

Engine Performance Characteristics



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Introduction

This report will be detailing work done by engineering students at the University of Wales Trisinity St David using an engine Dynamometer. Where they will be gathering data to use for this report to calculate an engine's Power, Torque, Specific Fuel Consumption, and Overall Thermal Efficiency. The report will also describe the equipment used for testing and the method used. Once the raw data is collected, it will be displayed in a table where the other data points will be calculated. The engineering students will also have to answer associated questions using their calculated data and plotted graphs.

The engineers anticipate a typical outcome from the engine dynamometer test. They expect a decline in power as the engine approaches its maximum RPM range, along with a corresponding reduction of torque as the engine RPM increases. Additionally, they predict that Specific fuel consumption will rise with RMP increases. At these elevated RPMs, the engine will consume more fuel to sustain these high speeds, reflecting a decrease in overall fuel efficiency.



Figure 1: Dyno testing Software

Testing Equipment

What is a Dynamometer?

An engine Dynamometer (Dyno) is a Mechanical device used to measure and test the power output of an engine. It is also possible for the Dynamometer to subject the engine to various operating conditions. The Dynamometer at the University of Wales Trinity St David (UWTSD) connects the engine to the dyno via its drive shaft. The dyno absorbs and records the power output as the engine runs on the dyno, providing the data required by the operator. For a dyno to properly test an engine, hydraulics provide a load to the engine, causing it to work harder, or electromagnets are used to generate the necessary load.

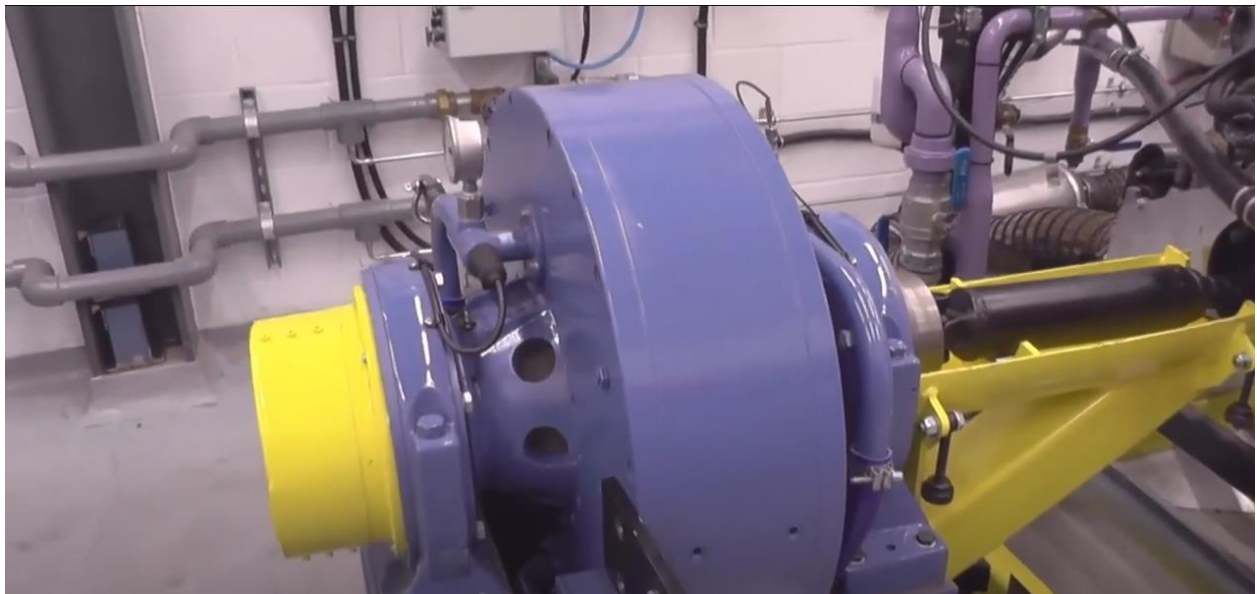


Figure 2 Engine Dyno Drive Shaft (From UWTSD Workshop YouTube)

The Dyno records the engine's torque and RPM. This data is sent to the dyno's computer, where the software can record various data points to assist with engine data. This can include;

- Ambient Temperature
- Pressure
- Humidity
- Specificity Gravity of Fuel
- Load (Newtons)
- Dyno speed
- Fuel flow rate

The Dyno's software calculates the power of the engine using;

$$Power = \frac{Torque \times RPM}{5252}$$

Baro mBar	Humidity %	Ambient temp Deg C	Specific gravity of fuel	Coloric value Mega joules	length on dino m
1018.9	46	27	0.75	44	0.815776

Figure 3: Dyno Software Recordings

Dynamometer Test

To evaluate the engine's performance, the engineering students utilize a dynamometer to subject the engine to a range of speeds, measuring data such as load, fuel consumption, and lambda across these different RPM levels. The engineering students at UWTSD then compile this raw data into excel spreadsheets, which they will use to calculate key performance factors, including the engine's power, torque, brake mean effective pressure (BMEP), specific fuel consumption (SFC), and overall thermal efficiency percentage.



Figure 4: Engine Dyno at UWTSD (Picture taken by author E Davies)

Safety When Operating a Dynamometer

When operating an engine dyno the operators must adhere to proper safety procedures to prevent injury. The operators have to wear the appropriate personal protective Equipment (PPE), including safety goggles, gloves, and hearing protection. This will guard them against flying debris, high temperatures, and excessive load noise. Furthermore, the engine must be mounted to a secure testing surface on the dyno, and all electrical connections have to be checked to lessen the risk of electrical hazards.

The dyno should have a ventilation system to properly ventilate harmful exhaust gases. This ventilation system's pipes should be at least twice the size of the engine's exhaust piping. Additionally, the fuel supply to the dyno should be outside the testing area and in its own separate enclosure to prevent fire.

Data Results

Raw data

The engineers were able to collect 91 Data entries across the dyno speed range of 1000-5500 RPM at an increase of 50 for every entry. Across the 91 data entries, they were able to collect the load, dyno speed, fuel flow rate, and lambda of the engine. This can be seen in Figure 5 below. When looking at the raw data, a steady increase of load can be observed for most of the data however, there are some points where the load does not increase constantly like the rest of the data. This would be due to the engine's condition when testing or human error when setting up the engine dyno.

Given that the raw data set exhibits variations that don't coincide with the rest of the data. The engineers can use specialized software to normalize it. This ensured that the data is smooth and more accurate, which will enhance the reliability of the data and make it more suitable for analysis.

	A	B	C	D
4	Load	Dyno Speed	Fuel Flow Rate	Lambda
5	Newtons	rpm	l/min	Lambda
6	102.275	1000	0.0704	1.2658
7	102.756	1050	0.0724	1.26783
8	103.689	1100	0.0737	1.27344
9	104.209	1150	0.0728	1.28476
10	105.811	1200	0.0744	1.29181
11	107.51	1250	0.07895	1.29729
12	109.488	1300	0.079	1.29895
13	111.797	1350	0.0796	1.29469
14	114.268	1400	0.0835	1.2855
15	115.783	1450	0.0847	1.27818
16	116.985	1500	0.08865	1.2795
17	117.788	1550	0.0932	1.27766
18	118.471	1600	0.0959	1.28235
19	118.772	1650	0.09875	1.29028
20	118.656	1700	0.10005	1.29942
21	118.861	1750	0.10305	1.31053
22	119.584	1800	0.1093	1.3149
23	119.934	1850	0.11415	1.31849
24	120.176	1900	0.11745	1.31892

Figure 5: Engine Dyno Raw data (continues to 91 data entries)

Calculated data

Using the calculations listed below, the engineers can calculate their needed data. The numbers that are not labeled can be seen in Figure 3. One of the downfalls of calculated data is that these formulas need to be correct to give usable data. This means that human error can give incorrect answers, making the data unreliable. To limit the risk of human error, the engineers used Excel to calculate the 91 data entries to keep the data consistent and reliable.

$$Power = ((2 \times 3.14 \times RPM \times Torque) \div 60) \div 1000$$

$$Torque = Load(N) \times 0.815776$$

$$SFC \left(\frac{Kg}{KWH} \right) = Fuel Flow Rate \times 0.75 \times 60 \div Power$$

$$\text{Thermal Efficiency} = \text{Power} \div \left(((\text{fuel Flow Rate} \div 60) \times 0.75) \times (44000) \right) \times 100$$

	A	B	C	D	E	F	G	H	I
3									
4	Load	Dyno Speed	Fuel Flow Rate	Lambda	Power	Torque	BMEP	SFC	Thermal Efficiency
5	Newtons	rpm	l/min	Lambda	Kw	Nm	Pa	kg/KwH	%
6	102.275	1000	0.0704	1.2658	8.732705	83.43349	6.549529	0.362774	22.55347451
7	102.756	1050	0.0724	1.26783	9.212464	83.82588	6.580331	0.353651	23.13526887
8	103.689	1100	0.0737	1.27344	9.738783	84.587	6.640079	0.340546	24.0256149
9	104.209	1150	0.0728	1.28476	10.23251	85.0112	6.673379	0.320156	25.55573156
10	105.811	1200	0.0744	1.29181	10.84155	86.31807	6.775969	0.308812	26.4945018
11	107.51	1250	0.07895	1.29729	11.47462	87.70408	6.88477	0.309618	26.42550945
12	109.488	1300	0.079	1.29895	12.15316	89.31768	7.011438	0.292517	27.97044731
13	111.797	1350	0.0796	1.29469	12.88675	91.20131	7.159303	0.27796	29.43523305
14	114.268	1400	0.0835	1.2855	13.65941	93.21709	7.317542	0.275085	29.742866
15	115.783	1450	0.0847	1.27818	14.33482	94.45299	7.41456	0.265891	30.77131232
16	116.985	1500	0.08865	1.2795	14.98307	95.43356	7.491534	0.266251	30.7297712
17	117.788	1550	0.0932	1.27766	15.58878	96.08862	7.542957	0.26904	30.4111933
18	118.471	1600	0.0959	1.28235	16.18495	96.6458	7.586695	0.266637	30.6852777
19	118.772	1650	0.09875	1.29028	16.73314	96.89135	7.605971	0.265566	30.80899542
20	118.656	1700	0.10005	1.29942	17.22336	96.79672	7.598542	0.261404	31.29955481
21	118.861	1750	0.10305	1.31053	17.76056	96.96395	7.61167	0.261098	31.33618052
22	119.584	1800	0.1093	1.3149	18.37913	97.55376	7.65797	0.267613	30.57328097
23	119.934	1850	0.11415	1.31849	18.94495	97.83928	7.680383	0.271141	30.17551974
24	120.176	1900	0.11745	1.31892	19.49623	98.0367	7.695881	0.271091	30.18109224

Figure 6: Dyno Test Results Data I

25	120.948	1950	0.12055	1.31484	20.13783	98.66648	7.745318	0.269381	30.37265213
26	122.157	2000	0.12555	1.31653	20.86064	99.65275	7.822741	0.270833	30.20982888
27	122.845	2050	0.12785	1.32098	21.50258	100.214	7.866799	0.267561	30.57927901
28	123.796	2100	0.1309	1.32287	22.19756	100.9898	7.9277	0.265367	30.83208458
29	124.794	2150	0.13435	1.32164	22.90928	101.804	7.99161	0.2639	31.00352843
30	125.137	2200	0.1377	1.31652	23.50649	102.0838	8.013575	0.263608	31.03781269
31	126.028	2250	0.14105	1.30465	24.2119	102.8106	8.070633	0.262154	31.20995195
32	126.66	2300	0.14495	1.29646	24.87406	103.3262	8.111106	0.262231	31.2007999
33	126.822	2350	0.14985	1.28229	25.4473	103.4583	8.12148	0.264989	30.87609304
34	126.69	2400	0.1537	1.27304	25.96169	103.3507	8.113027	0.266412	30.71116834
35	126.552	2450	0.15565	1.26984	26.47369	103.2381	8.10419	0.264574	30.92449388
36	126.438	2500	0.1596	1.27446	26.98963	103.1451	8.096889	0.266102	30.74690226
37	126.239	2550	0.1626	1.27876	27.4861	102.9827	8.084146	0.266207	30.73475906
38	126.161	2600	0.16805	1.27634	28.00772	102.9191	8.079151	0.270006	30.30236897
39	125.847	2650	0.17145	1.28027	28.47528	102.663	8.059043	0.270946	30.19728374
40	124.911	2700	0.17465	1.28371	28.79677	101.8994	7.999103	0.272921	29.9786787
41	123.927	2750	0.1784	1.2812	29.09899	101.0967	7.936089	0.275886	29.65653505
42	123.689	2800	0.18005	1.27448	29.57116	100.9025	7.920848	0.273992	29.86156826
43	123.389	2850	0.1831	1.26036	30.02622	100.6578	7.901636	0.27441	29.81601432
44	122.519	2900	0.1879	1.2531	30.33757	99.94806	7.845923	0.278714	29.35562217
45	121.837	2950	0.19255	1.23943	30.68884	99.3917	7.802248	0.282342	28.97839434

Figure 7: Dyno Test Results Data I.I

46	121.709	3000	0.199	1.22735	31.17621	99.28728	7.794052	0.287238	28.48442786
47	121.123	3050	0.20605	1.2193	31.5432	98.80924	7.756525	0.293954	27.8336696
48	121.124	3100	0.21005	1.20692	32.06057	98.81005	7.756589	0.294825	27.75146028
49	120.851	3150	0.21605	1.19274	32.50425	98.58735	7.739107	0.299107	27.35414594
50	120.596	3200	0.21795	1.18481	32.95051	98.37932	7.722777	0.297651	27.48796798
51	120.84	3250	0.22305	1.17378	33.53308	98.57837	7.738402	0.299324	27.33433283
52	121.633	3300	0.2255	1.16118	34.27241	99.22528	7.789185	0.296084	27.63347105
53	122.181	3350	0.2285	1.15104	34.94844	99.67233	7.824278	0.294219	27.80858597
54	122.933	3400	0.2342	1.14117	35.68837	100.2858	7.872435	0.295306	27.70621082
55	123.475	3450	0.23605	1.12669	36.37286	100.7279	7.907143	0.292038	28.01629833
56	123.428	3500	0.24195	1.11975	36.88596	100.6896	7.904134	0.295173	27.71869233
57	124.205	3550	0.24545	1.10622	37.64842	101.3235	7.953891	0.293379	27.88823465
58	124.066	3600	0.25505	1.09697	38.13595	101.2101	7.94499	0.300956	27.18607943
59	123.967	3650	0.25755	1.09401	38.63476	101.1293	7.93865	0.299982	27.27432617
60	123.815	3700	0.26445	1.09659	39.11599	101.0053	7.928916	0.30423	26.89354437
61	123.767	3750	0.2651	1.09808	39.62921	100.9661	7.925843	0.301028	27.17959821
62	123.509	3800	0.2693	1.09907	40.07389	100.7557	7.909321	0.302404	27.05593063
63	122.672	3850	0.27375	1.10533	40.32603	100.0729	7.855721	0.305479	26.78358306
64	122.157	3900	0.2759	1.11704	40.67825	99.65275	7.822741	0.305212	26.80698018
65	121.184	3950	0.28285	1.12259	40.87161	98.859	7.760431	0.31142	26.27258611
66	120.004	4000	0.28455	1.12461	40.98595	97.89638	7.684866	0.312418	26.18868861

Figure 8: Dyna Test Results Data 1.2

	A	B	C	D	E	F	G	H	I
67	118.734	4050	0.2871	1.1222	41.0591	96.86035	7.603537	0.314656	26.00240736
68	117.442	4100	0.28895	1.12394	41.1137	95.80636	7.5208	0.316263	25.87028568
69	116.5	4150	0.29305	1.12233	41.2813	95.0379	7.460475	0.319449	25.61232031
70	115.931	4200	0.2949	1.12179	41.57461	94.57373	7.424038	0.319197	25.63248595
71	115.034	4250	0.29715	1.12456	41.74404	93.84198	7.366595	0.320327	25.54206731
72	114.391	4300	0.3022	1.12278	41.99907	93.31743	7.325418	0.323793	25.26867562
73	114.016	4350	0.30605	1.11943	42.34814	93.01152	7.301404	0.325215	25.15818474
74	113.871	4400	0.3092	1.11986	42.78043	92.89323	7.292118	0.325242	25.15607924
75	113.985	4450	0.3099	1.11873	43.30989	92.98623	7.299419	0.321993	25.40988892
76	113.306	4500	0.31445	1.11563	43.53562	92.43232	7.255937	0.325027	25.17273773
77	113.074	4550	0.3171	1.10953	43.92922	92.24306	7.24108	0.324829	25.18804952
78	112.195	4600	0.3194	1.10569	44.06671	91.52599	7.18479	0.326165	25.0849391
79	111.061	4650	0.32055	1.09782	44.09546	90.6009	7.112171	0.327126	25.01124897
80	109.973	4700	0.3207	1.09558	44.13298	89.71333	7.042497	0.327	25.02082346
81	108.654	4750	0.32485	1.08827	44.06752	88.63733	6.95803	0.331724	24.66454373
82	107.076	4800	0.32455	1.08396	43.88466	87.35003	6.856977	0.332799	24.58489689
83	105.24	4850	0.3257	1.08221	43.58147	85.85227	6.739403	0.336301	24.32884254
84	103.632	4900	0.3277	1.0846	43.358	84.5405	6.636429	0.34011	24.05637286
85	102.335	4950	0.32845	1.08823	43.25225	83.48244	6.553371	0.341722	23.94290017
86	101.106	5000	0.3287	1.08687	43.16445	82.47985	6.474668	0.342678	23.87612574
87	99.3149	5050	0.32985	1.0891	42.82379	81.01871	6.359969	0.346612	23.60510451

Figure 9: Dyna Test Results Data 1.3

	A	B	C	D	E	F	G	H	I
88	97.5815	5100	0.3297	1.09185	42.49296	79.60465	6.248965	0.349152	23.43340221
89	95.8486	5150	0.33095	1.09407	42.14755	78.19099	6.137993	0.353348	23.15513117
90	94.8033	5200	0.3338	1.09346	42.09264	77.33826	6.071053	0.356856	22.92752071
91	93.0976	5250	0.3313	1.08804	41.73276	75.94679	5.961823	0.357237	22.90303206
92	91.7886	5300	0.3324	1.08339	41.53784	74.87894	5.877997	0.360105	22.72062263
93	90.5938	5350	0.3308	1.08007	41.38392	73.90425	5.801483	0.359705	22.74591365
94	89.6374	5400	0.3388	1.07895	41.32971	73.12404	5.740237	0.368887	22.17972909
95	88.9256	5450	0.3438	1.07923	41.38116	72.54337	5.694655	0.373866	21.88437068
96	88.6474	5500	0.3488	1.08366	41.63015	72.31642	5.676839	0.377034	21.70045519

Figure 10: Dyna Test Results Data 1.4

Plotted Data

Suggested reasons why the SFC varies as it does with engine speed.

Across the RPM range, the SFC could vary because of mechanical friction in the components of the engine like the pistons, bearings, and Crankshaft. Furthermore, during the engine test, the air fuel ratio changes, affecting the amount of fuel that's efficiency burnt during the combustion process. The Engine is only efficient at between the range of 1400-2400 RPM, meaning it has a lower SFC at these RPM ranges. Continually, in other ranges of the engine, it uses more fuel to produce the speed, meaning its fuel consumption rises as speed increases. This is reinforced by the data plotted on the graph.

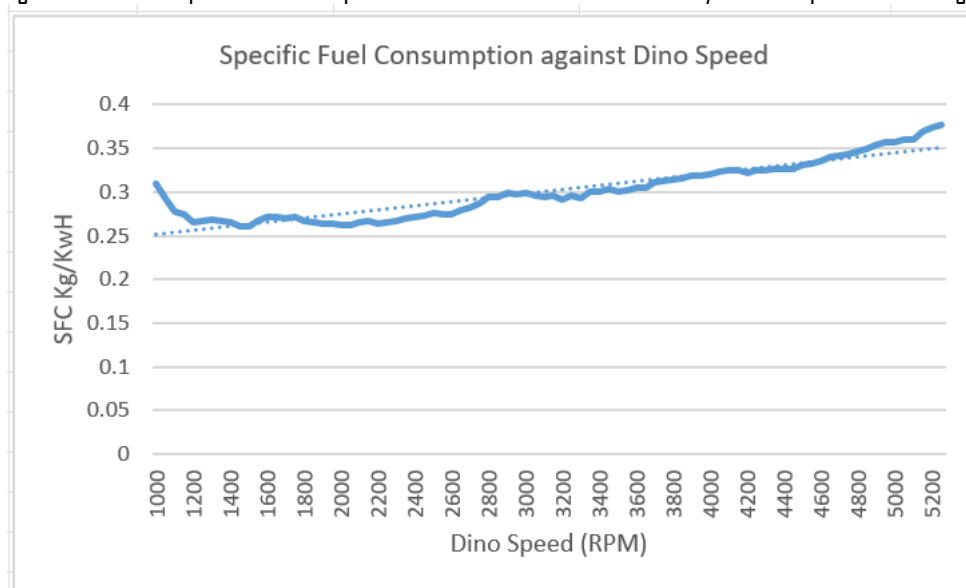


Figure 11: SFC vs Dyno Speed graph (unsmoothed)

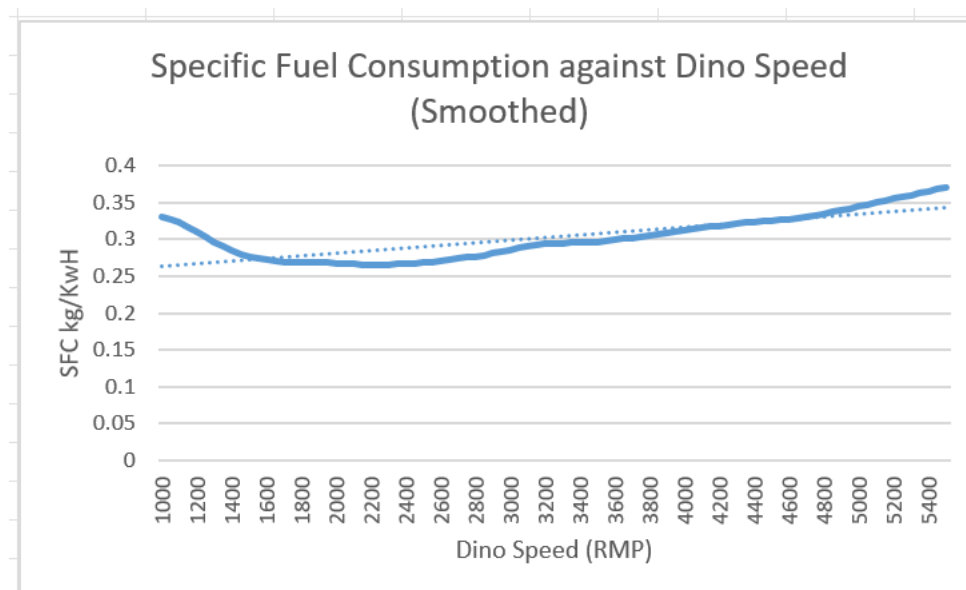


Figure 12: SFC vs Dyno speed Graph (smoothened)

Suggested reasons why Torque varies as it does with engine speed.

The torque of the engine progressively lowers as the engine speed rises. This can be due to the combustion process where at lower RPMs the engine is running relatively slow, allowing for a more complete combustion of the fuel and air mixture. This means greater torque production. On the other hand, at higher RPMs, there is less time to complete the combustion process, leading to the loss of torque shown in the graph. Furthermore, exhaust back pressure at lower RPMs is significant less, allowing the engine to maintain a higher efficiency, whereas high RPMs can impede flow of gasses reducing the engine's torque production.

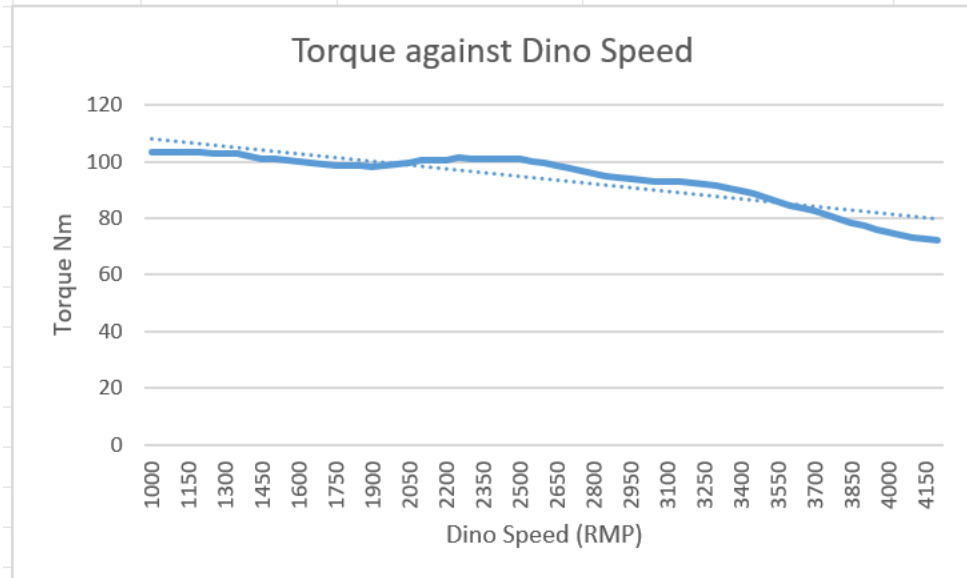


Figure 13: Torque against Dyno Speed Graph

Suggested reasons why Brake Power varies as it does with engine speed.

The engine has a steady increase until its peak brake power where it then starts to flatten out as the engine loses power, this can be due to the combustion process not being able to efficiently burn its fuel for the full power output. Additionally, it can be because of the mechanical losses due to friction at the higher speeds. Where the engine oil is no longer able to properly lubricate the engine as it turns. The Valves can restrict the amount of air and fuel the engine is supplied with as they won't be able to fully open at higher RPMs. This also means that they will not be able to properly dispel the exhaust gases out of the combustion chamber. These factors are all possible reasons why the brake power data shows the a decreased amount of power on the graph.

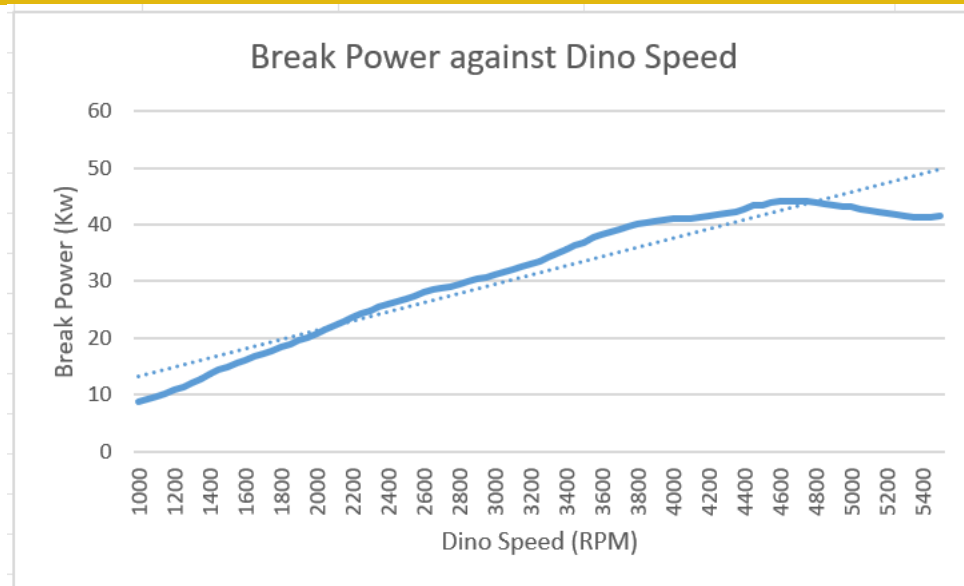


Figure 14: Break Power against Dyno Speed Graph

Evaluation

During the time when the students of UWTSD were performing their workshops, the engine dyno was not in operation. Meaning the engineering students could not perform these tests for themselves. To improve these tests, the task should be completed on an operational engine dynamometer. Therefore, students can compare their data sets as they would all have different measurements. This would allow them to further their respective knowledge and discuss their differences in their data.

The Data calculated shows the trend that is expected with this test. The specific engine that was tested shows it's highest thermal efficiency in lower RPMs and a loss of break power over 4600 revolutions. Furthermore, a loss of torque over the increase of RPM fits with the predictions of the engine testing.

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