

University of Wales Trinity Saint David

Wales Institute of Science and Art



Prifysgol Cymru

Y Drindod Dewi Sant

University of Wales

Trinity Saint David

Engine Performance Characteristics

Motorsport technology (ACHA4012)

Alexander Cook

2104599

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1 Introduction

This report will consist of an overview of an engine dynamometer test conducted on a 1.6 Honda VTEC D16 petrol engine.

An engine dynamometer also referred to as a dyno is a device consisting of the test rig bolted to the engine crankshaft, sensors and a computer to measure different characteristics allowing to calculate the power of the engine. (IQS Directory, 2024)

The data gathered during the test sequence consisted of the load on the dyno, the dyno speed, the fuel flow rate along with the values for lambda. The data for the ambient temperature, pressure and humidity were recorded to aid with further calculations.

This data will then be used to calculate various characteristics of the engine and allow for different graphs to be produced giving an understanding of how each characteristic is influenced by another.

1.1 Aims

- Run the Honda d16 on the dyno.
- Analyse the data gathered using various spreadsheets.
- Produce the following graphs,
 - SFC against Engine speed.
 - Torque compared to BMEP against Engine speed.
 - Brake power compared to corrected power against engine speed.
 - Corrected power compared to torque against Engine speed.
 - Specific fuel consumption compared to Overall thermal efficiency vs engine speed.

1.2 Objectives

- Give an understanding of a dynamometer test and the basic steps to recreate the test.
- Show a clear understanding of the data recorded and the results calculated using tables and graphs.

2 Experimental procedure

2.1 Dynamometer and equipment specifications

2.1.1 Dynamometer

The dyno used to conduct the test is a Schenck WS230 - limited to 10 000 rpm and max load of 230kW.

- It is an Eddy-current dyno meaning, the inner core spins freely bolted directly to the flywheel of the engine via a driveshaft and is powered by the engine. This meaning that the engine speed matches that of the dyno. The outer casing is fed by a current producing an electromagnetic field putting a load on the engine to slow it down. The reaction of this force on the outer casing causes it to turn. When it does so it is restricted by a strain gauge, this sends a voltage signal to the computer system that is then used to calculate the torque of the engine. Due to the amount of current passing through the system and the heat created from it, the dyno is fitted with a cooling system. (Schenck Pegasus GmbH, 2001)
- The system is calibrated using the calibration arms on either side of the casing, each have a length of 815.776mm from the dyno centre to the hook eye. A mass is hung on one end causing the casing to rotate and therefor the strain gauge to send a signal to the computer. This is then used to calculate the torque applied around central axis of dynamometer.
- Data recording: The dyno is fitted with a coolant temperature sensor and speed sensor. Depending on what is being measured it can be fitted with over 2000 different sensors.

2.1.2 Engine

Honda 1.6 VTEC (2000/2001) D16 – from a Honda Civic coupe CRX

Fitted with:

- A custom air filter.
- No silencer just an extraction pipe with an alternative silencer.

It is self-contained on the rig, the basic functions are controlled via the sensor modules.

2.1.3 Fuel supply board.

The fuel supply board consists of the following,

- Lift pump.
- Main tank situated in the fuel safe.
- Fuel filter.
- Fuel flow meter.
- Secondary swirl pod.
- Main fuel pump.

- Regulator – allowing non-fuel injected and fuel injected engines to be used.
→ The fuel then feeds the engine.
- Return system – fuel is fed back up through a cooling plate and into the secondary swirl pod.

The fuel flow meter only registers what is in system while its running as the return bypasses it.

2.1.4 Other equipment

- Sensor recorder modules which feeds the computers with the data.
- Exhaust extraction system.
- Computer control system

Engine Sensors:

- coolant temperature
- Fuel flow meter
- Lambda sensor

The throttle is controlled via the computer, it is actuated from the throttle actuator box which gives recorded readings of throttle position.

(Sandford, Youtube , 2020)

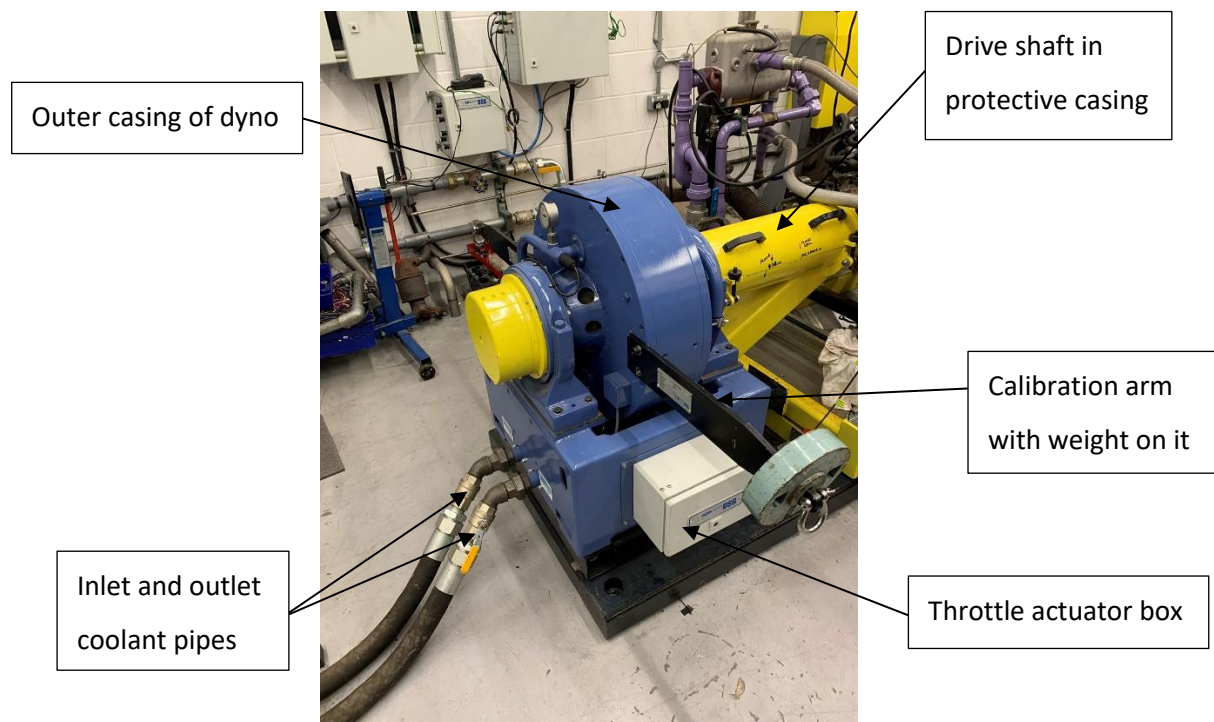


Figure 1 - Labelled photo of the engine dynamometer.

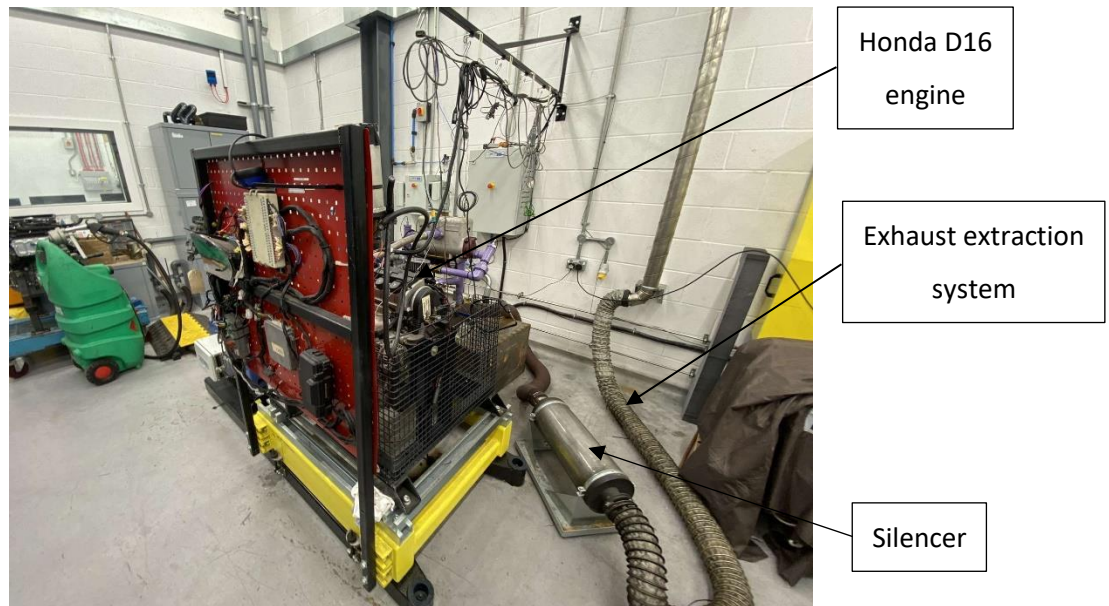


Figure 2 - Labelled photo showing the engine and extraction system.

2.2 Dynamometer tests

There are three ways to run tests:

Manual: The dyno is controlled by two dials.

Dynamometer, controlling the load applied to the engine and the engine dial controls the engine speed. This gives the user full control over all the settings of the dyno.

Test sequencing:

The user fills in various parameters defining the engine behaviour and then the system will run through each step automatically. Up to 1000 steps can input including loops between steps allowing to create drive cycles and program in specific tests.

P-curve test: The throttle is set to 100% allowing the dynamometer load to control the engine speed.

This consists of two types of tests:

- The step test is used for targeting specific areas, inputting selected engine speeds and holding them while data is gathered such as fuel consumption, emissions etc. This is targeted by inputting a start and finish RPM with steps in between and how long the data is logged for at that speed.

The step test isn't worth running over long periods as the throttle is being held open for longer this creates more heat and higher strain levels on the engine.

- The sweep test, this will be used to gather the data for this experiment.
The difference between the two test is that the sweep test does not pause at every step, it just takes readings, meaning the sensors aren't as accurate when measuring.
Not as accurate as the step test but won't allow engine to overheat.

Test run for the data:

Set Ramp time (time takes before test start) - set to 1 second.

Set start rpm to 1250.

Finish at 5500 rpm.

Log every 50rpm.

Total ramp time 15 seconds.

End test at idle 1000rpm.

0% throttle.

Ramp 5 seconds to get there.

(Sandford, Youtube, 2020)



Figure 3 - Labelled photo of the control panel for the dyno.

3 Data and equations

Table 1 - Data of the atmospheric characteristics in the dynamometer room along with the calorific value of fuel and standard values used for the equations.

Calorific value of fuel	Ambient pressure	Standard pressure	Humidity	Ambient temperature	Standard temperature	Specific gravity of fuel converts litres to kg
kJ/kg	mBar	Bar	%	Degrees C	Kelvin	
49 000	1018.9	1.01325	46	27	293	0.75

Calorific value of fuel – (Dincer, Khalid, & Rosen, 2018)

Table 2 - Data and results for the engine and dynamometer characteristics.

Torque Arm length mm	Torque Arm length m	Bore diameter mm	Bore diameter m	Stroke mm	Stroke m	Number of cylinders	Piston Area m ²
815.776	0.815776	75	0.075	90	0.09	4	0.004417865

Table 3 - Units and symbols

	Symbols	Units
Power	P	Kilowatts (kW)
Engine Speed	N	RPM
Torque	T	Newtons meters (N/m)
Engine load	W	Newtons (N)
Torque Arm length	R	Meters (m)
Corrected Power	P _s	Kilowatts (kW)
Stroke	L	Meters (m)
Piston area	A	Meters squared (m ²)
Number of cylinders	n	-
Ambient pressure	p _a	Bar
Ambient temperature	T _a	Kelvin (K)
Brake mean effective pressure	BMEP	Pascals (Pa)
Fuel flow rate	ffr	Litres per minute (l/min)
Overall thermal efficiency	η	%
Specific fuel consumption	SFC	kg/kWh

- Torque (N)

$$T = W \times R$$

Equation 1 - This equation is used to calculate the torque.

- **Power (kW)**

$$P = \left(\frac{2\pi \times N \times T}{60} \right) \times 10^{-3}$$

Equation 2 - Equation used to calculate the power of the engines.

- **Corrected power (kW)**

$$P_s = \frac{1.01325}{p_a} \times \sqrt{\frac{T_a}{293}} \times P$$

Equation 3 - Equation used to calculate the corrected power.

- **Brake mean effective pressure (Pa)**

$$BMEP = \frac{T \times 4\pi}{L \times A \times n}$$

Equation 4 - Equation used to calculate the BMEP.

- **Specific fuel consumption (kg/kWh)**

$$SFC = \frac{ffr \times 0.75 \times 60}{P_s}$$

Equation 5 - Equation used to calculate the specific fuel consumption of the engine.

The 60 in this case is converting the fuel flow rate from minutes to hours.

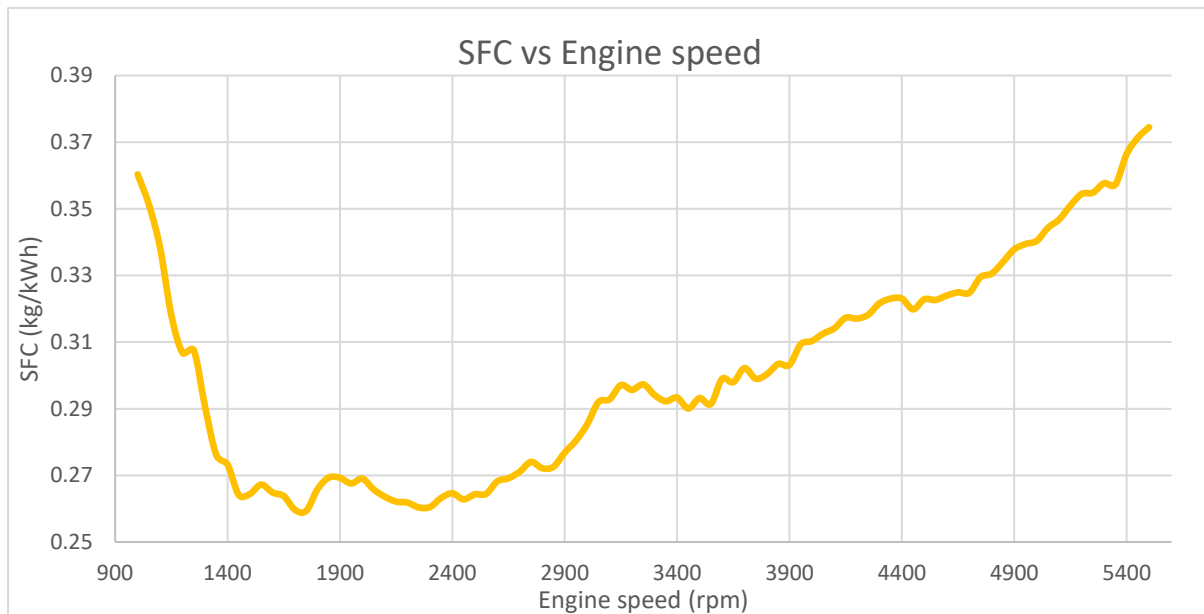
- **Overall thermal efficiency (%)**

$$\eta = \left(\frac{P_s}{\frac{ffr \times 0.75}{60} \times 49000} \right)$$

Equation 6 - Equation used to calculate the overall thermal efficiency of the engine.

(Penny, 2020)

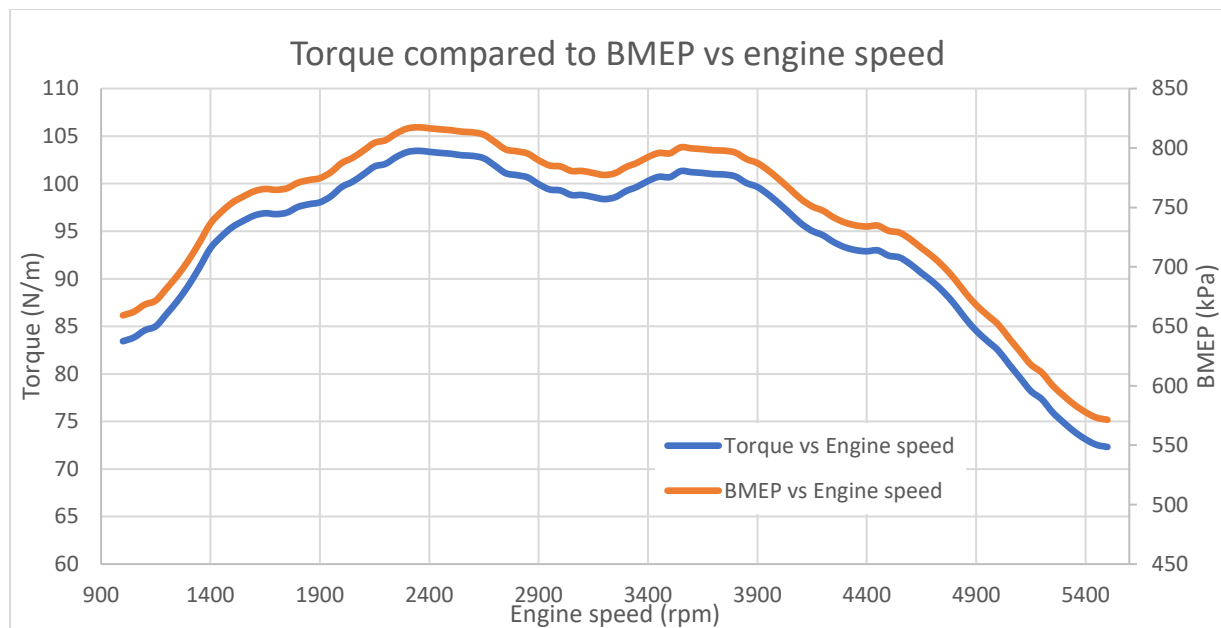
4 Data and graph analysis



Graph 1 - Graph showing the specific fuel consumption measured against the engine speed.

Specific fuel consumption measures the amount of fuel used by an internal combustion engine to produce power. It is an important figure for manufactures as it indicates how efficiently the engine converts fuel into power, this becoming more important with emissions rules getting stricter. (Sforza, 2014)

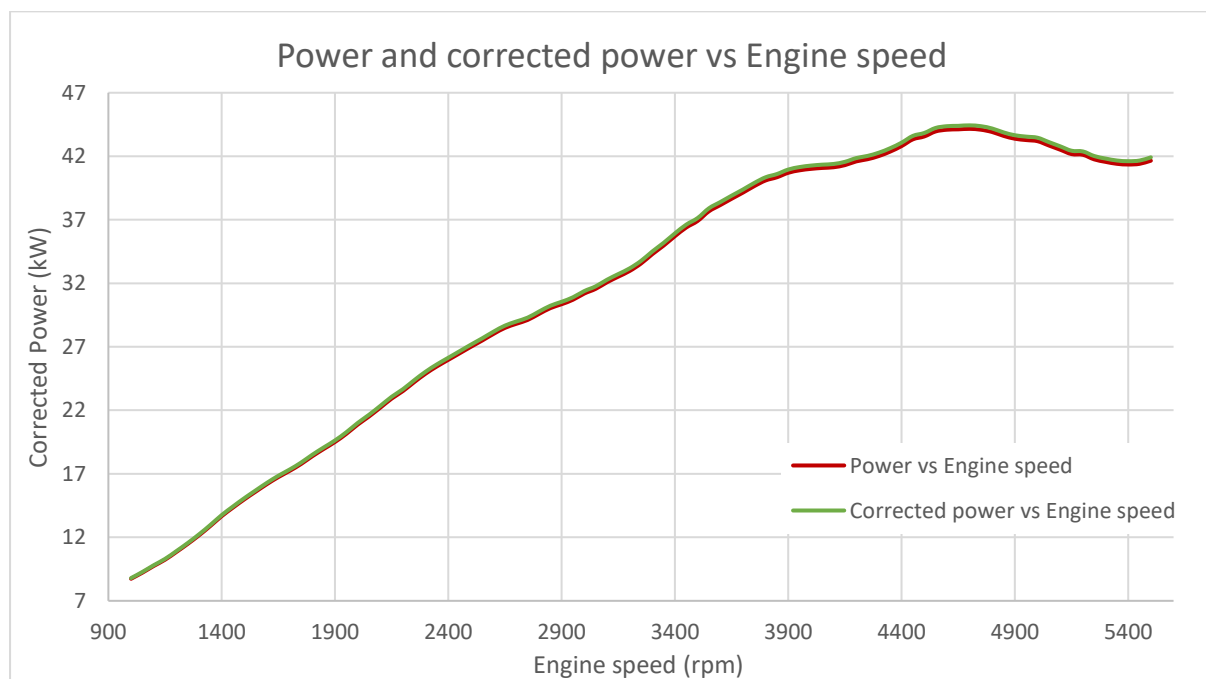
The graph shows that the fuel consumption is higher at idle speed before quickly dropping, it then gradually increases with the engine speed. The most efficient range is between 1700rpm and 2500rpm. This shows that engine speed affects the fuel consumption. As the engine revs higher, it demands more fuel to produce its power and torque therefor increasing the fuel consumption.



Graph 2 - Graph comparing the torque and brake mean effective pressure plotted against the engine speed.

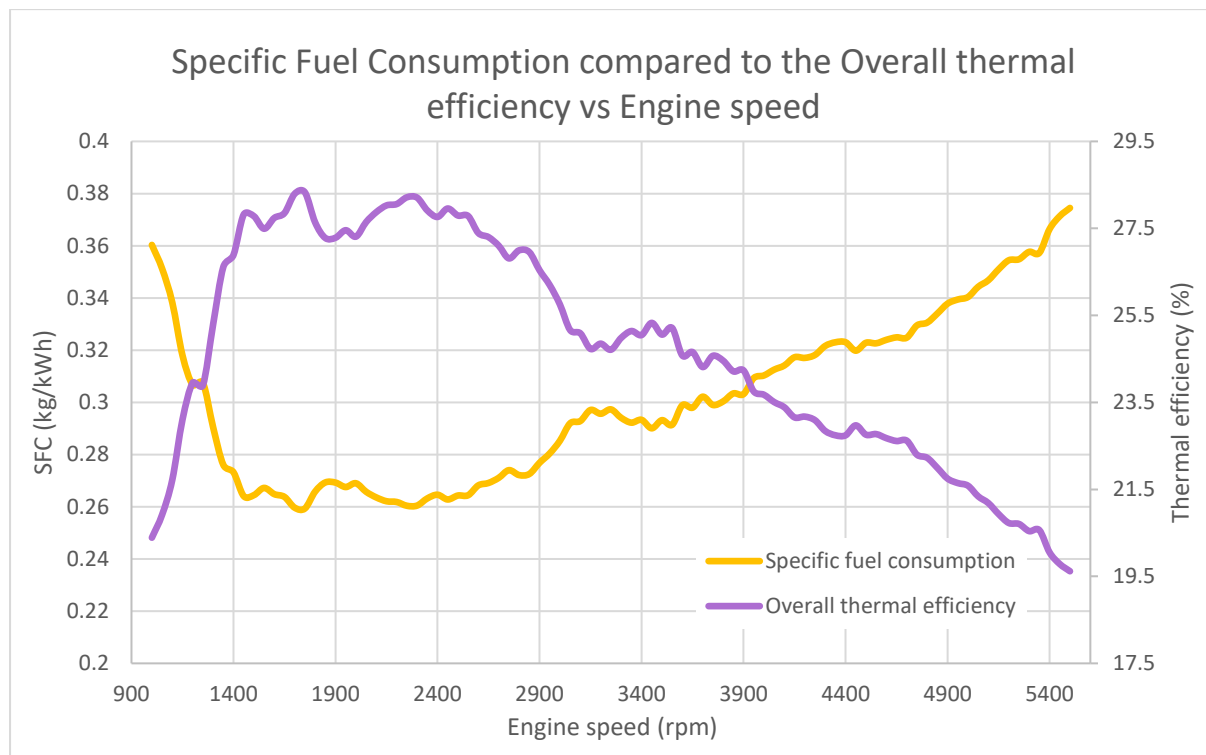
Torque is a force created by the engine that is a twisting moment about an axis. (Atkins & Escudier, 2013). BMEP is the pressure available within the cylinders to do work throughout the stroke. (Penny, 2020). The above graphs shows that torque and BMEP are proportional.

The torque created by the engine varies with engine speed, it is at its highest in the regions of 2400rpm and climbs again around 3400rpm to 3800rpm this could possibly be linked with the VTEC switching on which is Hondas form of variable valve timing, this can optimize engine performance, fuel efficiency and emission (Kuo, 2012).

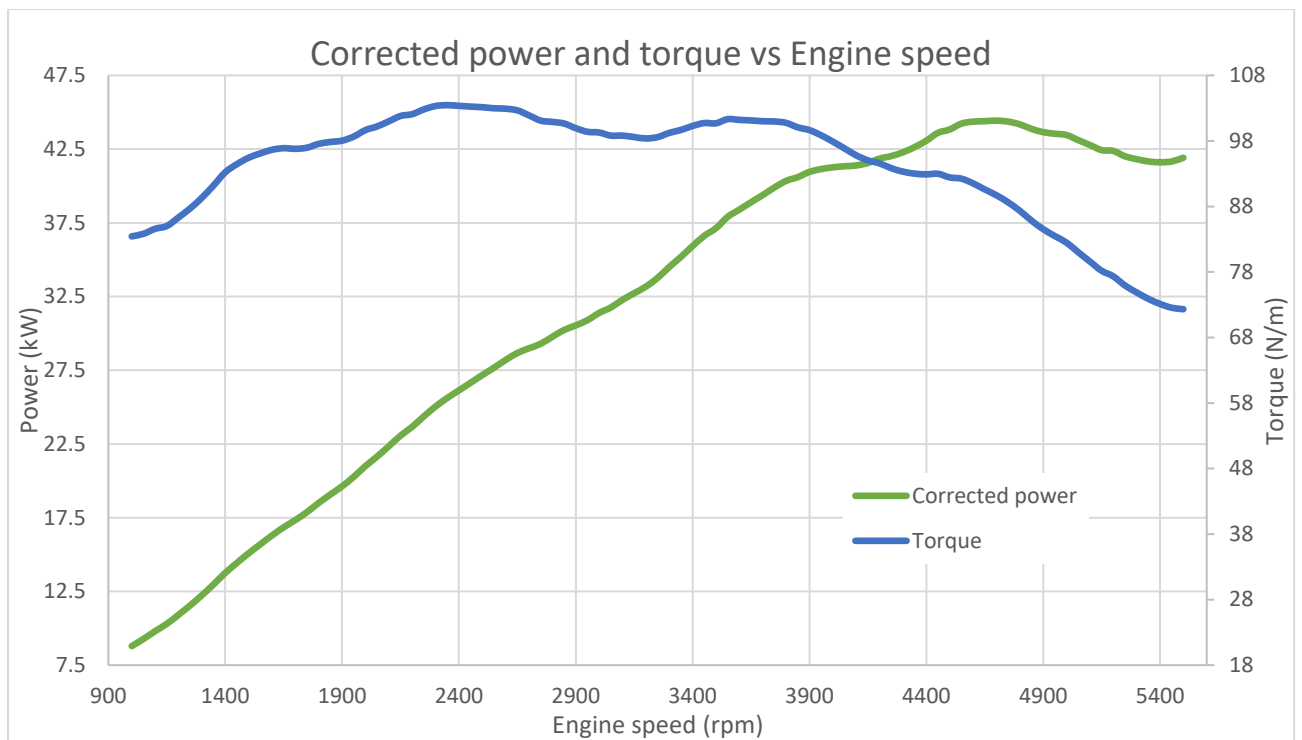


Graph 3 - A graph showing the comparison of the Power and corrected power in relation to the engine speed.

Brake power is the measurement at which the energy created by burning the fuel is converted into a force pushing the pistons down and creating a rotational movement on the crankshaft. (Heywood, 1998). The graph shows that the brake power increases with the engine speed. It is linear until around 3900rpm before the curve flattens out. It peaks at 44.16kW and 44.43kw for corrected power before decreasing. The engine power increases in the same manor the fuel consumption does.



Graph 4 - Graph looking at the specific fuel consumption compared to the overall thermal efficiency of the engine against the engine speed.



Graph 5 - This graph shows the torque and corrected power in relation to the engine speed.

5 Conclusion

Various external factors impact the engines power:

- Ambient pressure
- Ambient temperature
- Humidity
- Friction within the engine
- Fuel quality, therefor the calorific value.

The engine produces more power at a higher RPM when the fuel consumption is at its highest. The ideal engine speed window to reduce the fuel consumption is between 1400rpm and 2500rpm, the torque being consistent throughout. Proving the engine was designed for road use rather than that for motorsport.

The thermal efficiency of the engine is dependent on the fuel consumption and the curves on the graph almost mirror each other proving that to increase the efficiency of the engine the fuel consumption is one of the main characteristics to improve.

When looking at the accuracy of these results factors such as the age of the engine, the modified air filter and exhaust system must all be considered as these can have a big impact on the figures produced by the dynamometer.

6 Evaluation

Human error can impact multiple parts of the test.

- The setup of the engine
- Creating the software
- Programming the sweep test
- Calculating the data using Excel.

However, once the test is running the impact of human error is limited as the test is entirely automated.

One way of limiting any errors in the recorded data would be to revert the engine back to all its original components such as the aftermarket air filter along with servicing it and ensuring it is in full working order.

Running multiple tests with exactly the same parameters and checking the data of each test to look for consistency would be another way of limiting any errors.

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8 Appendix

Table 4 - Data gathered from the engine dyno sweep test

Dynamometer Load Newtons	Dyno Speed rpm	Fuel Flow Rate l/min	Lambda Lambda
102.275	1000	0.0704	1.2658
102.756	1050	0.0724	1.26783
103.689	1100	0.0737	1.27344
104.209	1150	0.0728	1.28476
105.811	1200	0.0744	1.29181
107.51	1250	0.07895	1.29729
109.488	1300	0.079	1.29895
111.797	1350	0.0796	1.29469
114.268	1400	0.0835	1.2855
115.783	1450	0.0847	1.27818
116.985	1500	0.08865	1.2795
117.788	1550	0.0932	1.27766
118.471	1600	0.0959	1.28235
118.772	1650	0.09875	1.29028
118.656	1700	0.10005	1.29942
118.861	1750	0.10305	1.31053
119.584	1800	0.1093	1.3149
119.934	1850	0.11415	1.31849
120.176	1900	0.11745	1.31892
120.948	1950	0.12055	1.31484
122.157	2000	0.12555	1.31653
122.845	2050	0.12785	1.32098
123.796	2100	0.1309	1.32287
124.794	2150	0.13435	1.32164
125.137	2200	0.1377	1.31652
126.028	2250	0.14105	1.30465
126.66	2300	0.14495	1.29646
126.822	2350	0.14985	1.28229
126.69	2400	0.1537	1.27304
126.552	2450	0.15565	1.26984
126.438	2500	0.1596	1.27446
126.239	2550	0.1626	1.27876
126.161	2600	0.16805	1.27634
125.847	2650	0.17145	1.28027
124.911	2700	0.17465	1.28371
123.927	2750	0.1784	1.2812
123.689	2800	0.18005	1.27448
123.389	2850	0.1831	1.26036

122.519	2900	0.1879	1.2531
121.837	2950	0.19255	1.23943
121.709	3000	0.199	1.22735
121.123	3050	0.20605	1.2193
121.124	3100	0.21005	1.20692
120.851	3150	0.21605	1.19274
120.596	3200	0.21795	1.18481
120.84	3250	0.22305	1.17378
121.633	3300	0.2255	1.16118
122.181	3350	0.2285	1.15104
122.933	3400	0.2342	1.14117
123.475	3450	0.23605	1.12669
123.428	3500	0.24195	1.11975
124.205	3550	0.24545	1.10622
124.066	3600	0.25505	1.09697
123.967	3650	0.25755	1.09401
123.815	3700	0.26445	1.09659
123.767	3750	0.2651	1.09808
123.509	3800	0.2693	1.09907
122.672	3850	0.27375	1.10533
122.157	3900	0.2759	1.11704
121.184	3950	0.28285	1.12259
120.004	4000	0.28455	1.12461
118.734	4050	0.2871	1.1222
117.442	4100	0.28895	1.12394
116.5	4150	0.29305	1.12233
115.931	4200	0.2949	1.12179
115.034	4250	0.29715	1.12456
114.391	4300	0.3022	1.12278
114.016	4350	0.30605	1.11943
113.871	4400	0.3092	1.11986
113.985	4450	0.3099	1.11873
113.306	4500	0.31445	1.11563
113.074	4550	0.3171	1.10953
112.195	4600	0.3194	1.10569
111.061	4650	0.32055	1.09782
109.973	4700	0.3207	1.09558
108.654	4750	0.32485	1.08827
107.076	4800	0.32455	1.08396
105.24	4850	0.3257	1.08221
103.632	4900	0.3277	1.0846
102.335	4950	0.32845	1.08823
101.106	5000	0.3287	1.08687
99.3149	5050	0.32985	1.0891
97.5815	5100	0.3297	1.09185
95.8486	5150	0.33095	1.09407
94.8033	5200	0.3338	1.09346

93.0976	5250	0.3313	1.08804
91.7886	5300	0.3324	1.08339
90.5938	5350	0.3308	1.08007
89.6374	5400	0.3388	1.07895
88.9256	5450	0.3438	1.07923
88.6474	5500	0.3488	1.08366

Table 5 - Data calculated for the Power, Corrected Power and Torque

Power W	Power kW	Corrected Power W	Corrected Power kW	Torque N/m
8737.134683	8.737134683	8791.862712	8.791862712	83.4334904
9217.13676	9.21713676	9274.871445	9.274871445	83.82587866
9743.72265	9.74372265	9804.755786	9.804755786	84.58699766
10237.705	10.237705	10301.83236	10.30183236	85.01120118
10847.04913	10.84704913	10914.99333	10.91499333	86.31807434
11480.43693	11.48043693	11552.34857	11.55234857	87.70407776
12159.32362	12.15932362	12235.48769	12.23548769	89.31768269
12893.28137	12.89328137	12974.04285	12.97404285	91.20130947
13666.33946	13.66633946	13751.94325	13.75194325	93.21709197
14342.08667	14.34208667	14431.92323	14.43192323	94.45299261
14990.66782	14.99066782	15084.56699	15.08456699	95.43355536
15596.68454	15.59668454	15694.3797	15.6943797	96.08862349
16193.15896	16.19315896	16294.59035	16.29459035	96.6457985
16741.62293	16.74162293	16846.4898	16.8464898	96.89134707
17232.09846	17.23209846	17340.0376	17.3400376	96.79671706
17769.57213	17.76957213	17880.87792	17.88087792	96.96395114
18388.45001	18.38845001	18503.63235	18.50363235	97.55375718
18954.55483	18.95455483	19073.28316	19.07328316	97.83927878
19506.11983	19.50611983	19628.30308	19.62830308	98.03669658
20148.04188	20.14804188	20274.24602	20.27424602	98.66647565
20871.22291	20.87122291	21001.95695	21.00195695	99.65274883
21513.49094	21.51349094	21648.24804	21.64824804	100.2140027
22208.81822	22.20881822	22347.93074	22.34793074	100.9898057
22920.90217	22.92090217	23064.47507	23.06447507	101.8039501
23518.41027	23.51841027	23665.72587	23.66572587	102.0837613
24224.1811	24.2241811	24375.91754	24.37591754	102.8106177
24886.67418	24.88667418	25042.56037	25.04256037	103.3261882
25460.21122	25.46021122	25619.68995	25.61968995	103.4583439
25974.8543	25.9748543	26137.55667	26.13755667	103.3506614
26487.11394	26.48711394	26653.02502	26.65302502	103.2380844
27003.32034	27.00332034	27172.46486	27.17246486	103.1450859
27500.03638	27.50003638	27672.29225	27.67229225	102.9827465
28021.92801	28.02192801	28197.45293	28.19745293	102.9191159
28489.72671	28.48972671	28668.18185	28.66818185	102.6629623

28811.37543	28.81137543	28991.84532	28.99184532	101.8993959
29113.75162	29.11375162	29296.11555	29.29611555	101.0966724
29586.16343	29.58616343	29771.48648	29.77148648	100.9025177
30041.44696	30.04144696	30229.62183	30.22962183	100.6577849
30352.95539	30.35295539	30543.0815	30.5430815	99.94805974
30704.40989	30.70440989	30896.73745	30.89673745	99.39170051
31192.01932	31.19201932	31387.40119	31.38740119	99.28728118
31559.20109	31.55920109	31756.88292	31.75688292	98.80923645
32076.82986	32.07682986	32277.75405	32.27775405	98.81005222
32520.7344	32.5207344	32724.43913	32.72443913	98.58734538
32967.22739	32.96722739	33173.72889	33.17372889	98.3793225
33550.08462	33.55008462	33760.23704	33.76023704	98.57837184
34289.79594	34.28979594	34504.58179	34.50458179	99.22528221
34966.16677	34.96616677	35185.18931	35.18518931	99.67232746
35706.47182	35.70647182	35930.13151	35.93013151	100.285791
36391.30855	36.39130855	36619.25795	36.61925795	100.7279416
36904.66594	36.90466594	37135.83092	37.13583092	100.6896001
37667.5154	37.6675154	37903.45875	37.90345875	101.3234581
38155.29568	38.15529568	38394.29441	38.39429441	101.2100652
38654.36099	38.65436099	38896.48578	38.89648578	101.1293034
39135.82815	39.13582815	39380.96878	39.38096878	101.0053054
39649.31368	39.64931368	39897.6707	39.8976707	100.9661482
40094.21772	40.09421772	40345.36155	40.34536155	100.755678
40346.4862	40.3464862	40599.2102	40.5992102	100.0728735
40698.88467	40.69888467	40953.81604	40.95381604	99.65274883
40892.33607	40.89233607	41148.47919	41.14847919	98.85899878
41006.74106	41.00674106	41263.6008	41.2636008	97.8963831
41079.92711	41.07992711	41337.24527	41.33724527	96.86034758
41134.55823	41.13455823	41392.21859	41.39221859	95.80636499
41302.23604	41.30223604	41560.94671	41.56094671	95.037904
41595.69784	41.59569784	41856.2467	41.8562467	94.57372746
41765.21234	41.76521234	42026.82302	42.02682302	93.84197638
42020.36829	42.02036829	42283.57722	42.28357722	93.31743242
42369.62302	42.36962302	42635.01963	42.63501963	93.01151642
42802.1272	42.8021272	43070.23295	43.07023295	92.8932289
43331.85257	43.33185257	43603.27643	43.60327643	92.98622736
43557.70248	43.55770248	43830.54103	43.83054103	92.43231546
43951.4993	43.9514993	44226.80453	44.22680453	92.24305542
44089.06379	44.08906379	44365.2307	44.3652307	91.52598832
44117.82308	44.11782308	44394.17013	44.39417013	90.60089834
44155.36435	44.15536435	44431.94656	44.43194656	89.71333405
44089.87535	44.08987535	44366.04735	44.36604735	88.6373255
43906.9145	43.9069145	44181.94046	44.18194046	87.35003098
43603.57724	43.60357724	43876.70314	43.87670314	85.85226624
43379.99544	43.37999544	43651.72086	43.65172086	84.54049843
43274.18876	43.27418876	43545.25143	43.54525143	83.48243696
43186.34756	43.18634756	43456.86	43.45686	82.47984826

42845.51132	42.84551132	43113.88881	43.11388881	81.01871186
42514.51294	42.51451294	42780.81712	42.78081712	79.60464574
42168.92648	42.16892648	42433.06596	42.43306596	78.19098751
42113.98526	42.11398526	42377.7806	42.3777806	77.33825686
41753.92732	41.75392732	42015.46731	42.01546731	75.94678774
41558.91089	41.55891089	41819.22933	41.81922933	74.87893695
41404.90581	41.40490581	41664.25958	41.66425958	73.90424779
41350.67022	41.35067022	41609.68427	41.60968427	73.12403962
41402.14564	41.40214564	41661.48212	41.66148212	72.54337027
41651.26866	41.65126866	41912.16561	41.91216561	72.31642138

Table 6 - Data calculated for the BMEP, SFC and Overall Thermal Efficiency

BMEP Pa	BMEP kPa	SFC kg/kWh	Overall Thermal Efficiency %
659227.5785	659.2275785	0.360333197	20.389292
662327.9301	662.3279301	0.351271715	20.91525864
668341.7099	668.3417099	0.338254218	21.72016899
671693.4415	671.6934415	0.31800168	23.10345898
682019.3528	682.0193528	0.30673404	23.95214687
692970.4909	692.9704909	0.307534869	23.88977487
705719.962	705.719962	0.290548288	25.28646385
720602.939	720.602939	0.276089731	26.61069192
736530.1094	736.5301094	0.273234112	26.88880508
746295.2502	746.2952502	0.264102015	27.81856392
754042.9065	754.0429065	0.264459033	27.781009
759218.7535	759.2187535	0.267229421	27.49300114
763621.1239	763.6211239	0.264842497	27.740785
765561.2608	765.5612608	0.263778986	27.85263104
764813.5669	764.8135669	0.259644766	28.29611741
766134.9226	766.1349226	0.259341293	28.3292286
770795.1185	770.7951185	0.265812674	27.63953523
773051.0916	773.0510916	0.269316507	27.27994231
774610.9359	774.6109359	0.269266782	27.28498008
779586.9681	779.5869681	0.26756852	27.4581583
787379.7439	787.3797439	0.269010646	27.31095922
791814.3425	791.8143425	0.265760536	27.64495771
797944.1438	797.9441438	0.263581451	27.87350461
804376.89	804.37689	0.262123893	28.02849708
806587.7437	806.5877437	0.261834352	28.05949149
812330.8067	812.3308067	0.260390198	28.21511265
816404.4497	816.4044497	0.260466578	28.2068388
817448.6429	817.4486429	0.263205761	27.91329011
816597.8188	816.5978188	0.264619225	27.76419123
815708.3208	815.7083208	0.26279381	27.95704651

814973.5181	814.9735181	0.264311686	27.7964962
813690.8363	813.6908363	0.264416115	27.78551824
813188.0765	813.1880765	0.268189117	27.39461936
811164.1463	811.1641463	0.269122403	27.29961788
805131.0296	805.1310296	0.271084849	27.10198971
798788.5223	798.7885223	0.274029504	26.81075826
797254.4606	797.2544606	0.272147983	26.99611693
795320.7693	795.3207693	0.27256378	26.95493425
789713.0646	789.7130646	0.276838472	26.53872033
785317.1398	785.3171398	0.280442232	26.19769046
784492.0982	784.4920982	0.285305558	25.75112394
780714.9547	780.7149547	0.291976074	25.16281103
780721.4003	780.7214003	0.292841007	25.08849034
778961.7412	778.9617412	0.297094473	24.72930142
777318.1037	777.3181037	0.295648103	24.85028218
778890.8392	778.8908392	0.29730982	24.71138953
784002.2298	784.0022298	0.294091378	24.9818231
787534.4392	787.5344392	0.292239439	25.14013437
792381.5586	792.3815586	0.293319272	25.04758292
795875.0941	795.8750941	0.290072781	25.3279151
795572.1492	795.5721492	0.293187192	25.05886672
800580.4095	800.5804095	0.291404805	25.21214013
799684.4659	799.6844659	0.298931135	24.57736221
799046.3478	799.0463478	0.297963936	24.65714098
798066.6109	798.0666109	0.302182764	24.31289818
797757.2203	797.7572203	0.299002418	24.57150291
796094.2458	796.0942458	0.300369102	24.4597022
790699.2472	790.6992472	0.30342339	24.21348852
787379.7439	787.3797439	0.303158562	24.2346405
781108.1385	781.1081385	0.309324919	23.75152572
773502.2863	773.5022863	0.310315866	23.67567885
765316.3266	765.3163266	0.312538969	23.50727274
756988.5629	756.9885629	0.314135131	23.38782917
750916.7723	750.9167723	0.317299076	23.1546176
747249.2046	747.2492046	0.31704945	23.17284819
741467.4677	741.4674677	0.318171802	23.09110593
737322.9228	737.3229228	0.321614227	22.84394831
734905.8087	734.9058087	0.323026707	22.7440599
733971.1913	733.9711913	0.323053744	22.74215643
734705.994	734.705994	0.319826883	22.97161108
730329.4061	730.3294061	0.322839957	22.75721641
728834.0182	728.8340182	0.322643703	22.77105891
723168.3028	723.1683028	0.323969915	22.67784274
715858.9498	715.8589498	0.32492442	22.61122376
708846.0962	708.8460962	0.324800085	22.6198795
700344.3003	700.3443003	0.329491827	22.2977876
690173.0843	690.1730843	0.33055927	22.2257835

678338.8937	678.3388937	0.334038315	21.99429957
667974.3086	667.9743086	0.337821733	21.74797549
659614.3167	659.6143167	0.339422773	21.6453914
651692.6282	651.6926282	0.340372038	21.58502449
640147.8468	640.1478468	0.344280008	21.34000987
628974.9787	628.9749787	0.346802633	21.18478375
617805.3334	617.8053334	0.350970397	20.933215
611067.7085	611.0677085	0.354454617	20.72744554
600073.3846	600.0733846	0.354833611	20.70530677
591636.0451	591.6360451	0.357682345	20.54040096
583934.7973	583.9347973	0.35728464	20.5632651
577770.1896	577.7701896	0.366405087	20.05141039
573182.1848	573.1821848	0.371350207	19.78439393
571389.0085	571.3890085	0.37449747	19.61812657