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Engine Performance Characteristics.

Motorsport and Vehicle Technology ACHA4012

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1 Introduction

1.1 Background

Fall, M(2021a), explains how this experiment is conducted on a Petrol 1.6L 2000-2001 V-Tech Honda engine attached to the dynamometer setup by the driveshaft. The engine is self-contained on the engine rig; however, its main functions are controlled by the sensor modules and programme within the control room. Moreover, Fall, M(2021a) further explains how the SCHENCK WS230 Dynamometer has a maximum speed of 10,000rpm and a maximum load of 230kW. Its inner core spins freely, powered by the engine, and its outer casing is fed by current which produces an electromagnetic field which applies a load to the inner core and therefore the engine, trying to slow it down. There is a Strain Gauge that prevents the outer casing from rotating and sends a signal between 0v and 10v to the computer system within the control cell, this is the only reading that is provided by the dynamometer. Calibration arms either side of the Dynamometer are utilised to convert these voltage readings into torque by hanging a mass on one end of the arms, allowing the torque at the centre axis of the outer casing to be calculated.

In Addition, Fall, M(2021b), explains how this setup allows for three different types of testing, Manual, Sequencing and P Curve. Firstly, Manual testing involves using two dials within the control cell, one allowing control of the engine's RPMs through the throttle box. The other allowing the alteration of the current flowing to the dynamometer to control the amount of electromagnetic field produced, which would increase or decrease the load on the engine, affecting the engine's Revolutions Per Minute (RPM) and torque.

Test Sequencing involves programming different parameters dictating how the engine is to behave through numerous different steps and cycles. This way of testing provides the freedom to perform complex tests such as mimicking different engine circumstances, or simple warm up tests.

Lastly, P Curve testing involves two separate types of testing, Step test and Sweep test, both produce a graph and provide the recorded data at the end of the test. Step testing targets specific areas such as specified RPMs, and operates in cycles, pausing at the end of each cycle, this provides time for the sensors to complete their readings and record them accurately. However, due to Step testing holding the engine at high RPMs for prolonged periods of time it produces extra heat in the engine and applies a lot of strain. On the other hand, Sweep tests involve setting when RPM recordings are taken, and it does not pause at these RPMs to record the readings. This can result in inaccurate readings as sensors may struggle to keep up with the rate at which RPMs are rising, but

this method does not allow unnecessary strain to be inflicted on the engine and does not cause it to overheat.

1.2 Aims

Aim 1 – To use the Honda engine with the Dynamometer to obtain a series of results.

Aim 2 – To analyse the results obtained and their accuracy.

Aim 3 – To investigate where the experiment and personal performance could have been improved.

2 Experimental Procedure

The experiment is setup as shown in the images below:

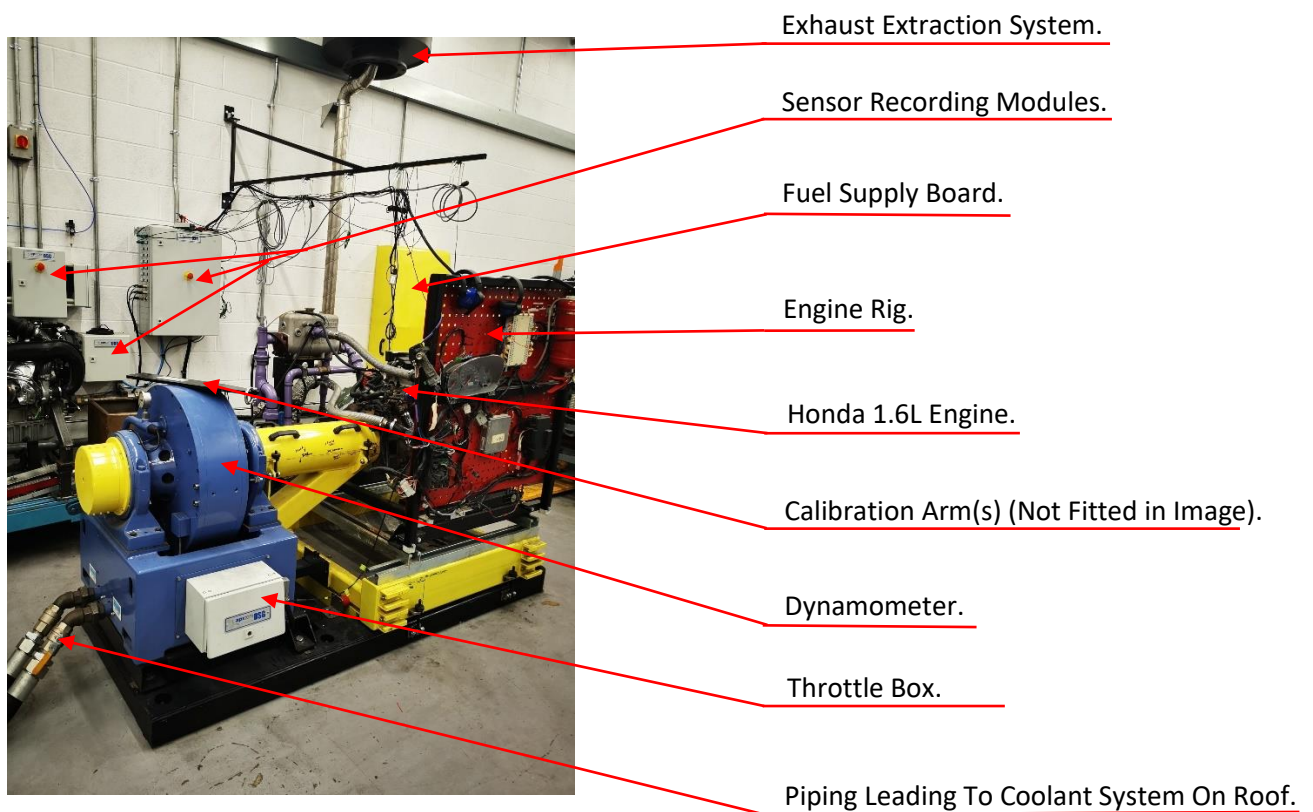
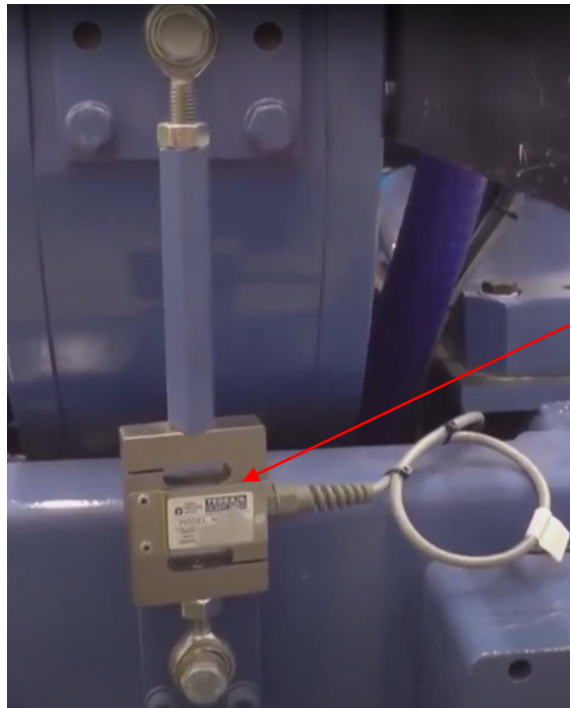
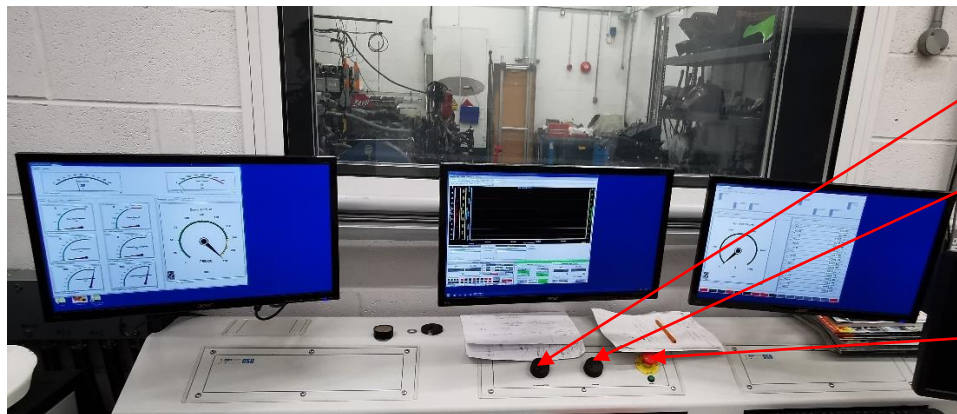


Figure 1: Image Displaying Dynamometer Setup.



Strain Guage.

Figure 2: Image Displaying The Strain Guage (Fall.M.(2021a)).



Dynamometer Dial.

Engine Dial.

Emergency Stop.

Figure 3: Image Displaying Inside The Control Cell.

1. Sweep Test used within this procedure.
2. Set ramp time to 1s.
3. Set hold time to 1s.
4. Set readings to be recorded at 50rpm increments from 1,000rpm up to 5,500rpm.
5. Set total ramp time in seconds.
6. Set end time RPMs and how long the engine takes to slow to this point.
7. Allow Dynamometer to control the speed but apply 100% throttle through the controller.
8. Run test.
9. Readings recorded are Load, Fuel Flow and Lambda readings.

3 Results

Figure 4: Excel Table Of Results.

							Baro	Humidity	Ambient temp	Arm length	Displacement	
							mBar	%	Deg C	m	cc	
							1018.90	46	27	0.815776	1590	
Load	Dyno Speed	Fuel Flow Rate	Lambda	Torque	Brake Power	Corrected Power	BMEP	SFC	Fuel flow	Overall Thermal Efficiency	Overall Thermal Efficiency	
Newtons	rpm	l/min		Nm	W	kW	Kpa	Kg/Kwh	Kg/s	Nt	%	
102.275	1000	0.0704	1.2658	83.43	8737.13	8.79	67.4407887	0.360333197	0.00088	0.218210157	21.82101569	
102.756	1050	0.0724	1.26783	83.83	9217.14	9.27	68.0766293	0.351271715	0.000905	0.223839154	22.38391539	
103.689	1100	0.0737	1.27344	84.59	9743.72	9.80	69.3184808	0.338254218	0.00092125	0.232453461	23.24534606	
104.209	1150	0.0728	1.28476	85.01	10237.70	10.30	70.0154881	0.31800168	0.00091	0.247257698	24.72576982	
105.811	1200	0.0744	1.29181	86.32	10847.05	10.91	72.1847242	0.30673404	0.00093	0.256340521	25.63405206	
107.51	1250	0.07895	1.29729	87.70	11480.44	11.55	74.5214656	0.307534869	0.000986875	0.255673003	25.56730034	
109.488	1300	0.079	1.29895	89.32	12159.32	12.24	77.2888258	0.290548288	0.0009875	0.27062064	27.06206397	
111.797	1350	0.0796	1.29469	91.20	12893.28	12.97	80.5830987	0.276089731	0.000995	0.284792785	28.47927853	
114.268	1400	0.0835	1.2855	93.22	13666.34	13.75	84.1846511	0.273234112	0.00104375	0.287769206	28.77692063	
115.783	1450	0.0847	1.27818	94.45	14342.09	14.43	86.4317409	0.264102015	0.00105875	0.297719666	29.77196657	
116.985	1500	0.08865	1.2795	95.43	14990.67	15.08	88.2356365	0.264459033	0.001108125	0.297317746	29.73177456	
117.788	1550	0.0932	1.27766	96.09	15596.68	15.69	89.4511152	0.267229421	0.001165	0.29423543	29.42354297	
118.471	1600	0.0959	1.28235	96.65	16193.16	16.29	90.491497	0.264842497	0.00119875	0.296887261	29.68872605	
118.772	1650	0.09875	1.29028	96.89	16741.62	16.85	90.9519057	0.263778986	0.001234375	0.298084259	29.80842586	
118.656	1700	0.10005	1.29942	96.80	17232.10	17.34	90.7743341	0.259644766	0.001250625	0.302830536	30.28305357	
118.861	1750	0.10305	1.31053	96.96	17769.57	17.88	91.0882636	0.259341293	0.001288125	0.303184898	30.31848981	
119.584	1800	0.1093	1.3149	97.55	18388.45	18.50	92.1997655	0.265812674	0.00136625	0.295803666	29.58036659	
119.934	1850	0.11415	1.31849	97.84	18954.55	19.07	92.7402582	0.269316507	0.001426875	0.291955233	29.19552327	
120.176	1900	0.11745	1.31892	98.04	19506.12	19.63	93.114894	0.269266782	0.001468125	0.292009148	29.2009148	
120.948	1950	0.12055	1.31484	98.67	20148.04	20.27	94.3150602	0.26756852	0.001506875	0.293862535	29.38625349	
122.157	2000	0.12555	1.31653	99.65	20871.22	21.00	96.2100369	0.269010646	0.001569375	0.292287182	29.22871817	
122.845	2050	0.12785	1.32098	100.21	21513.49	21.65	97.2968171	0.265760536	0.001598125	0.295861698	29.58616984	
123.796	2100	0.1309	1.32287	100.99	22208.82	22.35	98.8090875	0.263581451	0.00163625	0.298307652	29.83076516	
124.794	2150	0.13435	1.32164	101.80	22920.90	23.06	100.408638	0.262123893	0.001679375	0.299966411	29.99664111	
125.137	2200	0.1377	1.31652	102.08	23518.41	23.67	100.961348	0.261834352	0.00172125	0.300298119	30.02981193	
126.028	2250	0.14105	1.30465	102.81	24224.18	24.38	102.404196	0.260390198	0.001763125	0.301963607	30.1963607	
126.66	2300	0.14495	1.29646	103.33	24886.67	25.04	103.433836	0.260466578	0.001811875	0.301875059	30.18750588	
126.822	2350	0.14985	1.28229	103.46	25460.21	25.62	103.698592	0.263205761	0.001873125	0.298733444	29.87334438	
126.69	2400	0.1537	1.27304	103.35	25974.85	26.14	103.482839	0.264619225	0.00192125	0.297137759	29.71377586	
126.552	2450	0.15565	1.26984	103.24	26487.11	26.65	103.25752	0.26279381	0.001945625	0.299201733	29.92017332	
126.438	2500	0.1596	1.27446	103.15	27003.32	27.17	103.071752	0.264311686	0.001995	0.297483493	29.74834927	
126.239	2550	0.1626	1.27876	102.98	27500.04	27.67	102.74738	0.264416115	0.0020325	0.297366004	29.7366004	
126.161	2600	0.16805	1.27634	102.92	28021.93	28.20	102.620449	0.268189117	0.002100625	0.293182529	29.31825288	
125.847	2650	0.17145	1.28027	102.66	28489.73	28.67	102.110264	0.269122403	0.002143125	0.292165805	29.2165805	
124.911	2700	0.17465	1.28371	101.90	28811.38	28.99	100.597001	0.271084849	0.002183125	0.290050749	29.00507495	
123.927	2750	0.1784	1.2812	101.10	29113.75	29.30	99.0183162	0.274029504	0.00223	0.286933934	28.69339341	
123.689	2800	0.18005	1.27448	100.90	29586.16	29.77	98.638355	0.272147983	0.002250625	0.288917679	28.89176785	
123.899	2850	0.18331	1.26036	100.66	30041.45	30.23	98.1604528	0.27256378	0.00228875	0.288476933	28.84769335	
122.519	2900	0.1879	1.2531	99.95	30352.96	30.54	96.7810993	0.276838472	0.00234875	0.284022531	28.40225314	
121.837	2950	0.19255	1.23943	99.39	30704.41	30.90	95.7066374	0.280442232	0.002406875	0.280372764	28.03727636	
121.709	3000	0.199	1.22735	99.29	31102.02	31.39	95.5056473	0.285305558	0.0024875	0.275593522	27.5593522	
121.123	3050	0.20605	1.2193	98.81	31559.20	31.76	94.5881871	0.291976074	0.002575625	0.269297283	26.92972832	
121.124	3100	0.21005	1.20692	98.81	32076.83	32.28	94.589749	0.292841007	0.002625625	0.268501889	26.85018888	
120.851	3150	0.21605	1.19274	98.59	32520.73	32.72	94.16384	0.297094473	0.002700625	0.264657779	26.46577793	
120.596	3200	0.21795	1.18481	98.38	32967.23	33.17	93.766881	0.295648103	0.002724375	0.265952539	26.59525389	
120.84	3250	0.22305	1.17378	98.58	33550.08	33.76	94.146699	0.29730982	0.002788125	0.264466083	26.44660828	
121.633	3300	0.2255	1.16118	99.23	34289.80	34.50	95.3864094	0.294091378	0.00281875	0.267360315	26.73603153	
122.181	3350	0.2285	1.15104	99.67	34966.17	35.19	96.2478451	0.292239439	0.00285625	0.269054593	26.90545932	
122.933	3400	0.2342	1.14117	100.29	35706.47	35.93	97.4326242	0.293319272	0.0029275	0.26806409	26.80640896	
123.475	3450	0.23605	1.12669	100.73	36391.31	36.62	98.2973238	0.290072781	0.002950625	0.271064259	27.1064259	
123.428	3500	0.24195	1.11975	100.69	36904.67	37.14	98.2225144	0.293187192	0.003024375	0.268184851	26.81848511	
124.205	3550	0.24545	1.10622	101.32	37667.52	37.90	99.4630614	0.291404805	0.003068125	0.269825213	26.98252129	
124.066	3600	0.25505	1.09697	101.21	38155.30	38.39	99.2405642	0.298931135	0.003188125	0.263031696	26.30316964	
123.967	3650	0.25755	1.09401	101.13	38654.36	38.90	99.082247	0.297963936	0.003219375	0.263885504	26.38855043	
123.815	3700	0.26445	1.09659	101.01	39135.83	39.38	98.8394199	0.302182764	0.003305625	0.260201351	26.02013511	
123.767	3750	0.2651	1.09808	100.97	39649.31	39.90	98.7627996	0.299002418	0.00331375	0.262968989	26.2968989	
123.509	3800	0.2693	1.09907	100.76	40094.22	40.35	98.3514744	0.300369102	0.00336625	0.261772476	26.17724762	
122.672	3850	0.27375	1.10533	100.07	40346.49	40.60	97.022968	0.30342339	0.003421875	0.25913745	25.91374496	
122.157	3900	0.2759	1.11704	99.65	40698.88	40.95	96.2100369	0.303158562	0.00344875	0.259363822	25.93638222	
121.184	3950	0.28285	1.12259	98.86	40892.34	41.15	94.6384842	0.309324919	0.003535625	0.254193434	25.41934342	
120.004	4000	0.28455	1.12461	97.90	41006.74	41.26	92.8485463	0.310315866	0.003556875	0.253381706	25.33817062	
118.734	4050	0.2871	1.1222	96.86	41079.93	41.34	90.8937166	0.312538969	0.00358875	0.251579391	25.15793914	
117.442	4100	0.28895	1.12394	95.81	41134.56	41.39	88.9263652	0.314135131	0.003611875	0.250301083	25.03010832	
116.5	4150	0.29305	1.12233	95.04	41302.24	41.56	87.5053331	0.317299076	0.003663125	0.247805208	24.78052077	
115.931	4200	0.2949	1.12179	94.57	41595.70	41.86	86.6528454	0.31704945	0.00368625	0.248000315	24.8000315	
115.034	4250	0.29715	1.12456	93.84	41765.21	42.03	85.3711043	0.318171802	0.003714375	0.247125493	24.71254935	
114.391	4300	0.3022	1.12278	93.32	42020.37	42.28	84.3659842	0.321614227	0.0037775	0.244480365	24.44803647	
114.016	4350	0.30605	1.11943	93.01	42369.62	42.64	83.8137487	0.323026707	0.003825625	0.24341134	24.34113396	
113.871	4400	0.3092	1.11986	92.89	42802.13	43.07	83.607037	0.323053744	0.003865	0.243390968	24.33909683	
113.985	4450	0.3099	1.11873	92.99	43331.85	43.60	83.7681783	0.319826883	0.00387375	0.245846636	24.58466365	
113.306	4500	0.31445	1.11563	92.43	43557.70	43.83	82.7731495	0.322839957	0.003930625	0.243552143	24.35521431	
113.074	4550	0.3171	1.10953	92.24	43951.50	44.23	82.4345317	0.322643703	0.00396375	0.243700288	24.37002882	
112.195	4600	0.3194	1.10569	91.53	44089.06							

4 Analysis

4.1 Specific Fuel Consumption against Engine Speed

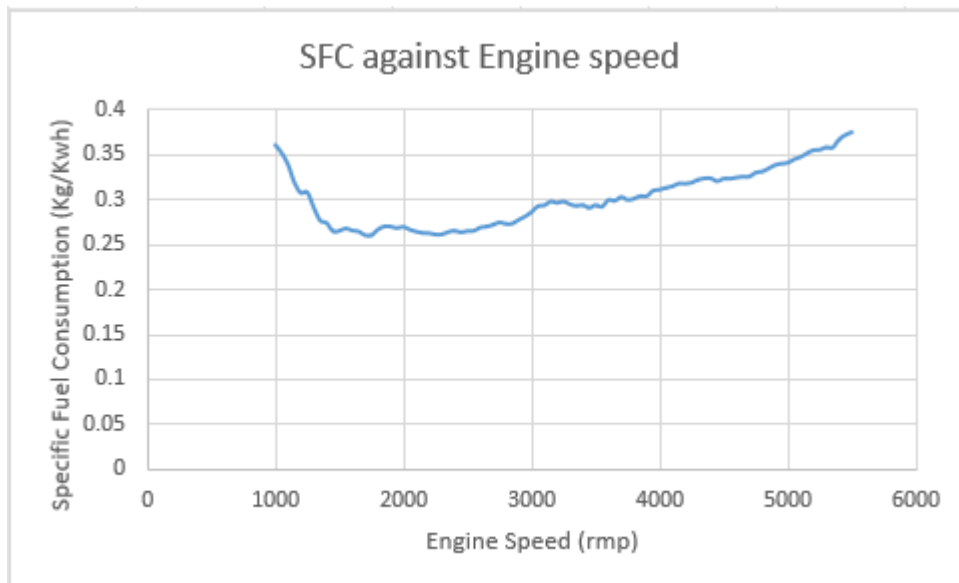


Figure 5: Graph Demonstrating the effects of increased Engine Speed on SFC.

The graph above displays how Specific Fuel Consumption (SFC) changes depending on the Engine Speed. Firstly, it is evident that, when the Engine Speed is very low, the SFC is high, indicating that the engine is not very fuel-efficient at this speed. This may be a result of poor volumetric efficiency when intake and exhaust flow are inhibited due to low speeds which could have a chain-reaction on the combustion of the air and fuel mixture within the cylinder, causing incomplete combustion. Additionally, upon first starting the engine, combustion may also be affected by lower temperatures within the cylinders, potentially also contributing to inefficient fuel usage. Lastly, the high SFC reading could also be impacted by frictional losses and other components consuming power, such as cooling systems and pumps.

However, as the Engine Speed increases from 1,000rpm to 2,000rpm, there is a drastic drop in SFC, meaning that the engine becomes more fuel efficient. Furthermore, from between roughly 1,500rpm to 3,000rpm, SFC remains in its lowest range, suggesting that this is where the engine operates most effectively and efficiently. This is due to a series of changes, such as the engine achieving optimal flow of air into and out of cylinders, allowing for better cylinder filling and power creation with minimal fuel wastage, which as a result also improves combustion as it provides the best air to fuel ratio, leading to a more complete combustion. In addition, the engine may reach its

ideal thermodynamic operating point which allows it to balance its fuel burning efficiency and any mechanical friction.

Moreover, as the Engine Speed increases beyond 3,000rpm the SFC begins to rise, which is an indication that the fuel consumed per unit of power output increases, resulting in the engine consuming more fuel, making it less efficient at higher RPMs. This could be impacted by the energy lost as heat due to an increase in friction between components, such as pistons and bearings, reducing overall efficiency. Valve timing may also be inefficient as it may not be able to operate fast enough to allow for sufficient cylinder filling and emptying. Finally, this may also be an effect of the engine running a richer fuel mixture at these higher speeds in attempts to prevent damage to the engine, at the cost of reduced efficiency.

4.2 Torque against Engine Speed

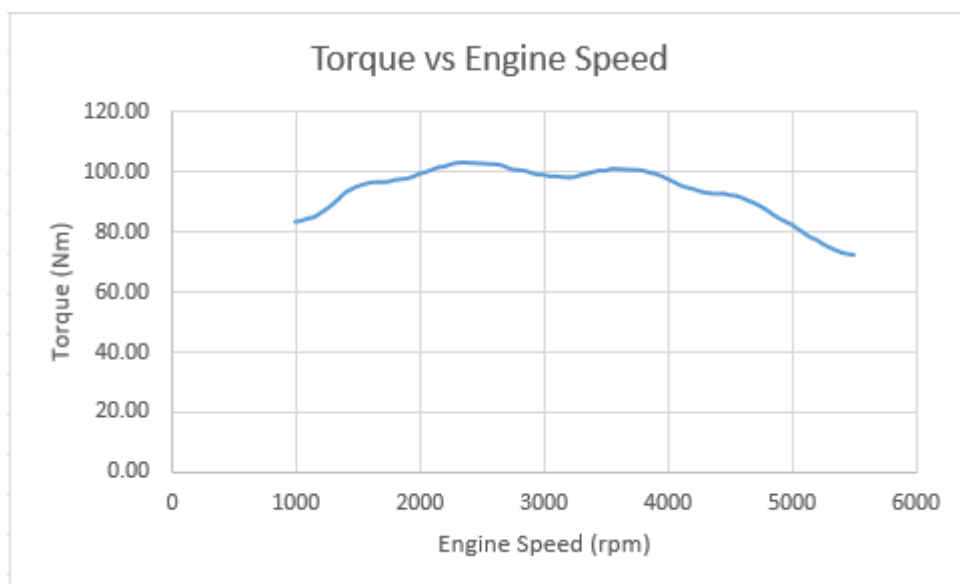


Figure 6: Graph showing effect of Engine Speed on Torque.

This graph demonstrates the change in Torque as Engine Speed increases and shows a typical torque curve for a combustion engine. Firstly, at low Engine Speeds the Torque increases as RPM increases, this is because as air intake and fuel combustion improves, so does cylinder filling and power generation.

Secondly, the engine reaches its peak Torque within the mid-range of its RPM spectrum, which is located roughly between 2,500rpm to 3,000rpm. This is where the engine operates most efficiently due to achieving optimal volumetric efficiency where the maximum amount of air and fuel flows into

the cylinders, which further leads to optimal combustion which generates a higher force on the pistons. Furthermore, valve timing is also optimized, especially in engines with varied valve timing as explained by Alphaprecision (2023), this is because valve timing is often tuned to maximise torque and power output between this range.

Lastly, this graph shows that beyond the peak of 3,000rpm the Torque begins to decrease as Engine Speed increases, with slight, brief fluctuations that do not quite equal the highest Torque value in the 2,500rpm to 3,000rpm range. This is caused by multiple factors, such as increased friction and heat loss to various engine components, a decrease in volumetric efficiency due to the air flow into the cylinders struggling to keep up with the increasing speed, which would also impair combustion. Furthermore, despite advanced valve timing, at extreme RPMs there are not only physical limitations to air flow, but also combustion as there may be inefficient time for complete combustion before the exhaust valve opens, resulting in wasted energy. This means that, despite the engine running at higher speeds, it produces less force to turn the crank shaft.

4.3 Brake Power against Engine Speed

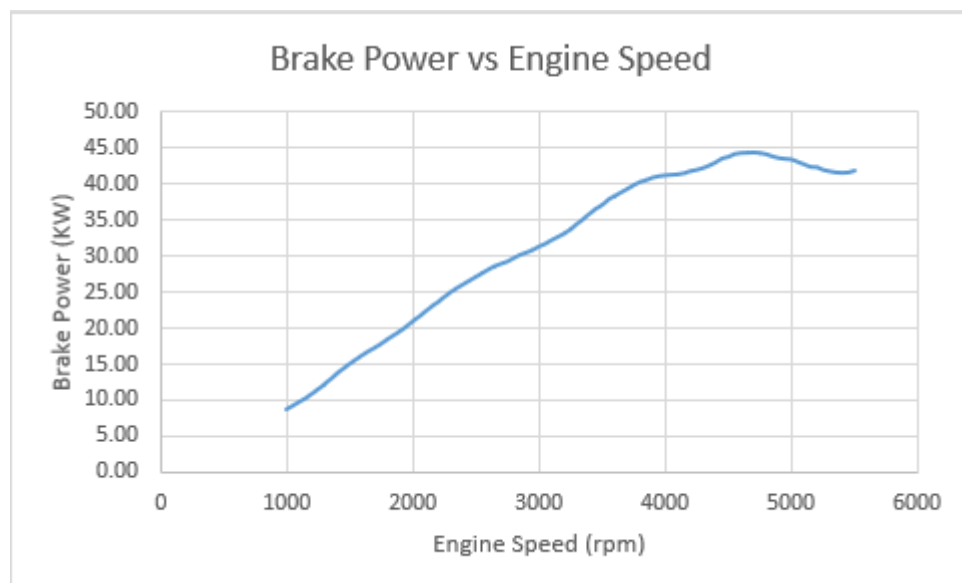


Figure 7: Graph Showing how Brake Power changes as Engine Speed increases.

The graph above demonstrates how Brake Power initially increases fairly proportionately to Engine Speed from 1,000rpm up to roughly 4,500rpm. This steady incline is due to the power increasing as a result of the positive contribution of torque and the speed of the engine.

From here Brake Power peaks at around 40kW to 45kW between 4,500rpm to 5,000rpm and then begins a slight decline after peaking. This is because, despite the Engine Speed increasing the torque is decreasing which reduces how much power can be produced, this eventually leads to the peak in Brake Power followed by the slight decline that is shown in the graph. Additionally, factors such as inefficient volumetric efficiency causing impaired combustion, and increased both, frictional and thermal losses at high rpms also contributes to the decrease shown.

5 Conclusion

The analysis of the results show that the engine operates most efficiently within its mid-range band of RPMs, where it is able to balance fuel efficiency, power output and its delivery of torque. Therefore, these results suggest that the engine is ideal for an everyday road vehicle as a result of demonstrating these qualities. To conclude, this experiment highlights the importance of selecting the correct operating RPM range depending on what the vehicle will be used for to allow it to achieve its maximum performance and potential.

6 Evaluation

Unfortunately, due to issues with the Dynamometer setup we were unable to personally carry out the experiment and where instead given previous test data. However, regardless of this there are still ways in which the test and accuracy of our data could have been improved. Firstly, the engine's power output is surprisingly low, this could be an indication of a fault within the engine, or it could be affected by the air filter system used as it is a second-hand filter from a lawnmower; thus, an investigation could be carried out on the engine and a new air filter system could be implemented. Moreover, instead of using Sweep testing in this experiment we could use Step testing, this is because step testing allows for more accurate readings due to the pause at the end of each cycle, however, we would then have to account for the extra heat and strain on the engine.

7 References

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- 2) Fall, M. (2021a). Engine Dynamometer Overview. [online] www.youtube.com. Available at:
<https://www.youtube.com/watch?v=-WajOAp2LUE>
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