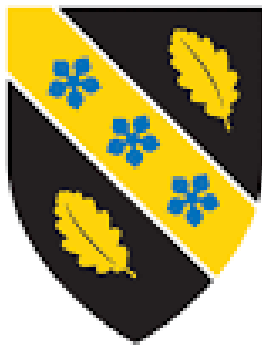


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Engine Performance Characteristics

Powertrain Technology (ACHA4029)

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Abbreviations

The following abbreviations are used in this report:

Specific Fuel Consumption	SFC
Revolutions Per Minute	RPM
Brake Mean Effective Pressure	BMEP
Spark Ignition	SI
Compression Ignition	CI
Variable Compression Ratio	VCR

1 Introduction

The purpose of this assignment is to understand the characteristics of an engine. This will be accomplished through the use of an Eddie Current Dynamometer. From this dynamometer, data will be collected and further data calculated. The 3 main aims of the test is to analyse Specific Fuel Consumption (SFC) against Engine Speed, Torque against Engine Speed and Brake Power against Engine Speed. This should give a fundamental understanding of the basic characteristics of engine performance. This is an important area of study because to effectively tune and design engines that will be competitive in motorsports and efficient and reliable enough for the automotive industry, the engineer must understand areas of weakness and therefore what areas should be improved.

2 Research

Due to a push from Governments and Environmental activists, there is a need to develop and produce more efficient and sustainable fuel alternatives (Zhou et al., 2016). Increased energy efficient vehicles and alternate fuel sources reduce the concern for importing gasoline which many countries have faced difficulties with (Ross, 1994), providing better security and assurance for manufacturers. In endurance racing this is already a desired route of development. Fuels that release the most energy through heat when ignited have a higher calorific value, improving engine performance (Wan Ghazali et al., 2015). During combustion the heat produced from igniting the fuel and air mixture is what generates the pressure that forces the piston down the cylinder. Therefore, a fuel with a higher calorific value will produce higher BMEP values, giving an overall improvement in engine performance without modifying the engine. A 12% increase in thermal efficiency and a 11% reduction in SFC was gained through adding ferrofluid nanoadditives to diesel (Shaafi et al., 2015), showing another way fuel can improve performance.

Variable Compression Ratio (VCR) engines are able to produce much higher power than conventional engines; In other words, VCR engines run a smaller capacity at the same power output reducing SFC, friction and heat losses (Shaik et al., 2007). These VCR engines could prove to be a solution to some of the areas of the engine that may need improvement. Diesel engines produce more torque than petrol engines because of that very fact that they have higher compression ratios. Petrol engines can operate at higher RPM producing higher amounts of power without pinking because they have much lower compression ratios. CI engines generally have a higher BMEP with a maximum of 18 bar due to the higher compression ratio, whereas petrol engines have a much lower Maximum BMEP around 12 bar (Shaik et al., 2007). Utilising the advantages of both types of engines would improve the overall performance of the engine and improve reduce SFC. A downsized engine reduces the fuel consumption while improving the engines performance specifically torque and acceleration (Chiara and Canova, 2013). Most engines are designed with a compromise in order to meet regulatory requirements while still having a good overall performance, however VCR engines can be designed without this compromise providing lower emissions, reduced fuel consumption and while still gaining better performance than a standard engine.

3 Methodology

3.1 The Dynamometer

In order to analyse how engines work, there needed to be a way of gathering the relevant data needed. This was completed using an Eddie Current Dynamometer (“WorkShop Manual - HONDA Civic - Chassis Maintenance And Repair,” n.d.). The engine is connected to the dynamometer via a driveshaft. That driveshaft is bolted directly to the crankshaft and dynamometer giving the same RPM for each component. This is useful because on a Chassis dynamometer there will be some discrepancy between the actual engine power and the recorded power, due to the drivetrain.

The engines fuel is fed from a supply board mounted on the wall. The supply board is fed from a fuel tank located in a locked safe, a lift pump pumps the fuel through a fuel flow metre to a swirl chamber. The main pump receives fuel from the swirl chamber and pumps it through a regulator to the engine. This allows for direct and indirect injection engines to be ran on the dynamometer. (Fall, 2020a)

An exhaust extraction system is set up to take away hazardous chemicals and emissions and direct them outside the building away from people. The engine doesn’t have a silencer on the exhaust but there is one built into the extraction system.

Sensor recorder modules send the data from the engine sensors to the computer. These sensors record everything that would usually be recorded on an engine. The dynamometer used to gather the data uses a strain gauge sensor connected to the outer casing which converts mechanical strain to an electronic signal between zero and ten volts which is sent to the computer. To calculate the voltage to load ratio there is two pivot arms connected to the outer casing, one on either side to balance out. These pivot arms can be loaded with mass which will exert a load on the strain gauge. This strain gauge then sends a voltage which can be recorded. This is repeated with different amounts of mass until a picture has been built up showing what each voltage means.

3.2 Testing Methods

There are several testing methods, most notably the stop test and the sweep test. They work in pretty much the same way however the stop remains at each interval of RPM for a set time specified for recording the data, whereas the sweep test records the data at each point specified but does not pause at the RPM. There is a clear audible difference between the two tests. The sweep test sounds like a long continuous drone that changes in pitch as the RPM increases. The Stop test is more of an interrupted rhythm, as the engine pauses when increasing in rpm. Both tests however return to idle in the same way. The length of time to return to idle can be set before the test along with the interval of RPM for measurement. (Fall, 2020b)

The engine dynamometer can be manually adjusted by two gauges which provide control over the Engine Speed (RPM) and the Load measured in newtons.

From this test the dynamometer will have recorded the Load at the matching Engine Speed. The fuel flow rate is also recorded from the sensors on the engine, with this data the Torque, Brake

Power, Corrected Power, Specific Fuel Consumption (SFC), Brake Mean Effective Pressure (BMEP) and the Overall Thermal Efficiency can be calculated. This is then used to analyse the characteristics of the engine.

4 Results

As mentioned in the previous section the raw data recorded from the dynamometer provided the values for Load measured in newtons, Engine Speed measured in RPM and fuel flow rate measured in litres per minutes. These values were recorded between 1000 and 5500 RPM being measured at 50 RPM intervals.

4.1 Equations

The calculated data was worked out using excel. This software enables the user to calculate the desired data at a single point of Engine speed and then the software applies the equation used to calculate the data for the rest of the data range allowing for graphs to be plotted. All the data used in the examples shown below were calculated using the values recorded at 1000 RPM.

4.1.1 Torque

Torque is work done or turning effort, it can be calculated by multiplying the Load (Force) by Distance (length of the pivot arm:

$$Torque = 102.275 * 0.815776$$

Equation 1 - Torque

Providing a value of 83.433Nm for Torque.

4.1.2 Brake Power

The Power or Brake Power is the rate at which the engine can do the work provided by the torque (work done / time) and can be calculated by the following equation:

$$\frac{2\pi * RPM * Torque}{60}$$

Equation 2 - Power

This is then divided by 1000 to get the units into kilowatts.

$$\therefore \frac{2 * \pi * 1000 * 83.433}{60 * 1000}$$

Providing a value of 8.737KW for Brake Power.

4.1.3 Corrected Power

Due to the change in pressure depending on atmospheric conditions like temperature or air pressure the engine performance change in accordance to the changing conditions. Therefore, the engine performance can be corrected to remove these changing variables.

The formula for Corrected Power is:

$$\frac{1013}{1018.9} * \sqrt{\frac{300}{293}} * 8.737$$

Equation 3 - Corrected Power

This provides a value of 8.790KW for the Corrected Power.

4.1.4 Specific Fuel Consumption (SFC)

The SFC indicates how efficiently the engine is able to convert the fuel into power, measured in g/KW.h and can be calculated by:

$$\frac{\text{Fuel Flow Rate (l/min)} * 0.75 * 60}{\text{Brake Power} * 1000}$$

Equation 4 - SFC

Therefore:

$$\frac{0.0704 * 0.75 * 60}{8.737 * 1000}$$

Giving a value of 362.590 g/KW.h

4.1.5 Brake Mean Effective Pressure (BMEP)

The BMEP is a value of the average pressure generated from combustion that forces the piston down during the power stroke. It is measured in Kpa.

$$\frac{\text{Torque} * N * CC}{1000}$$

Equation 5 - BMEP

Where N is the number of cylinders and CC is the cubic capacity measured in metres ("WorkShop Manual - HONDA Civic - Chassis Maintenance And Repair," n.d.):

$$\frac{83.433 * 4 * \pi}{0.00159} / 1000$$

Giving a value of 659.406Kpa

5 Analysis

				Baro		Humidity	Ambient temp			
				mBar		%	Deg C			
				1018.9		46	27			
Load	Dyno Speed	Fuel Flow Rate	Lambda							
Newtons	rpm	l/min	Lambda	Torque	Brake Power	Corrected Power	SFC	BMEP	Fuel / Hour	Efficiency
				N/m	KW	KW	g/KW.h	Kpa	Kg	%
102.275	1000	0.0704	1.2658							
102.756	1050	0.0724	1.26783	83.433	8.737	8.790	362.590	659.406	4.224	22.565
103.689	1100	0.0737	1.27344	83.826	9.217	9.273	353.472	662.508	4.344	23.147
104.209	1150	0.0728	1.28476	84.587	9.744	9.802	340.373	668.523	4.422	24.038
105.811	1200	0.0744	1.29181	85.011	10.238	10.299	319.994	671.876	4.368	25.569
107.51	1250	0.07895	1.29729	86.318	10.847	10.912	308.655	682.204	4.464	26.508
109.488	1300	0.079	1.29895	87.704	11.480	11.549	309.461	693.158	4.737	26.439
111.797	1350	0.0796	1.29469	89.318	12.159	12.232	292.368	705.911	4.74	27.985
114.268	1400	0.0835	1.2855	91.201	12.893	12.971	277.819	720.798	4.776	29.450
115.783	1450	0.0847	1.27818	93.217	13.666	13.749	274.946	736.730	5.01	29.758
116.985	1500	0.08865	1.2795	94.453	14.342	14.428	265.756	746.498	5.082	30.787
117.788	1550	0.0932	1.27766	95.434	14.991	15.081	266.116	754.247	5.319	30.745
118.471	1600	0.0959	1.28235	96.089	15.597	15.691	268.903	759.425	5.592	30.427
118.772	1650	0.09875	1.29028	96.646	16.193	16.291	266.501	763.828	5.754	30.701
118.656	1700	0.10005	1.29942	96.891	16.742	16.842	265.431	765.769	5.925	30.825
118.861	1750	0.10305	1.31053	96.797	17.232	17.336	261.271	765.021	6.003	31.315
119.584	1800	0.1093	1.3149	96.964	17.770	17.876	260.966	766.343	6.183	31.352
119.934	1850	0.11415	1.31849	97.554	18.388	18.499	267.478	771.004	6.558	30.589
120.176	1900	0.11745	1.31892	97.839	18.955	19.069	271.003	773.261	6.849	30.191
120.948	1950	0.12055	1.31484	98.037	19.506	19.623	270.953	774.821	7.047	30.196
122.157	2000	0.12555	1.31653	98.666	20.148	20.269	269.245	779.798	7.233	30.388
122.845	2050	0.12785	1.32098	99.653	20.871	20.997	270.696	787.593	7.533	30.225
123.796	2100	0.1309	1.32287	100.214	21.513	21.643	267.425	792.029	7.671	30.595
124.794	2150	0.13435	1.32164	100.990	22.209	22.342	265.232	798.161	7.854	30.848
125.137	2200	0.1377	1.31652	101.804	22.921	23.059	263.766	804.595	8.061	31.019
126.028	2250	0.14105	1.30465	102.084	23.518	23.660	263.474	806.807	8.262	31.054
126.66	2300	0.14495	1.29646	102.811	24.224	24.370	262.021	812.551	8.463	31.226
126.822	2350	0.14985	1.28229	103.326	24.887	25.036	262.098	816.626	8.697	31.217
126.69	2400	0.1537	1.27304	103.458	25.460	25.613	264.854	817.670	8.991	30.892
126.552	2450	0.15565	1.26984	103.351	25.975	26.131	266.277	816.819	9.222	30.727
126.438	2500	0.1596	1.27446	103.238	26.487	26.646	264.440	815.930	9.339	30.940
126.239	2550	0.1626	1.27876	103.145	27.003	27.166	265.967	815.195	9.576	30.762
126.161	2600	0.16805	1.27634	102.983	27.500	27.665	266.072	813.912	9.756	30.750
125.847	2650	0.17145	1.28027	102.919	28.022	28.190	269.869	813.409	10.083	30.318
124.911	2700	0.17465	1.28371	102.663	28.490	28.661	270.808	811.384	10.287	30.213
123.927	2750	0.1784	1.2812	101.899	28.811	28.985	272.783	805.349	10.479	29.994

Figure 1 - Raw Data Calculated in Excel

5.1 Graphs

5.1.1 SFC vs Engine Speed

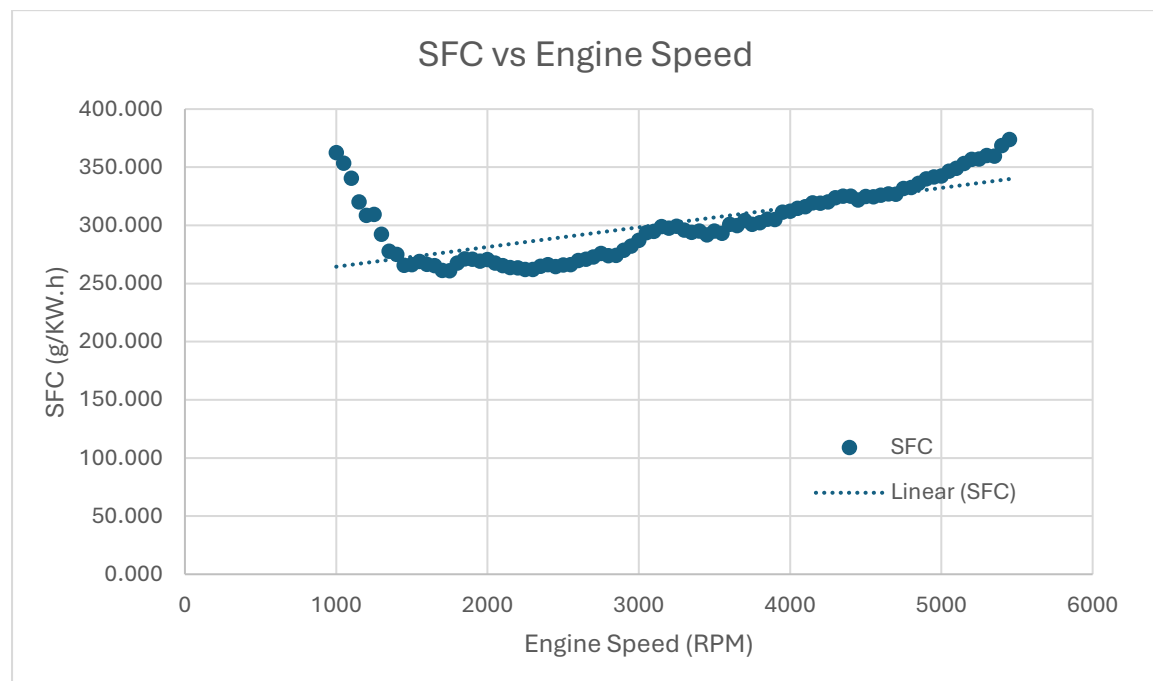


Figure 2 - Graph Showing SFC vs Engine Speed

5.1.2 Torque vs Engine Speed

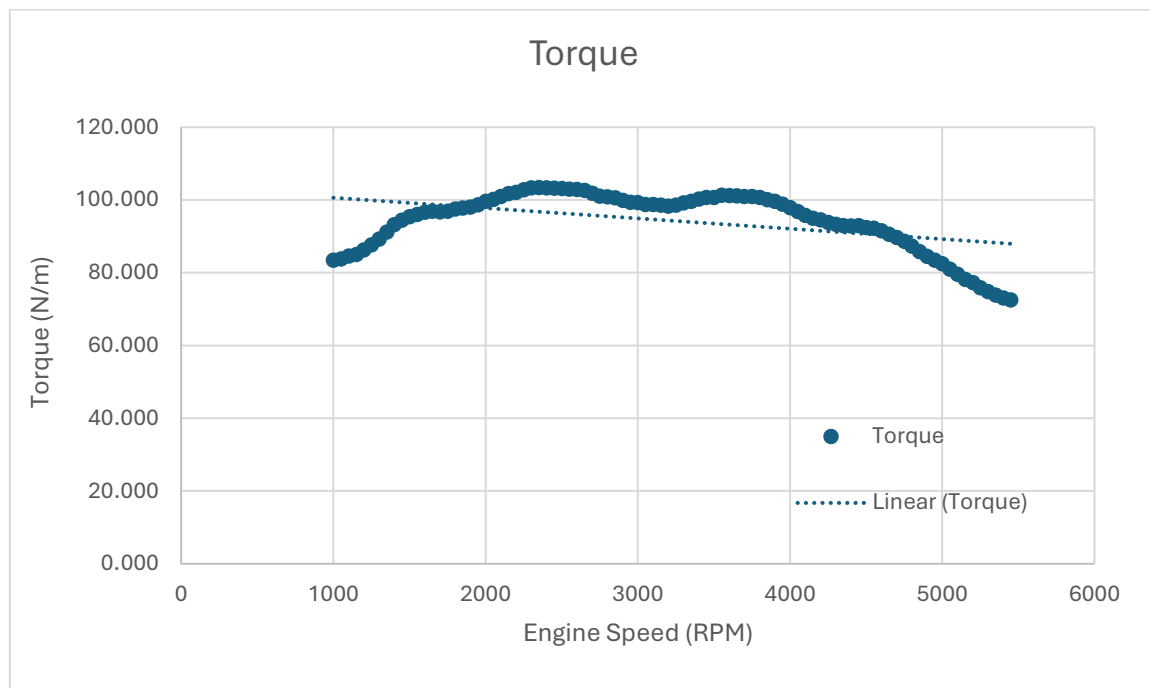


Figure 3 - Torque vs Engine Speed

5.1.3 Power vs Engine Speed

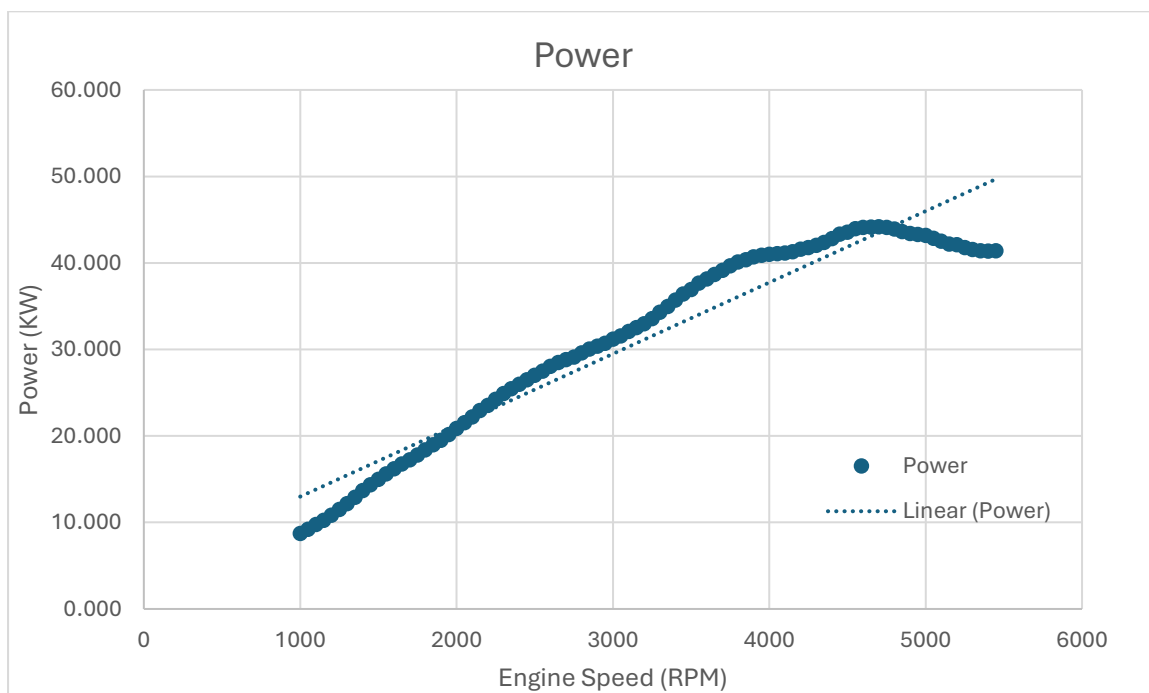


Figure 4 - Power vs Engine Speed

5.1.4 Thermal Efficiency vs Engine Speed

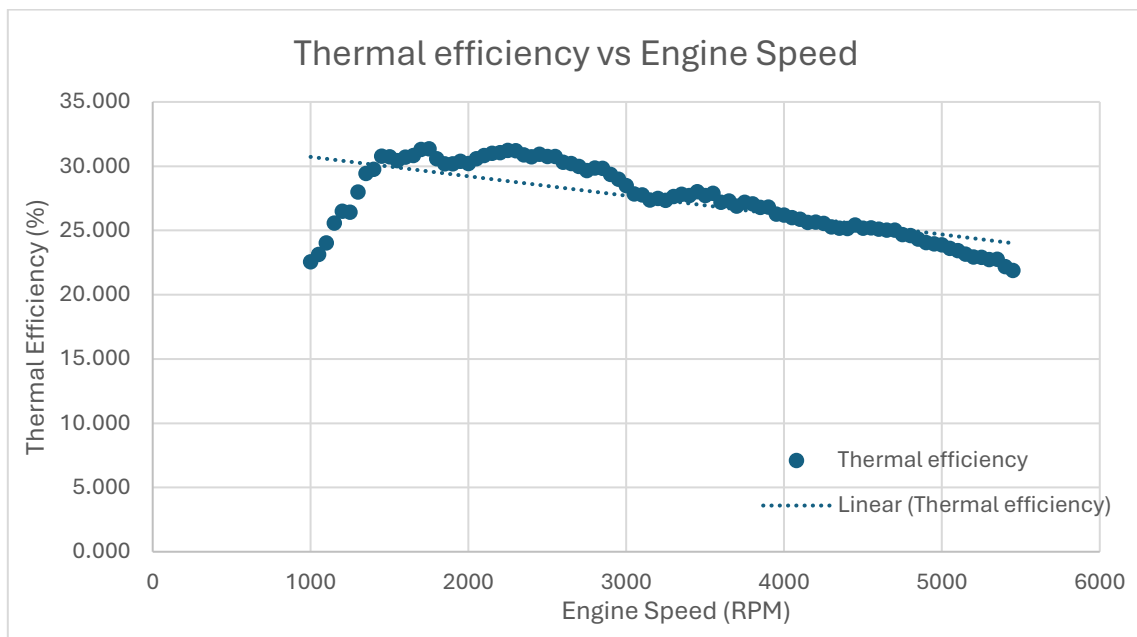


Figure 5 - Thermal Efficiency vs Engine Speed

5.1.5 Power vs Torque

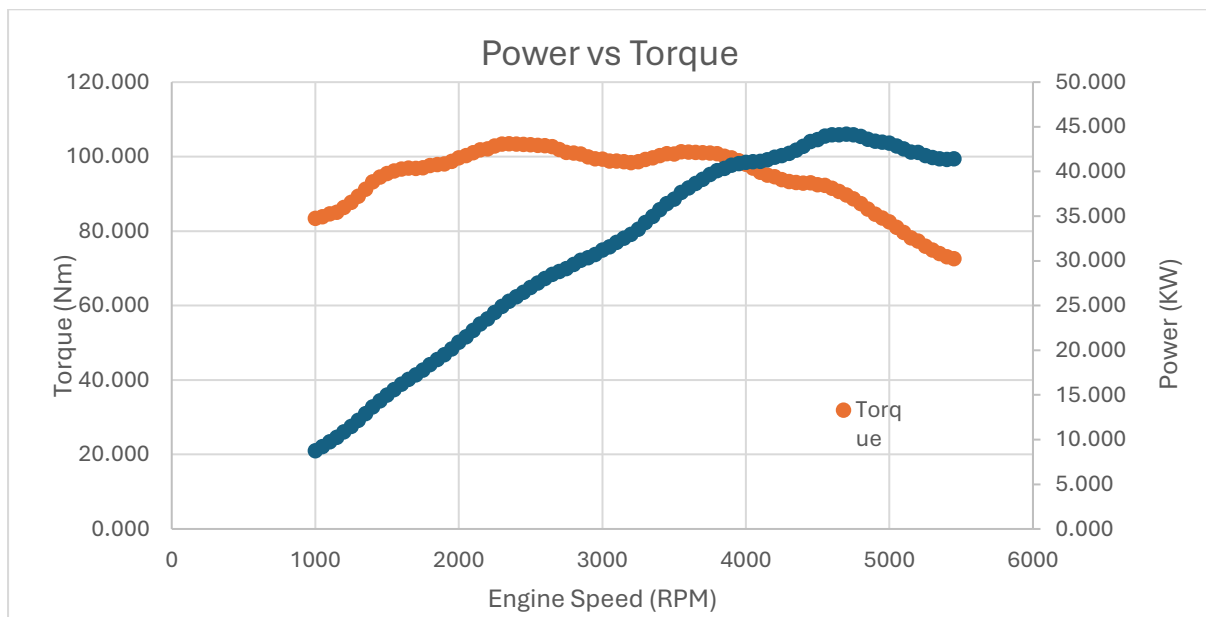


Figure 6 - Graph Showing Power vs Torque

5.1.6 SFC vs Power

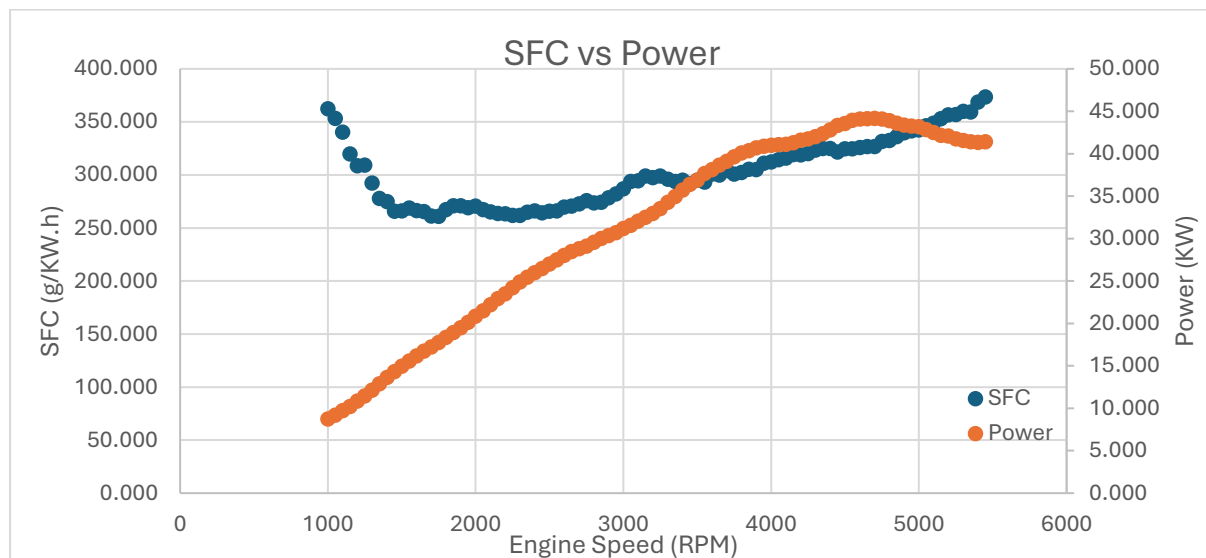


Figure 7 - SFC vs Power

5.2 SFC

From Figure 2 it is clear that the lowest values of SFC are around 1800 – 2500 RPM, and that it slowly increases as the RPM climbs from 2500 – 4000. Assuming that the intake of air increases with RPM and that the volume of fuel increases equivalent to the volume of air (Tamilarasan et al., 2021); then the SFC will increase due to the increase in volume of fuel respectively. There is a reduction in overall volumetric efficiency at high RPM due to friction losses. So, although there is an initial reduction which can be seen from 1000 to around 1700 RPM the SFC will start to increase slowly due to the increase in volume of fuel burnt and then at the high end of the engines RPM (4000+ as shown in figure 6)the SFC will start to increase drastically because of the reduced volumetric efficiency caused by friction losses. There are also more power strokes per minute and therefore more fuel being burnt fuel burnt.

5.3 Torque

Figure 3 shows that the engine produces a maximum of 103Nm of torque, 83Nm of torque at the lowest RPM and 72Nm of torque at the highest RPM. There is a decline in torque past 4000 RPM which is interesting because torque and power cross at 4000RPM. This is different from the 5252 RPM that it would usually cross at because the graph plotted uses brake power not horsepower and it isn't measured in imperial units. The torque drops off at above 4000 RPM due to a reduction in volumetric efficiency however the torque also struggles at low RPM because the engine isn't drawing in air as efficiently as it does during its sweet spot (2000 to 4000 RPM).

5.4 Power

The maximum power in this engine is at 4700 RPM. This is because as the engine RPM increases so does the number of power strokes being completed respectively. There will be an increase in power as RPM increases until the torque begins to drop off due to the frictional losses and the engine not being able to breath effectively. Figure 5 shows as the engine struggles to breath

efficiently at high RPM the thermal efficiency reduces meaning there is a loss in how much of the chemical energy of the fuel can be converted into kinetic energy. This means that there is less KW produced and more sound and thermal energy produced, which is why engines are louder at higher RPM.

6 Conclusions

From this study it is clear that at in this SI engine at high RPM the engines torque and thermal efficiency drops off. This is an area of performance that development like the variable compression ratio (VCR) could help improve. A reduced compression ratio (CR) at high RPM could mean that the effect of the poor volumetric efficiency and friction losses would have less of an impact on the torque and thermal efficiency therefore it could improve the power output past the peak power. An increased CR at low RPM would provide the benefits that diesel engines contain giving an increased initial torque. The vehicles acceleration may also be improved by an improvement of torque at low RPM. Further investigation should be conducted to validate the effectiveness of this emerging technology.

The use of nanoadditives in fuels should also be investigated to determine whether it would be beneficial to use them. The SFC at high RPM increases dramatically, this may be prevented by using VCR engines, however nanoadditives could improve the flow of the fuel and air mixture into the combustion chamber providing another route of development that may help the engine breath more efficiently.

In conclusion, the biggest issue that engines face preventing improved SFC, Torque and power is the engine's ability to breath. The more efficiently the engine can draw in air and expel exhaust gasses the better the overall performance of the engine will be improving Torque and Power at either end of the engines RPM

7 Evaluation

The dynamometer was broken during the time of this experiment; therefore, I cannot evaluate how I performed during this experiment. I improve my performance next time by completing the task set during the brief. This study could be improved by comparing the results of the engine tested with results of a modified engine that has been developed in the areas previously mentioned in this report.

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