TECHNICAL INFORMATION ON CONSIDERATIONS WHEN CHOOSING AND OPERATING A SPARK-PLUG SENSOR SOLUTION

This paper describes characteristics that must be considered when choosing the correct instrumented spark plugs to substitute for the original standard spark-plugs of an engine in order to allow reliable pressure measurements via the spark-plug bore.

Electrode gap

The integration of a pressure measurement function requires space inside the spark-plug body. This results in a smaller ceramic insulator for the spark-plug function, and therefore a lower arc-over resistivity. To compensate for the lower arc-over resistivity, the ignition voltage must be low enough to avoid damage to the unit. To reduce the ignition voltage, the Electrode Gap needs to be chosen wisely. This will ensure safe and long lasting operation of the unit. On the other hand, to avoid misfire and therefore insure proper ignition of the air-fuel mixture, the arc of the Electrode Gap requires a minimum length. Choosing this gap will require a tradeoff between a minimum sufficient size gap and engine operating condition versus risking an internal arc-over. The maximum Electrode Gap (EG) is determined by the Final Compression Pressure (FCP) from the compression stroke, as this is a convenient metric that is roughly proportional to the demand voltage required to jump the gap in the spark plug. It is necessary to match the spark-plug specifications exactly to have reliable firing of the engine and to insure that the demand voltage is not exceeding component limits to avoid permanent damage of the spark-plug sensor assembly. The evaluation of the final compression pressure for the desired operation point of the engine is therefore critical.

An accurate and simple approach is to use the first law of thermodynamics to calculate the FCP. This method is valid under the following assumptions:

- Optimized Inlet Valve Closing (IVC) at Wide Open Throttle (WOT) between Peak Torque and Peak Power, resulting in high Volumetric Efficiency
- PMAN = PCYL at a Crank Angle (CA) of -180°
- Spark advance close to Top Dead Center (TDC)

The Maximum Final Compression Pressure (FCP) can be calculated therefore as the following:

$$FCP = PMAN \cdot CR^{1.32}$$

with

$$PMAN \cong Baro+BP \cong PCYL_{(CA=-180)}$$

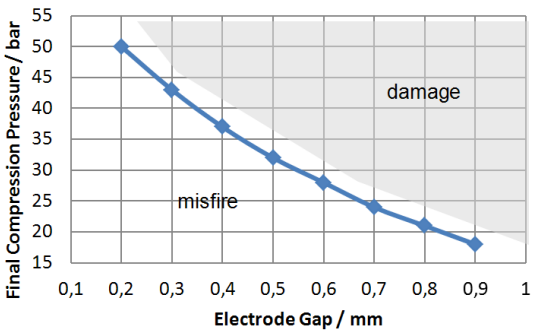
FCP…	final compression pressure in bar
$PCYL_{(CA=-180)}$ …	cylinder pressure at CA = -180°
$Baro_{(CA=-180)}$…	barometric pressure
$BP_{(CA=-180)}$…	maximum boost pressure of the e.g. supercharger or turbocharger
CR…	compression ratio

Examples

- The max possible pressure for a normally aspirated engine at WOT with a CR of 10:1 is:
  FCP = 1 bar · 10^1.32 = 20.9 bar (1 bar manifold pressure)
- For Boosted engines we need to comprehend boost. The PMAN term achieves this, the example below would be for an engine with 1.2 bar boost (PMAN = 2.2 bar absolute):
  FCP = 2.2 bar · 10^1.32 = 46 bar

This FCP pressure represents the final compression pressure which now defines the maximum allowed Electrode Gap for save operation according to the table below:

EG/mm	FCP/bar
0,9	18
0,8	21
0,7	24
0,6	28
0,5	32
0,4	37
0,3	43
0,2	50



The choice of the Electrode Gap according to this recommendation helps to insure safe operation of the unit. If the chosen Electrode Gap is larger than that recommended, AVL cannot take responsibility in the case of damage to the unit. Engines with forced induction will have to make a dynamic determination of the final compression pressures. A spark-plug sensor with a specific Electrode Gap can be either ordered from AVL, or can be adjusted by the customer. In any case of adjusting the gap of a spark-plug, great care must be taken to ensure that the fragile center electrode/insulator is not touched. The gapping tool used must bend only the ground electrode without applying pressure to the center electrode and then checked with a gauge. Please contact AVL for assistance. It has to be considered that by changing the final compression pressure or any other condition the ignition voltage gets modified. This means that by changing such conditions a previously successfully used spark-plug type might not be the right choice anymore under new conditions. Therefore it has to be always checked in advance if the used spark-plug still fits to the application. The customer is responsible to assure that the spark-plug is only operated under proper conditions to which AVL previously agreed to.

Heat Value

The heat value needs to match the heat value of the original standard spark-plug of the engine. If there are any doubts, it is better to choose a heat value one step cooler. AVL frequently recommends cooler than standard heat values in order to protect the engine during high stress operating conditions.

It has to be considered that by changing the load point or any other condition the heat transfer inside the spark-plug gets modified - that means that the necessary heat value of the used spark-plug may be now different. This means that by changing such conditions a previously successfully used spark-plug type might not be the right choice anymore under the new conditions. Therefore it has to be always checked in advance if the used spark-plug still fits to the application. The customer is responsible to assure that the spark-plug is only operated under conditions to which AVL previously agreed to.

Spark Position

The spark-position defines how far the inner electrode is projected from the spark-plug body. This is critical, as a wrong spark-plug can extend into the combustion chamber too far and will lead to a collision with the piston.

As the dimensions of the cylinder head or spark-plug body can vary between the different spark plugs or cylinders, it is better to measure the distance of the tip of the inner electrode to the sealing surface of the mounting threads as installed. This distance is measured without the sealing gasket, and accounts for any cylinder to cylinder or plug to plug variations.

Considering these recommendations regarding the Electrode Gap, heat value and spark position help to insure that the spark-plug sensor solution will give proper ignition and can operate for the expected lifetime.

It is within the customers' responsibility to check beforehand if the engine conditions have changed and if so to contact AVL to clarify if the spark-plug type in use is still the right type for the new measurement task. Please feel free to contact AVL for support and help in any case.