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Engine Testing

BEng Motorsport

Vehicle Technology

(ACHA4012)

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1. Aims

- Suggest reasons why sfc, Bmep and Torque varies with engine speed.
- Calculate corrected power, sfc, bmep, torque and thermal efficiency.

2. Introduction

This report will look at how effective the Honda 1.6i engine is. Using results provided from an engine lab session conducted in the engine test room. The aim of the exercise is to understand how a dynamometer works and to investigate the effectiveness of the Honda 1.6 vtec engine. By using the information provided the engine can be analysis its performance and suggest its short comings.



Figure 1- w230 engine dyno

3. Test Equipment and Methodology

The test equipment used to conduct the testing included a dynamometer w230 and a Honda 1.6 vtec engine.

To help with engine set up and calibration, a dynamometer is used to record and test engines to show performance and efficiency. This can also be used to tune engines to achieve higher outputs. (Xunzhao Yu a, 2022)

To set up for a run, the dyno needs to be calibrated. This is done by screwing a metal arm to the Dyno. The arm measures 815.776mm and by placing a weight on the end as shown in figure(2).

The Honda engine is rigged up to the dyno using a drive shaft connecting to the centre of it. The fuel and coolant are provided externally and plumbed into the engine to allow normal function.

The dyno works using eddy currents which are generated by a spinning iron wheel in the dyno. This is free spinning with the engine. The outer casing then provides a voltage and loads the inner wheel. The casing of the dyno wants to rotate under the load and a sensor mounted to the outside measures the amount it moves in volts. The output in volts is measured in KG.

The output gives a force value around the calibrated point that is matched to the rpm and fuel flow of the engine during the run. The information given by the dyno is given as load Newtons.

The test method used was a sweep test to collect the data, a sweep test allows for a wide range of data points to be collected during the test cycle. The dyno controls the load on the engine when the test starts, the speed of the engine is set to 100%. The load is taken off the engine accordingly by the dyno to reach the desired rpm given a reading of torque as the test is performed. This is controlled by the computers in our test but can also be adjusted manually.

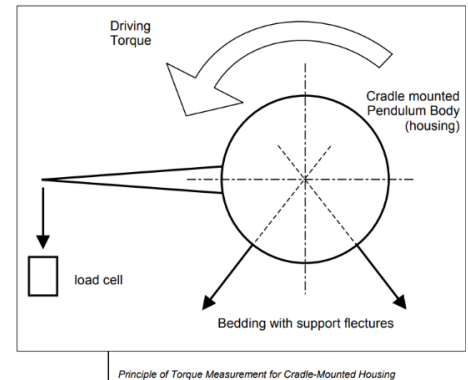


Figure 2- w230 working diagram.



Figure 3-engine dyno setup.



Figure 4-computer control room.

4. Spreadsheet Results

Load Newtons	Dyno Speed rpm	Fuel Flow Rate l/min	Lambda Lambda	power Watts	fuel calorific value kJ/kg	corrected power Watts	Torque Nm	mep Pa	IMEP pa	bsfc	imep kpa	BMEP KPa	bmeppa	SFC KG/Kwh	overall thermal efficiency
102.275	1000	0.0704	1.2658	8732.46	45800	8787.405612	83.4334904	1317783.7	158309.59	0.0410264	158.30959	663.0190315	663019.032	0.36051596	22.12734708
102.756	1050	0.0724	1.26783	9212.46	45800	9270.169481	83.8258787	1323981.2	167006.82	0.0379119	167.00682	666.1372144	666137.214	0.35144989	22.69814897
103.689	1100	0.0737	1.27344	9738.78	45800	9799.785192	84.5869977	1336002.7	176548.12	0.034534	176.54812	672.1855816	672185.582	0.33842579	23.57167271
104.209	1150	0.0728	1.28476	10232.51	45800	10296.60977	85.012012	1342702.7	185498.67	0.0308998	185.49867	675.5565902	675556.59	0.31816298	25.07287921
105.811	1200	0.0744	1.29181	10841.55	45800	10909.45989	86.3180743	1353344	196539.48	0.0281306	196.53948	685.9418895	685941.889	0.30688962	25.99391224
107.51	1250	0.07895	1.29729	11474.62	45800	11546.49202	87.7040778	1385235.1	208015.93	0.026648	208.01593	696.9560116	696956.012	0.30769085	25.92622344
109.488	1300	0.079	1.29895	12153.16	45800	12229.28482	89.3176827	1410721.1	220316.79	0.0237705	220.31679	709.7788093	709778.809	0.29069566	27.4419711
111.797	1350	0.0796	1.29469	12886.75	45800	12967.46556	91.2013095	1440471.9	233615.5	0.0213018	233.6155	724.7473837	724747.384	0.27622977	28.87908104
114.268	1400	0.0835	1.2855	13659.41	45800	13744.9716	93.217092	1472310	247622.66	0.0198889	247.62266	740.7661569	740766.157	0.2733727	29.18090154
115.783	1450	0.0847	1.27818	14334.82	45800	14424.60686	94.4529926	1491830.3	259866.64	0.0183184	259.86664	750.5874606	750587.461	0.26423597	30.18991631
116.985	1500	0.08865	1.2795	14983.07	45800	15076.91976	95.4335554	1507317.8	271618.39	0.0175496	271.61839	758.3796764	758379.676	0.26459317	30.14916007
117.788	1550	0.0932	1.27766	15588.78	45800	15686.42332	96.0886235	1517664.2	282598.9	0.0170444	282.5989	763.5852915	763585.291	0.26736496	29.83660141
118.471	1600	0.0959	1.28235	16184.95	45800	16286.32968	96.6457985	1526464.4	293406.52	0.0162699	293.40652	768.0129815	768012.982	0.26497683	30.10550723
118.772	1650	0.09875	1.29028	16733.14	45800	16837.94935	96.8913471	1530342.7	303344.23	0.0156737	303.34423	769.9642769	769964.277	0.26391278	30.22688742
118.656	1700	0.10005	1.29942	17223.36	45800	17331.24694	96.7967171	1528848.1	312231.24	0.0149889	312.23124	769.2122826	769212.283	0.25977646	30.70817813
118.861	1750	0.10305	1.31053	17760.56	45800	17871.81308	96.9639511	1531489.5	321969.81	0.0145186	321.96981	770.5412379	770541.238	0.25947283	30.74411184
119.584	1800	0.1093	1.3149	18379.13	45800	18494.2518	97.5537572	1540805.1	333183.36	0.01438	333.18336	775.2282363	775228.236	0.2659475	29.99562658
119.934	1850	0.11415	1.31849	18944.95	45800	19063.61382	97.8392788	1545314.8	343440.71	0.0141344	343.44071	777.4971844	777497.184	0.26945311	29.60538069
120.176	1900	0.11745	1.31892	19496.23	45800	19618.35236	98.0366966	1548432.9	353434.61	0.0137322	353.43461	779.0659989	779066	0.26940336	29.6108479
120.948	1950	0.12055	1.31484	20137.83	45800	20263.96784	98.6664756	1558379.9	365065.7	0.0132108	365.0657	784.070651	784070.651	0.26770423	29.79878844
122.157	2000	0.12555	1.31653	20860.64	45800	20991.30985	99.6527488	1573957.5	378169.14	0.0128218	378.16914	791.9082458	791908.246	0.26914709	29.63904159
122.845	2050	0.12785	1.32098	21502.58	45800	21637.2733	100.214003	1582822.2	389806.5	0.0122888	389.8065	796.3683494	796368.349	0.26589533	30.00151129
123.796	2100	0.1309	1.32287	22107.56	45800	22336.60129	100.989006	159507.5	402405.25	0.0118064	402.40525	802.3334053	802333.405	0.26371514	30.24954033
124.794	2150	0.13435	1.32164	22909.28	45800	23057.78236	101.80395	1607934.5	415307.61	0.0113764	415.30761	809.0031486	809003.149	0.2625685	30.41774941
125.038	2200	0.1377	1.31652	23506.49	45800	23653.72835	102.083761	1612353.9	426133.96	0.0110751	426.13396	811.2267177	811226.718	0.26196716	30.45138139
126.127	2250	0.14105	1.30465	24211.90	45800	24363.55999	102.810618	1623834.2	438921.94	0.0106931	438.92194	817.0028111	817002.811	0.26052227	30.26026824
126.66	2300	0.14495	1.29646	24874.06	45800	25029.86468	103.326188	1631977.3	450925.76	0.0104115	450.92576	821.099883	821099.883	0.26059869	30.6112891
126.822	2350	0.14985	1.29228	25447.30	45800	25606.70186	103.458344	1640646.6	463137.77	0.010284	463.13777	822.1500818	822150.082	0.26333926	30.29717729
126.69	2400	0.1537	1.27304	25961.69	45800	26124.30605	103.350661	1632363.9	470642.68	0.0101344	470.64268	821.294363	821294.364	0.26475344	30.13090869
126.552	2450	0.15565	1.26984	26473.69	45800	26639.51308	103.238084	1630585.8	479924.39	0.0098698	479.92439	820.3997505	820399.7505	0.26292971	30.34020364
126.69	2400	0.1537	1.27304	25961.69	45800	26124.30605	103.350661	1632363.9	470642.68	0.0101344	470.64268	821.294363	821294.364	0.26475344	30.13090869
126.552	2450	0.15565	1.26984	26473.69	45800	26639.51308	103.238084	1630585.8	479924.39	0.0098698	479.92439	820.3997505	820399.7505	0.26292971	30.34020364
126.438	2500	0.1596	1.27446	26989.63	45800	27158.68958	103.145086	1629116.7	489277.62	0.0097371	489.27762	819.6607217	819660.722	0.26444575	30.16596746
126.239	2550	0.1626	1.27876	27486.10	45800	27658.26358	102.982746	1626532.9	498277.7	0.009565	498.2777	818.3706627	818370.663	0.26455023	30.15405369
126.161	2600	0.16805	1.27634	28007.72	45800	28183.15802	102.919116	1625547.5	507733.94	0.0095208	507.73394	817.8650114	817865.011	0.26832515	29.7283322
125.847	2650	0.17145	1.28027	28475.28	45800	28653.54803	102.662962	1621502	516210.07	0.009397	516.21007	815.824409	815829.441	0.26925891	29.6267348
124.911	2700	0.17465	1.28371	28796.77	45800	28977.14769	101.893936	1609442	522038.07	0.0093599	522.03807	809.7616255	809761.626	0.27122325	29.41225878
123.927	2750	0.1784	1.2812	29098.99	45800	29281.26367	101.096672	1597673.4	527516.88	0.0093633	527.51688	803.3826402	803382.64	0.2741685	29.09630174
123.689	2800	0.18005	1.27448	29571.16	45800	29756.39366	100.902518	1593969.8	536076.58	0.0091505	536.07658	801.8397555	801839.755	0.27228602	29.29736104
123.389	2850	0.1831	1.26036	30026.22	45800	30134.2967	100.657785	1589831.4	544325.94	0.0090256	544.32594	799.8949429	799894.943	0.27270203	29.2526678
122.519	2900	0.1879	1.2531	30337.57	45800	30527.59746	99.9480597	1578621.7	549970.21	0.0090731	549.97021	794.2549863	794254.986	0.27697889	28.80097344
121.837	2950	0.19255	1.23943	30688.84	45800	30881.07412	99.3917005	1569834.4	556338.28	0.009086	556.33828	789.833779	789833.779	0.28058448	28.60072388
121.709	3000	0.199	1.22735	31176.21	45800	31371.48911	99.287182	1568185.1	565173.35	0.009099	565.17335	789.0039923	789003.9923	0.28545027	27.94624045
121.123	3050	0.20605	1.2193	31543.20	45800	31740.78345	98.8092364	1560634.7	571826.38	0.0092034	571.82638	785.205125	785205.125	0.29212417	27.7077768
121.124	3100	0.21005	1.20692	32060.57	45800	32261.3906	98.8100522	1560647.6	581205.38	0.0090817	581.20538	785.211607	785211.608	0.29298954	27.27212163
120.851	3150	0.21605	1.19274	32504.25	45800	32767.84923	98.5873454	1557130	589248.56	0.0090879	589.24856	783.4418282	783441.828	0.29724516	26.83731419
120.596	3200	0.21795	1.18481	32950.51	45800	33156.91122	98.3793225	1553844.4	597338.64	0.0089212	597.33864	781.7887375	781788.735	0.29579806	26.96860778
120.84	3250	0.22305	1.17378	33533.08	45800	33743.12203	98.5873818	1556988.3	607899.53	0.0088154	607.89953	783.705184	783705.184	0.29746062	26.8187542
121.633	3300	0.2255	1.16118	34272.41	45800	34487.08944	99.252822	1567205.9	621302.48	0.0085319	621.30248	788.5113064	788511.306	0.29424055	27.1131617
122.181	3350	0.2285	1.15104	34948.44	45800	35163.35191	99.6723275	1574266.7	633575.75	0.0083142	633.57575	792.0638308	792063.83	0.29238767	27.36318798
122.933	3400	0.2342	1.14117	35688.37	45800	35911.91646	100.285791	1583956	646971.46	0.0081719	646.97146	796.938277	796938.828	0.29346805	27.18227212
123.475	3450	0.23605	1.12669	36372.86	45800	36690.69355	100.727942	1590939.5	659380.13	0.0079294	659.38013	800.4524558	800452.4558	0.29201991	27.4687558
123.428	3500	0.24195	1.11975	36885.96	45800	37177.00464	100.6896	1593033.9	668681.74	0.007903	668.68174	800.1477685	800147.769	0.2933359	27.1949728
124.205	3550	0.24545	1.10622	37648.42	45800	37884.24331	101.323458	1600345.4	682503.94	0.0076959	682.50394	805.1848332	805184.833	0.29155261	27.36313177
124.066	3600	0.25505	1.09697	38135.95	45800	38374.83014	101.210065	1598554.4	691342.11	0.0077937	691.34211	804.2833767	804283.737	0.29908276	26.67242314
123.967	3650	0.25755	1.09401	38634.76	45800	38876.76692	101.129303	1597278.							

5. Graphical results

1. Specific Fuel Consumption

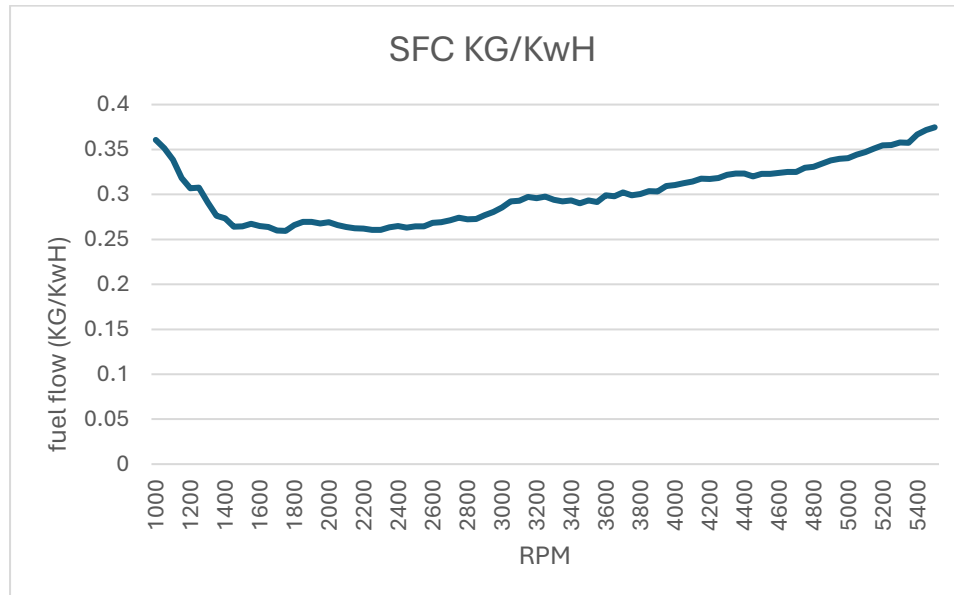


Figure 5- Specific fuel consumption graph.

The graph above shows the Specific Fuel Consumption of the engine. “SFC is the amount of fuel consumed for each unit of power output” (Sahadevan, 2022) The fuel flow is plotted against the rpm of the engine. For the best efficiency the lowest amount of fuel used is desired, the graph in figure (5) shows the lowest fuel flow in the lower range of rpm from 1400 rpm to 3000 rpm. As the rpm increases the fuel flow increases. SFC decreases at the start due to the engine producing power at its most efficient window but after this point it increases as the fuel flow going in doesn’t translate to more power as there is un combusted fuel increases, in turn reducing its efficiency. (Irawan, 2021)

Equation 1-SFC equation

$$SFC = \frac{V \times 0.75 \times 3600}{t \times 1000 \times P}$$

The calculation used to get the SFC. The results provided allows for the equation to be simplified, instead of using the volume of the engine the fuel flow rate can be used. Using the fuel flow rate in l/min and multiplying by the specific gravity of the fuel (0.75) and then by 60 to get the top line. For the bottom line the corrected power was used, times by 1000 to convert it into cc.

$$=(C6 \times 0.75 \times 60) / (G6 / 1000) \quad \text{Equation 2- actual SFC equation used}$$

2. Torque mapped against rpm.

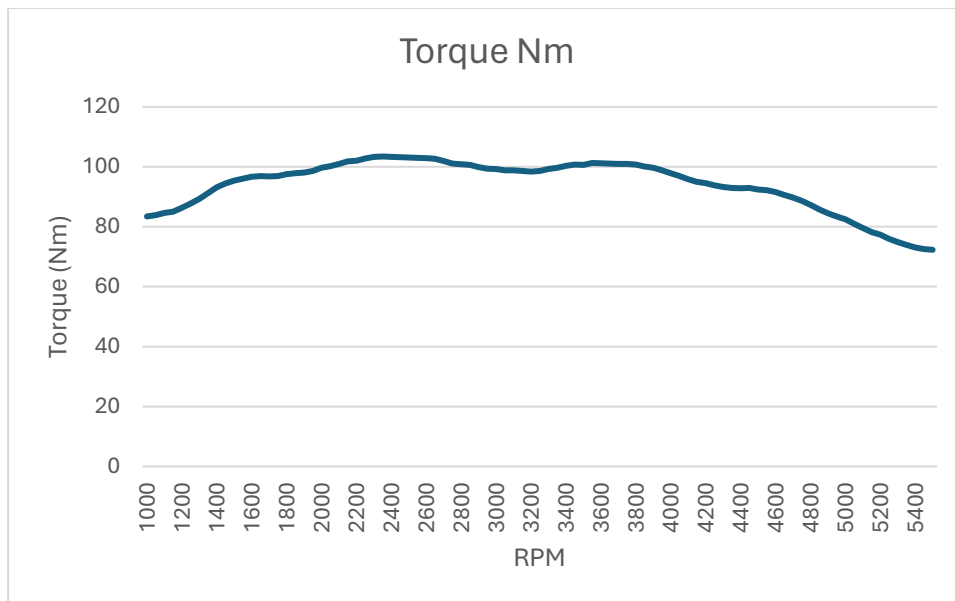


Figure 6- torque against Rpm.

The graph above shows the torque mapped against rpm. The graph shows that the peak torque is at the lower end of the rpm range with almost 2 peaks in the data before it drops off at high rpm. Usually there is one peak but because of the age of the engine its lacking in power compared to other more modern versions. At peak torque is where the engine is running at its most efficient.

3. Overall thermal efficiency

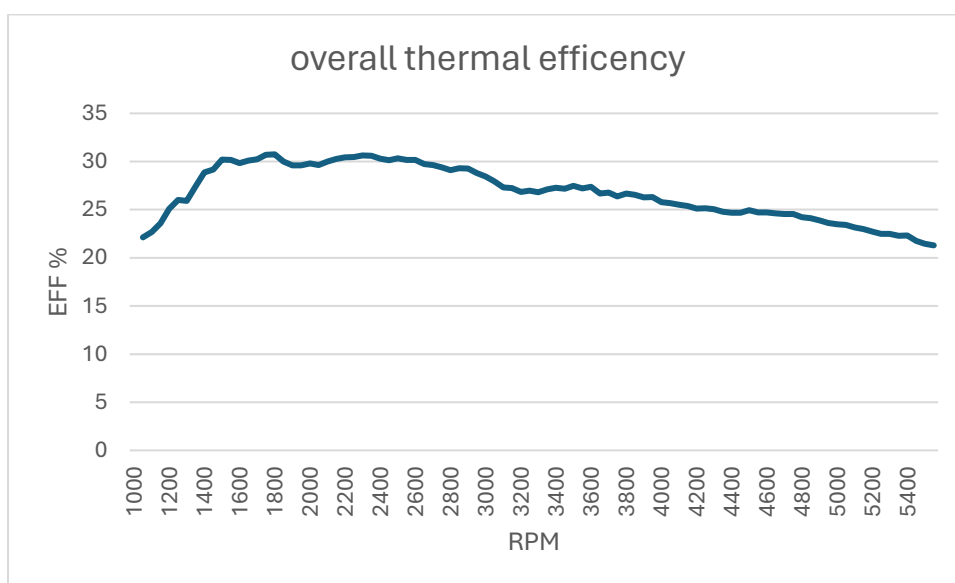


Figure 7- Overall thermal efficiency.

The graph of thermal efficiency shows where the peak torque occurs, the highest amount of efficiency is reached at just above 30%. Supporting the relation between max torque and efficiency.

4. Bmep plotted against rpm.

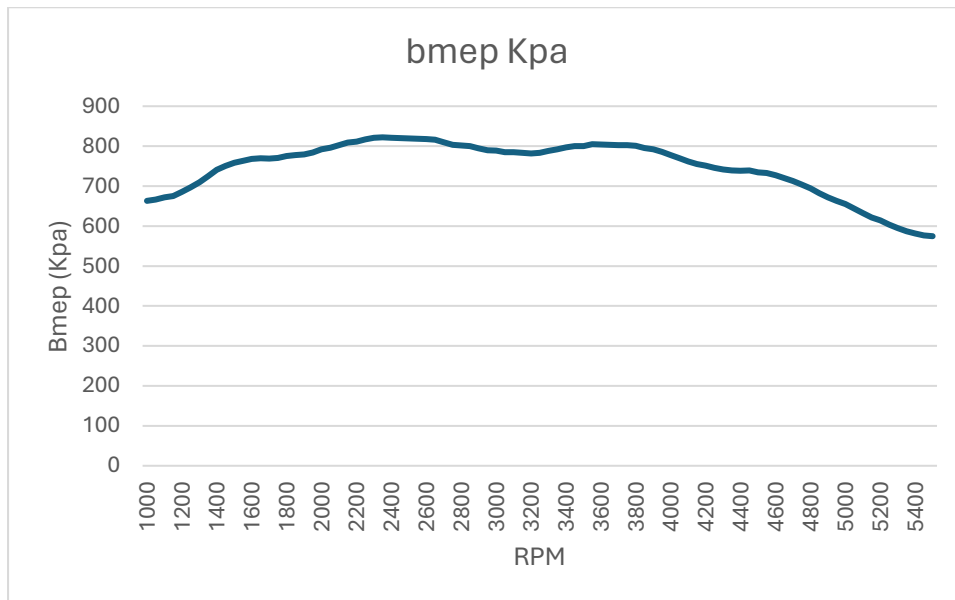


Figure 8- Break mean engine power.

In the last graph the bmep has been plotted against rpm. BMEP “is derived from measurements taken by a dynamometer (or brake), which are then used in the calculation of mechanical efficiency”. (Watson, 1988). The Bmep (brake mean engine pressure) follows the same trend as the torque graph in figure (8). This is due to the use of the corrected power to calculate the pressure. Bmep shows how efficiently the engine uses its power and displacement over the rpm range.

6. Conclusions

In conclusion, the graphs show that the increase in torque and bmep are relative to each other. The power produced by the engine suggests that parts are worn such as the valve and piston rings, consequently the peak power at the lower end in the rpm range is limited. The double peak in the torque and bmep results supports this evidence when researching newer versions results show that there's a lot larger peak in the lower ranges then tapers off. A limiting variable would also be the exhaust system used as the air isn't being extracted as efficiently as it could be.

The thermal efficiency of the engine is lower than modern engines this is due to several factors, improvement in technologies such as turbo charges and super chargers. Improved manufacturing techniques help with tolerance levels making the engines more efficient.

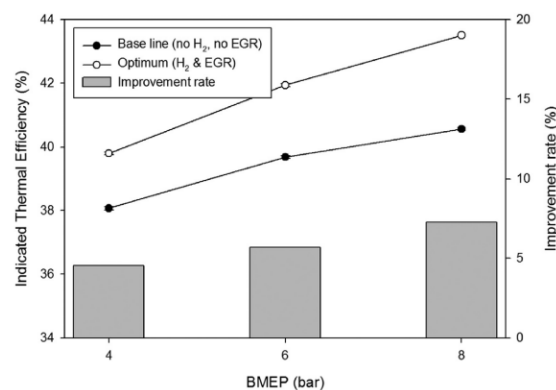


Figure 9- thermal efficiency in turbo charged engine
(Joonsuk Kim, 2017)

These results from testing with a turbo charged engine using petrol and hydrogen fuels, show far higher results were achieved than results from the Honda engine. By increasing the air flow and forcing air back into the system using a turbo, improves the amount of air available at the intake and allows the engine to run leaner. Therefore, lowering the SFC required to achieve the same power, as the naturally aspirated Honda.

For comparison, when the Honda engine reaches 8 bar on bmep (its peak efficiency), the overall thermal efficiency reaches 30%. In the turbo charged engine in figure 9 both results achieve a far higher thermal efficiency, showing the benefits of turbo charged engines.

The sweep test method used is good at measuring through a range of rpm ranges to find torque and power and can be run for a long time. The disadvantages are, that the sensors are delayed in readings. The accuracy of the tests can be less than the step method test, focusing on a certain rpm range and it takes an accurate reading through the selected range. A potential improvement on the test conducted, is to run a step test through the entire range of the engine at certain intervals, such as every 250 rpms to gain more accurate results. A downside to this method would be putting the engine under a lot of stress, causing the engine temp to increase significantly potentially effecting the results. (Engine Dynamometer testing, 2021)

7. References

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