

Engine Performance Characteristics Report

HONDA CIVIC 1.6 D16 2003 DYNO TESTS

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Introduction

The aims of this dynamometer test are to see the colorations between engine speed (rpm) against torque and engine speed against corrected power (watts). The test will help us answer why torque varies as it does with engine speed and why corrected brake power varies with engine speed.

Experimental Procedure



Figure 1 Honda Civic SOHC 1.6

For this test we will use an Eddy Current dynamometer to test a Honda Civic 1.6 D16 2003. Using the control centre, we used a sweep test up to 5500 rpm from an idle of 1000rpm. Compared to a step-test, where the engine speed stays at an engine speed for a period for every 50 added from 1000 to 5500, the sweep test continuously revs from 1000 to 5500 rpm at a constant and gradual manner.

Figure 1 shows a 1.6L SOHC (single overhead cam) Honda Civic engine, we can tell that it is a SOHC system as the

manual shows the upper case only having space for one camshaft pulley as shown in figure 2 directly from the manual. SOHC use two valves which makes them lighter than DOHC and cheaper. However, SOHC systems are only good for low engine speeds compared to the DOHC systems where the four valves allow for more charge at higher rpms (Part 2 Vehicle Technology 2021). This engine has VVT, Variable Valve Timing, which increases how longer and far valves are open for. In a SOHC Vtech system it mitigates the disadvantages of a SOHC slightly as at higher rpms, the valves allow for more air intake. Compared to a traditional SOHC system where there are only 2 valves per cylinder, one intake and one exhaust, the Honda engine has 4 per cylinder. As our test only went to a relatively safe rpm of 5500, our results will not show the effects of Vtech kick in as we did not redline the engine.

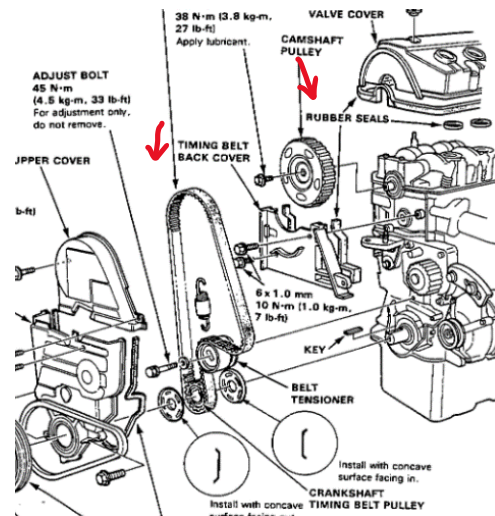


Figure 2 Manual illustration of SOHC engine.

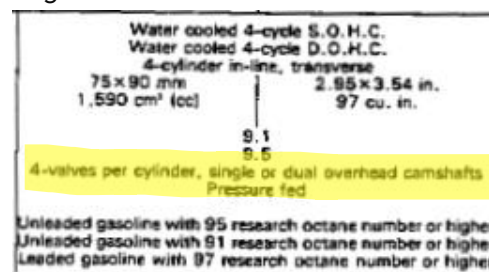


Figure 3 Manual Engine Design Specification

The eddy current dynamometer uses an electromagnetic motor that uses Faraday's Law electromagnetic induction that converts electrical energy from mechanical energy. As this system uses electrical energy, it can give accurate data and be easily controlled by the control centre (Elprocus 2013). We can input what we want it to do such as go through the rpm range the engine will go through, type of test to record data, simulate driving patterns and choose when and how much data should be recorded. For example, for our testing to give smooth graphs, we recorded the data every 50 rpms from 1000 rpm to 5500 rpm.



Figure 4 Uni's Eddy Current Dynamometer.

Before we start the test, we need to calibrate the dynamometer so that it's zeroed for our results to be accurate. We use calibration arms from the manufacturer of the dynamometer and a known weight when the system is in calibration mode. We use both arms within the calibration and put the known weight on one side; we use both arms so that their torque on the dynamometer cancel out and we can correct the torque only using the known weight and the distance from the centre of the dynamometer to the centre of the chain link end to that arm we attached the weight to.



Figure 6 Calibration Arms of a known length.



Figure 7 Calibration Weight



Figure 5 Drive shaft

The dynamometer gives the engine the correct load that is proportional to the engine's rpm from the dynamometer's drive shaft. If the simulated values are entered correctly for the sweep test, the engine will be able to successfully go through the whole rev range set without stalling or destroying itself. If anything were to go wrong, we can safely stall the engine and stop testing in the control room which is separate and closed off during the actual dynamometer run.

ENGINE PERFORMANCE CHARACTERISTICS

Results

Here are the results acquired after doing a sweep test with a rev range from 1000 rpm to 5500 rpm with 100% throttle:

W	N	T	P	Ps	BMEP
Force (N)	Engine speed (RPM)	Torque (Nm)	Power (W)	Corrected Power (W)	BMEP (Pa)
130.037	1000	106.0769025	11108.34726	11250.15405	848811.9854
130.61	1050	106.5443238	11715.16028	11864.71352	852552.2229
131.485	1100	107.2580998	12355.24614	12512.97059	858263.7549
132.641	1150	108.2010999	13030.41159	13196.75505	865809.5046
133.729	1200	109.0886294	13708.48147	13883.48102	872911.3867
135.143	1250	110.2420914	14430.65602	14614.8747	882141.2224
136.396	1300	111.2642186	15147.03025	15340.39401	890320.1362
137.723	1350	112.3467109	15882.64207	16085.3965	898982.0825
139.186	1400	113.5401444	16645.85456	16858.352	908531.764
140.496	1450	114.608769	17402.61323	17624.77129	917082.7433
141.522	1500	115.4457224	18134.17166	18365.66864	923779.9226
142.271	1550	116.0567146	18837.81764	19078.29721	928668.994
143.07	1600	116.7084941	19554.69587	19804.32696	933884.4386
143.631	1650	117.1661265	20244.85332	20503.29481	937546.3466
143.895	1700	117.3814829	20896.67224	21163.43471	939269.5974
143.984	1750	117.4540841	21524.58512	21799.36339	939850.5418
143.769	1800	117.2786991	22106.51398	22388.72103	938447.1368
143.411	1850	116.9866628	22664.00716	22953.33105	936110.3043
143.045	1900	116.6881005	23217.14368	23513.5288	933721.252
142.816	1950	116.5012951	23789.97483	24093.67259	932226.4625
142.873	2000	116.5477925	24409.71258	24721.32178	932598.528
143.19	2050	116.8063834	25075.46852	25395.57661	934667.7345
143.772	2100	117.2811464	25791.47115	26120.71958	938466.7192
144.551	2150	117.9166109	26548.62704	26887.54116	943551.6145
145.344	2200	118.5634959	27315.06857	27663.76693	948727.8944
146.106	2250	119.1850929	28082.32591	28440.81891	953701.8228
146.954	2300	119.8768438	28872.98957	29241.57601	959237.1133
147.835	2350	120.5955142	29677.52189	30056.37882	964987.8101
148.72	2400	121.3174477	30490.40019	30879.63415	970764.6167
149.675	2450	122.0964832	31325.48886	31725.38339	976998.3459
150.825	2500	123.0345888	32210.38003	32621.57088	984504.9309
152.138	2550	124.1056607	33140.60171	33563.66758	993075.4926
153.556	2600	125.2623857	34105.36052	34540.74229	1002331.438
155.005	2650	126.4443987	35089.25015	35537.19205	1011789.735
156.482	2700	127.6492526	36091.97588	36552.71837	1021430.801
157.786	2750	128.7129828	37066.6781	37539.86343	1029942.616
158.838	2800	129.5711455	37992.24415	38477.24505	1036809.509
159.646	2850	130.2302666	38867.39265	39363.56551	1042083.701

ENGINE PERFORMANCE CHARACTERISTICS

160.156	2900	130.6462961	39675.61958	40182.1101	1045412.708
160.53	2950	130.9513843	40453.93085	40970.35712	1047853.98
160.755	3000	131.1349267	41197.25224	41723.1676	1049322.66
160.772	3050	131.1487944	41888.30237	42423.03953	1049433.627
160.64	3100	131.0411162	42540.04014	43083.09725	1048572.001
160.269	3150	130.7384751	43126.33847	43676.88013	1046150.312
159.847	3200	130.3942312	43695.52626	44253.33405	1043395.721
159.295	3250	129.9439405	44225.01729	44789.58445	1039792.561
158.657	3300	129.4234958	44725.5494	45296.50625	1035628.038
158.007	3350	128.8932622	45217.19736	45794.43048	1031385.186
157.267	3400	128.2896116	45677.15283	46260.25765	1026554.861
156.714	3450	127.8385052	46185.89852	46775.49787	1022945.173
156.031	3500	127.2813521	46651.05207	47246.58947	1018486.914
155.394	3550	126.7617231	47124.32095	47725.9	1014328.919
154.841	3600	126.3106167	47617.98066	48225.86167	1010719.231
154.283	3650	125.8554316	48105.3574	48719.46016	1007076.905
153.895	3700	125.5389229	48641.69947	49262.64906	1004544.249
153.537	3750	125.2468865	49184.33733	49812.21411	1002207.416
153.207	3800	124.977691	49733.00615	50367.88713	1000053.353
152.982	3850	124.7941486	50313.38883	50955.67884	998584.6732
152.81	3900	124.6538406	50909.5067	51559.40663	997461.9492
152.686	3950	124.5526884	51520.35176	52178.04961	996652.5435
152.585	4000	124.4702982	52137.99661	52803.57918	995993.2695
152.443	4050	124.3544626	52740.59393	53413.86913	995066.3695
152.235	4100	124.1847878	53318.86235	53999.5196	993708.6567
151.91	4150	123.919671	53853.87606	54541.36319	991587.2305
151.399	4200	123.5028259	54319.37986	55012.8095	988251.6958
150.827	4250	123.0362203	54758.37215	55457.40588	984517.9858
150.068	4300	122.4170706	55123.78832	55827.48687	979563.6397
149.154	4350	121.6714806	55425.12328	56132.66861	973597.5366
148.116	4400	120.8247383	55672.04283	56382.74029	966822.0278
147.008	4450	119.920894	55883.48559	56596.88227	959589.5964
145.914	4500	119.02847	56090.84505	56806.88884	952448.5495
144.832	4550	118.145835	56293.52324	57012.15438	945385.8322
143.855	4600	117.3488531	56528.21855	57249.84576	939008.4988
142.954	4650	116.6138678	56784.7569	57509.65902	933127.2527
141.876	4700	115.7344957	56962.53385	57689.70544	926090.6453
140.982	4750	115.0052206	57205.76306	57936.03966	920255.0914
140.028	4800	114.2270008	57416.75306	58149.72312	914027.8897
139.039	4850	113.42023	57605.09276	58340.46711	907572.2266
137.983	4900	112.5588044	57756.9391	58494.25189	900679.2234
136.865	4950	111.6468026	57873.54783	58612.34923	893381.5174
135.733	5000	110.7233804	57974.62638	58714.71813	885992.4269
134.623	5050	109.8179045	58075.52554	58816.90535	878746.9405
133.253	5100	108.7003352	58053.66968	58794.77048	869804.3133
131.742	5150	107.467746	57958.07965	58697.96017	859941.3134

ENGINE PERFORMANCE CHARACTERISTICS

129.994	5200	106.0418255	57744.30481	58481.45632	848531.3044
128.245	5250	104.6150893	57515.14929	58249.37545	837114.7678
126.542	5300	103.2258772	57291.87951	58023.25546	825998.4947
125.13	5350	102.0740467	57187.05509	57917.09287	816781.7139
123.554	5400	100.7884342	56994.51679	57722.09666	806494.4288
122.083	5450	99.58847475	56837.39975	57562.97391	796892.5276
121.004	5500	98.70828698	56851.89202	57577.65118	789849.3927

Table 1 Engine excel data

The additional data needed for equations for corrected power, power, torque BMEP (Break mean effective pressure) and conditions within the dynamometer room:

Temperature	26	°C	299	K	Diameter (d)	0.075	m
Barometric Pressure	1010.67	mBar	1.01067	Bar	Stroke (l)	0.09	m
Humidity	42.8	%			Area (A)	0.004418	m ²
Torque arm	815.744	mm	0.81574 4	m			

Table 2 Additional excel data

COLOUR CODE:

MAX POWER/CORRECTED POWER@RPM

58075.52554W/ 58816.90535W @5050rpm

MAX TORQUE/FORCE@RPM

131.1487944Nm/ 160.772N @3050rpm

Analysis

From our raw data in table 1 we have found our peak power within 5500rpm which occurs at 5050rpm. We will use the corrected power value which uses the equation of Power which looks like:

$$P = \frac{(MEP)LANn}{60 \times 2}$$

Where **P** is the power from the engine (W), **N** is engine speed (rpm), **MEP** is the mean effective pressure (Pa), **L** is the engine stroke (m), **n** is the number of cylinders, **A** is the piston area (m²), **60** is the number of seconds in a minute, and **2** for idle strokes within the 4 strokes of a piston cycle.

For corrected power we would need to use this equation:

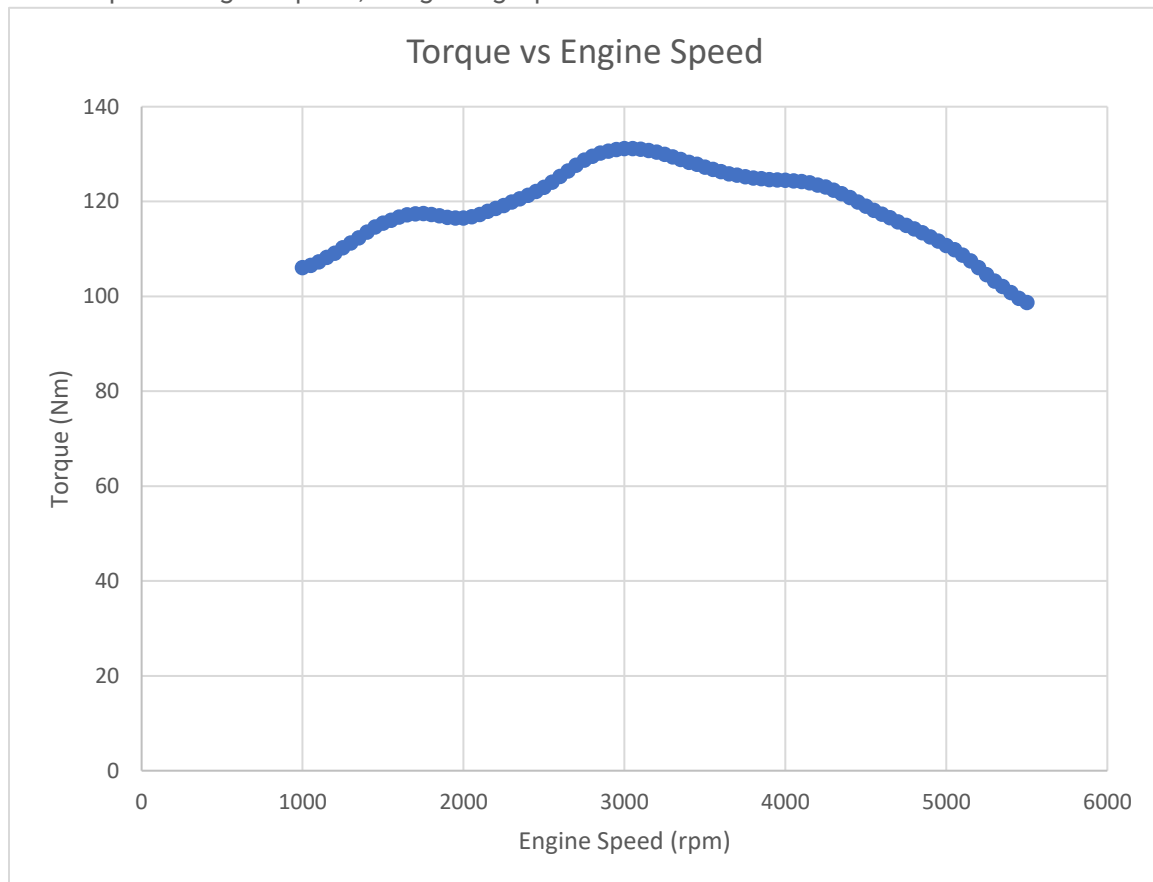
$$P_S = \left(\frac{1.01325}{p_a} \sqrt{\frac{T_a}{293}} \right) P$$

Where **P_s** is corrected power (W), **p_a** is ambient pressure, **T_a** is ambient temperature, **1.01325** is the standard pressure (Bar), **293** is the standard temperature (K).

The torque and force were directly calculated from the dyno, so no equations were needed to find the peak values of 131.1Nm and 160.8N at 3050rpm as shown in table 1. (Part 1 Vehicle Technology 2021)

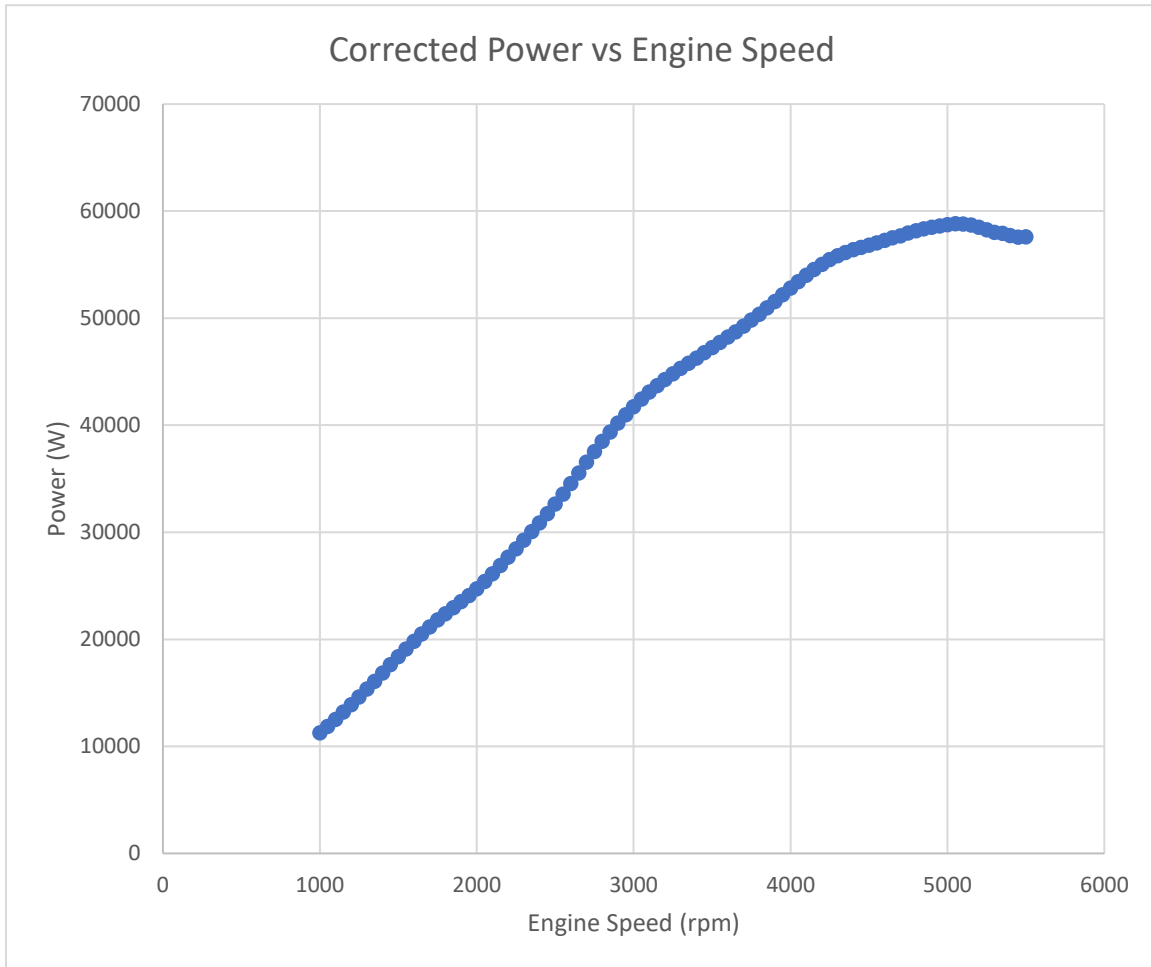
Now we can plot graphs of Corrected Power vs Engine Speed and Torque vs Engine Speed with the data from the excel result data to see how engine speed relates to the engines torque and corrected power.

For Torque vs Engine Speed, we get a graph that looks like this:



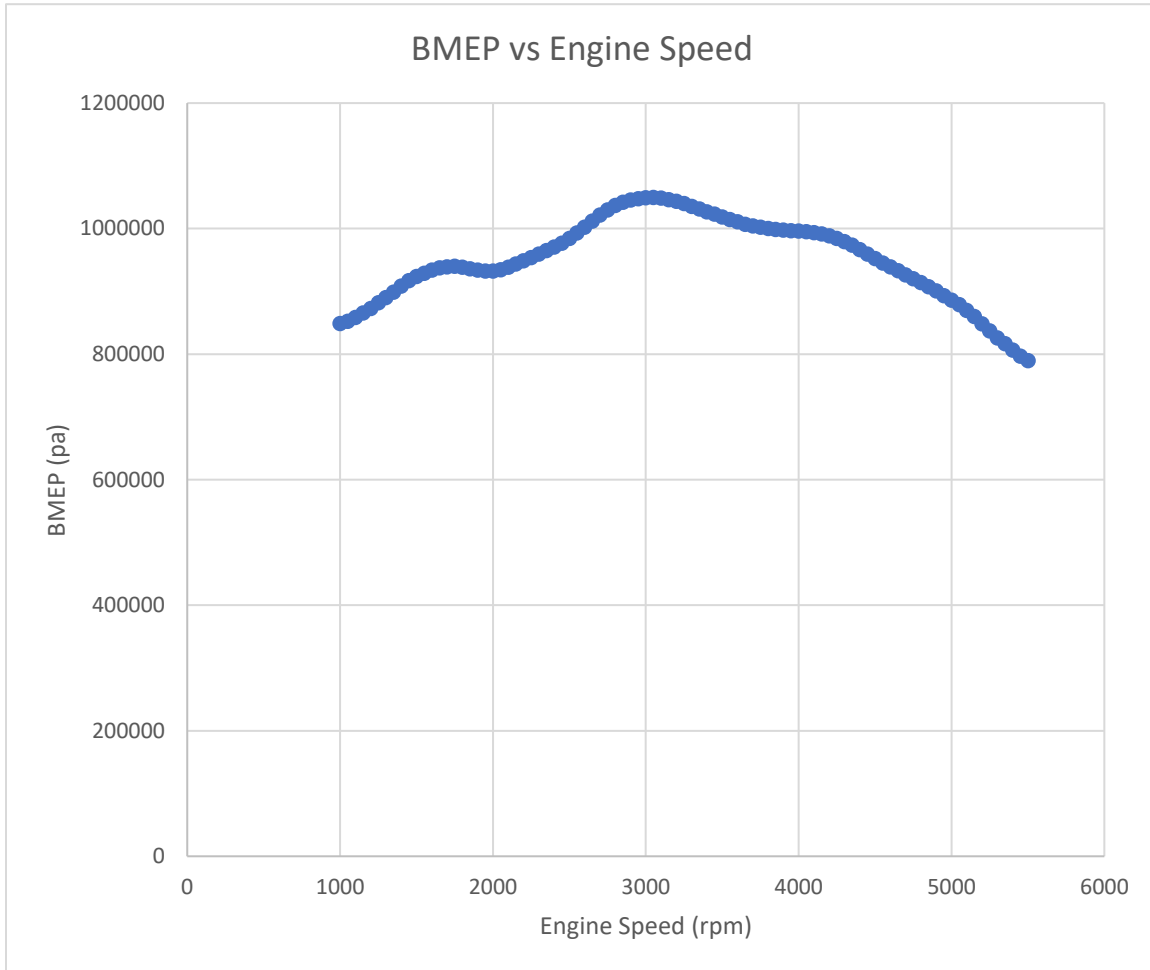
Graph 1 Torque vs RPM

For Corrected Power vs Engine Speed, we get a graph that looks like this:



Graph 2 CP vs RPM

For BMEP vs Engine Speed, we get a graph that looks like this:



Graph 3 BMEP vs RPM

Conclusion

From the graphs we can go back to our aims and see the correlation between Engine Speed vs Torque, Corrected Power and BMEP.

For Graph 1 (Nm v Rpm) we see that the torque gradually increases until the peak at 3050rpm where the torque gradually decreases as the engine speed speeds up to 5500rpm, this shows that the engine has peak torque in the mid-range of its engine speed it has its peak torque available around 3050rpm. As engine speed increases, the time that the valves are open decreases. With Vtech, low rpms will use the short cam lobes on the camshaft. With these shorter lobes and it being a SOHC engine, torque is around the lower to mid rpms. That's why the engine peaks relative early and begins to steadily decrease as the engine speed increases. We also notice that BMEP and Torque have almost identical graph patterns. As BMEP "is the equivalent of the mean pressure available throughout the stroke to do mechanical work after all frictional losses have been taken into account" (Part 1 Vehicle Technology, 2021, p.24) it is proportional to engine torque as it deals with the combustion within the cylinder heads.

For Graph 2 (CP v Rpm) we see a relatively linear increase in power to 4150rpm where after it begins to level out up to 5500rpm. 1000rpm to 4150rpm power increases at a greater speed than torque as engine speed increases. Within this rpm range we can see that both graphs have a positive gradient as with increases torque come more power, but as torque decreases, the power's gradient begins to become shallower until it flattens out. From this graph we can deduce that power band of this engine is between 3050-5500+ rpm and that with increased engine speed, power increases.

Evaluation



Figure 7 Calibration Weight

To eliminate errors, we should calibrate the dynamometer with more precise equipment. Figure 7 is an old calibration weight that has corroded and been damaged. To fix this we can use higher quality weights with tolerances that are stricter, e.g., having a 0.001+- accuracy.

In terms of my own performance, I think it would have been beneficial if I investigated further on the model of engine used to compare similar data online as the D16 model of engine was a popular platform that had been revised and improved with the latest model being made in 2007 and earliest in 1984 (MotorReviewer, 2015). To get better accuracy for this investigation we can repeat the test more than once and get the mean average between 3-4 tests, in between each series of testing recalibrating the eddy current dynamometer with the more precise weights so that each data set has been tested from zero and using the same testing method, limiting variables that are in our control.

Reference list

- Class notes: Vehicle Technology Part 1&2
- Elprocus (2013) *What is Eddy Current Dynamometer: Construction & Its Working*. Available at: <https://www.elprocus.com/what-is-eddy-current-dynamometer-construction-its-working/> (Accessed 10 December 2021).
- MotorReviewer (2015) *Honda D16A (B, V, W, Y, Z) Engine Specs, Problems & Reliability*. Available at: https://www.motorreviewer.com/engine.php?engine_id=82 (Accessed 10 December 2021).
- Figure 2 – Honda Motor Co., LTD. (1987) *Shop Manual Honda Civic Coupe CRX Chassis Maintenance and Repair*. EU: Service Publication Office, p. 16
- Figure 3 – Honda Motor Co., LTD. (1987) *Shop Manual Honda Civic Coupe CRX Chassis Maintenance and Repair*. EU: Service Publication Office, p. 8