HARDWARE SETUP FOR LDV MEASUREMENTS IN AN IC ENGINE

TECHNICAL NOTE PDPA-002 (A4)

Contents

Introduction

There is much interest in the application of a spark plug mounted LDV system to measure internal combustion engine flows. Data can be captured at various engine speeds, throttle positions, and operating conditions, all without any modifications to the engine, such as large windows or extended pistons. This technical note will examine seeding and system setup considerations when using the system for IC engine measurements.

Problem and Solution

The TSI EP-12 and EP-14 IC Engine Adaptors can be mounted in a standard 12-mm or 14-mm spark plug port, respectively, but how is a system set up? What TSI parts are needed? What do you need to be careful about in working with the IC Engine Adaptor?

LDV measurements can be performed in one or two dimensions, allowing examination of the “Swirl” and “Tumble” velocity components. A TSI TR110 LDV probe is needed for one component measurements, and a TSI TR210 LDV probe for two-component measurements. Three focusing lenses are available, starting with the TLN01-50EP 50-mm focal length lens, for measurements in the spark gap region. Also available are a TLN01-60EP 60-mm focal length lens for measurements out to about 15mm, and the TLN01-80EP 80-mm focal length lens for measurements from about 20 mm to about 35 mm out from the cylinder head. The recommended light source is a TSI LA-300 laser operating at up to 600mW with a fiberlight™ multicolor beam generator to launch the laser light into the fibers. A TSI model PDM1000 converts the scattered light signals into electronic signals containing the Doppler bursts, wherein the flow velocity information is contained. A TSI model FSA3500 signal processor, EB external input option and EIC connection box allow phasing of the data to the engine crankshaft rotation. Figure 1 shows the probe as installed in a dual spark plug engine.

Seeding of the flow is best accomplished using oil droplets from a TSI Model 9306 6-jet atomizer, which outputs a mean particle size of approximately 1 micron. This atomizer offers good control over the seeding density as engine speed and throttle settings are varied. For each operating condition, the seeding density can be optimized by adjusting the number of jets opened. Begin by using only one jet, and examine the effect on data rate of opening an additional two or three jets. Always bring the engine up to operating speed, adjust any settings (throttle, boost, etc.), and only then begin seed particle generation. A slight negative pressure can be applied to the crankcase to extract any blow-by gases. These practices help minimize window fouling. A constant atomizing pressure is recommended, typically 250 kPa (35 PSI). To prevent engine wear/deposits and reduce toxicity concerns, edible food-grade lubricating oil, baby oil, or silicone oil can be used in the atomizer.

The seed particles should be introduced far enough upstream of the inlet valves to allow adequate mixing with the incoming air, but not too far that the oil collects on walls and other surfaces, which would be expected to shed large drops during operation. A simple “Y” pipe can be used to introduce the seeding.

Retainer Cap Installation

The TR110 or TR210 probe is a stand-alone device and not solely for use with the IC Engine Adaptor; therefore, upon delivery you may have to install the probe retainer cap.

1. Referring to Figure 2, remove the two screws holding a split ring in the retainer cap.
2. Slide the cap over the probe, so that the internally threaded end is towards the lens.
3. After reaching the monocoil region, set the unit on a table.
4. Now set one of the split rings on the monocoil, just beyond the threaded end, and slowly bring the cap over the ring until it lines up with the screw hole.
5. Insert the screw, tighten securely, and repeat with the other split ring.

Lens Installation

A TR110 or TR210 fiberoptic probe is delivered with a multi-purpose lens for use in air or under water, but not for use with the EP-12 or EP-14 IC Engine Adaptor.

1. Begin by removing this lens and installing the appropriate EP type lens. An EP type lens consists of the lens and a lens holder (which screws onto the probe). TSI suggests starting with the 50-mm focal length lens.
2. Tightly screw the lens holder onto the probe.
3. Start the four set screws into the holes in the lens, and then push the lens onto the holder, as shown in Figure 2.
4. Lightly tighten the three set screws, but not so tight that the lens cannot be turned. You do not want the *lens holder* to turn relative to the *probe*, you do want the *lens* to turn relative to the *lens holder*.
5. Now install the probe in the test stand provided, such that the shifted green beam exits the top.
6. Make a mark on the top of the probe, at the very back. Positive velocity channel 1 points in this direction.
7. Remove the probe from the test stand.

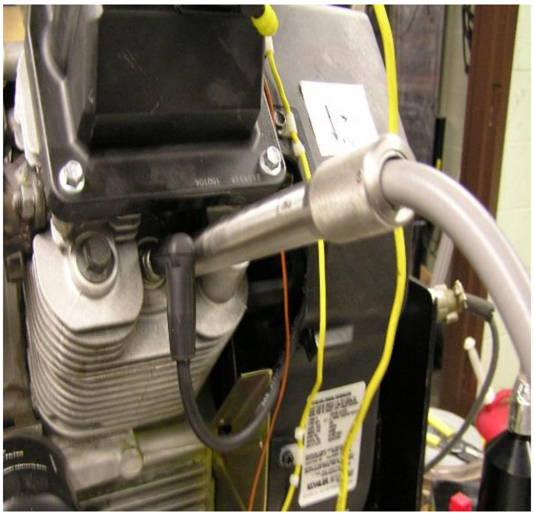

Figure 1. EP-14 and TR210 installed in a dual spark plug test engine

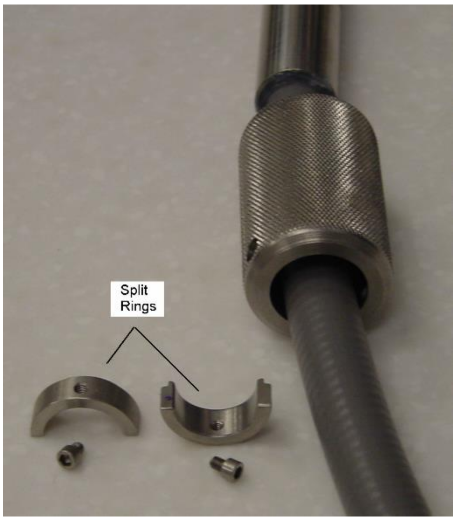

Figure 2. Probe retainer cap installation

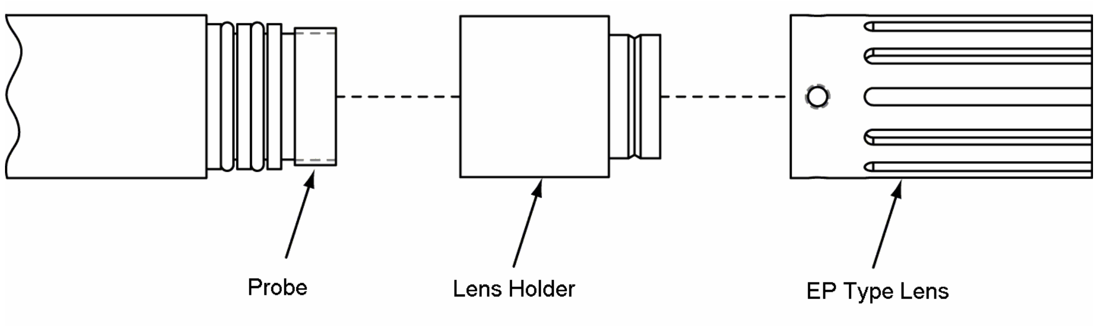

Figure 3. Probe with Lens Holder and Lens

Reference Direction

1. Next, install the EP-12 or EP-14 adaptor into the engine, and add the necessary washers or spacers to make the window flush with the inner head surface. A spark plug can be used to gauge the required depth. Use caution to avoid excessive protrusion into the engine because the piston or valves may hit the IC Engine Adaptor and cause damage. One 7.5-mm screw-on spacer is provided with the adaptor—other spacers and washers can be made in-house as needed.
2. Once the adaptor is torqued into the engine (use a 3/4inch wrench), make a mark on the end of the adaptor as to a reference direction, typically the dominant swirl direction.
3. Next, remove the adaptor and insert the probe into the adaptor. You may feel it "hit bottom" then turn slightly and go farther in. If not, gently turn the probe slightly to ensure that it is all the way in.
4. Then rotate the probe until the two alignment marks are aligned. Now the probe will sense channel one velocity in your reference flow direction.
5. Carefully withdraw the probe without turning it, and tighten the four set screws in the EP lens.

Measuring Position

Remove the probe from the adaptor. Using a flashlight, observe that there is a slotted ring in the bottom of the adaptor. This sets the depth to which the probe is inserted in the adaptor, and hence the measurement volume location (distance from the window). A large slotted screwdriver is provided to adjust the slotted ring. When the slotted ring is turned fully clockwise, the measurement volume is about 6.5-mm away from the window with the 50-mm focal length lens, 16.5-mm away with the 60-mm focal length lens, and 36.5-mm away with the 80-mm focal length lens. These distances are approximate, and a caliper or other measurement instrument may be used to determine it more accurately. Each rotation of the slotted ring moves the measurement volume location by 0.794 mm. Since the EP lenses are grooved, they provide 30-degree indexing of the probe, once a measuring position is decided. This allows a one-component probe, for example, to be used to make two-component measurements.

Results

The system was set up as described here and data was taken at 3060RPM in a test engine. Figure 4 shows the point-wise (raw) data and bin-averaged data, at full throttle position. From 0 to 180 degrees is the intake stroke, from 180 degrees to 360 degrees is the compression stroke. From 360 degrees to 540 degrees is the expansion process. The exhaust stroke is from 540 to 720 degrees. Large velocity magnitudes are seen during intake, with less and less variation (turbulence) seen during compression. It does not recover during expansion stroke, but during the exhaust process, you again see higher velocities and an interesting velocity trend for both swirl and tumble components.

Test engine image and data courtesy of Victor Salazar, Engine Research Center, University of Wisconsin–Madison.

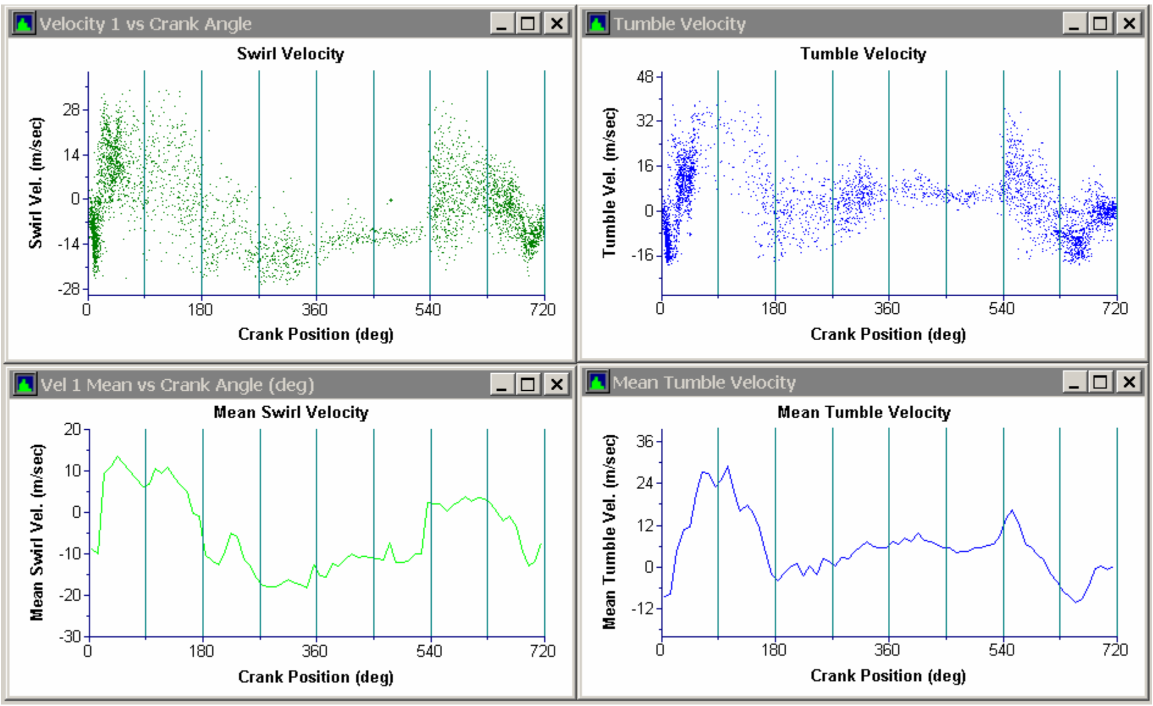

Figure 4. Swirl and Tumble components of velocity

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