

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



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

Engine Performance Characteristics

Motorsport Technology (ACHA4004)

Luke Anthony Dyas

Student ID: 2104531

26/03/2023

Contents

1	Introduction	2
2	Dynamometer Test Equipment.....	3
2.1	Dynamometer Run Tests.....	4
3	Dynamometer Data Calculations	5
4	Dynamometer Test Results - Graphs	6
4.1	Graph and Results Analysis	9
4.1.1	Specific Fuel Consumption Results	9
4.1.2	Engine Torque Output Results	9
4.1.3	Engine Brake Power Output Results	10
5	Conclusion.....	11
6	Evaluation	12
7	References	13
8	Appendix	14

1 Introduction

This analytical report will utilise an engine dynamometer to recreate and determine the characteristics of a 1.6 Honda VTEC D16 2001 Petrol Engine in a laboratory environment. The report will include a methodology, along with clear application of mathematical equations to take the raw results and present real world automotive design considerations in the form of graphs. Extensive external research will be conducted to improve the credibility and accuracy of the conclusions drawn. Furthermore, an evaluation of how the experiment has been conducted as well as how human input can impact the overall results.

Dynamometer or otherwise known as Dyno is the machine designed to measure engine power output. Originally, the dynamometer was a direct connection between the engine and a water brake, however it has developed, along with the internal combustion engine, to use electromagnetically induced current resistance. (Romandoni, N., Aminudin, A., Faizin, K.N., Puspitasari, I., Agus, A.T.S., Aziz, A. 2021)

2 Dynamometer Test Equipment

Dynamometer

Model: Schenck W230 (Limited to: 10,000 rpm; Max Load 230kW)

Eddy Current: Has an internal rotating core, powered by the direct driveshaft to the engine, and an external outer casing. An electrical current is induced to create an electromagnetic field, causing the rotating core and ultimately the engine to experience a resistive load. The counter rotational load encountered by the outer casing is measured by a strain gauge, providing a reading of 0 to 10 volts into the sensor computer system.

Calibration: Has two calibration arms (Opposed to negate each other) set at 815.776mm length from the Dyno's centre, to allow mass to be hung against the strain gauge and calibrate the system to accurately determine the engine torque.

Data Recording: Has sensors integrated to record Coolant Temperatures, Speed Readings and many more parameters depending on what information is required.

Cooling Measures: The dynamometer uses inlet and outlet valves connected to an external coolant tank to manage temperature.

Engine

Model: 1.6 Honda VTEC D16 2000/2001 Petrol Engine

- Has alternative air filter and silenced exhaust system installed.

Fuel Supply Board

- Lift Pump
- Filter
- Fuel Flow Meter
- Secondary Swirl Pot
- Main Fuel Pump
- Regulator – Allows running of fuel injected or non-injected engines.
- Return Fuel System:
 - o Cooling Plate

Additional Equipment

- Sensor Recording Module
- Exhaust Extraction system
- Fuel Safe
- Throttle Actuator Box
- Dynamometer and Engine Crankshaft are directly connected via driveshaft with RPM ratio of 1:1.
- Computer with screens to display information and control the dynamometer.

(Sandford, M. 2020)

2.1 Dynamometer Run Tests

There are 3 options available to an Eddy Dynamometer when deciding how the engine run is complete:

- Manual: The method which provides the most amount of freedom and control to the operator. Using the two hand dials, the engine throttle and Dynamometer resistance levels can be quickly adjusted. This is the trickiest and least accurate way to follow a predetermined run plan.
- Test Sequencing: Controlled by the software, the engine and dynamometer complete a pre-set program, used to simulate various situations. Both the throttle control and resistance levels are adjusted accurately by the computer if required.
- Dynamometer-Controlled Tests: The engine throttle position is set to 100% for the entire duration, allowing the dynamometers resistance to control the RPM. 2 methods of dynamometer-controlled tests are used, each with advantages and disadvantages:
 - o Step Test - The dynamometer allows the engine to run at full acceleration up to certain pre-set RPMs. It then increases the resistive current flow to hold the engine speed for a fraction of a second, providing the sensors with enough time to take a measurement. Then repeating again at the next set RPM until the test is complete.
 - + This method provides the sensors time to take accurate readings.
 - Unfortunately having to endure the high repetitive strain, the engine generates a lot of heat and wear. Meaning the test cannot be too long or repeated too many times.
 - o Sweep Test - *This is the method used to carry out this experiment.*
The engines acceleration under constant resistance is what determines the length of the run. The operator applies various parameters to the software to set the run plan and specifically the dynamometers required constant resistance. The throttle is then set to 100% and the engine pushes all the way through the RPM range until the selected end.
 - +This allows the engine to push smoothly through the RPMs, avoiding repetitive spikes in load, and reducing the engine temperature and wear experienced during the test.
 - This method is considered marginally less accurate due to the sensors having a shorter time to take measurements.

Dynamometer Pre-Set Run Plan Settings:

- Starting RPM = 1000
- Finishing RPM = 5500
- Data Interval RPM = 50
- Total Run Time = 15 Seconds
- From finishing RPM to Idle once complete = 5 Seconds

(Sandford M, 2020)

3 Dynamometer Data Calculations

Table 1: a table showing each symbol, fixed figures and units used during the mathematical equations and how they were determined. (Summerfield, A. 2021)

Symbol	Name	Figure/Unit	Equations Used
R	Rotational Arm Length	0.1815775m	Fixed Figure
L	Stroke Length	0.09m	Fixed Figure
Bd	Bore Diameter	0.075m	Fixed Figure
n	Number of Cylinders	4	Fixed Figure
A	Bore/Piston Area	0.0044179m	1
N	Number of Crankshaft Revolutions	rpm	Measured Figure
T	Engine Torque	Nm	4
P	Engine Power	Watts	2
Pc	Calculated Power	Kilowatts	3
Pa	Ambient Pressure	1.0189 Bar	Fixed Figure
Ta	Ambient Temperature	300K	Fixed Figure
W	Engine Load	N	Measured Figure
BMEP	Brake Mean Effective Pressure	Nm	5
FFR	Fuel Flow Rate	L/min	Measured Figure
ffr	Fuel Flow Rate	kg/h	8
SFC	Specific Fuel Consumption	Kg/kWh	6

Table 2: a table listing and numbering the equations used in this report and the excel document to determine further values. (Summerfield, A. 2021)

Equations	Equation Number
Bore Area	$A = \frac{\pi d^2}{4}$ 1
Power	$P = \frac{(2\pi NT)}{60}$ 2
Corrected Power	$P_c = \frac{1.01325}{P_a} \sqrt{\frac{T_a}{293}} * P$ 3
Torque:	$T = WR$ 4
BMEP:	$BMEP = \frac{(P*60*2)}{(LANn)}$ 5
SFC:	$SFC = \frac{(FFR*0.75*60)}{(\frac{P_c}{1000})}$ 6
Engine Thermal Efficiency	$Efficiency = \frac{(\frac{P}{1000})}{(\frac{FFR}{3600})^{4500}}$ 7
FFC>ffc (L/min > kg/h)	$ffc = FFR * 0.75 * 60$ 8

4 Dynamometer Test Results - Graphs

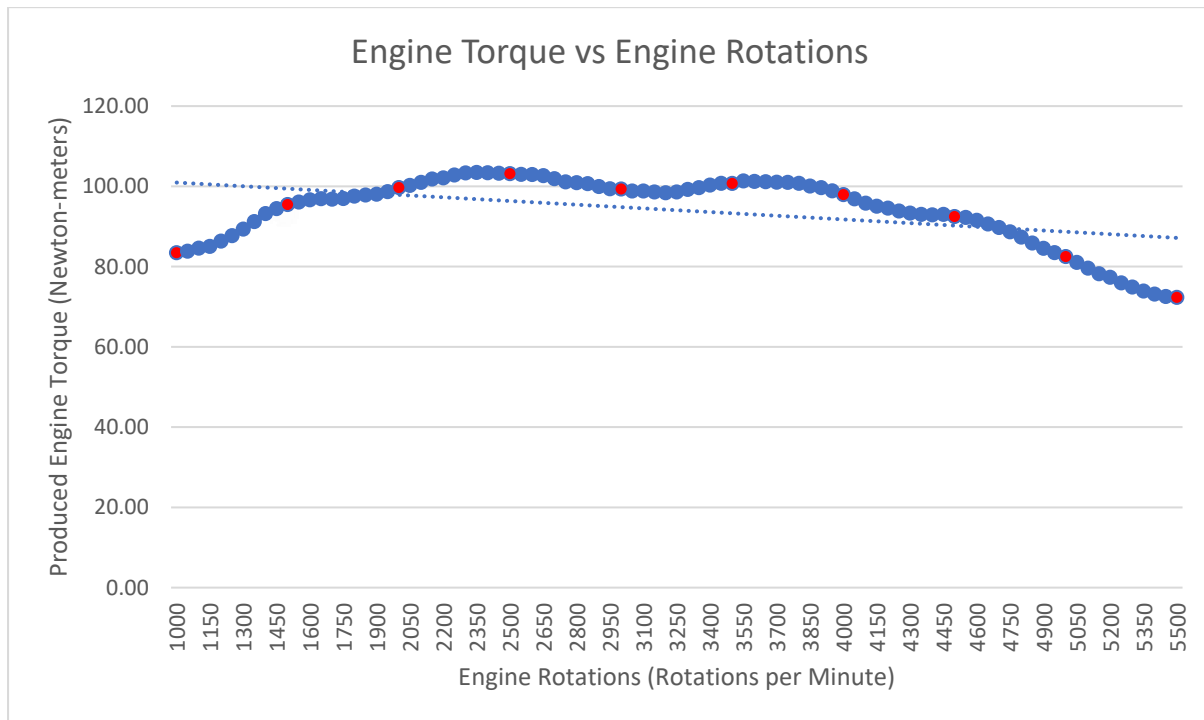


Figure 1: a line graph displaying Engine Torque against Engine rpm along with a trendline to show results general progression. It can be interpolated that the engine provides a consistent level of Torque (slight negative correlation) with only minor variation.

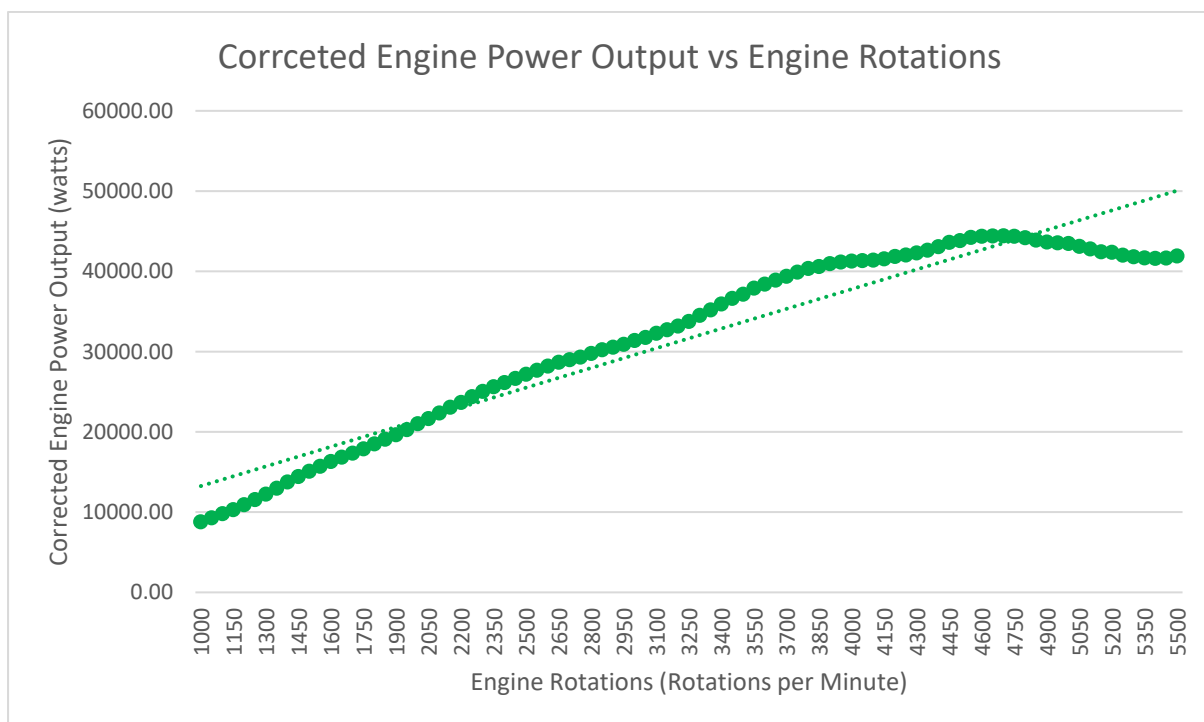


Figure 2: a line graph displaying Corrected Engine Power Output against Engine rpm along with a trendline to show results general progression. The Engines Corrected power Output follows a linear progression until the higher RPM range.

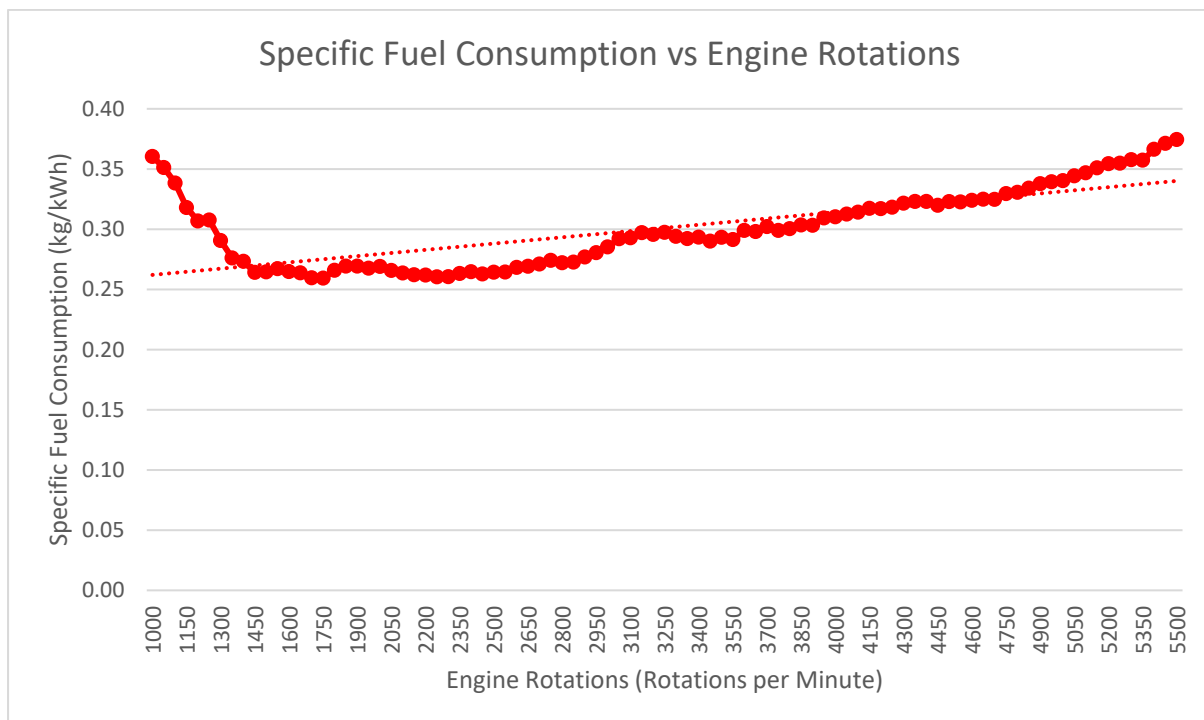


Figure 3: a line graph displaying Specific Fuel Consumption against Engine rpm along with a trendline to show results general progression. Initial spike in SFC maybe due to instant throttle set to 100% before returning to positive trendline linearity.

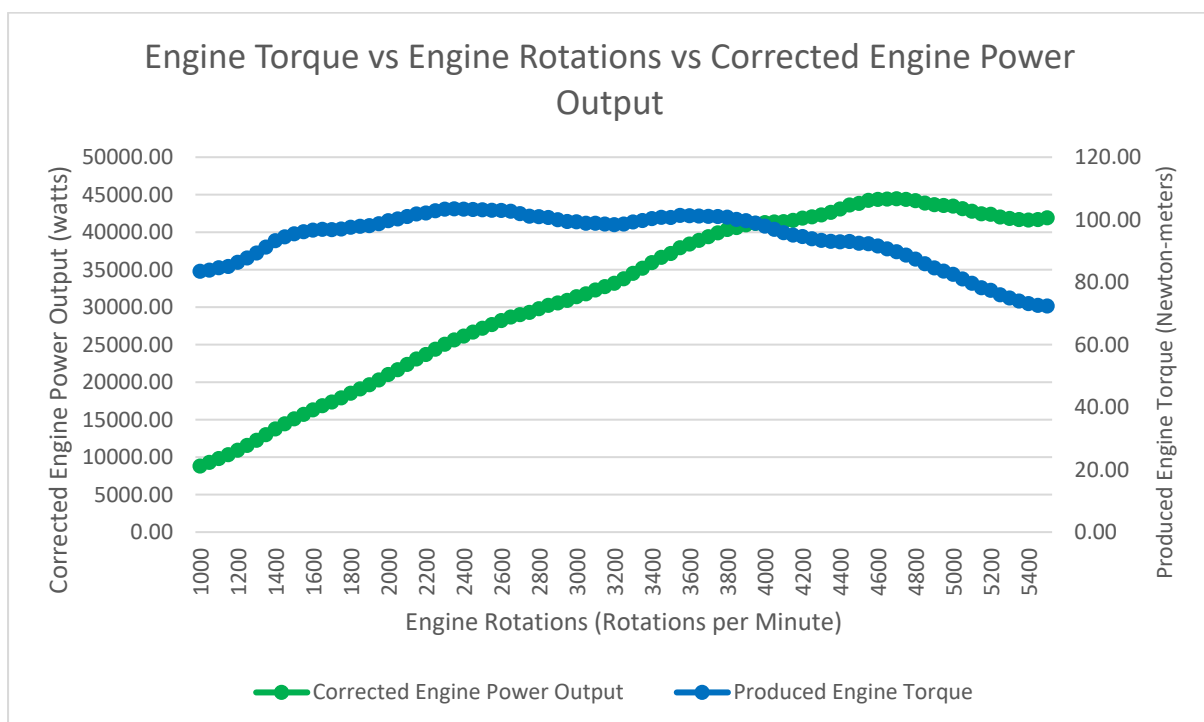


Figure 4: a colour-coded dual-axis line graph displaying Engine Torque and Corrected Engine Power Output against Engine RPM. This visually displays the correlation between Torque and Power against a time constant.

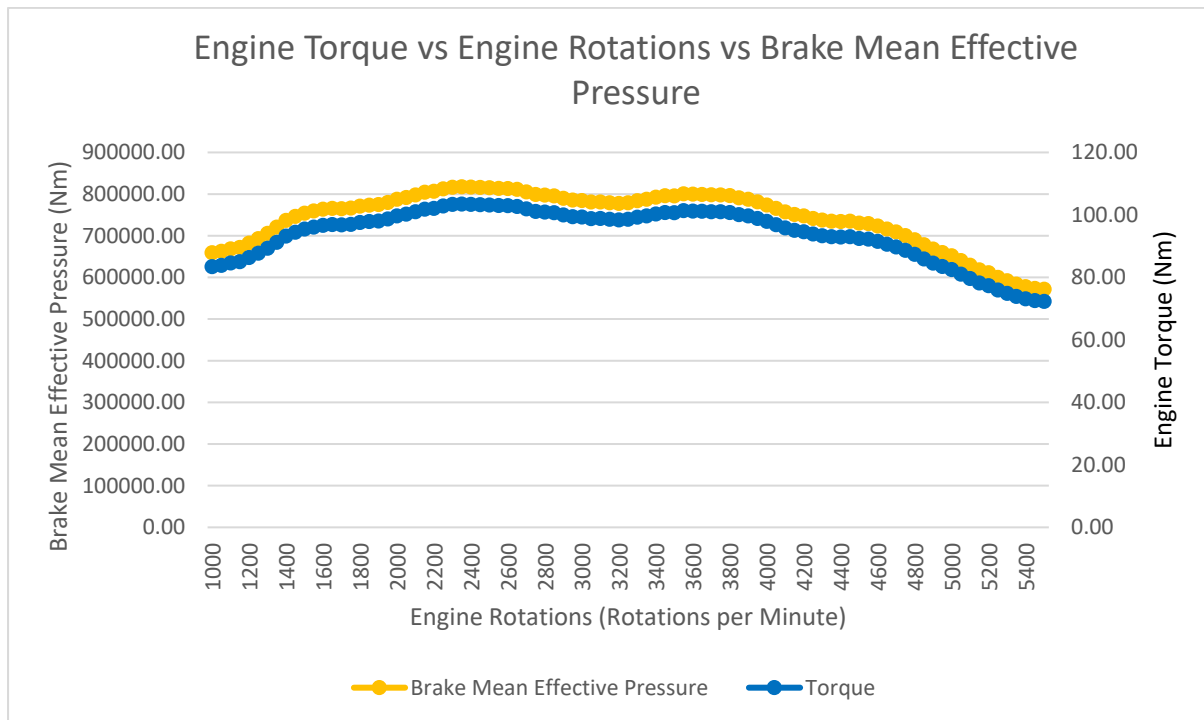


Figure 5: a colour-coded dual-axis line graph displaying Brake Mean Effective Pressure and Engine Torque against Engine RPM. This shows visually the direct comparison of linear Combustion Pressure and rotational Torque, with minor energy loss between conversion.

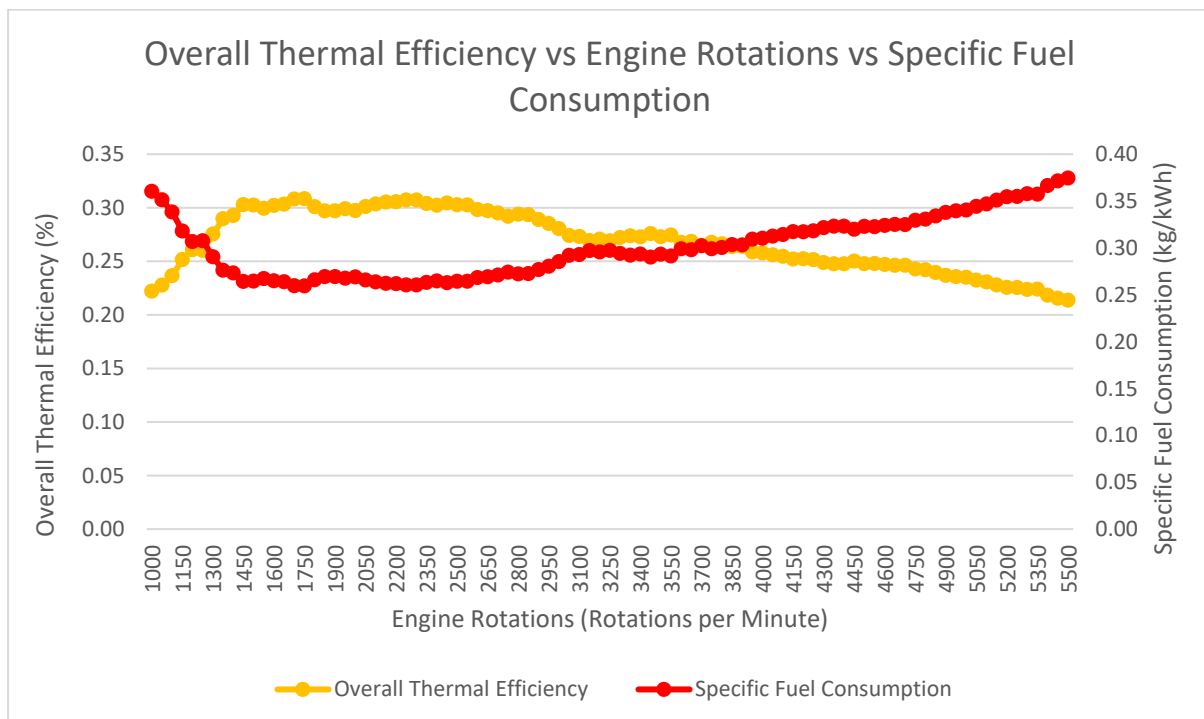


Figure 6: a colour-coded dual-axis line graph displaying Overall Thermal Efficiency and Specific Fuel Consumption against Engine RPM. This shows visually the direct comparison of the engines overall Efficiency and the levels of Fuel Consumption.

4.1 Graph and Results Analysis

4.1.1 Specific Fuel Consumption Results

Specific Fuel Consumption is the amount of fuel used by an internal combustion engine to produce a unit of power, in this case kilowatt-hours. It is vital that the engine's SFC is considered throughout its design as having a lower SFC improves the efficiency, economy and emissions of the engine.

Governmental implications are in place throughout the world to improve the environmental impact of producing and using a car (John Mikler. 2007). Figure 6 shows the direct correlation between SFC and Overall Engine Efficiency. The positive trendline of Figures 2 and 3 display the SFC of the Honda engine during its dynamometer run and demonstrates that the higher RPM uses more fuel to maintain or increase engine speed and power, this correlation is not linear. The higher RPM generates increased unwanted friction and less combustion time, meaning not all the chemical combustion is taking place, and un-burnt fuel is exhausted from the engine (Bağırov, Can, İ., Öner, C., Sugözü, İ., & Kapıcıoğlu, A. 2015).

4.1.2 Engine Torque Output Results

Torque is the rotational strength produced through the crankshaft. The crankshaft supplies angular motion to the car's systems and ultimately wheels. Torque, measured in Nm is affected by numerous factors, such as the engine shape and design, intake and exhaust gas utilisations, as well as the air-fuel mixture ratio (λ). The use of turbo and superchargers force more air into the engine, decreasing the λ ratio and increasing power (Lamchich. 2011). Large goods vehicles, such as Trucks, require extreme torque at low speeds for towing, while performance cars require torque at high engine speeds. Road cars are expected to have consistent sufficient torque throughout the RPM range to provide good acceleration and driving response as well as smoother power delivery (Heywood, J.B. 2018).

The direct correlation between the Mean Effective Pressure at the point of combustion with the overall engine torque output is visually represented in figure 5. The engine's ability to convert the linear movement into the crankshaft's rotational torque is effective and only uses up minor amounts of energy.

Figure 1 demonstrates Honda's objective to produce a consistent torque curve, however, the 'wavey' appearance could be a sign of a fault within the engine due to potentially the incorrect air filter being installed or something else further within the engine.

4.1.3 Engine Brake Power Output Results

The Engine Brake Power is the engine's ability to do work. Numerous factors impact the engine's capability to produce power (to name a few):

- Ambient Temperature
- Barometric Pressure
- Humidity
- Engine Temperature
- Fuel Quality

All of which are consistent or negligible changes during the 15 second dynamometer test.

The engine takes a mixture of air and fuel and ignites it with a spark under high compression. This causes a controlled explosion, inducing linear movement through the piston, which in turn, is then converted into a rotational force in the crankshaft. The overall produced power of the engine can be determined by the equation of:

Engine Power Output = Engine Torque x Engine Rotations per Minute (Summerfield, A. 2021)

Furthermore, for the results and graphs the following calculation has been used to determine a 'Corrected Engine Power Output', considering the previously listed factors, ensuring results are as accurate and representative as possible.

$$\text{Corrected Engine Power Output} = P_c = \frac{1.01325}{P_a} \sqrt{\frac{T_a}{293}} * P \quad (\text{Summerfield, A. 2021})$$

As previously determined the torque provided by this Honda Engine is consistent, causing the RPM to be the controlling factor of the engines output. This is supported by the linear progression of the Power Output curve in figure 4, which also levels out as the Torque curve begins to drop.

5 Conclusion

Listed below is a range of conclusions determined from the experiment and this report.

- It is evident that this engine has been designed and manufactured for road, as opposed to, performance applications because:
 - o The Torque Output is consistent across the low to mid-range RPM, providing better drivability.
 - o The level of fuel consumption and efficiency is at it's best during the low to mid-range RPM, typically used during road driving.
 - o The lambda ratio results show the engine is running very lean and using as little fuel as possible, again assisting with the economic and environmental costs of use.
- The mathematical theory of Engine Power Output = Torque x RPM, is evident and supported, as demonstrated by the linear trends of the graphical data.
- The energy lost in converting the pistons linear movement into the crankshaft rotational torque is very efficient as only a small amount is lost, as well as being consistent across the rpm range.
- These results cannot be used as an accurate representation of the engine's original figures because:
 - o The engine was manufactured in 2001.
 - o The engine has been used an uncountable number of times to complete the same or similar tests.
 - o The engine's original air filter has been replaced with the air filter from an old lawn mower, impacting the airflow and original engine characteristics.

6 Evaluation

Throughout the Dynamometer experiment there are numerous parameters in place to reduce the human impact on results:

- The entire run plan is controlled and managed by the computer software.
- All results are recorded and presented by the integrated sensors and software.
- The use of computer calculated equations massively reduces mathematical errors (Excel).

However, the risk of human interaction and error can never be completely avoided:

- All computer software parameters are pre-programmed.
- The interpretation and rearranging of mathematical equations, as well as imputing correctly into Excel.

It is possible to reduce the chance of human error, or at least increase the chances of noticing the error:

- Before completing the experiment ensure the engine assembly is correct with the same or as close to original components as possible so results and hypothesis can be compared.
- Complete the experiment more than once, with complete checks of rig assembly, and software programming between each run. An incorrect/faulty set of results will become more noticeable.

The overall nature of the experiment itself doesn't allow for too much human interaction to take place, however when it does, if not managed correctly, can cause major changes to results.

7 References

Bağirov, Can, İ., Öner, C., Sugözü, İ., & Kapıcıoğlu, A. (2015). Experimental investigation the effects of mixture impoverished on the specific fuel consumption, engine performance and exhaust emissions a pre-combustion chamber gasoline engine. *Journal of the Energy Institute*, 88(3), 205–208.
<https://doi.org/10.1016/j.joei.2014.09.009>

Heywood, J.B. (2018). *Internal combustion engine fundamentals*. New York: Mcgraw-Hill Education.

John Mikler. (2007) Framing Environmental Responsibility: National Variations in Corporations' Motivations. *Policy and Society* 26:4, pages 67-104.

Lamchich MT (ed.) (2011) Torque Control. InTech. DOI: 10.5772/636.

Mark Sandford (2020) *Engine Dynamometer Overview* 16 October. Available at: Engine Dynamometer Overview - YouTube

Mark Sandford (2020) *Engine Dynamometer testing* 16 October. Available at: Engine Dynamometer testing - YouTube

Romandoni, N., Aminudin, A., Faizin, K.N., Puspitasari, I., Agus, A.T.S. and Aziz, A. (2021). Design of Water Brake Dynamometer. *Journal of Physics: Conference Series*, 1845(1), p.012048.
doi:<https://doi.org/10.1088/1742-6596/1845/1/012048>.

Summerfield, A. (2021) 'Motorcycle/Motorsport/Vehicle Technology Handout'. University of Wales Trinity Saint David. Unpublished.

8 Appendix

Appendix 1

Engine Dyno Calculated Results						
Power W $P=(2\pi \cdot N \cdot T)/60$	Corrected Power W P_c	Corrected Power kW	Torque N/M $T=W/R$	BMEP N/M $MEP=(P \cdot 60 \cdot 2)/(\pi \cdot L \cdot A \cdot n)$	Brake SFC kg/kWh $SFC=((\text{ffr} \cdot 0.75 \cdot 60)/(\text{Pc}/1000))$	Overall Thermal Efficiency % $(\text{P}/1000)/((\text{ffr}/3600) \cdot 4500)$
8737.12	8791.85	8.79	83.43	659206.58	0.36	0.22
9217.13	9274.86	9.27	83.83	662306.83	0.35	0.23
9743.71	9804.74	9.80	84.59	668320.42	0.34	0.24
10237.69	10301.82	10.30	85.01	671672.04	0.32	0.25
10847.04	10914.98	10.91	86.32	681997.63	0.31	0.26
11480.42	11552.33	11.55	87.70	692948.41	0.31	0.26
12159.31	12235.47	12.24	89.32	705697.48	0.29	0.28
12893.27	12974.03	12.97	91.20	720579.98	0.28	0.29
13666.32	13751.93	13.75	93.22	736506.65	0.27	0.29
14342.07	14431.91	14.43	94.45	746271.48	0.26	0.30
14990.65	15084.55	15.08	95.43	754018.88	0.26	0.30
15596.67	15694.36	15.69	96.09	759194.57	0.27	0.30
16193.14	16294.57	16.29	96.65	763596.80	0.26	0.30
16741.60	16846.47	16.85	96.89	765536.87	0.26	0.30
17232.08	17340.02	17.34	96.80	764789.20	0.26	0.31
17769.55	17880.86	17.88	96.96	766110.52	0.26	0.31
18388.43	18503.61	18.50	97.55	770770.56	0.27	0.30
18954.53	19073.26	19.07	97.84	773026.46	0.27	0.30
19506.10	19628.28	19.63	98.04	774586.26	0.27	0.30
20148.02	20274.22	20.27	98.67	779562.13	0.27	0.30
20871.20	21001.93	21.00	99.65	787354.66	0.27	0.30
21513.46	21648.22	21.65	100.21	791789.12	0.27	0.30
22208.79	22347.90	22.35	100.99	797918.72	0.26	0.30
22920.87	23064.45	23.06	101.80	804351.26	0.26	0.31
23518.38	23665.70	23.67	102.08	806562.05	0.26	0.31
24224.15	24375.89	24.38	102.81	812304.93	0.26	0.31
24886.64	25042.53	25.04	103.33	816378.44	0.26	0.31
25460.18	25619.66	25.62	103.46	817422.60	0.26	0.30
25974.82	26137.52	26.14	103.35	816571.80	0.26	0.30
26487.08	26652.99	26.65	103.24	815682.33	0.26	0.30
27003.29	27172.43	27.17	103.14	814947.56	0.26	0.30
27500.00	27672.26	27.67	102.98	813664.91	0.26	0.30
28021.89	28197.42	28.20	102.92	813162.17	0.27	0.30
28489.69	28668.15	28.67	102.66	811138.30	0.27	0.30
28811.34	28991.81	28.99	101.90	805105.38	0.27	0.30
29113.72	29296.08	29.30	101.10	798763.07	0.27	0.29
29586.13	29771.45	29.77	100.90	797229.06	0.27	0.29
30041.41	30229.58	30.23	100.66	795295.43	0.27	0.29
30352.92	30543.04	30.54	99.95	789687.91	0.28	0.29
30704.37	30896.70	30.90	99.39	785292.12	0.28	0.29
31191.98	31387.36	31.39	99.29	784467.11	0.29	0.28
31559.16	31756.84	31.76	98.81	780690.08	0.29	0.27
32076.79	32277.71	32.28	98.81	780696.53	0.29	0.27
32520.69	32724.40	32.72	98.59	778936.93	0.30	0.27
32967.19	33173.69	33.17	98.38	777293.34	0.30	0.27
33550.04	33760.20	33.76	98.58	778866.03	0.30	0.27
34289.75	34504.54	34.50	99.23	783977.25	0.29	0.27
34966.12	35185.15	35.19	99.67	787509.35	0.29	0.27
35706.43	35930.09	35.93	100.29	792356.32	0.29	0.27
36391.26	36619.21	36.62	100.73	795849.74	0.29	0.28
36904.62	37135.79	37.14	100.69	795546.80	0.29	0.27
37667.47	37903.41	37.90	101.32	800554.91	0.29	0.27
38155.25	38394.25	38.39	101.21	799658.99	0.30	0.27
38654.31	38896.44	38.90	101.13	799020.89	0.30	0.27
39135.78	39380.92	39.38	101.01	798041.19	0.30	0.26
39649.27	39897.62	39.90	100.97	797731.81	0.30	0.27
40094.17	40345.31	40.35	100.76	796068.88	0.30	0.27
40346.44	40599.16	40.60	100.07	790674.06	0.30	0.26
40698.83	40953.77	40.95	99.65	787354.66	0.30	0.26
40892.29	41148.43	41.15	98.86	781083.25	0.31	0.26
41006.69	41263.55	41.26	97.90	773477.64	0.31	0.26
41079.88	41337.19	41.34	96.86	765291.95	0.31	0.26
41134.51	41392.17	41.39	95.81	756964.45	0.31	0.25
41302.19	41560.90	41.56	95.04	750892.85	0.32	0.25
41595.65	41856.20	41.86	94.57	747225.40	0.32	0.25
41765.16	42026.77	42.03	93.84	741443.85	0.32	0.25
42020.32	42283.53	42.28	93.32	737299.43	0.32	0.25
42369.57	42634.97	42.63	93.01	734882.40	0.32	0.25
42802.07	43070.18	43.07	92.89	733947.81	0.32	0.25
43331.80	43603.22	43.60	92.99	734682.59	0.32	0.25
43557.65	43830.49	43.83	92.43	730306.14	0.32	0.25
43951.45	44226.75	44.23	92.24	728810.80	0.32	0.25
44089.01	44365.18	44.37	91.53	723145.26	0.32	0.25
44117.77	44394.12	44.39	90.60	715836.14	0.32	0.25
44155.31	44431.89	44.43	89.71	708823.51	0.32	0.25
44089.82	44365.99	44.37	88.64	700321.99	0.33	0.24
43906.86	44181.89	44.18	87.35	690151.10	0.33	0.24
43603.52	43876.65	43.88	85.85	678317.28	0.33	0.24
43379.94	43651.67	43.65	84.54	667953.03	0.34	0.24
43274.14	43545.20	43.55	83.48	659593.30	0.34	0.24
43186.29	43456.81	43.46	82.48	651671.87	0.34	0.24
42845.46	43113.84	43.11	81.02	640127.45	0.34	0.23
42514.46	42780.76	42.78	79.60	628954.94	0.35	0.23
42168.87	42433.01	42.43	78.19	617785.65	0.35	0.23
42113.93	42377.73	42.38	77.34	611048.24	0.35	0.23
41753.88	42015.42	42.02	75.95	600054.27	0.35	0.23
41558.86	41819.18	41.82	74.88	591617.20	0.36	0.22
41404.86	41664.21	41.66	73.90	583916.19	0.36	0.22
41350.62	41609.63	41.61	73.12	577751.78	0.37	0.22
41402.09	41661.43	41.66	72.54	573163.92	0.37	0.22
41651.22	41912.11	41.91	72.32	571370.81	0.37	0.21

Appendix 2

Engine Dyno Raw Data				
Load	Dyno Speed	Fuel Flow Rate (FFR)	Lambda	Fuel Flow Rate (ffr)
Newton's	rpm	L/min		kg/h
102.28	1000	0.07	1.27	3.17
102.76	1050	0.07	1.27	3.26
103.69	1100	0.07	1.27	3.32
104.21	1150	0.07	1.28	3.28
105.81	1200	0.07	1.29	3.35
107.51	1250	0.08	1.30	3.55
109.49	1300	0.08	1.30	3.56
111.80	1350	0.08	1.29	3.58
114.27	1400	0.08	1.29	3.76
115.78	1450	0.08	1.28	3.81
116.99	1500	0.09	1.28	3.99
117.79	1550	0.09	1.28	4.19
118.47	1600	0.10	1.28	4.32
118.77	1650	0.10	1.29	4.44
118.66	1700	0.10	1.30	4.50
118.86	1750	0.10	1.31	4.64
119.58	1800	0.11	1.31	4.92
119.93	1850	0.11	1.32	5.14
120.18	1900	0.12	1.32	5.29
120.95	1950	0.12	1.31	5.42
122.16	2000	0.13	1.32	5.65
122.85	2050	0.13	1.32	5.75
123.80	2100	0.13	1.32	5.89
124.79	2150	0.13	1.32	6.05
125.14	2200	0.14	1.32	6.20
126.03	2250	0.14	1.30	6.35
126.66	2300	0.14	1.30	6.52
126.82	2350	0.15	1.28	6.74
126.69	2400	0.15	1.27	6.92
126.55	2450	0.16	1.27	7.00
126.44	2500	0.16	1.27	7.18
126.24	2550	0.16	1.28	7.32
126.16	2600	0.17	1.28	7.56
125.85	2650	0.17	1.28	7.72
124.91	2700	0.17	1.28	7.86
123.93	2750	0.18	1.28	8.03
123.69	2800	0.18	1.27	8.10
123.39	2850	0.18	1.26	8.24
122.52	2900	0.19	1.25	8.46
121.84	2950	0.19	1.24	8.66
121.71	3000	0.20	1.23	8.96
121.12	3050	0.21	1.22	9.27
121.12	3100	0.21	1.21	9.45
120.85	3150	0.22	1.19	9.72
120.60	3200	0.22	1.18	9.81
120.84	3250	0.22	1.17	10.04
121.63	3300	0.23	1.16	10.15
122.18	3350	0.23	1.15	10.28
122.93	3400	0.23	1.14	10.54
123.48	3450	0.24	1.13	10.62
123.43	3500	0.24	1.12	10.89
124.21	3550	0.25	1.11	11.05
124.07	3600	0.26	1.10	11.48
123.97	3650	0.26	1.09	11.59
123.82	3700	0.26	1.10	11.90
123.77	3750	0.27	1.10	11.93
123.51	3800	0.27	1.10	12.12
122.67	3850	0.27	1.11	12.32
122.16	3900	0.28	1.12	12.42
121.18	3950	0.28	1.12	12.73
120.00	4000	0.28	1.12	12.80
118.73	4050	0.29	1.12	12.92
117.44	4100	0.29	1.12	13.00
116.50	4150	0.29	1.12	13.19
115.93	4200	0.29	1.12	13.27
115.03	4250	0.30	1.12	13.37
114.39	4300	0.30	1.12	13.60
114.02	4350	0.31	1.12	13.77
113.87	4400	0.31	1.12	13.91
113.99	4450	0.31	1.12	13.95
113.31	4500	0.31	1.12	14.15
113.07	4550	0.32	1.11	14.27
112.20	4600	0.32	1.11	14.37
111.06	4650	0.32	1.10	14.42
109.97	4700	0.32	1.10	14.43
108.65	4750	0.32	1.09	14.62
107.08	4800	0.32	1.08	14.60
105.24	4850	0.33	1.08	14.66
103.63	4900	0.33	1.08	14.75
102.34	4950	0.33	1.09	14.78
101.11	5000	0.33	1.09	14.79
99.31	5050	0.33	1.09	14.84
97.58	5100	0.33	1.09	14.84
95.85	5150	0.33	1.09	14.89
94.80	5200	0.33	1.09	15.02
93.10	5250	0.33	1.09	14.91
91.79	5300	0.33	1.08	14.96
90.59	5350	0.33	1.08	14.89
89.64	5400	0.34	1.08	15.25
88.93	5450	0.34	1.08	15.47
88.65	5500	0.35	1.08	15.70

Appendix 3

Baro	Humidity	Ambient temp	Ambient temp
mBar	%	Deg C	Kelvin
1.0189	46	27	300