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Engine Performance Characteristics

Powertrain Technology (ACHA 4029)

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1 Introduction

This report will outline the uses of an engine dynamometer in calculating: Torque, Power, Brake Mean Effective pressure (BMEP), Specific fuel consumption (SFC) and Overall thermal efficiency of a Civic Coupe CRX engine, through using the recorded values of: Load, Dyno speed, Fuel flow rate and Lambda.

Unfortunately, due to faulty equipment, my class was unable to carry out the practical and therefore we have based our reports on the data and videos provided.

Through investigating this data, conclusions can be drawn to the relationship of SFC, Torque and Brake power with how they vary alongside engine speed and other factors. This can be used to diagnose inefficiencies, which when corrected can increase power and fuel economy.

2 Process

2.1 Equipment

The equipment required for the experiment:

- Engine Dynamometer, for recording dyno speed and calculating torque, as in Figure 1.
- Engine, to produce torque and other values, as in Figure 2.
- Dyno/Engine control software, as in Figure 3.
- Dyno cell controls, as in Figure 4.

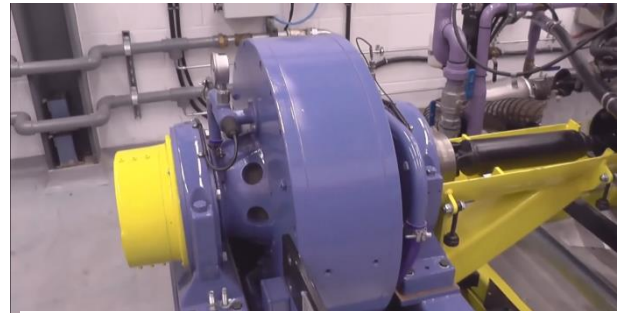


Figure 1: Engine Dynamometer



Figure 2: Engine, mounted to Dynamometer



Figure 3: Engine control software



Figure 4: Dynamometer controls from within Dyno cell

2.2 Methodology

The engine is mounted to the dynamometer, fuelling system, cooling system, exhaust and connected to different sensors around the apparatus, for example:

- RPM reader (One dyno rotation is equivalent to one engine rotation).
- Strain gauge (Which sends a voltage reading of 0-10 and using other values can be converted to useful readings such as Load (Newtons)).
- Fuel flow meter (Recording data in litres/minute which is needed to calculate Specific Fuel Consumption).
- Lambda sensor (Connected to the exhaust, reads the oxygen levels after combustion helping diagnose if a mixture is too rich or too lean (The most efficient Lambda reading is 1, but it is often ideal to run slightly richer to optimise power)).

With the engine set up, it is run until it reaches its ideal running temperature, which prevents the variable of expanding components from influencing the readings when conducting step and sweep tests.

From the Dyno cell the experiment can be controlled using two variables (present in Figure 3):

- “Dynamometer”, which can be adjusted to send greater or lesser current to the dyno, changing the strength of the magnetic field (which resists engine rotation). If increased the engine must compensate by producing torque to overcome the resistance.
- “Engine”, controlling engine rpm through the throttle body (turning it up allows more air/fuel mixture into the engine, increasing the combustion events and similarly the engine speed).

There are three different ways of testing an engine using this Dynamometer:

- Manual: This allows full control of both “Dyno” and “Engine” settings, letting the operator manually adjust the two dials to desired values at any point during testing. However, it doesn’t produce the most gradual results which isn’t ideal if looking at progressive values at different engine speeds.
- Step: This test is good for looking at individual values respective of Dyno speed as it holds at different intervals allowing for better analysis at select points and more accurate results. However, due to the longer run time it can lead to the engine overheating.

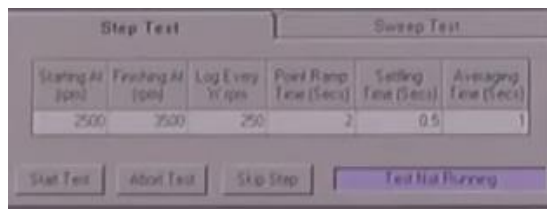


Figure 5: Step test setup within software

- Sweep: This is the test used to produce the results in this report. It doesn’t hold at different values; therefore the values aren’t as accurate as a step test, but it has a shorter run time which avoids issues with overheating.

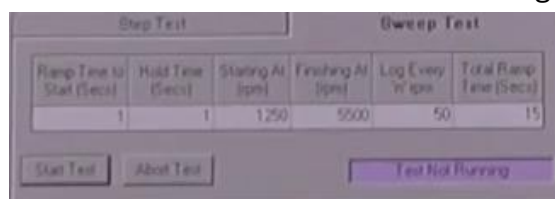


Figure 6: Sweep test setup within software

3 Data

3.1 Tables

$T = \text{Engine Load (Newtons)} \times \text{Distance from Pivot (Meters)}$	$P = (2\pi \times \text{Engine speed} \times \text{Torque})/60$	$\text{BMEP} = (\text{Torque} \times 4\pi/\text{Engine Capacity})/1000$	$\text{SFC} = (\text{Fuel Flow rate} \times 0.75 \times 3600)/60 \times (\text{Power}/1000)$	$P_s = \text{Measured Power} \times (\text{Standard pressure}/\text{Ambient Pressure}) \times ((\text{Ambient Temp}/\text{Standard Temp})^{0.5})$	$\eta_t = \text{BP (kW)}/\text{SFC} \times \text{Calorific value of Fuel}$
Torque	Power	Brake Mean Effective Pressure	Specific Fuel Consumption	Corrected Power (For Atmospheric condition)	Overall Thermal Efficiency (%)
Nm	W	kPa	kg/kWh	W	No units
83.4334904	8737.134683	659.2275785	0.362590267	8791.862712	15.08419252
83.82587866	9217.13676	662.3279301	0.353472026	9274.871445	15.54607872
84.58699766	9743.72265	668.3417099	0.340372989	9804.755786	16.29094656
85.01120118	10237.705	671.6934415	0.319993592	10301.83236	17.41536846
86.31807434	10847.04913	682.0193528	0.308655373	10914.99333	18.33266902
87.70407776	11480.43693	692.9704909	0.309461218	11552.34857	18.57853017
89.31768269	12159.32362	705.719962	0.292368236	12235.48769	20.02650004
91.20130947	12893.28137	720.602939	0.277819113	12974.04285	21.51972661
93.21709197	13666.33946	736.5301094	0.274945607	13751.94325	22.22524525
94.45299261	14342.08667	746.2952502	0.265756308	14431.92323	23.29860604
95.43355536	14990.66782	754.0429065	0.266115563	15084.56699	23.50870074
96.08862349	15596.68454	759.2187535	0.268903304	15694.3797	23.42467805
96.6457985	16193.15896	763.6211239	0.266501429	16294.59035	23.7728491
96.89134707	16741.62293	765.5612608	0.265431256	16846.4898	23.92934046
96.79671706	17232.09846	764.8135669	0.261271139	17340.0376	24.28661485
96.96395114	17769.57213	766.1349226	0.260965766	17880.87792	24.35704293
97.55375718	18388.45001	770.7951185	0.267477683	18503.63235	23.90860544
97.83927878	18954.55483	773.0510916	0.271003463	19073.28316	23.66661789
98.03669658	19506.11983	774.6109359	0.270953426	19628.30308	23.71875115
98.66647565	20148.04188	779.5869681	0.269244527	20274.24602	24.0226287
99.65274883	20871.22291	787.3797439	0.270695686	21001.95695	24.13269062
100.2140027	21513.49094	791.8143425	0.267425218	21648.24804	24.56540042
100.9898057	22208.81822	797.9441438	0.265232483	22347.93074	24.96023227
101.8039501	22920.90217	804.37689	0.263765796	23064.47507	25.30136485
102.0837613	23518.41027	806.5877437	0.263474441	23665.72587	25.398962
102.8106177	24224.1811	812.3308067	0.262021241	24375.91754	25.72167614
103.3261882	24886.67418	816.4044497	0.262098099	25042.56037	25.84308365
103.4583439	25460.21122	817.4486429	0.264854441	25619.68995	25.60684426
103.3506614	25974.8543	816.5978188	0.266276758	26137.55667	25.44355528
103.2380844	26487.11394	815.7083208	0.264439909	26653.02502	25.5923835
103.1450859	27003.32034	814.9735181	0.265967293	27172.46486	25.42249124
102.9827465	27500.03638	813.6908363	0.266072375	27672.29225	25.37245436
102.9191159	28021.92801	813.1880765	0.269869011	28197.45293	25.00004706
102.6629623	28489.72671	811.1641463	0.270808144	28668.18185	24.85134327
101.8993959	28811.37543	805.1310296	0.272782881	28991.84532	24.48794235
101.0966724	29113.75162	798.7885223	0.275745981	29296.11555	24.03396732
100.9025177	29586.16343	797.2544606	0.273852675	29771.48648	24.15365239
100.6577849	30041.44696	795.3207693	0.274271077	30229.62183	24.05831209
99.94805974	30352.95539	789.7130646	0.278572544	30543.0815	23.51981245

99.39170051	30704.40989	785.3171398	0.282198877	30896.73745	23.08833612
99.28728118	31192.01932	784.4920982	0.287092667	31387.40119	22.67092896
98.80923645	31559.20109	780.7149547	0.293804966	31756.88292	22.04632513
98.81005222	32076.82986	780.7214003	0.294675317	32277.75405	21.98139075
98.58734538	32520.7344	778.9617412	0.298955426	32724.43913	21.61785151
98.3793225	32967.22739	777.3181037	0.297499995	33173.72889	21.67777283
98.57837184	33550.08462	778.8908392	0.299172122	33760.23704	21.60022705
99.22528221	34289.79594	784.0022298	0.29593352	34504.58179	21.97991356
99.67232746	34966.16677	787.5344392	0.294069981	35185.18931	22.21885644
100.285791	35706.47182	792.3815586	0.295156577	35930.13151	22.27330869
100.7279416	36391.30855	795.8750941	0.291889751	36619.25795	22.62189121
100.6896001	36904.66594	795.5721492	0.29502367	37135.83092	22.37306844
101.3234581	37667.5154	800.5804095	0.293230118	37903.45875	22.65161776
101.2100652	38155.29568	799.6844659	0.300803592	38394.29441	22.05659573
101.1293034	38654.36099	799.0463478	0.299830335	38896.48578	22.11053456
101.0053054	39135.82815	798.0666109	0.304075589	39380.96878	21.77511344
100.9661482	39649.31368	797.7572203	0.300875321	39897.6707	21.9981935
100.755678	40094.21772	796.0942458	0.302250566	40345.36155	21.85245344
100.0728735	40346.4862	790.6992472	0.305323986	40599.2102	21.48588481
99.65274883	40698.88467	787.3797439	0.3050575	40953.81604	21.4143735
98.85899878	40892.33607	781.1081385	0.311262482	41148.47919	20.82031179
97.8963831	41006.74106	773.5022863	0.312259635	41263.6008	20.55173993
96.86034758	41079.92711	765.3163266	0.314496663	41337.24527	20.18960294
95.80636499	41134.55823	756.9885629	0.316102823	41392.21859	19.8684407
95.037904	41302.23604	750.9167723	0.319286587	41560.94671	19.51254741
94.57372746	41595.69784	747.2492046	0.319035398	41856.2467	19.43253379
93.84197638	41765.21234	741.4674677	0.320164779	42026.82302	19.21415934
93.31743242	42020.36829	737.3229228	0.323628768	42283.57722	18.90224806
93.01151642	42369.62302	734.9058087	0.325050095	42635.01963	18.75790033
92.8932289	42802.1272	733.9711913	0.325077301	43070.23295	18.73247708
92.98622736	43331.85257	734.705994	0.321830228	43603.27643	18.9404194
92.43231546	43557.70248	730.3294061	0.324862176	43830.54103	18.65187432
92.24305542	43951.4993	728.8340182	0.324664692	44226.80453	18.62500575
91.52598832	44089.06379	723.1683028	0.325999211	44365.2307	18.40457
90.60089834	44117.82308	715.8589498	0.326959696	44394.17013	18.16502837
89.71333405	44155.36435	708.8460962	0.326834581	44431.94656	17.99396174
88.6373255	44089.87535	700.3443003	0.331555712	44366.04735	17.52499595
87.35003098	43906.9145	690.1730843	0.332629841	44181.94046	17.21470764
85.85226624	43603.57724	678.3388937	0.336130678	43876.70314	16.74331348
84.54049843	43379.99544	667.9743086	0.339937795	43651.72086	16.30283554
83.48243696	43274.18876	659.6143167	0.341548864	43545.25143	16.02286118
82.47984826	43186.34756	651.6926282	0.342504074	43456.86	15.78628386
81.01871186	42845.51132	640.1478468	0.346436524	43113.88881	15.33061081
79.60464574	42514.51294	628.9749787	0.348974949	42780.81712	14.95346911
78.19098751	42168.92648	617.8053334	0.35316882	42433.06596	14.51349945
77.33825686	42113.98526	611.0677085	0.356674865	42377.7806	14.21410996
75.94678774	41753.92732	600.0733846	0.357056233	42015.46731	13.94346104
74.87893695	41558.91089	591.6360451	0.35992281	41819.22933	13.63791866
73.90424779	41404.90581	583.9347973	0.359522615	41664.25958	13.47537886
73.12403962	41350.67022	577.7701896	0.368700191	41609.68427	13.00123504
72.54337027	41402.14564	573.1821848	0.373676286	41661.48212	12.72623644
72.31642138	41651.26866	571.3890085	0.376843263	41912.16561	12.57980669

3.2 Graphs

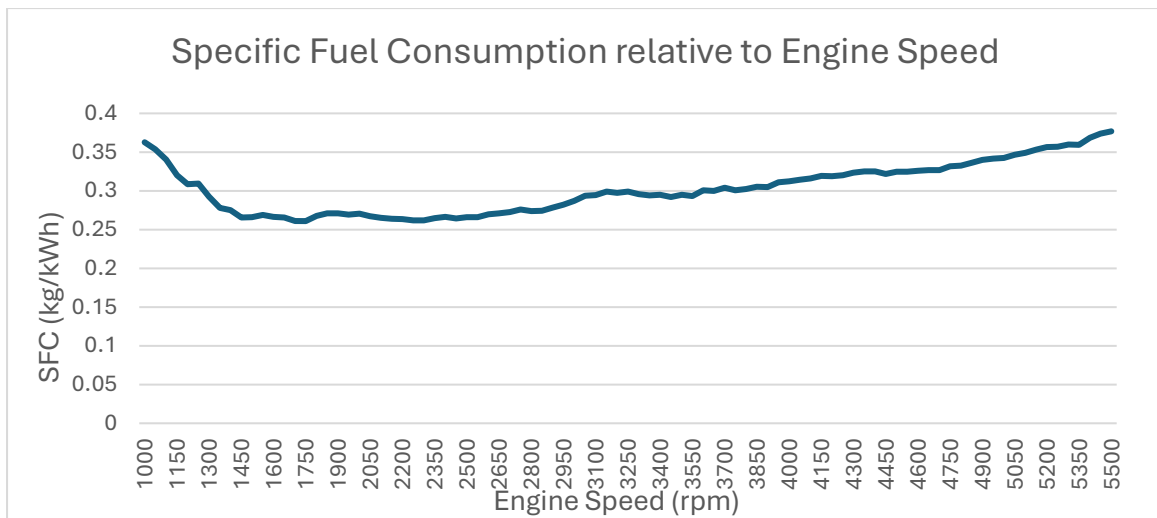


Figure 7

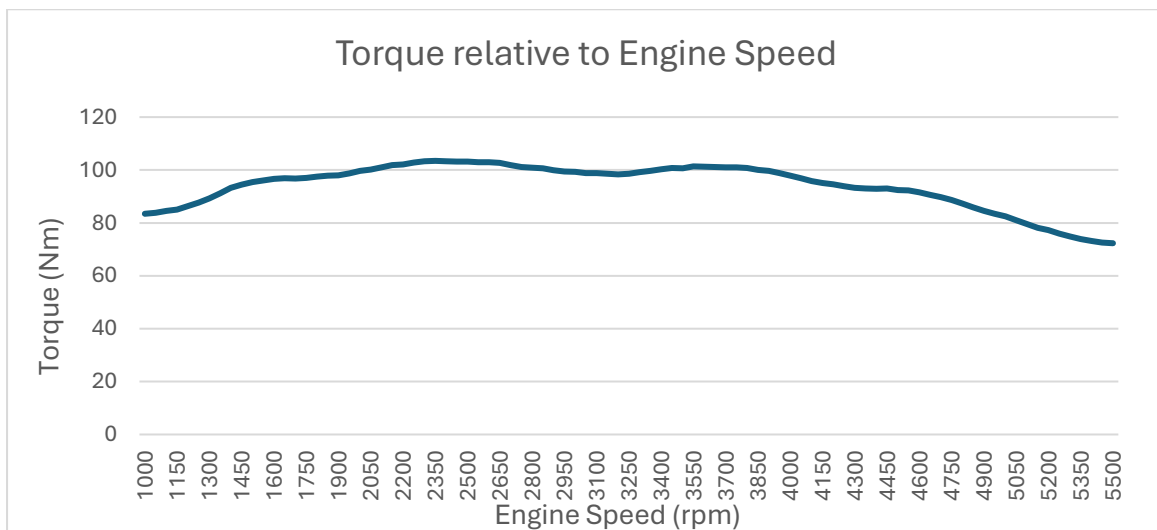


Figure 8

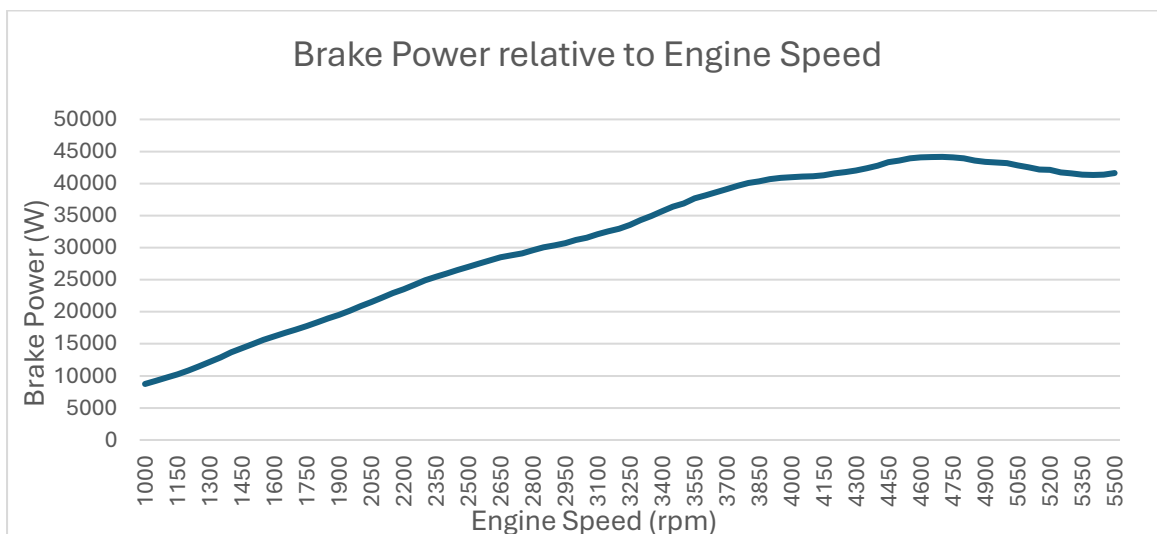


Figure 9

4 Analysis and Conclusions

4.1 SFC

In Figure 7 the SFC initially drops from a value of 0.363 kg/kWh at 1000rpm to 0.261 kg/kWh at 1750rpm. This decrease in fuel consumption could be due to an initial increase of thermal efficiency; from 1000rpm to 1750rpm the thermal efficiency increased to 24.36 %, which is closer to typical values for an SI engine (usually 20%-30%), as opposed to the initial 15.08%. This relationship continues along the graph until about 0.279kg/kWh at 2900rpm where there is a decrease in thermal efficiency until the end of the graph; incrementally decreasing from 23.52% to 12.58% at 5500rpm ending with a final SFC value of 0.377 kg/kWh. This trend may be caused by increased resistance due to greater frictional forces than when the engine is at a lower rpm.

4.2 Torque

Figure 8 display the relationship between torque and engine speed; the engine produces 83.43Nm of torque at 1000rpm, increasing to 103.35Nm when bringing engine speed to 2400rpm. As rpm increases the engine must produce more torque to overcome the magnetic resistance of the dynamometer. This tails off and decreases from 103.35 Nm to 72.32 Nm (between 2400rpm – 5500rpm), as the Power produced by the engine has increased enough that less torque is required to increase or maintain engine speed and overcome magnetic resistance.

If torque remains high against a small magnetic resistance it could produce a “runaway effect” where the engine overspeeds, causing overheating and potential failure.

4.3 Brake Power

Within the Figure 9 graph, Brake power increases steadily until 3900rpm, where the engine is producing 40698.88 Watts, due to the relation of Work done over time and engine speed; the more rotations per minute the more “Work” the engine is doing. The power then increases slower until a value of 44155.36 Watts at 4700rpm and then drops to a final value of 41651.27 Watts at 5500rpm. This is likely due to the efficiency of the engine at higher rpm, between 3700rpm and 4100rpm the Lambda value increases from 1.097 to 1.124, implying a leaner air-fuel mixture than required to continue producing as much power as before.

The final Lambda value is 1.084 which is a richer mixture likely meant to compensate for the loss of power, however, due to the increased engine speed and decreased thermal efficiency (21.78% to 12.58% Figure 7), it is insufficient and power drops 2504.09 Watts.

5 Evaluation

Due to a fault with the Dynamometer, my class was unable to complete the experiment before the report was due. Therefore, I didn't have the opportunity to collect personalised data, familiarise myself with the equipment or learn the procedure, allowing for a more rounded evaluation. However, we were provided with the required data sets, allowing for full analysis and reasonable conclusions.

Provided the opportunity to improve my report, result and greater engineering knowledge, the best next step would be to perform the practical and collect my own data sets.

With the provided information I believe to have appropriately calculated the required data and plotted it onto the suitable graphs with comprehensive analysis and further reasoning of what the data represents.