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Engine Performance Characteristics Assignment

Motorcycle Engineering (ACHA4003)

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1 Introduction

The aim of this test was to quantify the changes in specific fuel consumption (SFC), torque, brake power, brake mean effective pressure (BMEP) and thermal efficiency with the gradual increase of engine speed (RPM) for the connected engine. In this experiment a Honda Civic Coupe CRX, 1.6L D16 engine, was connected to an engine dyno where the throttle was wired up to a computer which allowed the RPM to be controlled accurately using a dial on the computer system. The aim of gradually increasing the RPM was to obtain readings through the dynamometer of engine load, which would later allow for calculations of torque for each RPM, and therefor obtain readings for brake power.

The fuel for the engine was pumped via a lift pump from the fuel safe through a flow meter and then into the engine, this allowed readings to be obtained for fuel flow rate as the RPM was increased. The reason for recording readings of fuel flow rate was to allow calculations to be made of SFC. The calculations made for torque, brake power and SFC were then plotted in graphs each against engine speed to evaluate how each parameter changed with the increase of RPM.

The engine's air filter had been replaced by one taken from a lawnmower, this would give for different readings had the engine been fitted with a stock air filter, allowing us to evaluate what the effect of restricting air flow through an engine would have on the torque and brake power produced. As well as the fuel consumed during the experiment.

2 Metric Data

Baro	Humidity	Ambient temp	Bore	Stroke	π	R	Area of Bore	Specific Gravity of Gasoline	Calorific Value of Gasoline
mBar	%	Deg C	m	m	pi	m	m ²	SG	kJ/kg
1018.9	46	27	0.075	0.09	3.1415926	0.815776	0.004417865	0.739	44000

Table 1 Metric Data

ii - Bore/Stroke - m

iii - Specific Gravity - SG

iv - Calorific Value – kJ/kg

3 Recordings and Calculations

Load	Dyno Speed	Fuel Flow Rate	Lambda	Torque	Brake Power	Corrected Power	BMEP	SFC	Thermal efficiency
Newtons	rpm	l/min	Lambda	Nm	W	W	kPa	kg/kWh	%
102.275	1000	0.0704	1.2658	83.4334904	8737.134534	8688.685413	1043.16649	0.357272283	22.90079185
102.756	1050	0.0724	1.26783	83.82587866	9217.136603	9166.025775	1050.251258	0.348287775	23.49154569
103.689	1100	0.0737	1.27344	84.58699766	9743.722484	9689.691635	1053.337442	0.335380857	24.3956028
104.209	1150	0.0728	1.28476	85.01120118	10237.70482	10180.93474	1067.508552	0.315300358	25.94928284
105.811	1200	0.0744	1.29181	86.31807434	10847.04894	10786.89993	1082.766392	0.304128433	26.90250989
107.51	1250	0.07895	1.29729	87.70407776	11480.43674	11416.77547	1100.923141	0.304922459	26.83245507
109.488	1300	0.079	1.29895	89.31768269	12159.32341	12091.89758	1122.477655	0.288080174	28.40118456
111.797	1350	0.0796	1.29469	91.20130947	12893.28115	12821.78538	1145.713503	0.273744438	29.88852759
114.268	1400	0.0835	1.2855	93.21709197	13666.33923	13590.5567	1159.422978	0.270913076	30.20089801
115.783	1450	0.0847	1.27818	94.45299261	14342.08643	14262.55675	1170.066579	0.261858553	31.24518212
116.985	1500	0.08865	1.2795	95.43355536	14990.66757	14907.54138	1176.789068	0.262212539	31.20300128
117.788	1550	0.0932	1.27766	96.08862349	15596.68427	15510.1976	1182.381095	0.264959393	30.87951736
118.471	1600	0.0959	1.28235	96.6457985	16193.15869	16103.36445	1184.227575	0.262592746	31.15782259
118.772	1650	0.09875	1.29028	96.89134707	16741.62264	16648.78707	1181.984603	0.261538269	31.28344554
118.656	1700	0.10005	1.29942	96.79671706	17232.09817	17136.54281	1183.002454	0.257439167	31.7815594
118.861	1750	0.10305	1.31053	96.96395114	17769.57183	17671.03607	1189.226754	0.257138272	31.81874914
119.584	1800	0.1093	1.3149	97.55375718	18388.4497	18286.48215	1191.7871	0.263554681	31.04410114
119.934	1850	0.11415	1.31849	97.83927878	18954.55451	18849.44779	1193.31955	0.26702875	30.6402145
120.176	1900	0.11745	1.31892	98.03669658	19506.1195	19397.95425	1200.153622	0.266979447	30.64587281
120.948	1950	0.12055	1.31484	98.66647565	20148.04153	20036.3167	1211.353452	0.265295612	30.84038268
122.157	2000	0.12555	1.31653	99.65274883	20871.22255	20755.48754	1217.414552	0.266725487	30.67505199
122.845	2050	0.12785	1.32098	100.2140027	21513.49057	21394.19406	1226.109294	0.263502986	31.05019155
123.796	2100	0.1309	1.32287	100.9898057	22208.81784	22085.66559	1235.293081	0.261342411	31.30689026
124.794	2150	0.13435	1.32164	101.8039501	22920.90178	22793.80089	1238.018397	0.259897235	31.4809743
125.137	2200	0.1377	1.31652	102.0837613	23518.40987	23387.99568	1246.189306	0.259610154	31.51578652
126.028	2250	0.14105	1.30465	102.8106177	24224.18069	24089.85286	1251.820156	0.258178267	31.69057668
126.66	2300	0.14495	1.29646	103.3261882	24886.67376	24748.67228	1252.828898	0.258253998	31.68128369
126.822	2350	0.14985	1.28229	103.4583439	25460.21079	25319.02893	1250.958361	0.260969913	31.35157644
126.69	2400	0.1537	1.27304	103.3506614	25974.85385	25830.8182	1249.053366	0.26237137	31.18411194
126.552	2450	0.15565	1.26984	103.2380844	26487.11348	26340.23725	1247.408446	0.260561461	31.40072264
126.438	2500	0.1596	1.27446	103.1450859	27003.31988	26853.58118	1244.946979	0.262066443	31.22039616
126.239	2550	0.1626	1.27876	102.9827465	27500.03591	27347.54283	1243.699411	0.262169985	31.20806596
126.161	2600	0.16805	1.27634	102.9191159	28021.92753	27866.54045	1240.145185	0.265910937	30.76901718
125.847	2650	0.17145	1.28027	102.6629623	28489.72623	28331.74512	1230.483272	0.266836295	30.66231366
124.911	2700	0.17465	1.28371	101.8993959	28811.37494	28651.61022	1220.371353	0.26878207	30.44032126
123.927	2750	0.1784	1.2812	101.0966724	29113.75113	28952.30968	1217.624994	0.271701711	30.11323759
123.689	2800	0.18005	1.27448	100.9025177	29586.16293	29422.10186	1214.284389	0.269836174	30.32142825
123.389	2850	0.1831	1.26036	100.6577849	30041.44645	29874.86074	1205.35152	0.270248439	30.2751728
122.519	2900	0.1879	1.2531	99.94805974	30352.95487	30184.64179	1198.285636	0.274486818	29.80769073
121.837	2950	0.19255	1.23943	99.39170051	30704.40936	30534.1474	1196.682862	0.278059965	29.42465369
121.709	3000	0.199	1.22735	99.28728118	31192.01878	31019.05293	1190.590306	0.282881979	28.92308027
121.123	3050	0.20605	1.2193	98.80923645	31559.20055	31384.1986	1190.280168	0.289495831	28.26230051
121.124	3100	0.21005	1.20692	98.81005222	32076.82932	31898.95702	1187.28846	0.290353417	28.17882519
120.851	3150	0.21605	1.19274	98.58734538	32520.73384	32340.40001	1184.484729	0.294570751	27.77539232
120.596	3200	0.21795	1.18481	98.3793225	32967.22683	32784.4171	1186.591513	0.293136667	27.91127517
120.84	3250	0.22305	1.17378	98.57837184	33550.08405	33364.04226	1194.095704	0.294784269	27.7527408
121.633	3300	0.2255	1.16118	99.22528221	34289.79535	34099.65173	1199.200169	0.291593166	28.05901896
122.181	3350	0.2285	1.15104	99.67232746	34966.16618	34772.27194	1206.312224	0.28975696	28.2368306
122.933	3400	0.2342	1.14117	100.285791	35706.47121	35508.47184	1211.368709	0.290827619	28.1328789
123.475	3450	0.23605	1.12669	100.7279416	36391.30793	36189.51101	1210.65327	0.287680706	28.44774167
123.428	3500	0.24195	1.11975	100.6896001	36904.66531	36700.02172	1218.025909	0.290696662	28.14555262
124.205	3550	0.24545	1.10622	101.3234581	37667.51476	37458.64101	1216.421441	0.288929415	28.31770585
124.066	3600	0.25505	1.09697	101.2100652	38155.29503	37943.71645	1215.216321	0.296391811	27.60473763
123.967	3650	0.25755	1.09401	101.1293034	38654.36033	38440.01433	1213.498545	0.295432828	27.69434334
123.815	3700	0.26445	1.09659	101.0053054	39135.82748	38918.81166	1212.806585	0.2996515819	27.30769761
123.767	3750	0.2651	1.09808	100.9661482	39649.313	39429.4498	1210.063254	0.296462489	27.59815659
123.509	3800	0.2693	1.09907	100.755678	40094.21703	39871.88675	1201.654777	0.297817563	27.47258457
122.672	3850	0.27375	1.10533	100.0728735	40346.48551	40122.75635	1196.408182	0.300845906	27.19604292
122.157	3900	0.2759	1.11704	99.65274883	40698.88398	40473.2007	1186.683518	0.300583328	27.21980035
121.184	3950	0.28285	1.12259	98.85899878	40892.33537	40665.57937	1174.940182	0.306697304	26.67717676
120.004	4000	0.28455	1.12461	97.8963831	41006.74036	40779.34996	1162.324171	0.307679832	26.59198726
118.734	4050	0.2871	1.1222	96.86034758	41079.92641	40852.13018	1149.501151	0.309884051	26.40283733
117.442	4100	0.28895	1.12394	95.80636499	41134.55753	40906.45835	1140.111441	0.311466654	26.26868101
116.5	4150	0.29305	1.12233	95.037904	41302.23534	41073.20635	1134.378311	0.314603723	26.00674304
115.931	4200	0.2949	1.12179	94.57372746	41595.69713	41365.04084	1125.441692	0.314356217	26.02721923
115.034	4250	0.29715	1.12456	93.84197638	41765.21163	41533.61536	1118.995965	0.315469035	25.93540817
114.391	4300	0.3022	1.12278	93.31743242	42020.36757	41787.3564	1115.176838	0.318882218	25.65780632
114.016	4350	0.30605	1.11943	93.01151642	42369.62229	42134.67444	1113.611463	0.320282699	25.54561391
113.871	4400	0.3092	1.11986	92.8932289	42802.12647	42564.7803	1114.582389	0.320309506	25.54347598
113.985	4450	0.3099	1.11873	92.98622736	43331.85183	43091.56822	1107.803032	0.317110057	25.50119426
113.306	4500	0.31445	1.11563	92.43231546	43557.70174	43316.16575	1105.398261	0.320097536	25.86039101
113.074	4550	0.3171	1.10953	92.24305542	43951.49855	43707.77888	1096.672811	0.319902949	25.5759386
112.195	4600	0.3194	1.10569	91.52598832	44089.06303	43844.58055	1085.460038	0.321217895	25.4712403
111.061	4650	0.32055	1.09782	90.60089834	44117.82232	43873.18036	1074.702146	0.322164292	25.39641537
109.973	4700	0.3207	1.09558	89.71333405	44155.3636	43910.51346	1061.692157	0.322040102	25.40613731
108.654	4750	0.32485	1.08827	88.6373255	44089.8746	43845.38761	1046.157096	0.3266929	25.04437096
107.076	4800	0.32455	1.08396	87.35003098	43906.91375	43663.44131	1028.107386	0.327751276	24.96349758
105.24	4850	0.3257	1.08221	85.85226624	43603.5765	43361.78613	1012.290963	0.331200767	24.70350007
103.632	4900	0.3277	1.0846	84.54049843	43379.9947	43139.44413	999.5176126	0.334952046	24.42683443
102.335	4950	0.32845	1.08823	83.48243696	43274.18802	43034.22417	987.413073	0.336539486	24.31161429
101.106	5000	0.3287	1.08687	82.47984826	43186.34682	42946.87007	969.8239879	0.337480687	24.24381155
99.3149	5050	0.32985	1.0891	81.01871186	42845.51058	42607.92384	952.8036806	0.341355461	23.96861667
97.5815	5100	0.3297	1.09185	79.60464574	42514.51222	42278.76092	935.7933727	0.343856656	23.7942702
95.8486	5150	0.33095	1.09407	78.19098751	42168.92577	41935.09082	925.5006071	0.347989016	23.51171386
94.8033</									

4 Graphical Results

4.1 Correlation between Torque and Engine Speed

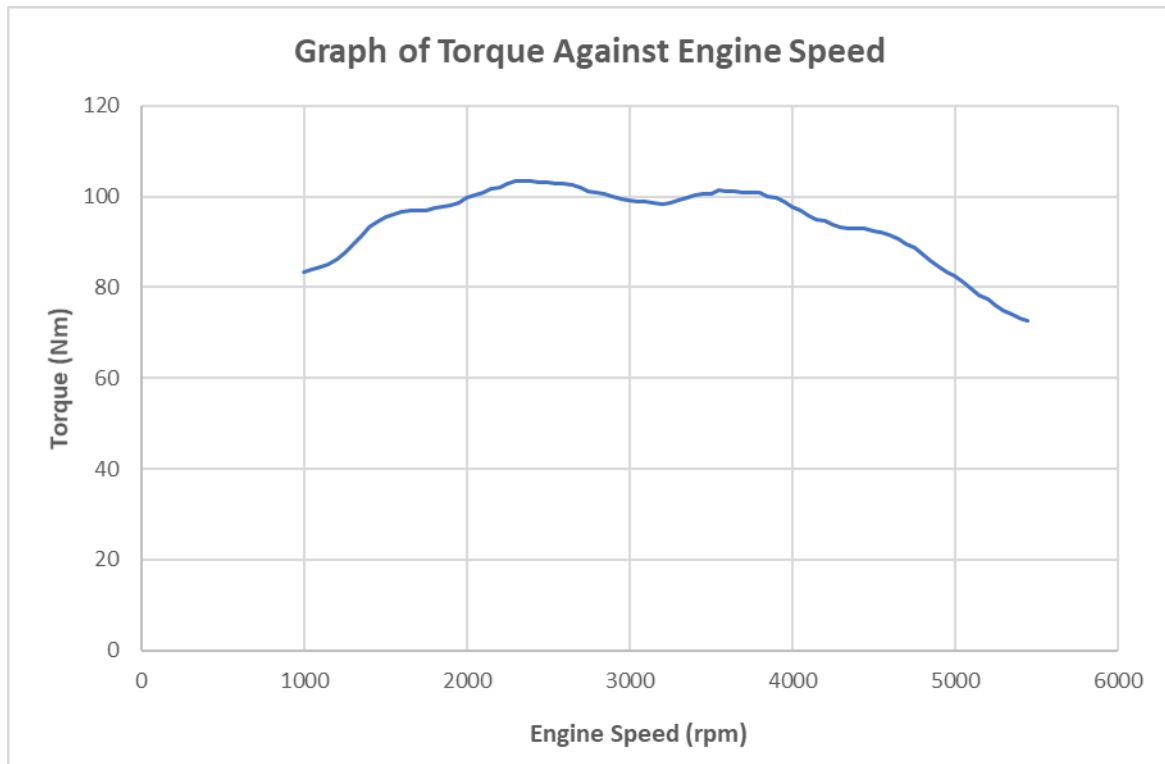


Figure 1 Graph for Torque

Figure 1 shows that torque increases to peak at 103.5Nm at 2350rpm and then decreases. The reason for it peaking at this RPM is due to the efficiency of the airflow, which allows combustion to occur at maximum efficiency. At lower RPM's there is a weaker intake of air and therefore not providing enough air or swirl of the mixture for the maximum efficiency of combustion to occur. At an RPM, any higher than 2350rpm, a higher volume of air is being drawn in, however a greater volume of air means then that air is accelerating slower into the vacuum again meaning there is insufficient air for maximum efficiency combustion to happen.

This peak might also occur at a lower RPM than seen for other cars of similar age, this could be due to the air filter being from a lawnmower and not one that's stock for this type of engine. This graph shows us that at 2350rpm is where the balance is allowing for combustion to be most efficient. As well as this, the torque drops off after peak torque because as RPM increases, friction also increases which, would restrict the torque of the engine.

4.2 Correlation between Brake Power and Engine Speed

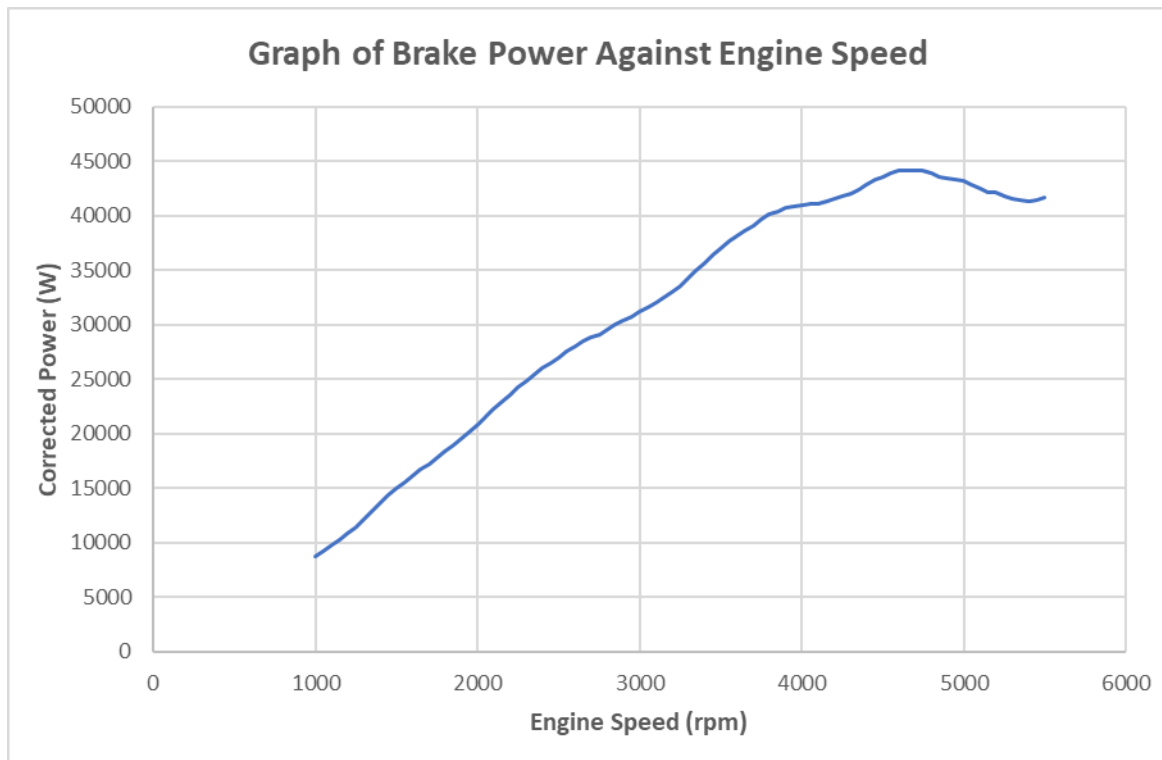


Figure 2 Graph for Brake Power

Figure 2 shows that brake power increases gradually to a peak of 44.2kW at 4700rpm. This peak occurs at a much higher RPM than that of torque and is due to the equation:

$$\text{power} = \text{torque} * \text{RPM}$$

The RPM is increasing at a higher rate than the torque is decreasing at, which is why the power does not start to decrease where the torque does in Figure 1. This relationship also means the dips in power found in figure 2 correspond to those seen in Figure 1. The reason for the power reaching its peak and starting to decrease is very similar to the reason explained above. Lower RPM causes a weaker intake of air, resulting in a worse mix of the fuel/air mixture. Higher RPM results in a stronger intake of air, greater volume of air, however, means a lower acceleration of that air causing the air to be drawn in slower. Friction also increases as RPM increases. However, there are also other aspects such as wear and tear to consider.

The engine provided for this experiment was said to be roughly 20 years old, this means components like piston rings and fuel pumps degrade over long periods of time causing the engine to be less efficient than on release. Also, just general carbon build-up in the engine over time can start to clog up areas of the exhaust and pistons making both air flow and combustion less efficient.^v

4.3 Correlation between SFC and Engine Speed

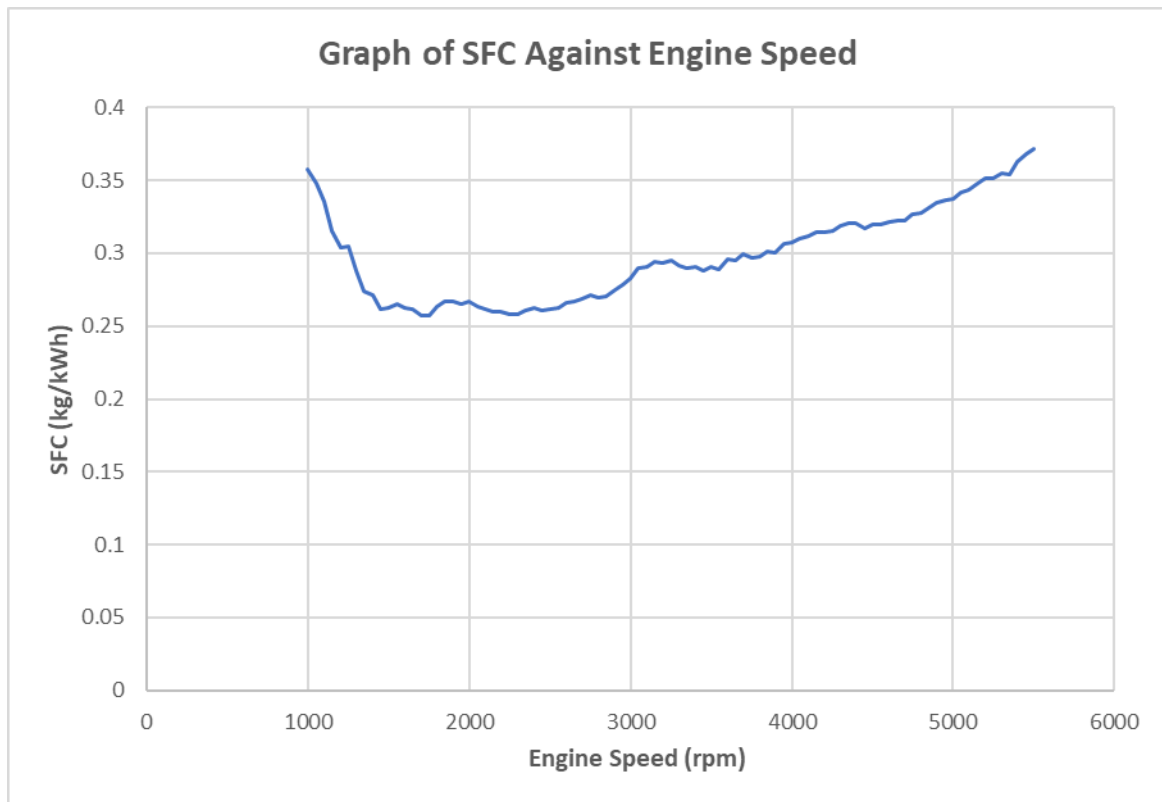


Figure 3 Graph for SFC

Figure 3 shows a high fuel consumption at 1000rpm, a rapid decrease then to roughly 1500rpm, followed by a steady increase. This graph also shows us that the most fuel-efficient engine speeds are between about 1500 to 2500rpm.

The increase in SFC with RPM is because each cylinder undergoes combustion once every 2 revolutions, so simply increasing the number of revolutions per minute, is going to increase the number of times each cylinder undergoes combustion in a minute, therefore using more fuel.

The SFC is seen to be quite high at 1000rpm, this could be due to the below standard air filter fitted to the engine, not allowing the engine to suck in enough air at his engine speed. This would cause the air/fuel ratio in the cylinder to be too fuel rich, burning more fuel than is necessary for this engine speed.

Figure 3 also shows that the most fuel-efficient engine speed for this engine is between roughly 1500 and 2500rpm, this mean that between these 2 engine speeds, the combination of the cylinders having a more balanced air/fuel ratio, as well as undergoing combustion at a steadier rate than higher RPMs, means the least amount of fuel is required to be burnt.

5 Conclusions

The engine produced less torque than expected, due to the restricted air intake. The torque curve also displays a few dips and peaks in the torque at various RPMs, still following the general flow of the graph, however it gives the impression the engine is not very consistent with producing torque. This is understandable due to the engines age and could be due to various depleting components within the engine, as well as carbon build up and overall residue building up over those 20 years.

The engine also had a lower power output than expected, also being due to the restricted air intake. The brake power curve also has dips that line up with those found in Figure 1 and occur for the same reasons. The general shape of the brake power graph is as you would expect, just with the values being lower than you would see for the same engine with a stock air filter.

The engine's SFC is higher than you would expect to see so the engine is burning more fuel than it should. This could also just be due to the limitations in air intake, causing the air/fuel mixture to be more fuel orientated, in turn producing more carbon build up. However, Figure 3 follows a correlation you would expect to see with regards to fuel consumption increasing with engine speed. The graph displays a rough curve which follows the general expected shape but does suggest the engine is performing relatively inconsistently with how much fuel it is using as engine speed is increased.

In conclusion the old Honda Civic Coupe CRX, 1.6L D16 engine, performs worse than expected, however taking into consideration that the air filter was taken from a lawnmower, and with the engine being roughly 20 years old, the engines results that were obtained show what you would expect for an old engine with a below standard air intake.

6 Evaluation

The task went well, a few errors were made in the calculations process, leading the results to be considerably different to what was expected. The errors in calculations did not take long to put right, just a matter of making sure everything was in the correct units for the equation being used. Every equation used could be found in written notes taken during lectures, which made the excel part of this assignment relatively straight forward.

Creating the graphs from the calculated and researched data and putting them into a line graph was not a complicated process. The graphs then proved that the calculations used were correct as readings seen in the graphs matched up with engine speed/torque images found online.

To carry out some of the calculations, certain metrics were needed through my research. Values for bore and stroke, which was made easy as the exact engine details were given to us, making finding the statistics online achievable. The specific gravity and calorific value of gasoline also had to be researched. There were several websites that contained these values, which was part of the research for this experiment.

More research was conducted on the general wear and tear of an engine over time, not specifically the Honda Civic CRX D16. This was to aid my description of why the engine might display lower readings for torque and power output than a newer model of the same engine type.

7 References

ⁱ <https://www.uwtsd.ac.uk/>

ⁱⁱ <https://www.ultimatespecs.com/car-specs/Honda/7932/Honda-CRX-II-16i.html>

ⁱⁱⁱ https://www.engineeringtoolbox.com/specific-gravity-liquids-d_336.html

^{iv} <https://www.world-nuclear.org/information-library/facts-and-figures/heat-values-of-various-fuels.aspx>

^v <https://www.carthrottle.com/post/4-reasons-why-engines-lose-power-over-time-and-how-to-win-your-horses-back/>