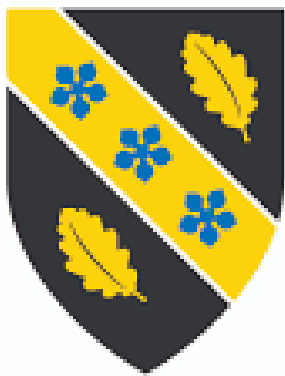


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Engine Performance Characteristics

Powertrain Technology (ACHA4029)

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Table of Abbreviations

Abbreviations	Meaning
BMEP	Brake Mean Effective Pressure
SFC	Specific Fuel Consumption
Dyno	Dynamometer
RPM	Revolutions Per Minute

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1. Introduction

This experiment aims to investigate the performance characteristics of an internal combustion engine using dynamometer (dyno) testing. Engine performance is typically evaluated by analysing key parameters such as torque, brake power, specific fuel consumption (SFC), brake mean effective pressure (BMEP), and overall thermal efficiency (Ganesan, 2012).

Understanding how these parameters vary with engine speed is essential in automotive engineering, as it allows engineers to optimise engine performance, efficiency, and fuel consumption. The relationship between torque and engine speed determines the drivability of a vehicle, while brake power indicates the engine's ability to perform work. Additionally, SFC and thermal efficiency are critical indicators of how effectively the engine converts fuel energy into useful mechanical output. These relationships are fundamental to internal combustion engine analysis and are widely documented in modern engine theory (Stone, 2017).

During this investigation, a Honda engine was tested under controlled conditions using a dynamometer. Data collected from the test was used to calculate performance metrics and generate graphs showing how engine behaviour changes with speed. These results were then analysed to identify trends and explain the underlying mechanical and thermodynamic principles affecting engine performance.

2. Equipment and Methodology

2.1 Equipment

The engine performance testing was conducted using a W-series eddy current dynamometer coupled to a Honda Civic 1.6L D16 engine (Honda, n.d.). An eddy current dynamometer applies a controllable electromagnetic load to measure engine performance (Martyr and Plint, 2012). This enables precise control of engine operating conditions while allowing accurate measurement of output torque at steady-state speeds.

The dynamometer system incorporates a range of sensors to capture key performance data. A load cell is used to measure the reaction force generated by the applied load, which is subsequently used to determine engine torque. Engine speed is measured using a rotational speed sensor, providing readings in revolutions per minute (RPM). Additionally, a fuel flow metre records the rate of fuel consumption, enabling assessment of engine efficiency.

All measured parameters are transmitted to a data acquisition system, where they are continuously monitored and recorded for post-processing. The collected data forms the basis for further analysis, allowing the calculation of critical performance indicators including brake power, BMEP, SFC and overall thermal efficiency.

The raw dynamometer data, consisting of engine speed, applied load and fuel flow rate, was imported into a spreadsheet. Using established engineering relationships, these values were processed to derive the required performance parameters, forming the foundation for subsequent graphical analysis and evaluation.

2.2 Method

The engine testing was conducted using a steady-state dynamometer testing procedure, as observed in the recorded test sessions. Initially, the engine was started and allowed to reach normal operating temperature to ensure stable thermal conditions and consistent lubrication, reducing the influence of temperature-related variations on performance.

Once the engine stabilised, the test was carried out across a range of engine speeds. At each test point, the throttle position was adjusted while the eddy current dynamometer applied a controlled electromagnetic load to the engine. This load was varied by the operator to maintain a constant engine speed, effectively allowing the engine to operate under steady-state conditions.

The dynamometer works by applying a braking force to the rotating shaft, simulating real-world resistive forces such as vehicle mass and aerodynamic drag. By increasing or decreasing this load, the operator can hold the engine at specific RPM values while measuring the corresponding torque output.

At each speed increment, the engine was allowed to stabilise before measurements were recorded. This ensured that transient effects, such as fluctuations in combustion or throttle response, did not affect the accuracy of the data. The primary parameters recorded during testing were RPM, applied load and fuel flow rate.

The testing procedure was repeated across multiple engine speeds to generate a full performance profile of the engine. This step-by-step approach enabled the identification of key performance regions, including peak torque, peak power, and optimal efficiency range.

Following the completion of the test, the collected data was transferred to a spreadsheet for analysis. Standard engineering equations were applied to calculate brake power, brake mean effective pressure (BMEP), specific fuel consumption (SFC), and thermal efficiency. The processed data was then used to generate performance graphs, allowing trends in engine behaviour to be analysed and interpreted.

3. Results

3.1 Raw Data

The raw data collected from the dynamometer test included engine speed, applied load, and fuel flow rate. This data was recorded directly from the test equipment and used as the basis for further calculations.

Table 1- Raw and Calculated data

Baro	Baro	Humidity	Ambient temp	Distance from pivot to hook eye			Distance from pivot to hook eye		
Bar	mBar	%	Deg C	mm			m		
1.0189	1018.9	46	27	815.776			0.815776		
Load	Dyno Speed	Fuel Flow Rate	Lambda	Torque	Brake Power	Fuel Flow	BMEP	SFC	Thermal Efficiency
N	rpm	l/min	Lambda	N/m	kW	kg/s	kPa	kg/kWh	%
102.275	1000	0.0704	1.2658	83.43	8.74	8.7E-04	659.2275785	0.36	22.87
102.756	1050	0.0724	1.26783	83.83	9.22	8.9E-04	662.3279301	0.35	23.46
103.689	1100	0.0737	1.27344	84.59	9.74	9.1E-04	668.3417099	0.34	24.36
104.209	1150	0.0728	1.28476	85.01	10.24	9.0E-04	671.6934415	0.32	25.91
105.811	1200	0.0744	1.29181	86.32	10.85	9.2E-04	682.0193528	0.30	26.87
107.51	1250	0.07895	1.29729	87.70	11.48	9.7E-04	692.9704909	0.31	26.80
109.488	1300	0.079	1.29895	89.32	12.16	9.7E-04	705.719962	0.29	28.36
111.797	1350	0.0796	1.29469	91.20	12.89	9.8E-04	720.602939	0.27	29.85
114.268	1400	0.0835	1.2855	93.22	13.67	1.0E-03	736.5301094	0.27	30.16
115.783	1450	0.0847	1.27818	94.45	14.34	1.0E-03	746.2952502	0.26	31.20
116.985	1500	0.08865	1.2795	95.43	14.99	1.1E-03	754.0429065	0.26	31.16
117.788	1550	0.0932	1.27766	96.09	15.60	1.1E-03	759.2187535	0.27	30.84
118.471	1600	0.0959	1.28235	96.65	16.19	1.2E-03	763.6211239	0.26	31.12
118.772	1650	0.09875	1.29028	96.89	16.74	1.2E-03	765.5612608	0.26	31.24
118.656	1700	0.10005	1.29942	96.80	17.23	1.2E-03	764.8135669	0.26	31.74
118.861	1750	0.10305	1.31053	96.96	17.77	1.3E-03	766.1349226	0.26	31.78
119.584	1800	0.1093	1.3149	97.55	18.39	1.3E-03	770.7951185	0.26	31.00
119.934	1850	0.11415	1.31849	97.84	18.95	1.4E-03	773.0510916	0.27	30.60
120.176	1900	0.11745	1.31892	98.04	19.51	1.4E-03	774.6109359	0.27	30.60
120.948	1950	0.12055	1.31484	98.67	20.15	1.5E-03	779.5869681	0.27	30.80
122.157	2000	0.12555	1.31653	99.65	20.87	1.5E-03	787.3797439	0.27	30.63
122.845	2050	0.12785	1.32098	100.21	21.51	1.6E-03	791.8143425	0.26	31.01
123.796	2100	0.1309	1.32287	100.99	22.21	1.6E-03	797.9441438	0.26	31.26
124.794	2150	0.13435	1.32164	101.80	22.92	1.7E-03	804.37689	0.26	31.44
125.137	2200	0.1377	1.31652	102.08	23.52	1.7E-03	806.5877437	0.26	31.47
126.028	2250	0.14105	1.30465	102.81	24.22	1.7E-03	812.3308067	0.26	31.65
126.66	2300	0.14495	1.29646	103.33	24.89	1.8E-03	816.4044497	0.26	31.64
126.822	2350	0.14985	1.28229	103.46	25.46	1.8E-03	817.4486429	0.26	31.31
126.69	2400	0.1537	1.27304	103.35	25.97	1.9E-03	816.5978188	0.26	31.14
126.552	2450	0.15565	1.26984	103.24	26.49	1.9E-03	815.7083208	0.26	31.36
126.438	2500	0.1596	1.27446	103.15	27.00	2.0E-03	814.9735181	0.26	31.18
126.239	2550	0.1626	1.27876	102.98	27.50	2.0E-03	813.6908363	0.26	31.17

3.2 Calculated Results

The raw dynamometer data was processed using Microsoft Excel to determine key engine performance parameters. These included torque, brake power, brake mean effective pressure (BMEP), specific fuel consumption (SFC), and overall thermal efficiency. These calculated values provide a clearer understanding of engine performance under varying operating conditions.

3.2.1. Torque Equation

Torque can be measured directly by the dynamometer, which applies a controlled load to the engine and measures the resulting force. This force is then converted into torque using the known radius of the dynamometer arm.

Equation 1- Torque calculation from force and lever arm

$$T = F * r$$

Where:

- T = Torque (Nm)
- F = Force applied (N)
- r = Lever arm distance (m)

3.2.2 Brake Power Equation

Brake power is the useful mechanical power output of the engine measured at the crankshaft. It represents the actual power available to perform work after internal losses (such as friction and heat losses) have occurred.

Brake Power was calculated using the standard equation:

Equation 2 - Brake Power Calculation

$$P = \frac{2\pi NT}{60}$$

Where:

- P = Brake Power (W)
- N = Engine Speed (RPM)
- T = Torque (Nm)

3.2.3 Brake Mean Effective Pressure Equation

BMEP was calculated using the following equation:

Equation 3 - Brake Mean Effective Pressure Calculation

$$BMEP = \frac{2\pi T}{V_d}$$

Where:

- T = Torque (Nm)
- V_d = Engine Displacement (m^3)

3.2.4 Specific Fuel Consumption Equation

SFC was calculated using the following equation:

Equation 4 - Specific Fuel Consumption calculation

$$SFC = \frac{\dot{m}_f}{P}$$

Where:

- $\dot{m}_f$ = Fuel mass flow rate (kg/s)
- P = Brake Power (kW)

3.2.5 Thermal Efficiency Calculation

Thermal Efficiency was calculated using the following equation:

Equation 5 - Thermal efficiency calculation

$$\eta_{th} = \frac{P}{\dot{m}_f \cdot CVP}$$

Where:

- η_{th} = Thermal Efficiency
- P = Brake Power (kW)
- $\dot{m}_f$ = Fuel mass flow rate (kg/s)
- CV = Calorific value of the fuel (J/kg)

These equations are widely used in engine performance analysis (Ferguson and Kirkpatrick, 2015).

4. Graphs

4.1 SFC against Engine Speed

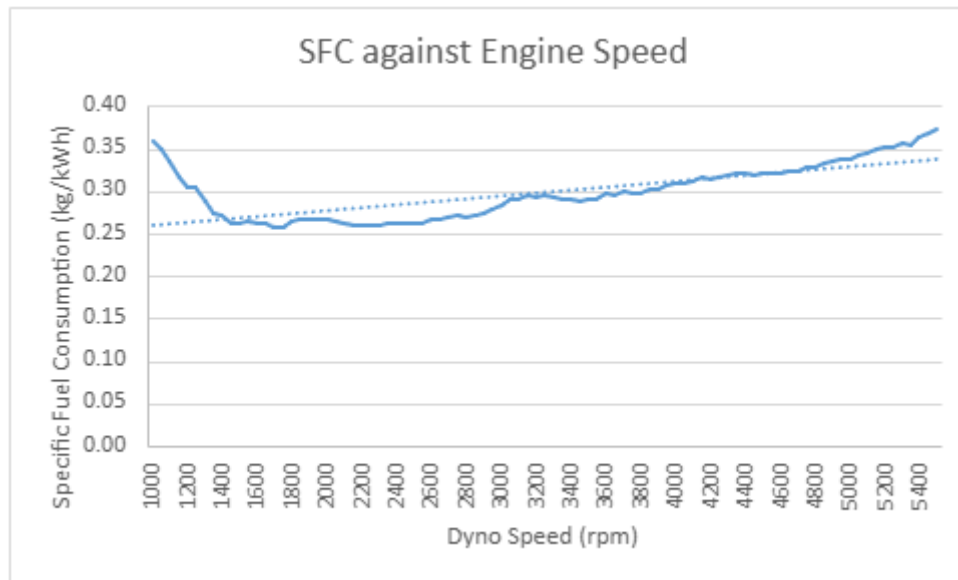


Figure 1 - Graph showing SFC against Engine Speed

The variation of SFC with engine speed follows a typical trend due to changes in engine efficiency across the operating range. At low engine speeds (around 1000-1400 rpm), SFC is relatively high because combustion is less efficient at lower temperatures and pressures, leading to incomplete fuel combustion and higher relative heat losses. As engine speed increases to the mid-range (roughly 1500-2500 rpm), SFC decreases to its minimum value, indicating the most efficient operating region. This behaviour is consistent with experimental findings reported in SAE studies, which show that minimum specific fuel consumption occurs at mid-range speeds where combustion efficiency and volumetric efficiency are optimised (SAE International, n.d.; Rakopoulos and Giakoumis, 2006). This reflects improved thermal efficiency, where a greater proportion of fuel energy is converted into useful work, along with better air–fuel mixing and more complete combustion, allowing the engine to produce more power with less fuel (Heywood, 2018; Zhao, 2012). Beyond this range, SFC begins to increase gradually as engine speed rises (2500-4000 rpm), primarily due to increasing frictional losses and reduced time available for complete combustion (Pulkrabek, 2014). At high engine speeds (above 4000 rpm), SFC increases further as efficiency decreases significantly. This is caused by high mechanical losses, reduced volumetric efficiency as airflow becomes restricted and incomplete combustion due to shorter cycle times (Stone, 2012). In some cases, richer fuel mixtures are also used at high engine speeds to prevent overheating and engine knock, further increasing fuel consumption. Overall, the engine is most fuel-efficient at mid-range speeds, which aligns with expected internal combustion engine efficiency characteristics (Çengel and Boles, 2015).

4.2 Torque against Engine Speed

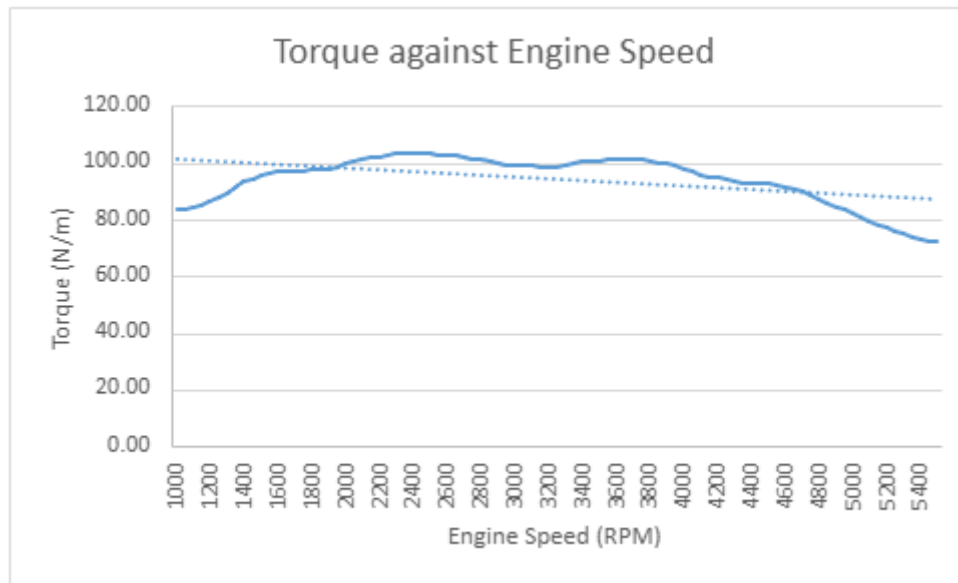


Figure 2 - Graph showing Torque against Engine Speed

Torque varies with engine speed due to the combined effects of airflow dynamics, combustion efficiency, and mechanical losses. At low engine speeds (approximately 1000–1500 rpm), torque is relatively low (83–90 Nm) due to poor volumetric efficiency, limiting air intake and resulting in incomplete combustion (Bosch, 2018).

As engine speed increases into the mid-range (2000–3000 rpm), torque rises significantly, peaking at approximately 100–103 Nm around 2400–2600 rpm. This corresponds to peak volumetric efficiency, where valve timing and intake dynamics maximise cylinder filling and combustion pressure (Taylor, 1985).

Beyond this point, torque decreases despite increasing engine speed due to reduced cylinder filling time and increasing mechanical losses (Ferguson and Kirkpatrick, 2015). At higher speeds (above 4000 rpm), this decline becomes more pronounced as airflow restrictions and shorter combustion durations reduce efficiency (Heywood, 2018).

The relatively smooth torque curve suggests stable engine operation; however, the peak torque is slightly lower than expected for a typical 1.6L engine (110–120 Nm). This discrepancy may be due to experimental limitations such as dynamometer calibration, environmental conditions, or data resolution, indicating some uncertainty in the absolute values.

4.3 Brake Power against Engine Speed

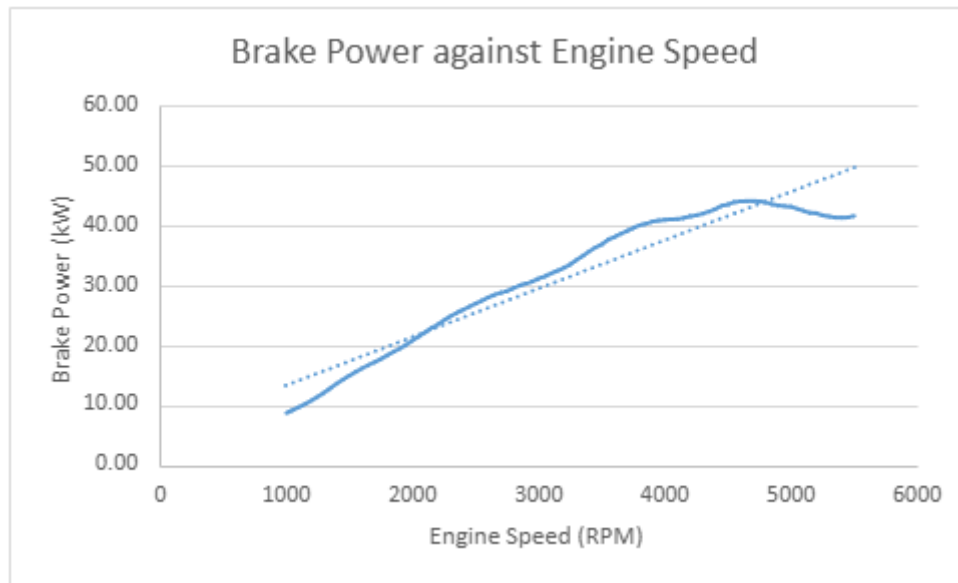


Figure 3 - Graph showing Brake Power against Engine Speed

Brake power varies with engine speed as it is directly proportional to both torque and rotational speed (Heywood, 2018). At low engine speeds, brake power is relatively low due to both low torque output and low rotational speed. As engine speed increases, brake power rises significantly because torque increases while engine speed also contributes to greater power output (Pulkrabek, 2014).

Brake power continues to increase even after torque begins to decline, as the effect of increasing engine speed outweighs the reduction in torque. This reflects the increasing influence of angular velocity on power output, despite the gradual reduction in torque (Stone, 2012). However, at very high engine speeds, brake power begins to stabilise or decrease slightly as the reduction in torque and increasing mechanical losses offset the benefits of higher rotational speed (Ferguson and Kirkpatrick, 2015).

This trend is consistent with typical internal combustion engine behaviour, where maximum power occurs at higher RPM than peak torque, indicating that the results are realistic and align with established engine performance characteristics (Bosch, 2018). Although the overall trend of increasing brake power with engine speed is consistent with theoretical expectations, the slight drop at higher RPM may indicate increasing mechanical losses or limitations in airflow. Additionally, the absence of repeat testing limits the ability to confirm the reliability of the data, meaning results should be interpreted with caution.

5. Conclusion

The analysis of engine performance characteristics demonstrates how brake power, torque, and specific fuel consumption (SFC) vary with engine speed due to changes in airflow, combustion efficiency, and mechanical losses. Torque increases with engine speed to a peak in the mid-range, where cylinder filling and combustion are most effective, before decreasing at higher speeds due to reduced air intake efficiency and increased frictional losses. Similarly, brake power rises with engine speed due to the combined influence of torque and rotational speed, reaching a maximum at higher RPM before levelling off as torque declines.

The SFC results indicate that the engine operates most efficiently within the mid-speed range, where fuel consumption per unit power output is minimised. At low speeds, high SFC values result from incomplete combustion and greater heat losses, while at high speeds, increased friction and reduced combustion time lead to decreased efficiency. The rise in SFC at higher speeds is also influenced by richer fuel mixtures used to maintain engine stability.

Overall, the findings confirm that the engine has an optimal operating range in the mid-speed region, which is consistent with established engine performance theory. Outside this range, performance decreases due to airflow limitations, increased mechanical losses, and reduced combustion effectiveness, highlighting the interaction between thermodynamic efficiency, airflow dynamics, and mechanical losses in determining engine performance.

However, due to the reliance on pre-recorded data and limited experimental control, the results should be considered indicative rather than definitive, highlighting the importance of repeatability and controlled testing conditions in engine performance analysis.

6. Evaluation

Overall, the investigation into engine performance characteristics was successful in demonstrating how key parameters such as torque, brake power, and specific fuel consumption vary with engine speed. The tasks were completed effectively, including data processing, calculations, and graphical analysis, which allowed clear trends to be identified and linked to underlying engine theory.

A key limitation of this investigation was that the practical experiment could not be carried out directly due to the dynamometer not functioning during the session. As a result, the analysis relied on pre-recorded data rather than data collected first-hand, reducing the ability to validate results through repeatability and potentially affecting reliability.

There are also areas where my own performance could be improved. Some calculations required careful unit conversions, where minor errors could affect accuracy. Additionally, a more consistent link between theoretical principles and observed data would strengthen the analysis.

Another limitation was the number of data points, which may reduce graph accuracy and introduce uncertainty in identifying exact peak values.

To improve the investigation, a fully operational dynamometer test with direct data collection would allow greater control over variables and improved accuracy. Increasing the number of data points and comparing results with manufacturer specifications would further enhance reliability.

In conclusion, while the investigation successfully demonstrated key engine performance trends, improvements in experimental conditions and data analysis would enhance the overall reliability of the investigation.

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