

Seminar Paper

Research methods and project

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BSC MOTORSPORT ENGINEERING

Topic of interest

'Understanding the cylinder pressure of a Not engine versus a turbo charged engine with the aim of preventing knock with ignition timing'

Introduction

In this project I will be looking at various ways of how ignition systems are controlled, from what the systems use to be like to what the technology is as now. From this I will be using a dynamometer to gather data from two different engines one being a turbocharged engine and one being a naturally aspirated engine.

I will then be using data which is in an excel document to create various graph which show the cylinder pressure, I will then compare data sets and expand my knowledge of the subject matter to then answer my question of preventing knock with ignition timing.

Abstract

In this project I will be looking at two different types of an engine, one being the Ford sigma 1.6 naturally aspirated engine and the other being the turbocharged 1.6 sigma engine.

I will be investigating various data which has been collected via different testing methods and interpreting this data using various graphical techniques.

From this I will hope to expand my knowledge of the subject and be able to then look at how to control ignition timing, when we see a pressure increase.

Abstract 2 - Technical

Ignition control has varied over the years as technology has become much greater. Before having the ECU technology, we would see ignition control be all mechanically controlled this had many flaws. I am interested in looking into the various cylinder pressures of an internal combustion engine, one being a naturally aspirated and the other a turbocharged. From various data I gather I can then compare both and comment on what the data shows.

I will then look at how we would prevent knock in relation with retarding the ignition timing by using a stand alone ECU. I would hope my findings are as expected and can be applied to many gas laws.

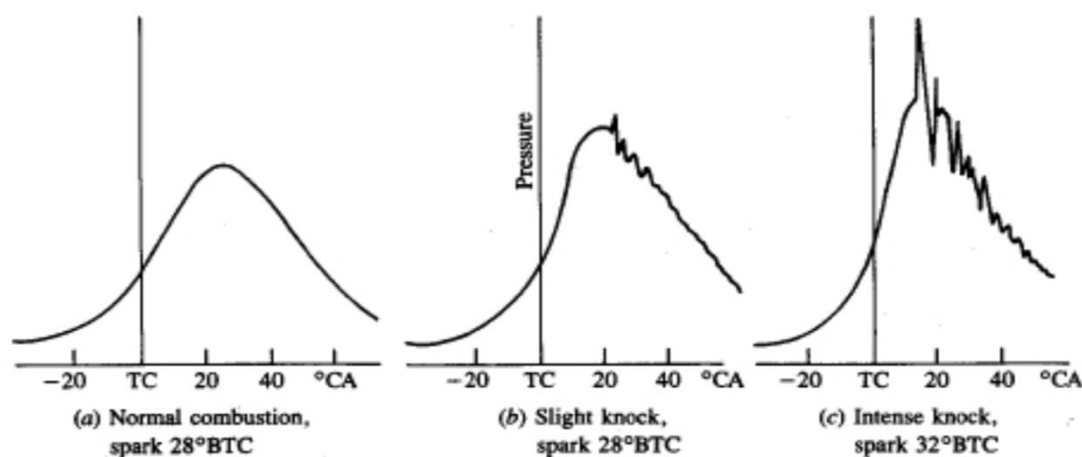
Introduction

What is Knock?

Engine knock which is also known as premature combustion, pinking or pining is only found in a spark ignition engine.

Knock occurs when the the engine is undergoing the compression stroke and is close to hitting Top dead centre or more commonly known as TDC. In normal circumstances combustion would ignite the air fuel ratio just before TDC to gain full expansion or constant velocity to push the piston down, however we see knock occur when in the cylinder does not result in propagation of the flame which is ignited by the spark plug, but in the cylinder we can see pockets of the A/F (Air/fuel Ratio) explode outside the normal flame burn pattern.

Knock creates shock waves and make a metallic “pining” sound, and cylinder pressure increases dramatically. Fig.1 bellow shows a typical example of various shockwaves of what we would see in a cylinder. First, we can see Normal combustion with a smooth combustion curve whereas the slight knock we see the curve oscillate slightly then under intense knock we see the oscillations become very aggressive.



“If there is no knock control, there must still be some means to define a clear safety margin to the knock limit. This margin is necessary to ensure that, even in the most knock-sensitive case regarding engine tolerances, engine aging, environmental conditions and fuel quality, no cylinder can rear or exceed the knock limit” (Bosch Automotive Handbook, 2011)

Ignition control

There are three main types of ignition control we see throughout older vehicles unlike the new vehicles being produced today. The three main ignition types are the mechanical distributor, DIS-less ignition and Coil-On-Plug ignition system which is the latest one being used today. These different systems are respectively, fully mechanical, one-part mechanical and part electric and then the newest one which is fully electronically controlled.

As stated in the fundamentals of motor technology

“The duty of the control module, or trigger box, is to switch the primary circuit current on and off in accordance with the signal it receives from the pulse generator.” (Hillier, n.d.)

Mechanical distributor Ignitions System

This type of ignition system is mechanically connected to the camshaft by gears, these gears are used to spin an internal distributor shaft. Inside the top of the distributor there are a pair of breaker points commonly known as ignition points, the internal shaft has a multi sided cam in the top of the cap which opens and closes the points, these act as a mechanical switch.

This switch stops and also starts the travel of the current which then follows down to the ignition coil, once the coil has reached enough voltage in its primary windings to fire the spark plug it then goes through its secondary windings which goes into the top of the distributor cap where a rotating disc which is also run by the primary shaft and distributes the power to each high tension lead to fire the spark plug at the right time needed.

This type of system was only used for a certain amount of time due to the fact that the mechanical part was subject to wear and only last 10-12,000 miles.

Coil on plug ignition

Current technology does not use any mechanical parts like the mechanical distributor, but it does use a hall effect sensor, located on the flywheel this sensor uses a magnetic field which varies voltage to send to the ECU, this sensor lets the ECU at what degrees the crankshaft is at.

Before the desired moment of ignition, the ignition driver stage switches a current through to the primary winding of the coil. While the primary current circuit is closed (dwell period), a magnetic field builds up in the primary winding. At the moment of ignition, the current through the primary winding is interrupted again and the magnetic field energy is discharged, mainly via the magnetic coupled secondary windings. Flash over can occur if the ignition system voltage supply of the ignition exceeds the demand of the spark plug. After flash over the remaining energy is converted at the spark plug while the spark is present.
(As stated in the Bosch Automotive Handbook, 2011, P 637)

Methodology

Through the use of a dynamometer on the two selected engines, one being the Ford sigma 1.6 naturally aspirated and the other being the ford sigma 1.6 turbocharged engine and putting these engines through various drive cycles, data has been extracted and tabulated in excel spreadsheets.

The data represents a full rotation of the various crank angles at various pressures along the cylinder's cycle. This data is repeated for various RPM ranges being 1000 RPM (Base Idle) up until 6000 RPM where it will be reaching's its rev limiter

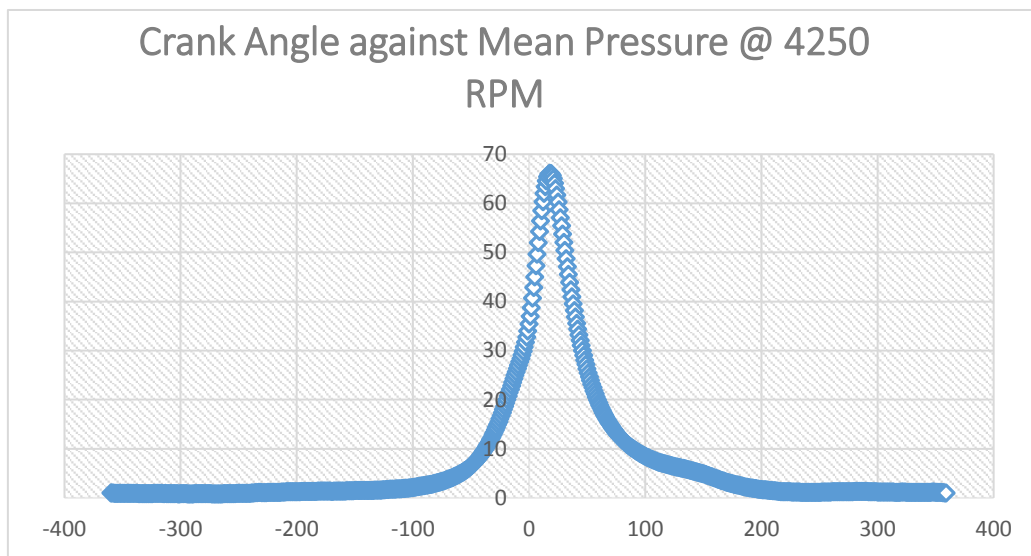
Example of the data set is show below –

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
Crank Angl deg	CYLPR1 bar	CYLPR2 bar	CYLPR3 bar	CYLPR4 bar	AVRG P bar	AVRG P N/m ²	Fgas N	Fradiat N	Ffriction N	RodAngle radians	Piston Tra m	WD J	TOTAL WD/c J	Fmep N/m ²	Fmep bar			
-360	0.886	1.053	0.994	0.931	0.966	96600	485.5646	26.94883	2.694883	7.11E-17	0	2.11E-05	4.919281	12298.2	0.122982			
-359	0.886	1.065	0.994	0.944	0.97225	97225	488.7062	27.12319	2.712319	0.005061	7.81E-06	6.36E-05						
-358	0.886	1.065	0.994	0.944	0.97525	97525	490.2141	27.20688	2.720688	0.010121	3.12E-05	0.000107						
-357	0.886	1.065	1.033	0.944	0.985	98500	495.115	27.47888	2.747888	0.015178	7.03E-05	0.000151						
-356	0.911	1.078	1.033	0.944	0.9915	99150	498.3823	27.66022	2.766022	0.020231	0.000125	0.000195						
-355	0.911	1.078	1.045	0.956	0.9975	99750	501.3862	27.82716	2.782716	0.025278	0.000195	0.00024						
-354	0.924	1.091	1.058	0.956	1.00725	100725	506.2991	28.0996	2.80996	0.030318	0.000281	0.000286						
-353	0.924	1.104	1.071	0.969	1.017	101700	511.2	28.3716	2.83716	0.035349	0.000382	0.000332						
-352	0.937	1.104	1.084	0.982	1.02675	102675	516.1008	28.6436	2.86436	0.040371	0.000498	0.00038						
-351	0.95	1.117	1.084	0.995	1.0365	103650	521.0017	28.9156	2.89156	0.045382	0.00063	0.000427						
-350	0.963	1.13	1.084	0.995	1.043	104300	524.269	29.09693	2.909693	0.050379	0.000778	0.000475						
-349	0.976	1.13	1.097	1.008	1.05275	105275	529.1699	29.36893	2.936893	0.055363	0.00094	0.000523						
-348	0.989	1.142	1.097	1.008	1.059	105900	532.3115	29.54329	2.954329	0.060331	0.001118	0.000569						
-347	0.989	1.13	1.097	1.02	1.059	105900	532.3115	29.54329	2.954329	0.065282	0.001311	0.000613						
-346	0.989	1.13	1.097	1.008	1.056	105600	530.8035	29.45959	2.945959	0.070215	0.001518	0.000653						
-345	0.976	1.117	1.084	1.008	1.04625	104625	525.9026	29.18759	2.918759	0.075128	0.001741	0.000689						
-344	0.963	1.104	1.071	0.995	1.03325	103325	519.3681	28.82493	2.882493	0.08002	0.001978	0.000721						
-343	0.95	1.091	1.045	0.982	1.017	101700	511.2	28.3716	2.83716	0.08489	0.00223	0.000752						
-342	0.937	1.078	1.033	0.969	1.00425	100425	504.7911	28.01591	2.801591	0.089735	0.002497	0.000783						
-341	0.924	1.078	1.02	0.956	0.9945	99450	499.8902	27.74391	2.774391	0.094556	0.002778	0.000815						
-340	0.911	1.078	1.007	0.944	0.985	98500	495.115	27.47888	2.747888	0.099349	0.003073	0.00085						
-339	0.911	1.078	1.007	0.944	0.985	98500	495.115	27.47888	2.747888	0.104115	0.003382	0.000891						
-338	0.911	1.091	1.02	0.944	0.9915	99150	498.3823	27.66022	2.766022	0.108851	0.003706	0.000934						
-337	0.911	1.104	1.02	0.944	0.99475	99475	500.0159	27.75088	2.775088	0.113556	0.004043	0.00098						
-336	0.924	1.117	1.033	0.956	1.0075	100750	506.4247	28.10657	2.810657	0.118229	0.004394	0.001029						
-335	0.937	1.13	1.045	0.956	1.017	101700	511.2	28.3716	2.83716	0.122868	0.004758	0.001076						
-334	0.95	1.13	1.058	0.969	1.02675	102675	516.1008	28.6436	2.86436	0.127473	0.005135	0.001124						
-333	0.963	1.142	1.058	0.982	1.03625	103625	520.8761	28.90862	2.890862	0.132041	0.005526	0.001169						
-332	0.976	1.142	1.058	0.982	1.0395	103950	522.5097	28.99929	2.899929	0.136571	0.00593	0.001209						
-331	0.976	1.142	1.058	0.995	1.04275	104275	524.1433	29.08995	2.908995	0.141062	0.006346	0.001246						
-330	0.976	1.13	1.058	0.995	1.03975	103975	522.6354	29.00626	2.900626	0.145513	0.006775	0.00128						
-329	0.976	1.13	1.058	0.995	1.03975	103975	522.6354	29.00626	2.900626	0.149922	0.007216	0.001311						
-328	0.976	1.13	1.045	0.982	1.03325	103325	519.3681	28.82493	2.882493	0.154286	0.00767	0.001341						
-327	0.976	1.13	1.045	0.982	1.03325	103325	519.3681	28.82493	2.882493	0.15861	0.008135	0.001371						
-326	0.963	1.13	1.045	0.969	1.02675	102675	516.1008	28.6436	2.86436	0.162885	0.008612	0.001397						
-325	0.95	1.13	1.045	0.969	1.0235	102350	514.4672	28.55293	2.855293	0.167114	0.009101	0.001422						
-324	0.95	1.117	1.045	0.956	1.017	101700	511.2	28.3716	2.83716	0.171294	0.0096	0.001449						
-323	0.95	1.117	1.045	0.956	1.017	101700	511.2	28.3716	2.83716	0.175425	0.010111	0.001475						
-322	0.937	1.117	1.045	0.944	1.01075	101075	508.0584	28.19724	2.819724	0.179504	0.010633	0.0015						
-321	0.937	1.117	1.045	0.944	1.01075	101075	508.0584	28.19724	2.819724	0.183532	0.011165	0.001532						
-320	0.937	1.117	1.058	0.944	1.014	101400	509.692	28.28791	2.828791	0.187505	0.011707	0.00157						
-319	0.95	1.13	1.058	0.956	1.0235	102350	514.4672	28.55293	2.855293	0.191404	0.012250	0.001605						
▶	1000rpm	1500rpm	1700rpm	2000rpm	2500rpm	3000rpm	3500rpm	4000rpm	4500rpm	5000rpm	5500rpm	5700rpm	6000rpm	+				

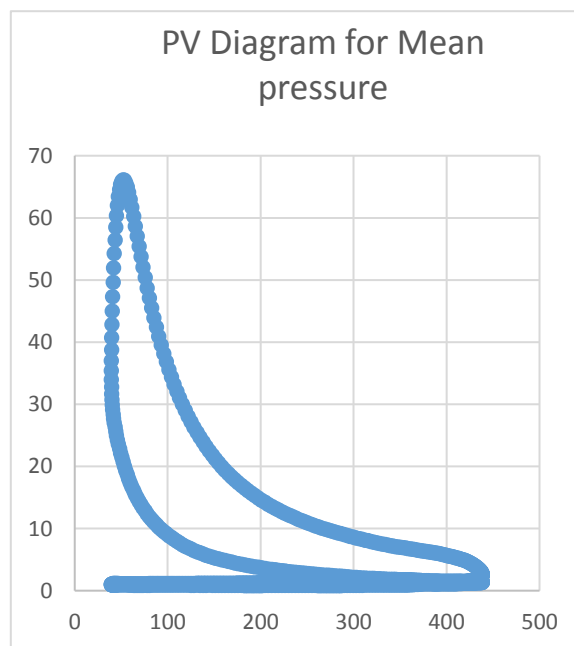
With this data I am going to construct various graphs one being crank angle against pressure and from this I will be able to see the various stages of an engines cycle. From this graph I can then go on and create Pressure V Volume Graphs, as I have two data sets from the same engine just on being turbocharged and one being naturally aspirated and I will be able to show the clear differences between the two.

Below are examples of the types of graph I will use.

Ford Sigma 1.6 Naturally aspirated



Above is a graph that I have plotted for Crank angle against the Mean pressure this was done at 4250 RPM. As I have various data across all the rev ranges I will be able to use and compare the data to show my understanding and from the graph we can also interpret at the engines complete compression cycle.



The graph above shows the Pressure V Velocity diagram for the mean pressure at again 4250 RPM. If we were to compare this to a theoretical Otto cycle this graphs shown are both different. Please see fig.1 below.

Fig.1

- 1-2 isentropic compression of air through a volume ratio V_1/V_2 , the compression ratio r_v
- 2-3 addition of heat Q_{23} at constant volume
- 3-4 isentropic expansion of air to the original volume, $V_4/V_3 = r_v$
- 4-1 rejection of heat Q_{41} at constant volume to complete the cycle.

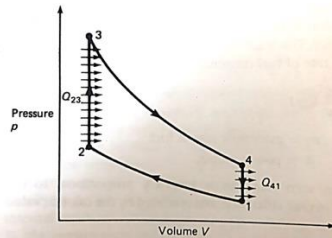


Figure 2.1
Ideal air standard Otto cycle.

(stone, 2015)

The above image shows the theoretical Otto cycle for an internal combustion spark engine. From my data I will hope to be able to compare various points and conclude various issues.

Conclusion

From the data in the analysis we can see how both engines would act under the complete drive cycle, represented from the data that was collected in the dynamometer, from this data I will be able to produce various graphs for both engines and compare the factors of each.

As the turbocharged engine will have a higher pressure we would also be seeing knock appear earlier than in the naturally aspirated engine and from this we would have to look into the factors of retarding or advancing the ignition timing

Bibliography

References

Bosch Automotive Handbook. (2011). 9th ed. [Erscheinungsort nicht ermittelbar]: Robert Bosch, p.633.

Hillier, V. (n.d.). *Hillier's fundamentals of motor vehicle technology*. 4th ed. p.545.

S.Kuo, P. (2018). Cylinder Pressure in a Spark-Ignition Engine: A Computational Model. *Engineering Science*. [online] Available at:
<http://www.gofastforless.com/junk/cylinder-pressure.pdf> [Accessed 18 Nov. 2018].

stone, R. (2015). *Introduction to internal combustion engines*. 4th ed.

Syrimis, M. and Assanis, D. (2003). Knocking Cylinder Pressure Data Characteristics in a Spark-Ignition Engine. *Journal of Engineering for Gas Turbines and Power*, 125(2), p.494.