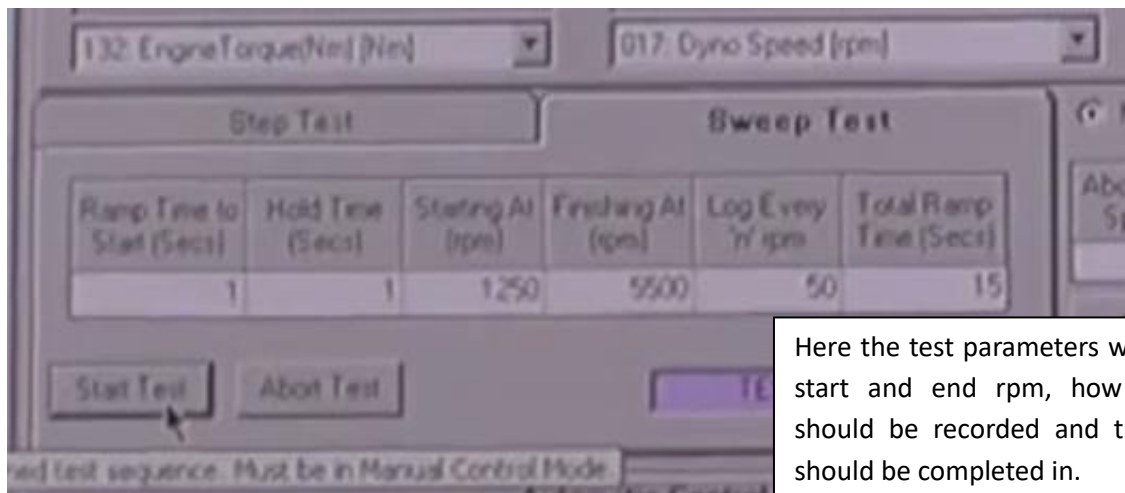
Figure 4 Dynamometer Strain Gauge (UWTSD WISA Workshops, 2020)

A known mass was hung on the hook and converted to a weight. This put a force on the outer casing, which then tried to turn it. This force pulled on the strain gauge which is mounted on the casting. A signal was then sent to the computer from the strain gauge which measured the reaction force, this value is between 0-10 volts, this is the main function in the dynamometer all other data points are calculated by the computer from sensors or extrapolated from the computer.



Figure 5 Computer Controls for Dynamometer (UWTSD WISA Workshops, 2020)

The computer was then set up to run the dynamometer, for this experiment it completed a sweep test, this allows for a large data set to be taken of the engines operating range without the dyno pausing to collect data at set intervals. This test was chosen due to its efficient data collection, and it lowers the risk of overheating the engine. However, while an overall idea of performance can be taken, the data gathered would have been less accurate than if a step test had been performed.



Here the test parameters were set, including start and end rpm, how frequently data should be recorded and the time the test should be completed in.

Figure 6 Dynamometer Sweep Test Parameters (UWTSD WISA Workshops, 2020)

Once set up, the test was run at full throttle, and the dyno was allowed to control speed. Once, the sweep test was completed, the raw data was then collected, and put into an Excel file, where further necessary values such as brake power and BMEP could be calculated. Graphical results were then produced and have been displayed and analysed in *Chapter 3*.

Chapter 3- Results

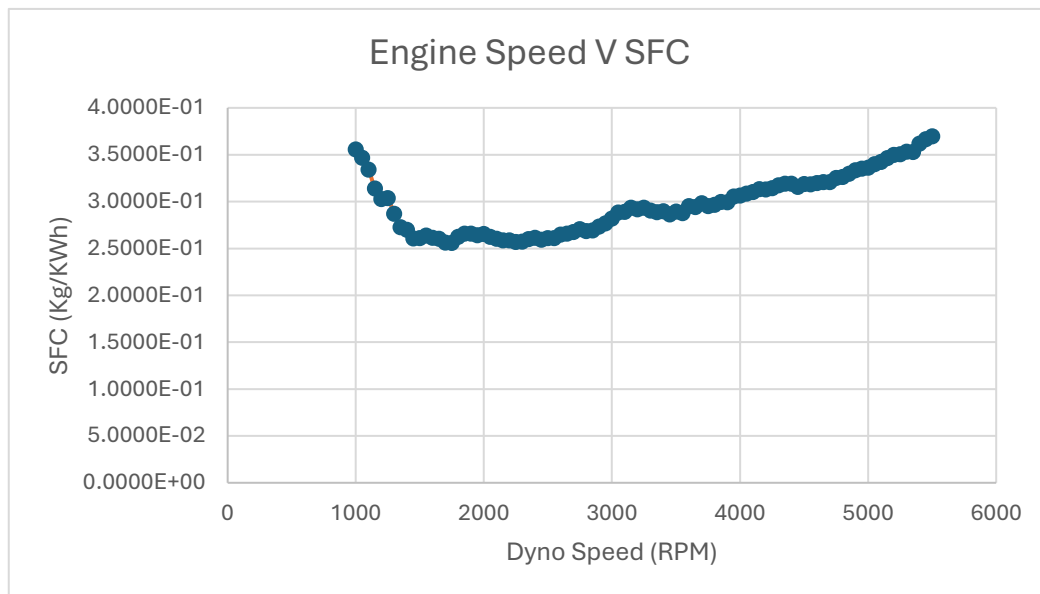


Figure 7 Engine Speed V SFC Graph

The above graph shows engine speed Vs Specific Fuel Consumption (SFC). “SFC is the amount of fuel consumed for producing a unit brake power in the engine.” (Elavarasan G, Kannan M and Karthikeyan, 2019). A lower SFC highlights that an engine has a higher fuel efficiency. The graphical trend suggests that at a lower RPM (around 1000-1600) that there is a high, but quickly declining SFC. This behaviour is typical of spark-ignition engines operating under unstable combustion conditions and shows that at a low RPM the engine is inefficient (Yang *et al.*, 2016). From the raw data it can be seen that the lambda value at this point is running lean fuel ($\lambda \approx 1.27$) which could lead to cycle-to-cycle variations in pressure (Ayala and Heywood, 2007), leading to poor thermal efficiency which can be seen in *Figure 8*.

Data from the RPM range 1600-2200 has the best performing SFC at a minimum of ≈ 0.25 kg/kWh. This is where the optimal engine performance is and this is reflected in the Overall Thermal Efficiency (OTE) graph which is inversely correlated to the SFC graph. At which it reaches its maximum efficiency at around 32% in this RPM range.

As RPM increases the SFC begins to increase again, to a maximum of 0.369 Kg/KWh. This higher SFC value indicates lower fuel efficiency which could be due to higher friction at the higher RPM and may be affected by less efficient combustion. At higher RPM, the combustion timings can vary from the desired timings, leading to early, late, or incomplete combustion, which can have a direct impact on the thermal efficiency (Caton, 2014). This effect can also be seen in *Figure 8* as it begins to decline in OTE at around 3000 RPM and from there gets steadily less efficient through the higher engine speeds.

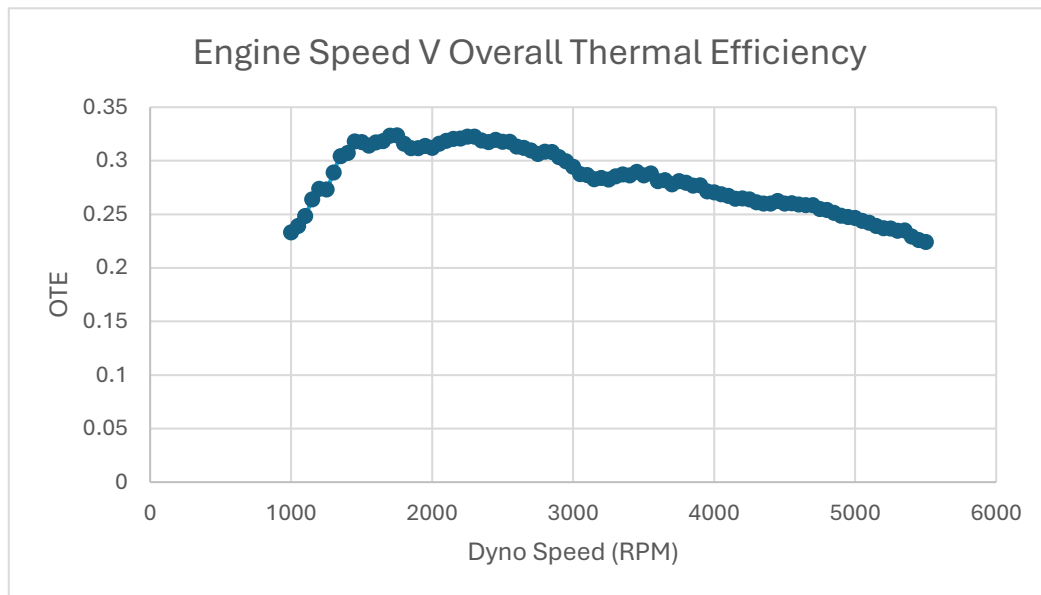


Figure 8 Engine Speed V Overall Thermal Efficiency Graph

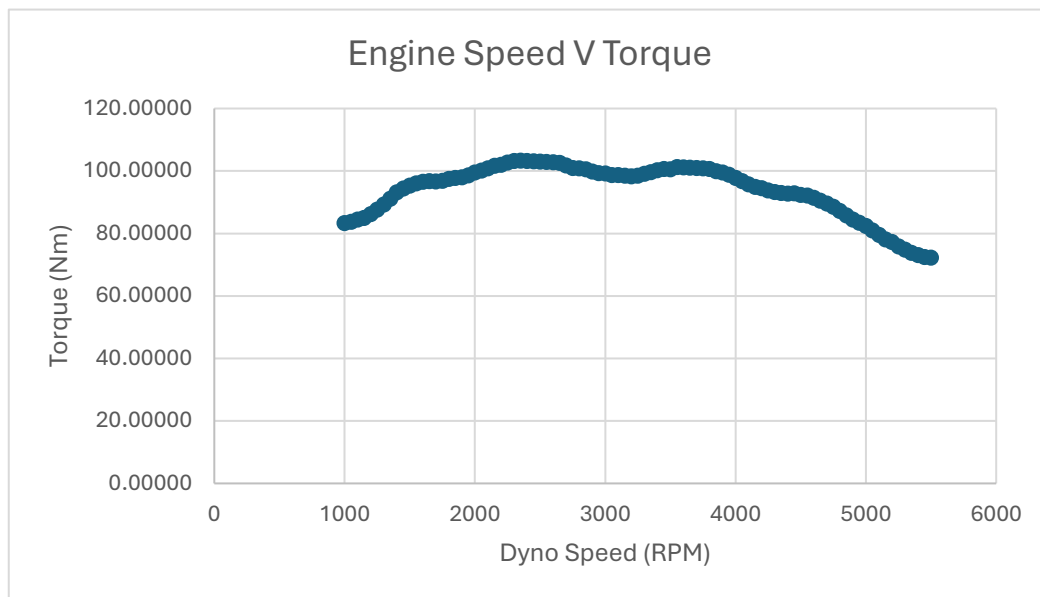


Figure 9 Engine Speed V Torque Graph

The above graph shows how torque varies with engine speed. It shows that the torque increases from around 86 Nm to approximately 100 Nm in the RPM range of 1000-2000. It reaches a maximum and primary torque range of 99-103 Nm in the mid-range RPM; this peak torque range corresponds well with the optimal SFC and OTE ranges (*Figure 7 and 8*) to show that the best engine performance for this engine is in the mid RPM range. The peak torque at this point could be attributed to maximum volumetric efficiency and optimum combustion timing. The torque results then lower slightly likely due to pumping losses before returning to a secondary plateau of high torque values between 3400-3800 RPM. The engine that was tested was a Honda VTEC, which has variable valve timing (VVT), this means that the valve timing systems adjust at a higher RPM to improve the volumetric efficiency and airflow in the engine (Li *et al*, 2018 and Ghajar, Kakaee, Mashadi, 2016). This allows for a broader torque curve and secondary high torque values at a higher RPM than if the timings were not variable. At high engine speeds (above 3800 RPM) the torque follows a negative correlation this could be due to increase mechanical friction, and pumping losses according to (Hardy *et al*, 2009 and Li *et al*, 2018).

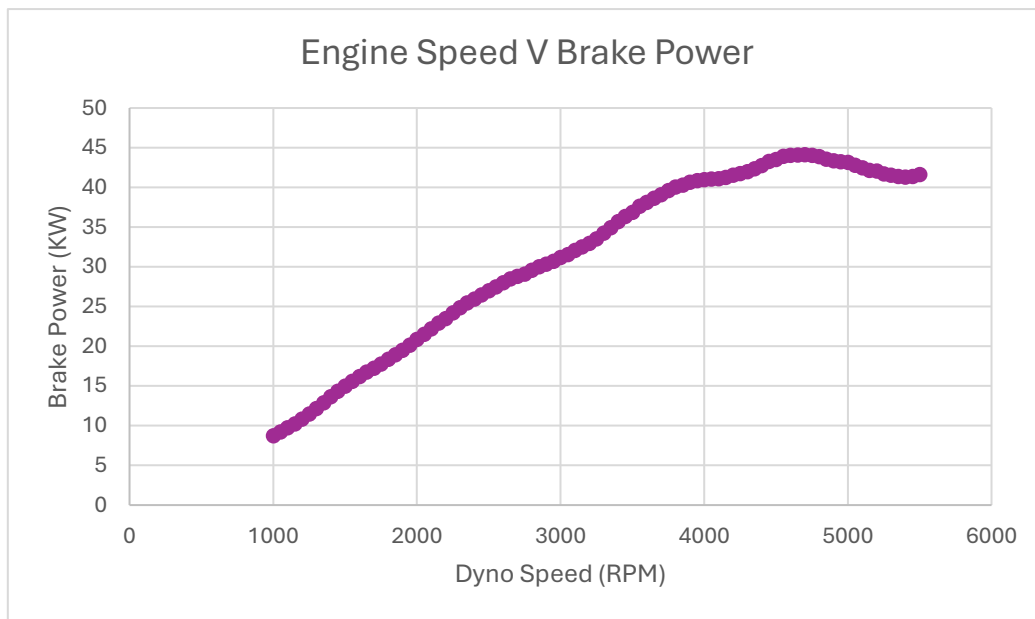


Figure 10 Engine Speed V Brake Power Graph

Figure 10 shows an engine speed V brake power graph. The graph shows a high positive linear correlation between the variables until the engine reaches 4000 RPM, the R^2 Value between 1000-4000 RPM is 0.9959 (See Appendix 1). The increase in brake powers as engine speed increases can be attributed to several things including increased volumetric efficiency and higher torque which approaches the optimal operating window for the engine (Sivashankar *et al*, 2018). Beyond 4000 RPM a small non-linear increase occurs before reaching its peak brake power at 44 KW, where the engine reaches its highest rate of useful work output. A decline in brake power follows this as engine speed increases from this point, leading to an increase in friction and valve timing inefficiency.

Chapter 4 - Evaluation

Overall, this experiment and analysis went well, the data was provided; calculations were made in excel and graphical data was produced. The results and findings were then processed into a report of which I researched key topics to evaluate points and backed them up with relevant literature. This allowed for critical discussion and analysis of the engines overall performance to be completed.

However, this assignment could have been improved, due to a maintenance issue the dynamometer that the experiment was to be completed on was broken and could not have been fixed in time to allow for staff and student availability, leading to no practical element being completed. While supplementary data and video demonstrations of the dynamometer in use were provided and used, the firsthand experience of conducting this test was lost. This had a significant impact on general confidence in the topic, especially when completing the methodology section of this report. First hand observations of testing and use of the computer programmes could have improved clarity and furthered my knowledge on the general procedure of testing on a dynamometer. General explanation and images were taken from the video; therefore, this report could have been improved with first hand sources and self-measured data as analysis regarding uncertainty in data can only be speculated.

Such as the validity of the conclusions is somewhat limited by the nature of the data collection process. The use of a sweep test, while efficient, may reduce measurement accuracy compared to step testing which is a form of steady state testing (SuperFlow, 2021), as dynamic operating conditions can influence torque and fuel consumption readings. Also, not being directly involved in the experimental process introduces uncertainty regarding calibration accuracy, sensor reliability, and potential systematic errors within the dynamometer system. Therefore, while clear performance trends are identified, the absolute values should be interpreted with caution.

However, given that the data was provided from the same dynamometer as the experiment was meant to have taken place on, this report was still successful in meeting the objectives of the investigation.

Chapter 5 - Conclusion

In summation, the analysis of the Honda 1.6 VTEC D16 engine has given this a comprehensive understanding of its performance characteristics across a range of engine speeds. Using dynamometer data, supported by the calculated parameters including brake power, torque, SFC, and OTE, the report has identified clear trends that define the engine's optimal performance window. The results consistently show that the mid-range engine speeds, particularly between 1600–2200 RPM, shows the highest efficiency, lowest SFC, and peak thermal performance. This corresponds well with the torque characteristics, which also reach their best working values within this range, indicating strong volumetric efficiency and stable combustion.

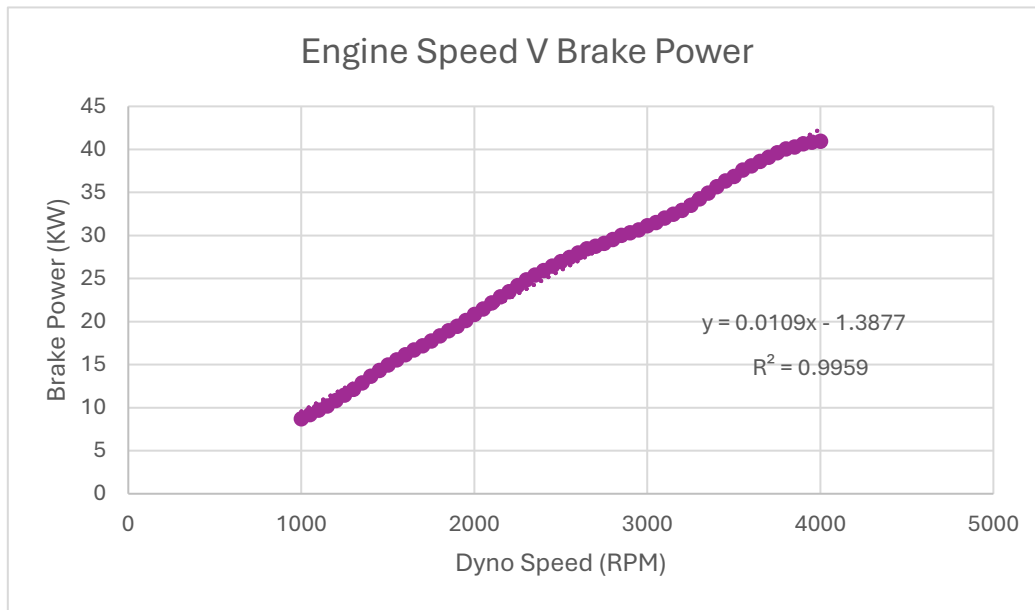
At higher engine speeds, the decline in efficiency and torque, alongside the eventual drop in brake power, reflects the expected mechanical and combustion-related limitations such as friction and valve timing efficiency of naturally aspirated engines. The presence of Honda's VTEC system contributes to a broader torque curve and improved at higher RPM, but the overall trends remain consistent with established engine behaviour.

While the analysis was thorough, the lack of a practical dynamometer session due to equipment failure limited the opportunity for hands-on data collection. Reliance on provided data and video demonstrations ensured the report could still be completed, but firsthand experimentation would have strengthened methodological confidence and allowed for greater involvement with the testing process. Overall, the investigation successfully met its objectives, offering a clear and well-supported evaluation of the engine's performance and the factors influencing its efficiency and output.

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Appendices



Appendix 1 Engine Speed V Brake Power to 4000 RPM Correlation