

University of Wales Trinity Saint David

Wales Institute of Science and Art



Prifysgol Cymru

Y Drindod Dewi Sant

University of Wales

Trinity Saint David

Engine Performance Characteristics

Motorsport Technology ACH4012

Sam Bennett

2204486

March 2024

Contents

1	Introduction	1
1.1	Aims	1
1.2	Objectives	1
2	Method	2
2.1	Eddy Current Dynos	2
2.2	Experimental Method.....	4
3	Results and Discussion	5
3.1	Calculated Results.....	6
4	SFC Against Engine Speed	7
4.1	Torque Against Engine Speed	8
4.2	Brake Power Against Engine Speed	9
5	Conclusion.....	10
6	References	11

1 Introduction

Engine dynamometers (dynos) are used by all car manufacturers from high performance Formula1 engines to your everyday car engine. In this experiment, the 1.6L Honda B16 vtec will be used to demonstrate the uses, advantages and disadvantages of an engine dyno.

1.1 Aims

In this report the B16 Honda will be run at different RPMs (revolutions per minute) to understand how the engine is affected by different loads being applied to the crankshaft. This will produce a variety of different types of data, which will then be used to produce values such as overall thermal efficiency, horsepower and BMEP (Brake Mean Effective Pressure) for the engine. Overall, it will give a good understanding of how efficient the engine is, what sort of power it is running and how economical the engine is.

1.2 Objectives

1. To understand how an engine is attached to an engine dyno and runs on a dyno.
2. To understand the reason why engines are run on engine dynos.
3. To calculate corrected power, torque, BMEP, SFC (specific fuel consumption), and overall thermal efficiency.

2 Method

2.1 Eddy Current Dynos

The equipment required to complete the experiment is the 1.6L B16 VTEC Honda engine, and an eddy current engine dyno as seen in Figure 1.

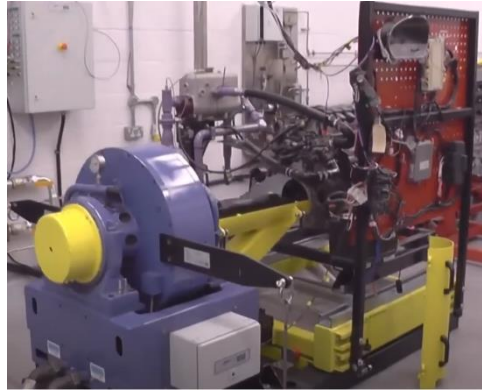


Figure 1 (Eddy current engine dyno)

An Eddy current dyno works by having an Eddy current brake at the core of the dyno. This brake consists of a rotor connected to the engine's crankshaft as seen in Figure 3 and a stator as seen in Figure 2 fixed within the dyno. (Jyotindra S, 2012)

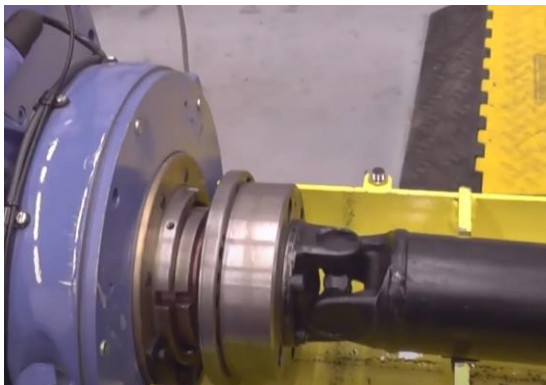


Figure 3 (crank shaft attached to the dyno via drive shaft)

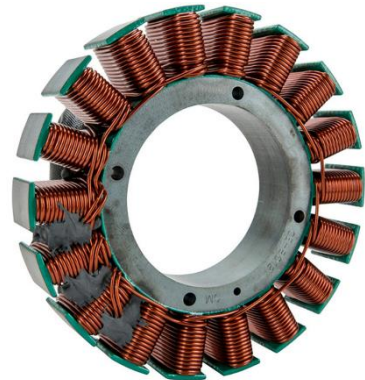


Figure 2 (Stator a wire continually wrapped around pegs from a central core)

When the engine is running and power is applied to the rotor, it generates a rotating magnetic field. The stator, which surrounds the rotor, produces a stationary magnetic field.

As the rotor spins within this stationary magnetic field, it induces Eddy currents “circulating electrical currents” (electrical4u, 2020) within the rotor material. These Eddy currents create a resistive force, known as Eddy current brake torque, which opposes the rotation of the rotor.

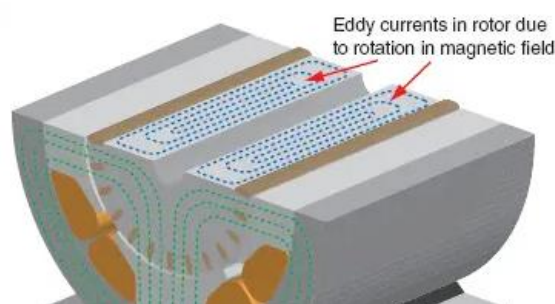


Figure 4 (eddy current visualised with cross section of similar style stator)

By adjusting the strength of the magnetic field produced by the stator, the amount of resistive force exerted on the rotor can be controlled. This allows the Eddy current dyno to simulate the different load conditions on the engine, such as those encountered during acceleration and breaking of driving conditions at various speeds. This is controlled by an external control panel where you can monitor the engine statistics as the parameters are adjusted.



Figure 5 (control panel where dyno is operated behind safety glass)

The amount of electrical power required to maintain a constant speed, or to vary the speed of the rotor against the resistive force of the Eddy currents, is measured by a strain gauge as seen in Figure 6. The electrical power input is proportional to the engine's torque output at a given speed.

The electrical power input along with the other relevant parameters, such as engine speed (RPM), is recorded by the dyno's data logging system. From this data, measurements such as torque, horsepower and specific fuel consumption can be calculated and analysed.



Figure 6 (strain gauge for measuring the movement of the dyno housing)

2.2 Experimental Method

The test method used to complete the experiment was the step test which consists of taking the data in 50rpm increments with a hold time of 1 second for each data read. The start rpm of the test is 1000rpm and ends at 5500rpm, logging the data every 50 rpm increments. This test should take a total of 15 seconds. (motortrend, 1998) The sweep test isn't as accurate as the step test but as it is a continual short acceleration it puts less strain on the engine, meaning it is less likely to overheat. The dyno will control the speed of the engine because the whole process is automated by the software. The engine will be run at 100 percent throttle for the duration of the test. The results taken from this test are 'load' and measured in newton meters. The fuel flow rate is measured in litres per minute and lambda. Figure 7 is a copy of the data taken from the test.

Load	Dyno Speed	Fuel Flow Rate
Newtons	rpm	l/min
102.275	1000	0.0704
102.756	1050	0.0724
103.689	1100	0.0737
104.209	1150	0.0728
105.811	1200	0.0744
107.51	1250	0.07895
109.488	1300	0.079
111.797	1350	0.0796
114.268	1400	0.0835
115.783	1450	0.0847
116.985	1500	0.08865
117.788	1550	0.0932
118.471	1600	0.0959
118.772	1650	0.09875
118.656	1700	0.10005
118.861	1750	0.10305
119.584	1800	0.1093
119.934	1850	0.11415
120.176	1900	0.11745
120.948	1950	0.12055
122.157	2000	0.12555
122.845	2050	0.12785
123.796	2100	0.1309
124.794	2150	0.13435
125.137	2200	0.1377
126.028	2250	0.14105
126.66	2300	0.14495
126.822	2350	0.14985

Figure 7 (raw data taken from the sweep test)

3 Results and Discussion

Below is the finalised data table with the calculated values for corrected power, torque, BMEP, SFC and overall thermal efficiency. This gives an overview of the engines running capabilities and the specifications of the engine.

Load	Dyno Speed	Fuel Flow Rate	Lambda	Horse power	Horse power	Corrected Power	Torque	SFC	Overall Thermal Efficiency	BMEP	BMEP
Newtons	rpm	l/min	Lambda	W	KW	KW	NM	kg/kwh	%	PA	KPA
102.28	1000	0.07	1.27	8848.70	8.85	8.90	84.50	0.34	22.09	672365.00	672.37
102.76	1050	0.07	1.27	9322.29	9.32	9.38	84.78	0.34	22.63	674620.11	674.62
103.69	1100	0.07	1.27	9828.15	9.83	9.89	85.32	0.33	23.44	678898.78	678.90
104.21	1150	0.07	1.28	10363.10	10.36	10.43	86.05	0.32	25.02	684727.53	684.73
105.81	1200	0.07	1.29	10940.52	10.94	11.01	87.06	0.31	25.85	692759.67	692.76
107.51	1250	0.08	1.30	11554.39	11.55	11.63	88.27	0.30	25.72	702364.97	702.36
109.49	1300	0.08	1.30	12201.31	12.20	12.28	89.62	0.29	27.15	713163.08	713.16
111.80	1350	0.08	1.29	12873.96	12.87	12.95	91.06	0.28	28.43	724609.72	724.61
114.27	1400	0.08	1.29	13556.22	13.56	13.64	92.46	0.28	28.54	735760.34	735.76
115.78	1450	0.08	1.28	14222.63	14.22	14.31	93.66	0.27	29.51	745311.53	745.31
116.99	1500	0.09	1.28	14868.54	14.87	14.96	94.65	0.27	29.48	753186.91	753.19
117.79	1550	0.09	1.28	15491.01	15.49	15.59	95.43	0.27	29.21	759405.57	759.41
118.47	1600	0.10	1.28	16092.44	16.09	16.19	96.04	0.27	29.49	764236.48	764.24
118.77	1650	0.10	1.29	16672.41	16.67	16.78	96.49	0.26	29.68	767786.24	767.79
118.66	1700	0.10	1.30	17237.90	17.24	17.35	96.83	0.26	30.28	770479.80	770.48
118.86	1750	0.10	1.31	17808.36	17.81	17.92	97.17	0.26	30.37	773235.43	773.24
119.58	1800	0.11	1.31	18392.95	18.39	18.51	97.57	0.27	29.58	776434.28	776.43
119.93	1850	0.11	1.32	18982.81	18.98	19.10	97.98	0.27	29.23	779676.90	779.68
120.18	1900	0.12	1.32	19584.51	19.58	19.71	98.43	0.27	29.31	783221.89	783.22
120.95	1950	0.12	1.31	20212.18	20.21	20.34	98.98	0.27	29.47	787597.63	787.60
122.16	2000	0.13	1.32	20862.98	20.86	20.99	99.61	0.27	29.21	792633.04	792.63
122.85	2050	0.13	1.32	21518.02	21.52	21.65	100.23	0.27	29.58	797580.12	797.58
123.80	2100	0.13	1.32	22180.52	22.18	22.32	100.86	0.26	29.78	802561.41	802.56
124.79	2150	0.13	1.32	22841.70	22.84	22.98	101.45	0.26	29.88	807264.20	807.26
125.14	2200	0.14	1.32	23487.17	23.49	23.63	101.95	0.26	29.98	811211.04	811.21
126.03	2250	0.14	1.30	24129.12	24.13	24.28	102.40	0.26	30.07	814863.46	814.86
126.66	2300	0.14	1.30	24749.87	24.75	24.90	102.76	0.26	30.01	817656.49	817.66
126.82	2350	0.15	1.28	25336.88	25.34	25.50	102.95	0.26	29.72	819240.00	819.24
126.69	2400	0.15	1.27	25892.30	25.89	26.05	103.02	0.26	29.61	819757.22	819.76
126.55	2450	0.16	1.27	26425.57	26.43	26.59	103.00	0.26	29.84	819566.25	819.57

Figure 8 (calculated data for engine to 2 DP)

3.1 Calculated Results

Figure 9 shows the engines horsepower, torque and overall thermal efficiency from 1700rpm to 4400rpm. Colour coordinated data shows at what points in the rpm bands the engine is producing the maximum amount of that value and at what point in the cycle. This shows us at what points in the step test the engine is at peak performance.

Torque	Horse power	Overall Thermal Efficiency
NM	KW	%
96.8263	17.2379003	30.28333132
97.1726	17.80836213	30.37472528
97.5746	18.39295005	29.57791835
97.9821	18.98281338	29.22947661
98.4276	19.58450518	29.30865971
98.9775	20.2121819	29.47015091
99.6103	20.86298042	29.20760924
100.232	21.51802283	29.58271353
100.858	22.18052152	29.78300285
101.449	22.84169547	29.88319595
101.945	23.48717143	29.98010529
102.404	24.12912347	30.06802008
102.755	24.7498691	30.01173223
102.954	25.33688344	29.71890629
103.019	25.89230286	29.60964409
102.995	26.42556812	29.84087712
102.906	26.94156456	29.67059817
102.753	27.43953817	29.66146741
102.539	27.91930045	29.20131384
102.223	28.36851503	29.08275132
101.791	28.78162111	28.96563396
101.329	29.18156351	28.75080992
100.929	29.59484763	28.8907861
100.536	30.00603205	28.80425193
100.111	30.40338255	28.44012496
99.7292	30.80962823	28.12414389
99.4375	31.24018222	27.59286895

Figure 9 (colour coordinated data to show the engines peak performance)

4 SFC Against Engine Speed

SFC or specific fuel consumption, is a measurement of “how much fuel an engine consumes to produce a unit of thrust or power” (P. Saranya, 2022). It is typically expressed in units of kilogram of fuel per kilowatt hour. SFC varies with engine speed due to several factors.

Thermodynamic efficiency varies at engine speeds. Engines are designed to work optimally at certain speed bands, and outside these bands, combustion efficiency may decrease, leading to higher fuel consumption per kilowatt hour produced.

Mechanical efficiency in various mechanical components of the engine, such as oil pumps, vacuum pumps, and injectors, can vary with engine speed. These components may operate optimally at different speed bands affecting overall engine and fuel consumption.

Load conditions that are applied to the engine, or the strain the engine is put under as a result of the work it must undergo can vary with engine speed. Higher engine speeds may correspond to higher loads, which will in turn increase fuel consumption.

The throttle position, which controls the amount of airflow the engine receives is adjusted based on engine speed. Changes in throttle position can affect the air-fuel mixture ratio and combustion efficiency, leading to variations in SFC.

These are all contributing factors to why the SFC will vary when the engine speed changes. Below is a graph comparing engine speed to SFC values with a smoothed factor of 0.4.

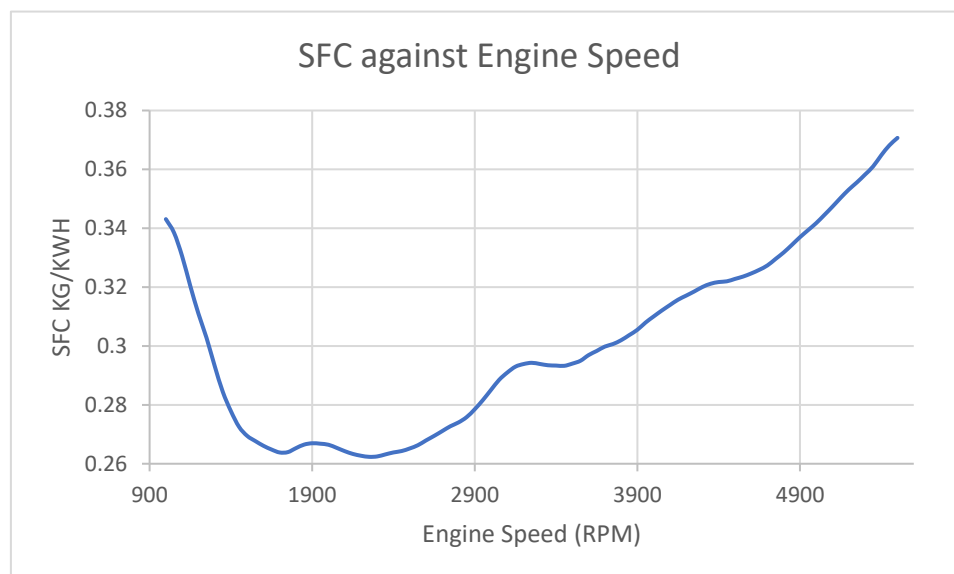


Figure 10 (SFC against Engine Speed smoothed to factor of 0.4)

4.1 Torque Against Engine Speed

Torque (muir, 2016) is a measurement of rotational force produced by an engine. Its main varying factor is engine speed. It is also influenced by several factors.

Power Stroke Frequency in internal combustion engines, torque is generated during the power stroke of each cylinder. As engine speed increases, the frequency of power strokes also increases, leading to more torque being produced.

The timing and lift of intake and exhaust valves play a significant role in determining torque output. At higher engine speeds, the timing and lift of these valves may be adjusted to optimise performance, affecting torque delivery.

The amount of air and fuel entering the combustion chamber also increases. Proper mixing and combustion of this air-fuel mixture contribute to higher torque output.

Engines have a powerband, a range of engine speeds within which they produce the most torque. Below and above this range, torque output may decrease as engine speed deviates from the optimal operating range.

These factors all contribute to why torque will vary at different engine speeds. Below is a graph that shows the torque figures compared to engine speed smoothed to a factor of 0.4.

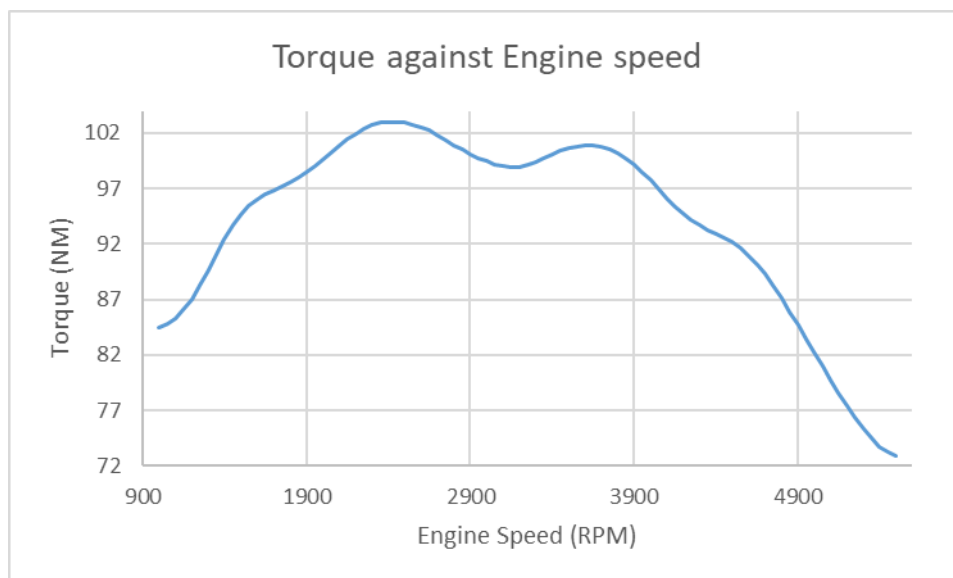


Figure 11 (Torque against Engine speed smoothed to factor 0f 0.4)

4.2 Brake Power Against Engine Speed

Brake power is the power output of an engine measured at the crankshaft, it represents the actual usable power output of the engine.

Break power is directly related to torque and engine speed through the equation $Break\ Power = Torque \times Angular\ Speed$. As engine speed changes torque output also changes, affecting the overall brake power output.

Engine efficiency can vary with engine speed due to factors such as combustion efficiency, heat loss and pumping losses at different engine speeds, the efficiency of converting fuel energy into mechanical power can vary affecting brake power output.

As engine speed changes the amount of air and fuel entering the combustion chamber also changes. Proper mixing and combustion of this air-fuel mixture influenced the power output of the engine.

Back pressure in the exhaust system affects the engine's ability to expel exhaust gases efficiently at different engine speeds. Exhaust back pressure may vary, affecting the power output.

Below is a graph showing how brake power varies with engine speed smoothed to a factor of 0.4.

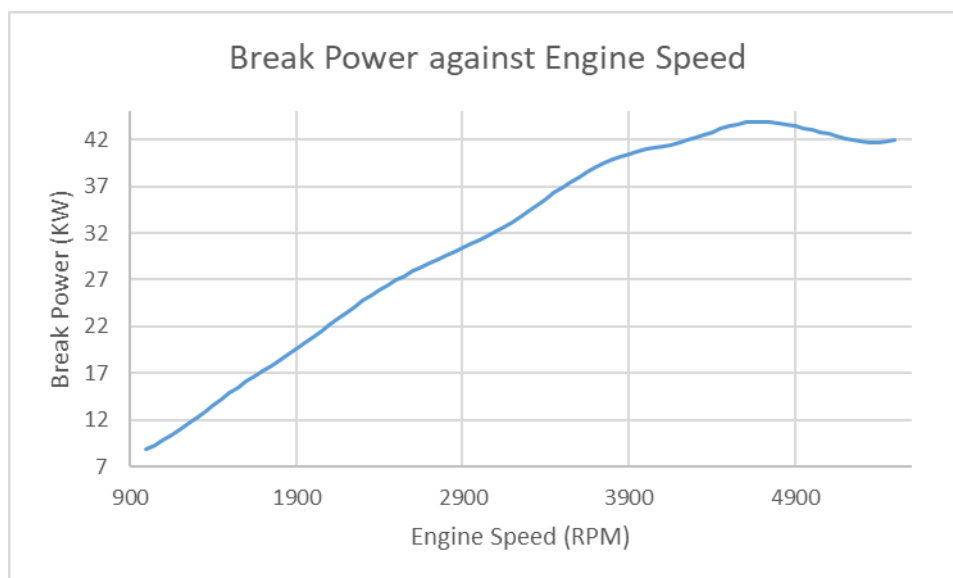


Figure 12 (break power against engine speed smoothed to a factor of 0.4)

5 Conclusion

Engine dynamometers are crucial to engine development, to understand where the engine's strengths and weaknesses are and to understand the characteristics of engines, comparing the data that an engine dyno produces shows what application the engine best fits towards and allows the engine to be improved to get the most out of what the engine can produce in terms of thermal efficiency, torque, and horsepower.

6 References

- electrical4u. (2020, october 26). *eddy current theory and applications*. Retrieved from electrical4u:
https://www.electrical4u.com/eddy-currents-theory-and-applications/?utm_content=cmp-true
- Jyotindra S, K. (2012). *Dynamometer: Theory and Application to Engine Testing*. thechnology and engineering.
- motortrend. (1998, june 1). *How to read a dyno sheet*. Retrieved from motortrend:
<https://www.motortrend.com/how-to/reading-dyno-sheet/#:~:text=In%20a%20step%20test%2C%20the%20engine%20is%20stabilized,and%20the%20test%20moves%20to%20the%20next%20step.>
- muir, a. (2016, dec 10). *torque and bhp explained*. Retrieved from how a car works:
<https://www.howacarworks.com/technology/torque-and-bhp-explained>
- P. Saranya, M. V. (2022). *Biofuels and Bioenergy*. london: Elsevier.

Figure 1 (Eddy current engine dyno)	2
Figure 2 (Stator a wire continually wrapped around pegs from a central core).....	2
Figure 3 (crank shaft attached to the dyno via drive shaft).....	2
Figure 4 (eddy current visualised with cross section of similar style stator).....	2
Figure 5 (control panel where dyno is operated behind safety glass).....	3
Figure 6 (strain gauge for measuring the movement of the dyno housing).....	3
Figure 7 (raw data taken from the sweep test)	4
Figure 8 (calculated data for engine to 2 DP)	5
Figure 9 (colour coordinated data to show the engines peak performance).....	6
Figure 10 (SFC against Engine Speed smoothed to factor of 0.4).....	7
Figure 11 (Torque against Engine speed smoothed to factor Of 0.4)	8
Figure 12 (break power against engine speed smoothed to a factor of 0.4)	9