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Engine Performance Characteristics

ACHA4003

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1 Introduction

Testing is an essential step in developing and analyzing the performance of engines, enabling engineers to evaluate and optimize engine designs.

Engine dynamometers are a key tool in recording necessary data in order to evaluate an engine.

Whilst there are many types of test which can be carried out, for the purpose of this assignment we will be looking solely at a sweep test carried out on a Honda 1.6 engine.

A sweep test on an engine dynamometer involves measuring an engine's torque output at various speeds. The engine is mounted on a dynamometer which consists of a brake connected to the output of the engine. In the case of the W230 Dynamometer the resistance of the brake can be varied, in this instance this load is kept at a constant after the test is initiated. The test begins with the engine running at idle speed. The engine speed is then gradually increased while measuring the torque produced at each speed increment (50rpm) .

The test is conducted in a controlled environment with variables such as air/coolant temperature and fuel flow rate also measured.

With the torque recorded at each rpm, along with fuel flow and atmospheric conditions, the engine power is then able to be calculated along with corrected power, brake mean effective pressure (BMEP), specific fuel consumption (SFC) and overall thermal efficiency.

2 Relationship between SFC and RPM

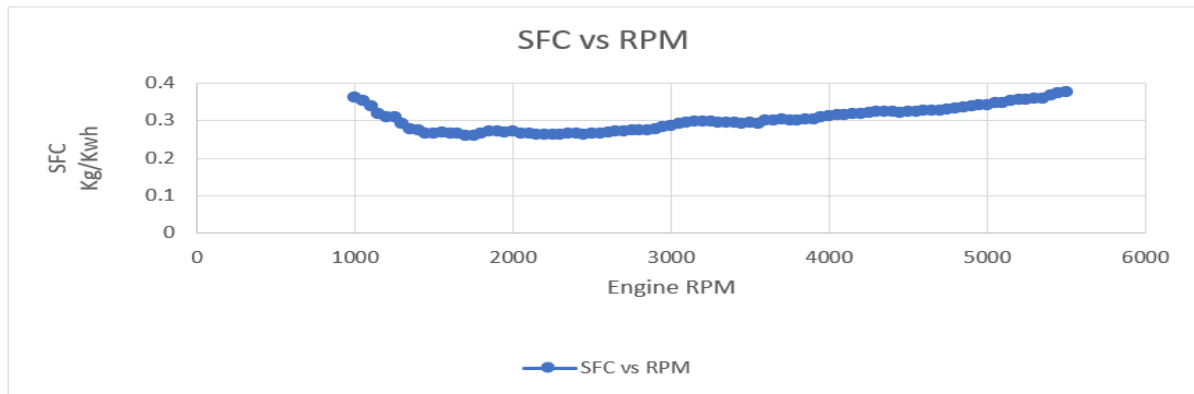


Fig. 1.1 B-SFC plotted against RPM

Specific fuel consumption (SFC) is a critical parameter in internal combustion engines that represents the fuel mass required to produce a unit of power. Shown above in Fig 1.1 is B-SFC plotted against engine speed. The engine producing the most work per Kg of fuel between around 1500rpm and 2400rpm.

B-SFC is calculated using the mass of fuel M' , and with the formula $B\ SFC = \frac{M'}{BP}$ (Ashok, 2019)

SFC is a crucial factor that influenced by engine performance and efficiency.

Seeing as the formula for Brake Thermal Efficiency is $\eta T = \frac{BP}{SFC * CV}$ we can see that SFC is related to the engine's thermal efficiency, which is a measure of how effectively the engine converts the fuel's chemical energy into useful work. The thermal efficiency is influenced by several factors, including the engine's compression ratio, combustion temperature, and heat transfer characteristics as well as in this case as we are studying brake thermal efficiency, other losses are also considered. The SFC and thermal efficiency are inversely proportional, meaning that a higher thermal efficiency corresponds to a lower SFC, this is present in Fig 1.2 which shows SFC plotted against Overall Thermal Efficiency.

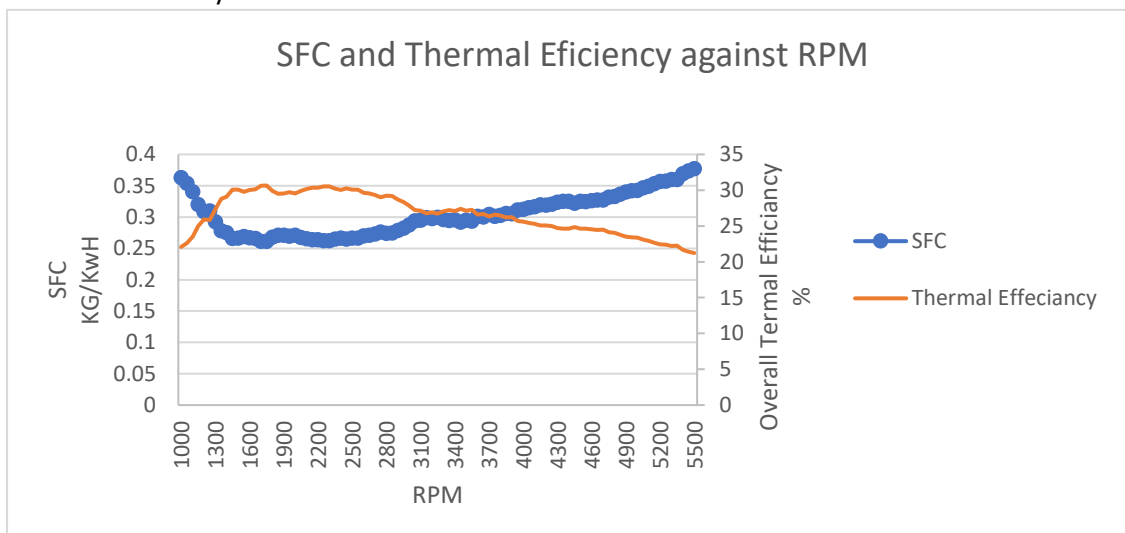


Fig 1.2, SFC against ηT

Between 1000rpm and 1500rpm η_T rises before reaching a plateau until 2400rpm where it begins to fall.

There are 3 main factors which effect η_T in a combustion engine, all of which vary in significance throughout the rpm range creating variation in brake thermal efficiency

1: Mechanical losses

Friction mean effective pressure is the metric for the mechanical losses of an engine and can be calculated using the formula $FMEP = IMEP - BMEP$, or alternatively $FMEP = W_f + W_p + W_a$ (Jääskeläinen, 2020)

Within an engine there are 3 main areas to be considered when looking at engine mechanical losses. Frictional Work (W_f), Pumping Work (W_p) and Auxiliary Work (W_a)

Firstly there is frictional losses, these come from multiple places around the engine. Below Fig 1.3 shows the average percentage of frictional losses each component accounts for, though should be noted that factors such as temperature and rpm can influence these figures.

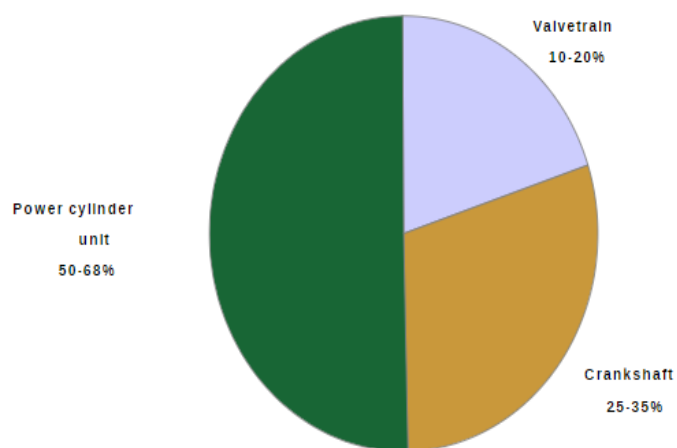


fig 1.3, percentage split of friction losses per component, (Jääskeläinen, 2020)

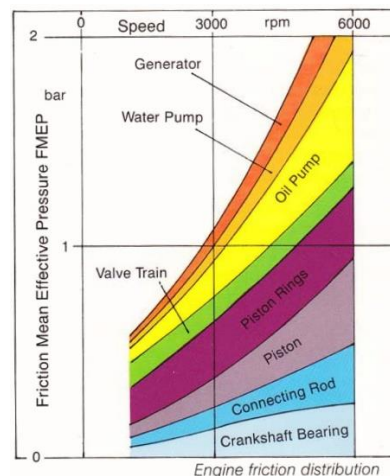


Fig1.4 FMEP against RPM, (X-Engineer, 2023)

Pumping losses within a naturally aspirated engine come from the intake of air into the engine and during the exhaust stroke.

Finally there are auxiliary losses, these pertain to items such as water and oil pumps, alternators and any other devices that may be directly attached to the engine.

In Fig 1.4 FMEP is plotted against rpm, it is clearly visible that with an increase in rpm there is an increase in friction, this will lead to a decrease in brake power, therefore decreasing efficiency.

2: Combustion Efficiency

Combustion efficiency in an internal combustion engine is influenced by a variety of factors. One of the most significant factors is the fuel-to-air ratio, which determines the amount of oxygen available for the combustion process. A lean mixture of fuel and air may result in incomplete combustion, while a rich mixture can cause excessive emissions and a both cause a reduction in efficiency, (Heywood, 1988)

Other factors that can affect combustion efficiency include the engine's compression ratio, the design of the combustion chamber, and the ignition timing. Higher compression ratios typically result in better combustion efficiency as well as a well-designed combustion chamber and intake can also improve combustion efficiency by facilitating the mixing of fuel and air, at lower engine speeds however this may not be fully optimized due to low intake velocity these also have a lesser effect then that of air/fuel ratio (Heywood,1988).

Finally, ignition timing plays a crucial role in combustion efficiency, as it determines when the fuel mixture ignites. Optimal ignition timing can vary depending on the engine's load and speed.

3: Heat Losses

Heat energy is lost in an internal combustion engine through several mechanisms. One of the most significant sources of heat loss is through the engine's exhaust system, where hot gases are expelled from the engine and cooled down through contact with the surrounding air. Additionally, some heat energy is lost through the engine's cooling system, which circulates coolant through the engine block to absorb and dissipate heat. The energy transferred to the surroundings by these two mechanisms can significantly impact the engine's overall efficiency. Below in fig 1.5 shows a generic heat balance of an SI engine, is shows as rpm increases, typically so does the combustion efficiency, however much of this energy can be wasted through the exhaust gasses. The degree in which this will affect an engine will vary based on design, this shows there is only generally a correlation between rpm and heat loss.

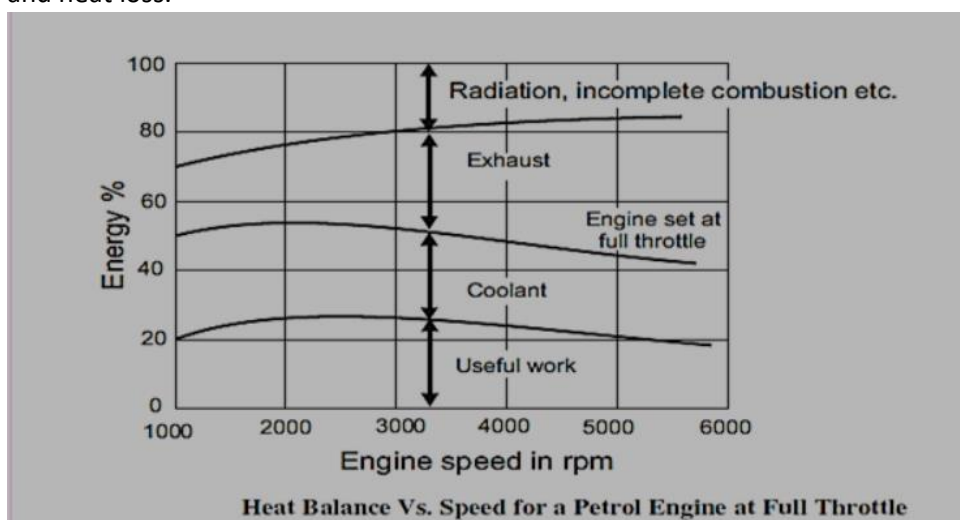


fig 1.5 Heat balance for an SI Engine

3 Relationship between Torque and RPM

Torque in this instance has been calculated by measuring the force produced by an engine at a set distance, giving us the results in fig. 2.1

Torque however can be calculated using the formula $T = \frac{MEP * L * A * n}{4\pi i}$

This shows that torque is related to the Mean effective Pressure (MEP) as well as fixed characteristics of the engine, such as number of cylinders, bore and stroke. Therefore for the torque produced to change, so must the MEP, (Heywood, 1988)

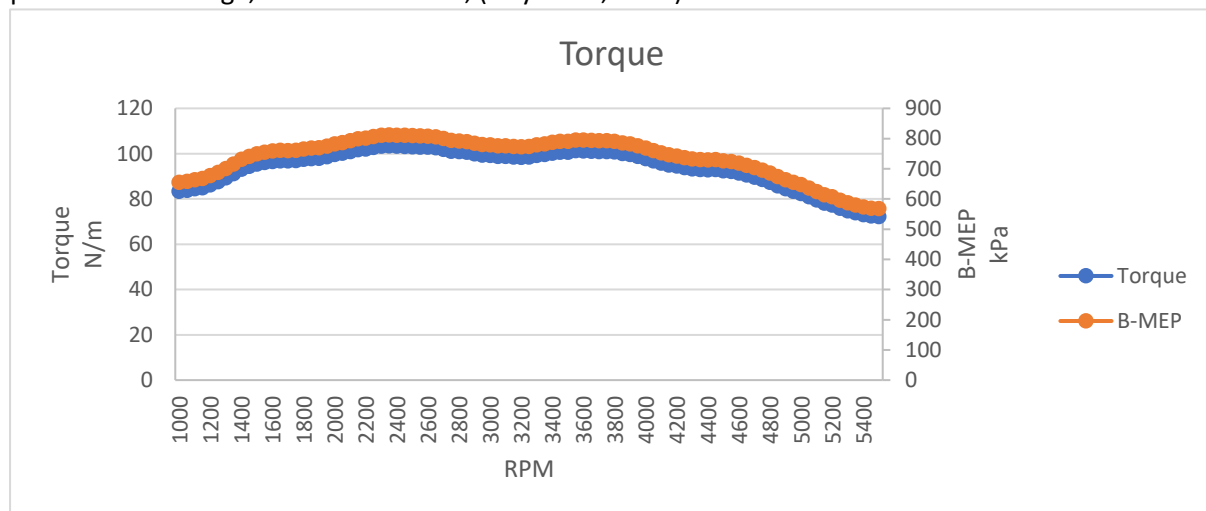


Fig.2.1 Torque and B-MEP against Engine speed

As shown in fig 2.1, as the Torque increases or decreases, so does the mean effective pressure.

The MEP is a fundamental parameter in internal combustion engines that represents the average pressure exerted on the piston during the power stroke. This parameter is a critical factor that influences engine performance, efficiency, and emissions. The MEP varies with engine speed due to several complex physical phenomena.

At low engine speeds, the MEP is generally lower due to a decrease in the cylinder filling efficiency, which is primarily caused by a reduced intake airflow rate. The cylinder filling efficiency is a measure of how effectively the engine can fill its cylinders with a fresh air-fuel mixture. At high speeds, the engine's intake valve may close before the cylinder is completely filled with the air-fuel mixture, leading to a lower MEP, (Stone, 1992). The filling efficiency is also influenced by the engine's valve timing and lift, which affect the intake and exhaust flow rates.

Additionally, the cylinder filling is affected by factors such as the intake and exhaust manifold design, the valve timing and lift, and the piston-cylinder geometry. At higher speeds, the gas dynamics become more complex, and the pressure waves inside the engine become more significant, leading to a higher MEP. However, if the gas dynamics are not optimized, they can lead to pressure waves that interfere with the engine's combustion process, leading to a decrease in the MEP.

At higher engine speeds, the MEP generally increases due to an increase in the combustion rate and the combustion efficiency. The combustion rate is a measure of how fast the air-fuel mixture burns inside the engine, and it is influenced by factors such as the spark timing, fuel injection timing, and combustion chamber design. At higher speeds, the combustion rate increases, resulting in a higher MEP. The combustion efficiency is a measure of how effectively the air-fuel mixture is burned, and it is influenced by factors such as the air-fuel ratio, turbulence, and combustion chamber design. At higher speeds, the combustion efficiency increases, leading to a higher MEP. However as stated, higher engine speeds can also come with the drawback of decreased cylinder filling.

4 Relationship between RPM and Power

Brake power is the relationship between torque and RPM, to calculate brake Power the formula

$$P = \frac{2\pi i * n * t}{60}$$

Therefore, Initially both torque and RMP are increasing therefore so does power, torque begins to drop at around 2400RPM however with the increase in rpm power still increases. At around 4800RPM torque begins to fall enough for power to also decrease even with the rpm increasing.

5 References

Ashok, B. (2019) Advances in Eco-Fuels for a Sustainable Environment, 2019. P 11.6.1.2

Jääskeläinen, H. (2020) Engine Efficiency, P 1.1

Jääskeläinen, H. (2020) Friction and Ancillary Losses

X-Engineer, Mechanical efficiency and friction mean effective pressure (FMEP). Date Accessed :20/3/2021

Heywood, J. (1988) Internal Combustion Engine Fundamentals. P50, P82

Stone, R. (1992) Introduction to Internal Combustion Engines. P231, P252