



## Introduction

This document explains in greater detail the use of Lambda probe on two strokes engines with an EGT thermocouple.

### Aim of the test:

Improving performances of a two strokes engine with an optimum carburation that won't damage engine reliability.

### The test

- The petrol is made with Elf pump petrol and oil.
- The fuel is a petrol of hydrocarbons with different hydrocarbon chain lengths: being a petrol it is slightly different from one manufacturer to the other.
- Used probe is a wide band Bosch LSU 4.9.
- We remind you that the Lambda probe measures the quantity of oxygen remaining in the gas after combustion and that Stoichiometric value for the fuel is around 14.57. This means that a total combustion of the fuel is obtained adding 14.57 parts of air for each part of fuel.

The Lambda value can be defined as:

$$\text{Lambda} = (A/F) / 14.57$$

Where:

**A** = air parts

**F** = fuel parts;

In general we can say that LAMBDA values lower than 1 indicates a low presence of oxygen remaining after combustion (rich mixture), while LAMBDA value higher than 1 indicates that presence of oxygen remaining after combustion is in excess of the quantity needed to burn the fuel (lean mixture). This is absolutely true in 4 strokes Otto cycle and Diesel four strokes for street use engines. On the contrary, it is true but with some corrections in the case of two strokes engines. In two strokes engines, in fact, there are moments during the cycle when incoming and exhaust gases ports are open simultaneously. Depending on the type of two strokes engine, at certain RPM values, part of the incoming gas passes directly to the exhaust gas pipe without taking part in the combustion. This leads to a false reading of the quantity of remaining oxygen because its value results from the addition of left incoming gas and not combusted gas. This means that a reading corresponding to lean mixture doesn't always reflect a real situation of lean mixture engine. In the same way a Lambda value higher than 1 (apparently lean mixture engine) can be due to the partial combustion of the mixture caused by a weak ignition that cannot brake the dielectrical between the electrodes of the spark. In fact higher compression ratio engines need more power to make the plug spark. If the signal is weak a delay occurs and there is a variation in the ignition advance curve (i.e. the ignition curve is late). This too leads to a reading of excess in oxygen not consistent with the real engine carburation.

Let us now learn how to distinguish a truly lean mixture Lambda value from that of a false reading. Together with the probe, we need an EGT thermocouple<sup>1</sup> to detect the exhaust gas temperature. This measure is very important. With really lean mixture, exhaust gas temperature is higher than with lean mixture. In fact, in a situation near to lean mixture for excessive heat we can reach self-ignition of the engine which can cause serious damage. Using a thermocouple on exhaust gases allows you to measure this temperature and verify that exhaust gas temperature is, in fact, increasing as Lambda value increases.

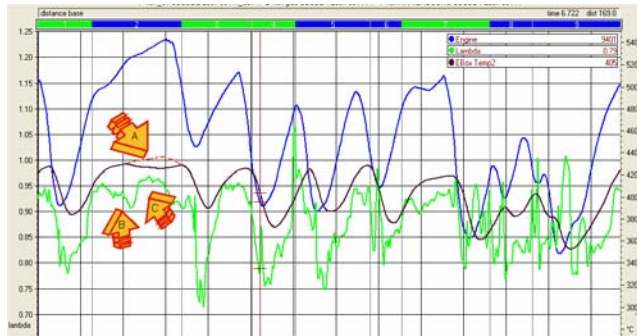


Figure 1. Plot of RPM, Lambda, and EGT vs. distance

Analyzing this situation at point A you can see that as the RPM value increases, exhaust gas temperature increases as well. Immediately after point A, as seen in figure 2, exhaust gas temperature decreases slightly even though RPM is still increasing.

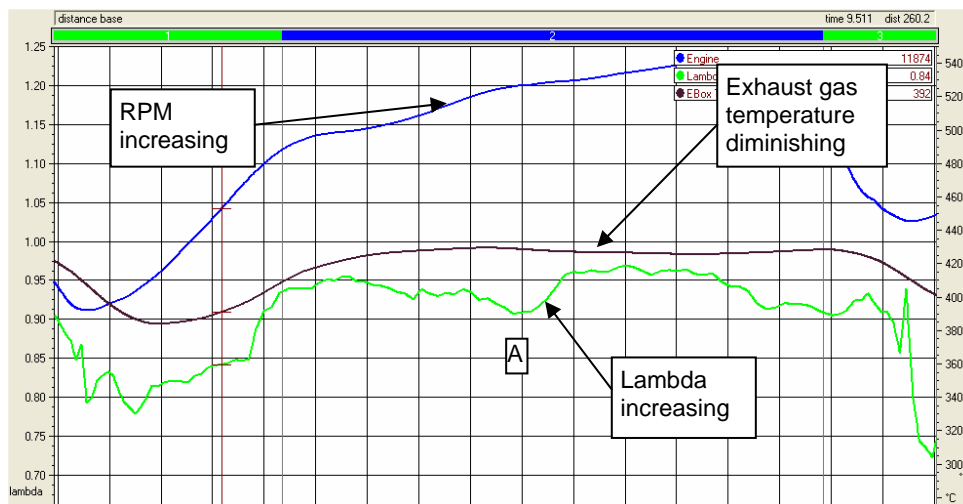


Figure 2. Plot of RPM, Lambda and EGT vs. distance

This is inconsistent with the global carburation analysis detected by Lambda value.

<sup>1</sup> Thermocouple that measures the exhaust gas temperature

This results in an X-Y diagram with X=RPM and Y=Lambda like the one shown below in figure 3.

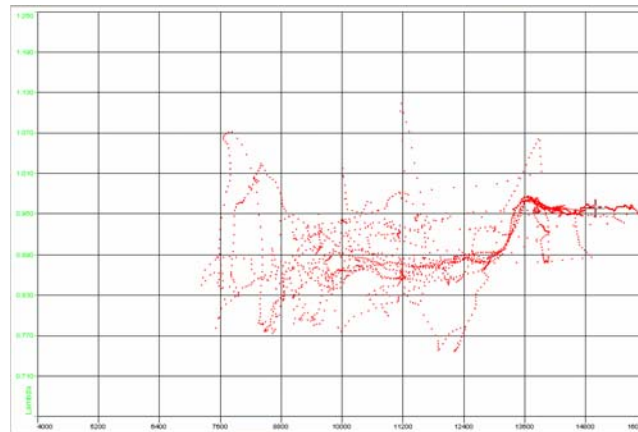


Figure 3. X-Y Diagram of RPM(x) and Lambda(y)

The graph indicates the average variation of the temperature obtained diagramming it for one entire lap. This graph shows that carburetion passes from an average Lambda value 0.89 to 0.95. If this was true, exhaust gas temperature should increase, increasing RPM value. To verify this figure 4 shows exhaust gas temperature as a function of RPM value.

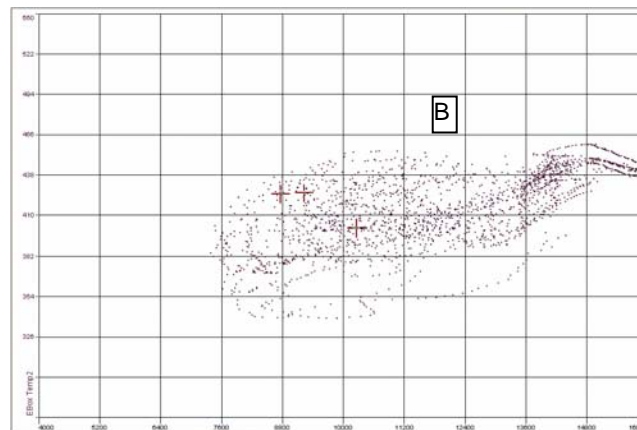


Figure 4. Plot of Exhaust Gas Temperature as a function of RPM

This is in contrast with what Lambda probe reads. After B point, the exhaust gas temperature decreases as RPM increases, even though it should increase due to the increasing RPM.

In reality we are in this condition:

- 1) Spark signal is too weak (comes late) and cannot burn completely the incoming gases completely because the engine is too compressed in comparison with the power made by the ignition
- 2) Scavenge phase has a lean rendering and part of the incoming gases goes directly to the exhaust port without taking part in the combustion leaving excess oxygen in the exhaust gases

We remind you that the more the engine is performing the more difficult is to have consistent and easy to read values.

The above quoted situations can be easily distinguished. If Lambda value diminishes decompressing the engine (changing the seal between cylinder and head with a thicker one is sufficient), ignition does not produce a lot of energy and there is a delay in the ignition advance curve. If this does not happen, we are in the second case. Let us now analyse, with a look at the data, the behavior of our engine and see how its performances can be increased using the Lambda probe. According to the results of the previous graphs a modification to the engine has been made. In this case it has been decompressed slightly increasing the head of the cylinder.

Let us now see how these modifications influenced the rendering of the same engine, and if there have been improvements. Making the X-Y diagram of the Lambda value we can see that the black scatter plot in figure 5 below, the less compressed engine has a lower Lambda value that leads to a leaner mixture, carburetion being equal.

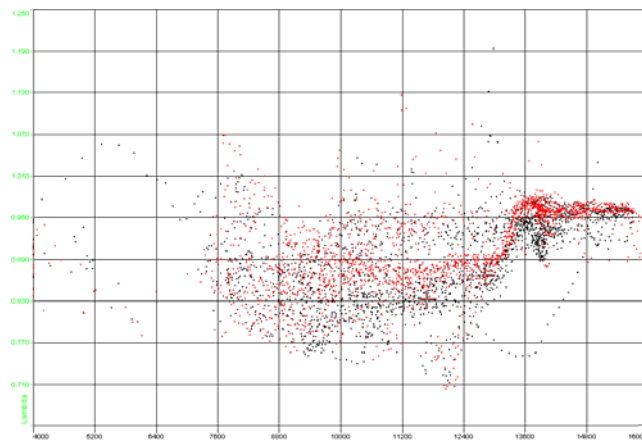


Figure 5. Comparison scatter plot of Lambda before and after cylinder head resizing

The speed diagram below shows how the engine performs better:

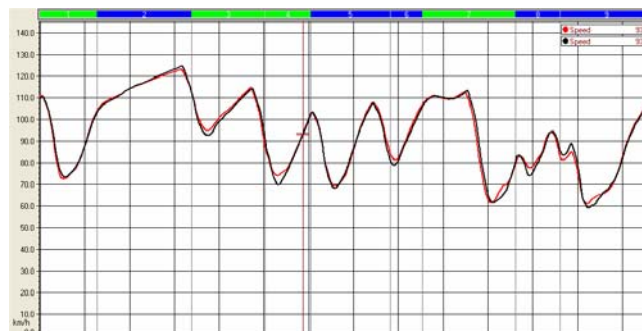


Figure 6. Plot of speed vs. distance

Analyzing the graph in detail (figure 7) we can see that at point C the engine that is less compressed keeps pushing even after having reached the max power speed with a speed difference of 1.5 km/h on the main straight and a time difference of 0.15 seconds on best lap time.

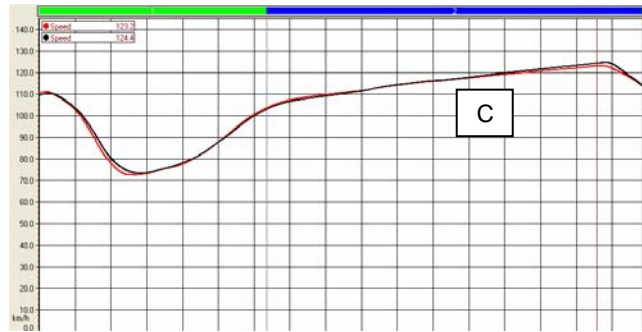


Figure 7. Detail plot of speed vs. distance

In fact lap time with the more compressed engine was 43.900 seconds, in comparison to the lap time of 43.750 seconds with the engine less compressed.

- 1) Engine compressed: 43.900 sec
- 2) Engine decompressed 43.750 sec

0.15 seconds can seem small, but it can be the difference between a pole position and starting mid-pack. In this case, choosing to decompress the engine gave positive results.

### WARNING

If Lambda value increases and exhaust gas temperature increases too I am sure engine mixture is lean (or rich if both decreases). As said before, we prefer using rich mixture than lean because the latter is very dangerous for engine reliability. Each engine has got its Lambda target, a lambda value which optimizes its potential. LCU-ONE helps you to identify this value and maintain it steady.



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