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Engine Performance Characteristics

Vehicle & Motorsport Technology (ACHA4004)

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March 2023

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1 Introduction

This technical report will be a discussion on the results collected from a dynamometer session and aims to explore the relationship between engine and other engine characteristics such as Torque, Specific Fuel Consumption (SFC) and Brake Power (BP). The results of the dyno provided the engine load, revolutions per minute (RPM), Fuel Flow rate and Lambda which allowed the previously mentioned parameters to be calculated.

2 Methodology

To obtain the results for this report, a Schenck W230 Eddy-Current Dynamometer was connected via driveshaft to a Honda D16 1.6 litre VTEC from 2000-2001. A load was then applied to the motor which then gave us a reading in current.

The experiment was performed manually by applying a current to the dynamometer to produce a torque whilst also increasing the RPM of the engine. Each parameter was increased until the engine speed could no longer overcome the torque applied to the dynamometer, this gave us our values for Load and engine RPM which was used to calculate the values required for this report.

2.1 Testing Equipment

For the purpose of this experiment a Schenck W230 dynamometer was used which is a specific device that uses eddy-currents to convert mechanical energy in the form of heat into electrical energy. An Eddy-Current dynamometer consists of an outer frame that remains stationary during the experiment and an inner rotor that once a load is applied, generates an electromagnetic field giving a reading in currents for angular torque of the connected arms and the total load applied via the motor.

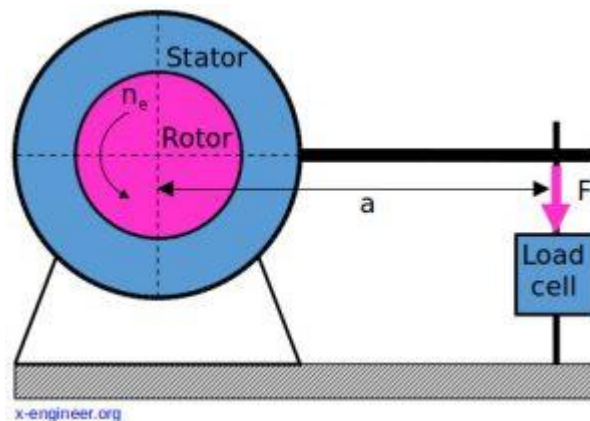


Figure 1 - Engine Dynamometer (<https://x-engineer.org/power-vs-torque/>)

The benefits of using an Eddy-Current dynamometer compared to that of a mechanical version is the improved efficiency due to the absence of physical contacts between the components which would absorb the energy produced.

The Internal Combustion Engine used for the experiment was a 4-cylinder 1.6 litre Honda VTEC from approximately 2000-2001 belonging to the D16 architecture. The engine was connected to the dynamometer rotor via a driveshaft. Sensors connected to the engine included coolant temperature, flow meter and a lambda sensor with the throttle controlled via computer.

3 Results

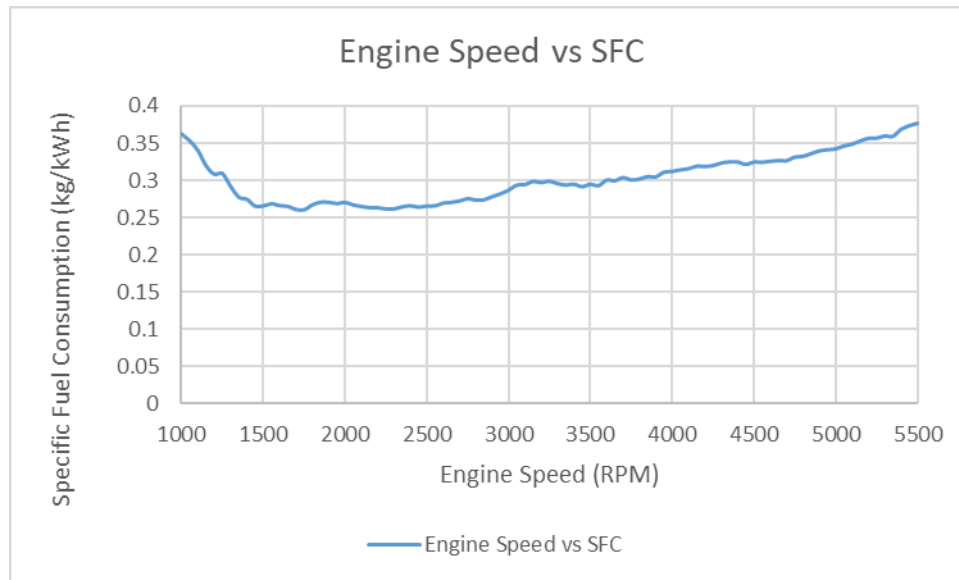


Figure 2 - Engine speed vs SFC results

SFC is the amount of fuel used per unit of power produced (Costa and Sodré, 2009). To calculate this, we used the formula:

$$SFC = \frac{\text{Fuel flow rate}}{\text{power}} = \frac{\text{kg}}{\text{kWh}}$$

Figure 2 is the graph showing us how the SFC changes in respect to the engine speed which is an important aspect in determining the efficiency of an engine. What stands out is the rapid decrease in SFC as the engine speed increases from 1000-1500 RPM, this may be caused in part since the engine completes less revolutions, the heat energy produced during each combustion may be lost as it has more time to escape via the cylinder walls instead of being transferred to the crankshaft. What we can also gather from the graph is that the most optimal engine speed for SFC recorded during the dyno test was at 1750 RPM and began to increase at a steady rate at approximately 2750 RPM, after this point the SFC increased until it became its highest value of 0.37 kg/kWh at 5500 rpm (the highest engine speed tested), this may be caused due to the increased friction of the components as the engine speed increases so does the heat produced, this means that the engine cannot transfer this energy to the crankshaft therefore reducing our overall SFC and Thermal Efficiency.

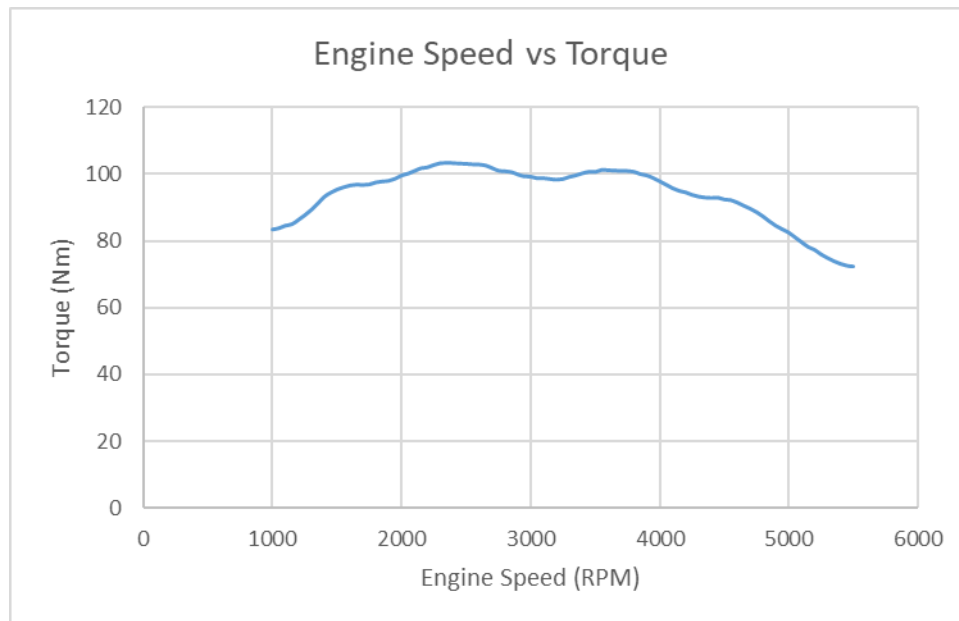


Figure 3- Engine Speed vs Torque results

Figure 3 is the relationship between engine speed and torque produced at the crankshaft and how the torque increases or decreases depending on the RPM (Enaburekhan and Bello, 2013). An important aspect in understanding the torque curve is the parameter called Volumetric Efficiency, this is the ratio of air drawn into the engine vs the cylinder volume of the engine which can vary dependant on air temperature and density (Thomaz *et al.*, 2021).

The results show us that as the engine speed increases, so does the torque produced due to the combustion cycles allowing more air and fuel to be burnt at any given moment. The torque will continue to increase until the engine reaches its maximum volumetric efficiency and can no longer increase its air and fuel volume. As the engine speed continues to increase the torque will begin to decrease due to the loss of air intake caused by the intake valves and other mechanical losses such as friction which will reduce the overall volumetric efficiency thus reducing the torque (Heywood, 2018). The engine produces its maximum torque at approximately 2350 RPM plateauing until 4000 RPM after which it then decreases at a fast rate.

$$T = \text{Force} * \text{Distance} = \text{Newtons} * \text{meters} = \text{Nm}$$

The Torque (Nm) produced at each recorded engine speed was calculated by multiplying the force (Newtons) exerted by the engine on the Dynamometer and the distance of the pivot arm which was measured at 0.815776m.

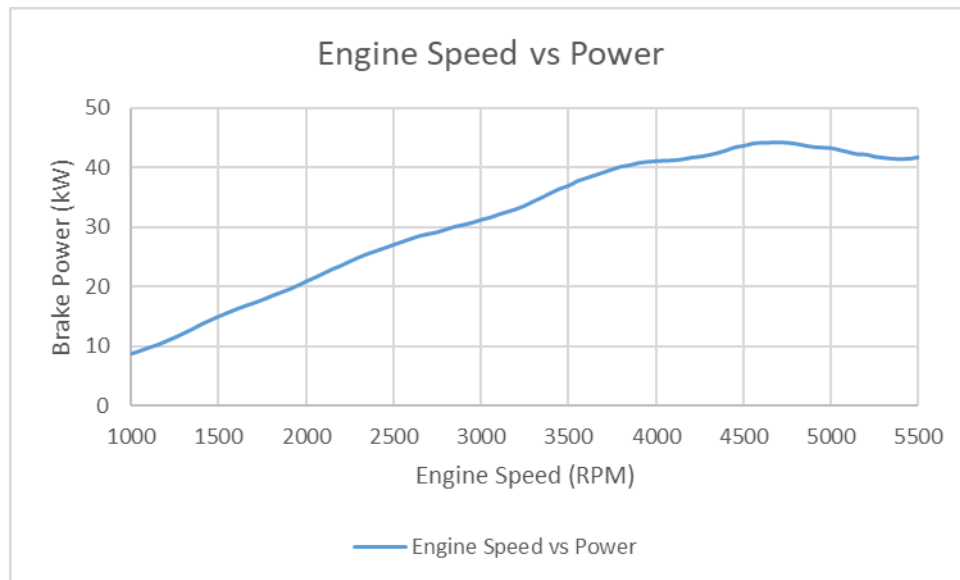


Figure 4 - Engine speed vs Power

Figure 4 above shows the relationship between engine speed and how the power produced by the engine varies dependant on the RPM. The graph shows us that as the engine speed is increased so does the power produced, this is because the engine is able to do more work per second. The engine will continue to produce more and more power until it reaches a stage where it can no longer produce power due to the increased friction. As the RPM increases it becomes more difficult for the engine to intake the optimal amount of air and fuel and to be able to combust it at the optimal rate and to exhaust it through the exhaust valves, this is another reason as to why the power starts to drop off after the peak of 44.16kW at 4700RPM.

Table 1 - Engine Dyno Results

Load	Dyno Speed	Fuel Flow Rate		Lambda	Power		Torque	BMEP		SFC	Thermal Efficiency
Newtons	rpm	l/min	l/sec	Lambda	Watts	kW	Nm	Pa	kPa	kg/KWh	%
102.275	1000	0.0704	0.00117333	1.2658	8737.13468	8.7371347	83.4334904	0.655285101	655.2851013	0.362590267	22.88161633
102.756	1050	0.0724	0.00120667	1.26783	9217.13676	9.2171368	83.82587866	0.658366911	658.3669114	0.353472026	23.47187551
103.689	1100	0.0737	0.00122833	1.27344	9743.72265	9.7437226	84.58699766	0.664344726	664.3447261	0.340372989	24.37517563
104.209	1150	0.0728	0.00121333	1.28476	10237.705	10.237705	85.01120118	0.667676413	667.6764128	0.319993592	25.92755472
105.811	1200	0.0744	0.00124	1.29181	10847.0491	10.847049	86.31807434	0.677940571	677.9405705	0.308655373	26.87998361
107.51	1250	0.07895	0.00131583	1.29729	11480.4369	11.480437	87.70407776	0.688826216	688.826216	0.309461218	26.80998745
109.488	1300	0.079	0.00131667	1.29895	12159.3236	12.159324	89.31768269	0.701499439	701.4994394	0.292368236	28.37740339
111.797	1350	0.0796	0.00132667	1.29469	12893.2814	12.893281	91.20130947	0.71629341	716.2934096	0.277819113	29.86350103
114.268	1400	0.0835	0.00139167	1.2855	13666.3395	13.666339	93.21709197	0.732125328	732.1253283	0.274945607	30.17560988
115.783	1450	0.0847	0.00141167	1.27818	14342.0867	14.342087	94.45299261	0.741832069	741.8320692	0.265756308	31.21901959
116.985	1500	0.08865	0.0014775	1.2795	14990.6678	14.990668	95.43355536	0.749533391	749.5333911	0.266115563	31.17687406
117.788	1550	0.0932	0.00155333	1.27766	15596.6845	15.596685	96.08862349	0.754678284	754.6782841	0.268903304	30.85366101
118.471	1600	0.0959	0.00159833	1.28235	16193.159	16.193159	96.6457985	0.759054326	759.0543264	0.266501429	31.1317332
118.772	1650	0.09875	0.00164583	1.29028	16741.6229	16.741623	96.89134707	0.76098286	760.9828604	0.265431256	31.25725096
118.656	1700	0.10005	0.0016675	1.29942	17232.0985	17.232098	96.79671706	0.760239638	760.239638	0.261271139	31.7549474
118.861	1750	0.10305	0.0017175	1.31053	17769.5721	17.769572	96.96395114	0.761553091	761.5530914	0.260965766	31.79210634
119.584	1800	0.1093	0.00182167	1.3149	18388.45	18.38845	97.55375718	0.766185417	766.1854172	0.267477683	31.01810698
119.934	1850	0.11415	0.0019025	1.31849	18954.5548	18.954555	97.83927878	0.768427899	768.4278987	0.271003463	30.61455852
120.176	1900	0.11745	0.0019575	1.31892	19506.1198	19.50612	98.03669658	0.769978414	769.9784144	0.270953426	30.6202121
120.948	1950	0.12055	0.00200917	1.31484	20148.0419	20.148042	98.66647565	0.774924688	774.9246876	0.269245427	30.81455909
122.157	2000	0.12555	0.0020925	1.31653	20871.2229	20.871223	99.65274883	0.782670859	782.6708591	0.270695686	30.64936685
122.845	2050	0.12785	0.00213083	1.32098	21513.4909	21.513491	100.2140027	0.787078937	787.0789368	0.267425218	31.02419229
123.796	2100	0.1309	0.00218167	1.32287	22208.8182	22.208818	100.9898057	0.793172079	793.1720792	0.265232483	31.28067605
124.794	2150	0.13435	0.00223917	1.32164	22920.9022	22.920902	101.8039501	0.799566355	799.5663547	0.263765796	31.45461433
125.137	2200	0.1377	0.002295	1.31652	23518.4103	23.51841	102.0837613	0.801763986	801.7639865	0.263474441	31.4893974
126.028	2250	0.14105	0.00235083	1.30465	24224.1811	24.224181	102.8106177	0.807472703	807.4727034	0.262021241	31.66404121
126.66	2300	0.14495	0.00241583	1.29646	24886.6742	24.886674	103.3261882	0.811521984	811.5219841	0.262098099	31.65475599
126.822	2350	0.14985	0.0024975	1.28229	25460.2112	25.460211	103.4583439	0.812559919	812.5599919	0.264854441	31.32532482
126.69	2400	0.1537	0.00256167	1.27304	25974.8543	25.974854	103.3506614	0.811714197	811.7141968	0.266276758	31.15800054
126.552	2450	0.15565	0.00259417	1.26984	26487.1139	26.487114	103.2380844	0.810830018	810.8300184	0.264439909	31.37442988
126.438	2500	0.1596	0.00266	1.27446	27003.3203	27.00332	103.1450859	0.81009961	810.0996102	0.265967293	31.19425436
126.239	2550	0.1626	0.00271	1.27876	27500.0364	27.500036	102.9827465	0.808824599	808.8245993	0.266072375	31.1819345
126.161	2600	0.16805	0.00280083	1.27634	28021.928	28.021928	102.9191159	0.808324846	808.3248463	0.269869011	30.74325335
125.847	2650	0.17145	0.0028575	1.28027	28489.7267	28.489727	102.6629623	0.80631302	806.3130202	0.270808144	30.63663918
124.911	2700	0.17465	0.00291083	1.28371	28811.3754	28.811375	101.8993959	0.800315984	800.3159842	0.272782881	30.41485354
123.927	2750	0.1784	0.00297333	1.28812	29113.7516	29.113752	101.0966724	0.794011408	794.0114079	0.275745967	30.08802287
123.689	2800	0.18005	0.00300083	1.27448	29586.1634	29.586163	100.9025177	0.792486521	792.4865206	0.273852675	30.29603921
123.389	2850	0.1831	0.00305167	1.26036	30041.447	30.041447	100.6577849	0.790564394	790.5643936	0.274271077	30.24982248
122.519	2900	0.1879	0.00313167	1.2531	30352.9554	30.352955	99.94805974	0.784990226	784.9902256	0.278572544	29.78273185
121.837	2950	0.19255	0.00320917	1.23943	30704.4099	30.70441	99.39170051	0.78062059	780.6205904	0.282198877	29.40001554
121.709	3000	0.199	0.00331667	1.22735	31192.0193	31.192019	99.28728118	0.779800483	779.8004829	0.287092637	28.89886121
121.123	3050	0.20605	0.00343417	1.2193	31559.2011	31.559201	98.80923645	0.776045928	776.0459283	0.293804966	28.38635623
121.124	3100	0.21005	0.00350083	1.20692	32076.8299	32.07683	98.81005222	0.776052335	776.0523354	0.294675317	28.15523031
120.851	3150	0.21605	0.00360083	1.19274	32520.7344	32.520734	98.58734538	0.7743032	774.3031999	0.298955426	27.75213514
120.596	3200	0.21795	0.0036325	1.18481	32967.2274	32.967227	98.3793225	0.772669392	772.669392	0.297499995	27.88790422
120.84	3250	0.22305	0.0037175	1.17378	33550.0846	33.550085	98.57837184	0.774232722	774.2327219	0.299172127	27.73203376
121.633	3300	0.2255	0.00375833	1.16118	34289.7959	34.289796	99.2258221	0.779313544	779.3135441	0.295935322	28.03552498
122.181	3350	0.2285	0.00380833	1.15104	34966.1668	34.966167	99.67232746	0.782824629	782.8246293	0.294069981	28.21318704
122.933	3400	0.2342	0.00390333	1.14117	35706.4718	35.706472	100.285791	0.787642761	787.6427607	0.295156577	28.10932239
123.475	3450	0.23605	0.00393417	1.12669	36391.3086	36.391309	100.7279416	0.791115403	791.1154034	0.291889751	28.42392151
123.428	3500	0.24195	0.0040325	1.11975	36904.6659	36.904666	100.6896001	0.79081427	790.8142701	0.29502367	28.12198549
124.205	3550	0.24545	0.00409083	1.10622	37667.5154	37.667515	101.3234581	0.795792579	795.7925789	0.293230118	28.29399484
124.066	3600	0.25505	0.00425083	1.09697	38155.2957	38.155296	101.2100652	0.794901993	794.9019934	0.300803592	27.58162335
123.967	3650	0.25755	0.0042925	1.09401	38654.361	38.654361	101.1293034	0.794267691	794.2676915	0.299830335	27.67115403
123.815	3700	0.26445	0.0044075	1.09659	39135.8282	39.135828	101.0053054	0.793293814	793.2938139	0.304075589	27.28483205
123.767	3750	0.2651	0.00441833	1.09808	39649.3137	39.649314	100.9661482	0.792886274	792.8862736	0.300875321	27.57504782
123.509	3800	0.2693	0.00448833	1.09907	40094.2177	40.094218	100.755678	0.791333244	791.3332444	0.302250566	27.44958095
122.672	3850	0.27375	0.0045625	1.10533	40346.4862	40.346486	100.0728735	0.78597051	785.9705103	0.305323986	27.17327086
122.157	3900	0.2759	0.00459833	1.11704	40698.8847	40.698885	99.65274883	0.782670859	782.6708591	0.30505075	27.19700839
121.184	3950	0.28285	0.00471417	1.12259	40892.3361	40.892336	98.85899878	0.776436761	776.4367608	0.311262482	26.65483915
120.004	4000	0.28455	0.0047225	1.12461	41006.7411	41.006741	97.8863831	0.768876395	768.8763949	0.312259635	26.56972099
118.734	4050	0.2871	0.004785	1.1222	41079.9271	41.079927	96.86034758	0.760739391	760.739391	0.314496623	26.38072944
117.442	4100	0.28895	0.00481583	1.12394	41134.5582	41.134558	95.80636499	0.752461431	752.4614311	0.316102823	26.24668545
116.5	4150	0.29305	0.00488417	1.12233	41302.236	41.302236	95.037904	0.746425953	746.4259525	0.319286587	25.98496681
115.931	4200	0.2949	0.004915	1.12179	41595.6978	41.595698	94.57372746	0.742780318	742.7803185	0.319035338	26.00542586
115.034	4250	0.29715	0.0049525	1.12456	41765.2123	41.765212	93.84197638	0.737033159	737.033159	0.320164779	25.91369167
114.391	4300	0.3022	0.00503667	1.12278	42020.3683	42.020368	93.31743242	0.7329134	732.9134003	0.323626768	25.63632227
114.016	4350	0.30605	0.00510083	1.11943	42369.623	42.369623	93.01151642	0.730510742	730.5107417	0.325050095	25.5242238
113.871	4400	0.3092	0.00515333	1.11986	42802.1272	42.802127	92.8932289	0.729581714	729.5817137	0.325077301	25.52208766
113.985	4450	0.3099	0.005165	1.11873	43331.8526	43.331853	92.98622736	0.730312122	730.3121219	0.321830223	25.77959014
113.306	4500	0.31445	0.								

Table 1 provides a complete dataset from the initial values collected from the completion of the dyno run which were noted in the introduction. Those results were then used to populate the remaining parameters and highlighted to denote the highest value in red and lowest value in green, this allows us to visualise how as the engine speed increases, the torque varies as well as the power produced. Given these we can then understand where the engine is at its most efficient speed for fuel consumption or engine performance.

4 Conclusion

This report set out to establish the relationship between the speed of an engine and the effect that has on its Torque, Power and SFC.

What we can conclude is that engine speed is an important factor in determining the performance and efficiency of the overall engine. The findings of the experiment show us that each of the characteristics explored will perform at varying engine speeds comparatively and the potential relationship they have with each other.

A finding that stands out from the results reported earlier is the relationship between Torque, Power and Engine speed. As the engine speed increases so does the power and torque, the power of the engine will continue to increase past the peak torque until the rate of loss in torque overcomes the ability for the speed to increase.

5 Evaluation

Upon further evaluation of the test performed, improvements could be made to improve the accuracy of the data by installing components from the Original Manufacturer. The test was performed using an aftermarket air intake which would affect ratio of air entering the cylinders thus affecting overall volumetric efficiency.

Performing more tests of the engine whilst using alternative fuels in different atmospheric settings would have provided more data and results to evaluate which may further add to the understanding of engine performance.

6 References

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