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Introduction 1

In this report I will be discussing some of the key characteristics of an internal combustion engine, the process of measuring the torque a specific engine produces, and the figures that can be calculated using retrieved data. I will outline and go over the engine dynamometer testing process that is used to measure the torque, then using formulas and retrieving data in a lab environment, such as ambient room temperature, humidity, and pressure, amongst other information, to calculate corrected power and BMEP at individual revolution per minute.

Research 2

4-Stroke Petrol ICE 2.1

The first stroke of the standard 4-stroke “otto” engine is the induction stroke, in which the inlet valve opens, allowing in a flammable air fuel mixture, with the piston descending within the cylinder. This action is followed up by the compression stroke, the piston begins to move upwards, with the valves closed to prevent the air and fuel leaving, the mixture is compressed due to the seal between the piston rings and cylinder, the compression stroke is designed to create a stronger charge pressure, it also puts the piston head in the optimal position for the next step, the power stroke. Just before ethe piston reaches TDC a spark is created via the spark plug, meaning by the time the mixture is fully ignited the piston has reached the top and is forced back downwards, in turn rotating the crank shaft, which converts the reciprocating linear motion of the piston into a rotational motion. Following the combustion, the exhaust gases need to move out for the next cycle, in the exhaust stroke the exhaust valve opens and the piston head pushes the gases out towards the exit.

Torque Explanation 2.2

Torque is the rotational force produced by an engine, it can often be confused with power, however torque only refers to the work done, whilst power considers the speed the work is delivered. For this reason, torque is important for building up the initial drive and maintaining movement at lower speeds as it is the ‘Pulling power’.

Torque is measured in newton meters, which is the force (N) multiplied by the torque arm radius (M).

An example of the comparison between the uses of torque and power would be a HGV engine and the engine in an F1 car, a 10.8L DAF PACCAR MX11 produces approximately a maximum of 327kw of power and 2304nm of torque, whereas the estimated specifications of a 1.6L modern F1 engine is approximately 735kw of power and 670nm of torque. The ratio of power to torque is much lower in the truck engine than the F1 engine, the truck has a low revving large displacement engine designed for hauling weight, whereas the F1 car is high revving with the same number of cylinders but is only 14% of the displacement, designed for speed in an extremely light vehicle.

Method 3

Equipment 3.1

When measuring the torque of our selected engine (Honda Civic 1.6 D16 2003) we used an eddy-current engine dynamometer, which uses electromagnetic resistance to measure the torque coming directly from the prime mover (in this case the Honda engine). The force applied is measured by a strain gauge, an electrical sensor and transducer that produces electrical resistance that varies depending on the force applied. The information picked up by the strain gauge is then sent to a computer which works out the torque from the measurements and statistics it's been given.

Setting up 3.2

Before the test it is always interesting to push the 'free'-housing, the large drum attached to the engine, although it doesn't feel as though it is moving the strain gauge is still measuring this force, and it will show up on the graph. This shows how sensitive the dynamometer is, it can even pick up on the slightest movement, therefore you can assume the test results will be more accurate.

For the set up the first thing to do is calibrate the machine, to do this you need to a known mass and length to attach to the side of the free housing, you will need to bolt a duplicate length on each side, to essentially zero the effect the mass of the arm has on the dynamometer, meaning it will only measure the mass on the end of the arm. It is crucial that this mass is accurately weighed, using an older or damaged weight could affect the calibration, as the measurements are so accurate this will sway the validity of the results massively.



Calibration Equipment: Arms, hook, known mass.

Test 3.3

There are two key types of engine dyno testing, the step and sweep test. With a step test the dyno is programmed to build up through the rev range pausing at set intervals, for example you could set up a step test to measure the torque the engine produces between idle at 1500rpm to 5000rpm, with the engine maintaining revs at 500rpm intervals. In a sweep test the engine quickly goes through the set rev range without intervals, it will still measure at set engine speeds, but only in passing and will not maintain the speed for any unnecessary duration. A step test will give much more accurate results, due to the fact it lingers on the engine speed for a longer period it can get a better average, the downside to such a test however is that it can only measure the RPMs you set it to measure, meaning you have less broad results. The opposite is the case for the sweep test, you have a much wider selection of results, with far less accuracy.

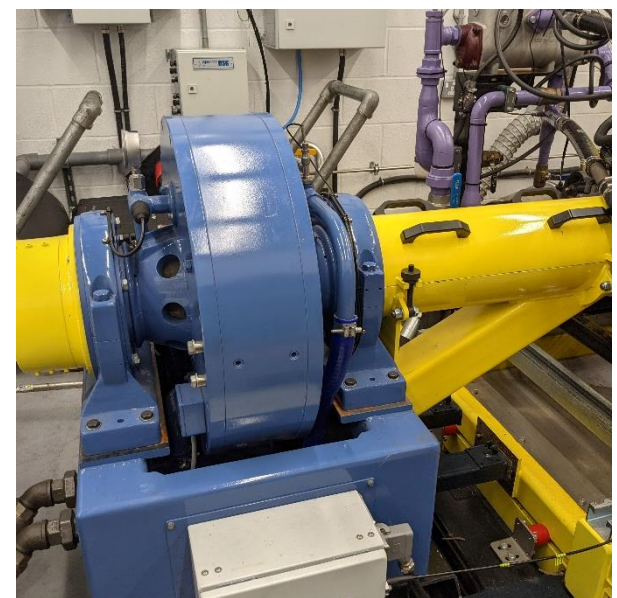
For our experiment we opted for the sweep test, as we don't need the most accurate figures and it is better practice in Excel.

We first started the engine, by turning on the fuel pump the cooling system and then pressing "ignition", once the instruction for what we want the test to do is entered into the system we can press start test.

The dynamometer acts like a giant water brake, the engine crankshaft is connected to the impeller housing which has, within the housing there is water that creates resistance against the torque of the engine, this puts a serious load on the housing as it tries to rotate the dyno frame with the force it creates. The strain gauge mounted to both the housing and the frame is pulled, measuring the rotational force, and relaying what it reads to the computer, which in turn translates that into horsepower and torque. Whilst this is going on the water is being pumped in and out, with hot water being displaced back into the main storage tank and cold being pumped in. Whilst the majority of the water is used to absorb the torque, some of this water is used to regulate the engine temperature, insuring efficient, consistent and therefore accurate readings.



Strain gauge.



Impeller housing.

Results 4

Spreadsheet 4.1

	Engine:	Honda Civic 1.6 D16 2003				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	0.815744	m				
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	11108.3473	11250.15405	848837.99									
130.61	1050	106.5443238	11715.1603	11864.71352	852578.34									
131.485	1100	107.2580998	12355.2461	12512.97059	858290.05									
132.641	1150	108.2010999	13030.4116	13196.75505	865836.03									
133.729	1200	109.0886294	13708.4815	13883.48102	872938.13									
135.143	1250	110.2420914	14430.656	14614.8747	882168.24									
136.396	1300	111.2642186	15147.0302	15340.39401	890347.41									
137.723	1350	112.3467109	15882.6421	16085.3965	899009.62									
139.186	1400	113.5401444	16645.8546	16858.352	908559.59									
140.496	1450	114.608769	17402.6132	17624.77129	917110.84									
141.522	1500	115.4457224	18134.1717	18365.66864	923808.22									
142.271	1550	116.0567146	18837.8176	19078.29721	928697.44									
143.07	1600	116.7084941	19554.6959	19804.32696	933913.05									
143.631	1650	117.1661265	20244.8533	20503.29481	937575.07									
143.895	1700	117.3814829	20896.6722	21163.43471	939298.37									
143.984	1750	117.4540841	21524.5851	21799.36339	939879.33									
143.769	1800	117.2786991	22106.514	22388.72103	938475.88									
143.411	1850	116.9866628	22664.0072	22953.33105	936138.98									
143.045	1900	116.6881005	23217.1437	23513.5288	933749.85									
142.816	1950	116.5012951	23789.9748	24093.67259	932255.02									
142.873	2000	116.5477925	24409.7126	24721.32178	932627.1									
143.19	2050	116.8063834	25075.4685	25395.57661	934696.37									
143.772	2100	117.2811464	25791.4711	26120.71958	938495.47									
144.551	2150	117.9166109	26548.627	26887.54116	943580.52									
145.344	2200	118.5634959	27315.0686	27663.76693	948756.96									
146.106	2250	119.1850929	28082.3259	28440.81891	953731.04									
146.954	2300	119.8768438	28872.9896	29241.57601	959266.5									
147.835	2350	120.5955142	29677.5219	30056.37882	965017.37									
148.72	2400	121.3174477	30490.4002	30879.63415	970794.35									
149.675	2450	122.0964832	31325.4889	31725.38339	977028.27									
150.825	2500	123.0345888	32210.38	32621.57088	984535.09									
152.138	2550	124.1056607	33140.6017	33563.66758	993105.91									
153.556	2600	125.2623857	34105.3605	34540.74229	1002362.1									
155.005	2650	126.4443987	35089.2501	35537.19205	1011820.7									
156.482	2700	127.6492526	36091.9759	36552.71837	1021462.1									
157.786	2750	128.7129828	37066.6781	37539.86343	1029974.2									
158.838	2800	129.5711455	37992.2441	38477.24505	1036841.3									
159.646	2850	130.2302666	38867.3926	39363.56551	1042115.6									
160.156	2900	130.6462961	39675.6196	40182.1101	1045444.7									
160.53	2950	130.9513843	40453.9309	40970.35712	1047886.1									
160.755	3000	131.1349267	41197.2522	41723.1676	1049354.8									
160.772	3050	131.1487944	41888.3024	42423.03953	1049465.8									
160.64	3100	131.0411162	42540.0401	43083.09725	1048604.1									
160.269	3150	130.7384751	43126.3385	43676.88013	1046182.4									
159.847	3200	130.3942312	43695.5263	44253.33405	1043427.7									
159.295	3250	129.9439405	44225.0173	44789.58445	1039824.4									
158.657	3300	129.4234958	44725.5494	45296.50625	1035659.5									
158.007	3350	128.8932622	45217.1974	45794.43048	1031416.8									
157.267	3400	128.2896116	45677.1528	46260.25765	1026586.3									
156.714	3450	127.8385052	46185.8985	46775.49787	1022976.5									
156.031	3500	127.2813521	46651.0521	47246.58947	1018518.1									
155.394	3550	126.7617231	47124.3209	47725.9	1014360									
154.841	3600	126.3106167	47617.9807	48225.86167	1010750.2									
154.283	3650	125.8554316	48105.3574	48719.46016	1007107.8									
153.895	3700	125.5389229	48641.6995	49262.64906	1004575									
153.537	3750	125.2468865	49184.3373	49812.21411	1002238.1									
153.207	3800	124.977691	49733.0062	50367.88713	1000084									
152.982	3850	124.7941486	50313.3888	50955.67884	998615.26									
152.81	3900	124.6538406	50909.5067	51559.40663	997492.5									
152.686	3950	124.5526884	51520.3518	52178.04961	996683.07									
152.585	4000	124.4702982	52137.9966	52803.57918	996023.78									
152.443	4050	124.3544626	52740.5939	53413.86913	995096.85									
152.235	4100	124.1847878	53318.8623	53999.5196	993739.1									
151.91	4150	123.919671	53853.8761	54541.36319	991617.61									
151.399	4200	123.5028259	54319.3799	55012.8095	988281.97									
150.827	4250	123.0362203	54758.3722	55457.40588	984548.14									
150.068	4300	122.4170706	55123.7883	55827.48687	979593.65									
149.154	4350	121.6714806	55425.1233	56132.66861	973627.36									
148.116	4400	120.8247383	55672.0428	56382.74029	966851.64									
147.008	4450	119.920894	55883.4856	56596.88227	959618.99									
145.914	4500	119.02847	56090.845	56806.88884	952477.73									
144.832	4550	118.145835	56293.5232	57012.15438	945414.79									
143.855	4600	117.3488531	56528.2185	57249.84576	939037.26									
142.954	4650	116.6138678	56784.7569	57509.65902	933155.84									
141.876	4700	115.7344957	56962.5339	57689.70544	926119.01									
140.982	4750	115.0052206	57205.7631	57936.03966	920283.28									
140.028	4800	114.2270008	57416.7531	58149.72312	914055.89									
139.039	4850	113.42023	57605.0928	58340.46711	907600.03									
137.983	4900	112.5588044	57756.9391	58494.25189	900706.81									
136.865	4950	111.6468026	57873.5478	58612.34923	893408.88									
135.733	5000	110.7233804	57974.6264	58714.71813	886019.57									
134.623	5050	109.8179045	58075.5255	58816.90535	878773.86									
133.253	5100	108.7003352	58053.6697	58794.77048	869830.96									
131.742	5150	107.467746	57958.0797	58697.96017	859967.66									
129.994	5200	106.0418255	57744.3048	58481.45632	848557.3									
128.245	5250	104.6150893	57515.1493	58249.37545	837140.41									
126.542	5300	103.2258772	57291.8795	58023.25546	826023.8									
125.13	5350	102.0740467	57187.0551	57917.09287	816806.73									
123.554	5400	100.7884342	56994.5168	57722.09666	806519.13									
122.083	5450	99.58847475	56837.3998	57562.97391	796916.94									
121.004	5500	98.70828698	56851.892	57577.65118	789873.59									

To the left are the results of the dyno test, using the force and engine speed measurements, along with information based on the engine displacement and lab data, I was able to use Excel and a range of formulas to calculate the other figures.

(Letters are represented in spreadsheet)

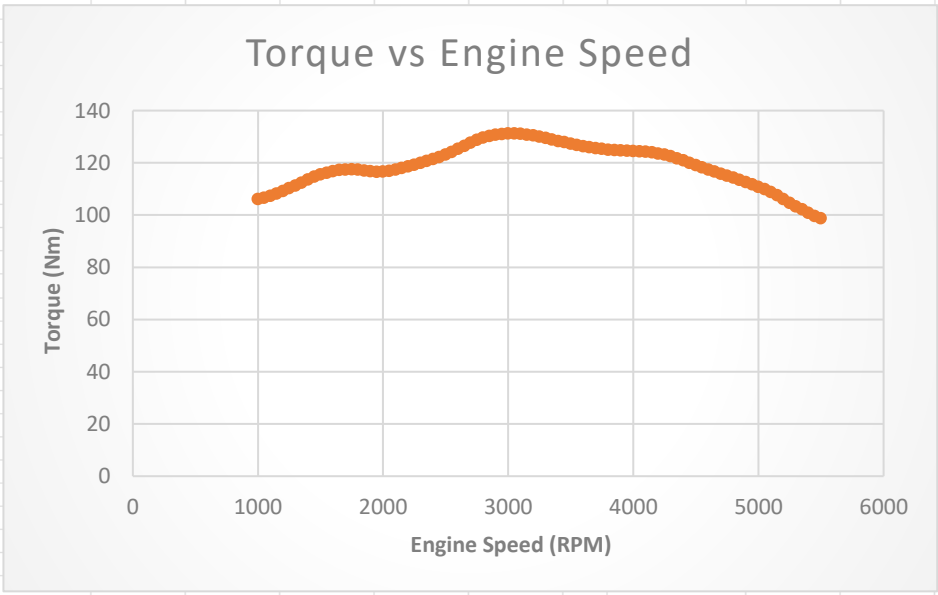
T=W*N

P=(2π (N*T) /60)

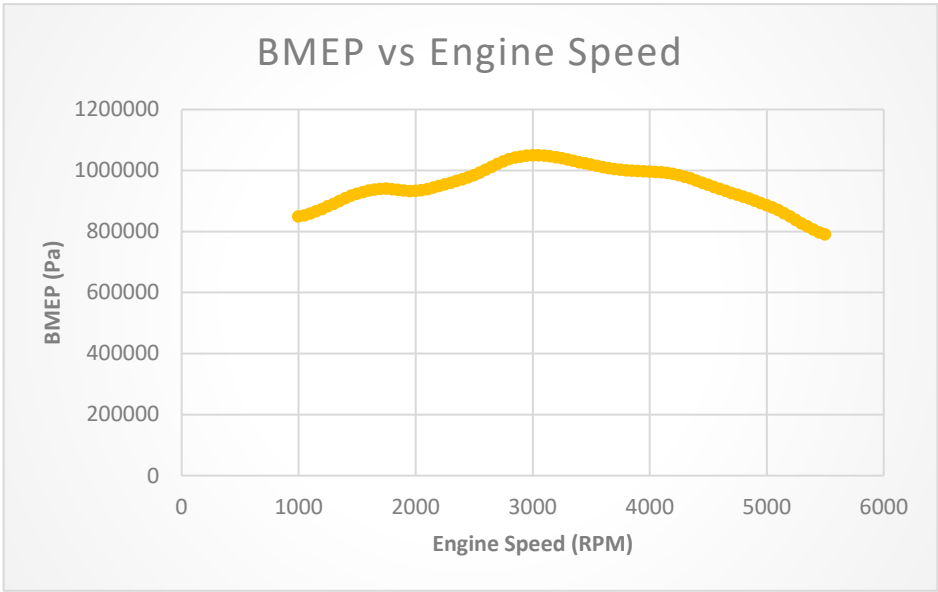
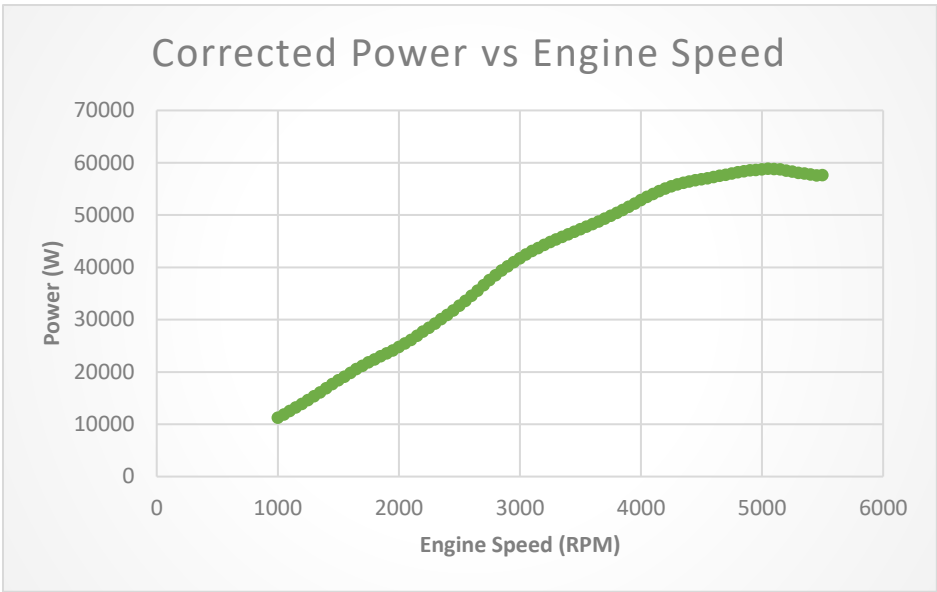
Ps=(1.01325 /Humidity)*(√(Barometric pressure/293)*P)

BMEP=(60*2*Ps) / (l*A*N*4)

Graphs 4.2



This second graph displays the power (corrected) produced by the engine through 1000rpm to 5500rpm. The power fairly consistently increases throughout the rev range but begins to plateau and drop at around 5000rpm.



This graph is showing BMEP in comparison to engine speed, the shape of the results is near identical to the torque graph. The formula for calculating $BMEP = (60 \cdot 2 \cdot P_s) / (I \cdot A \cdot N \cdot 4)$, this is why the graph is such a similar shape, because the measurement is based on torque.

Conclusion 5

In this report I have researched some of the key characteristics of an internal combustion engine and discussed the basics of how the 4-stroke cycle works. I also completed some research on torque, discussing its uses and units it is measured in.

Within the main section of this report, I went over the method of measuring torque using an engine dynamometer, based on my practical experience with the machinery, I mentioned the equipment used and how to set it up, following that up with a brief description of different types of engine dyno testing and the pros and cons for these. I finished off the method section by reporting how the dyno measures the torque produced.

Next I showed the results achieved and used excel to calculate other key figures and created three graphs to display some of this data and how the numbers interact with each other, this gave a good visual representation of how engine speed can effect torque and power.

In conclusion I think my performance throughout this investigation was of a good enough standard to get the results needed, however my discussion of the actual dyno testing process could've been much more detailed, rather than an overview of how the test itself works.

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