OPTIMIZING LDV MEASUREMENTS IN AN IC ENGINE

TECHNICAL NOTE PDPA-001 (US)

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 optimizing seeding settings, laser power, software settings, and other parameters in order to get the best IC engine measurements.

Problem and Solution

TSI EP-12 and EP-14 IC Engine Adaptors utilize a standard 12-mm or 14-mm spark plug port, respectively. LDV measurements can be performed in one or two dimensions, allowing examination of the “Swirl” and “Tumble” 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 farther out from the cylinder head. The recommended light source is a TSI LA-300 laser operating at up to 600 mW 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 test engine.

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Optimization of the System

Seeding

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 opened jets. Begin by using only one jet, and examine the effect on data rate of opening an additional two or three jets. Recall that the upper valve on the Model 9306 opens one jet, the middle valve opens two jets, and the lower valve opens 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.

Laser Power

After seeding, laser power is probably the most important parameter for getting good quality velocity data in an engine. During setup and alignment, you especially need to be concerned about safety, so the minimum laser power necessary to produce visible beams should be used. Here, it is advised to use the IC Engine Probe Test Fixture, located in the accessory kit, to enable a power meter to be used to fully optimize the couplers for maximum laser power.

After the probe is inserted in the EP-12 or EP-14 IC Engine Adaptor (installed in the engine), the power can be increased, because there is no light escaping into the lab. TSI advises using at least 300 mW laser power when taking data. Air cooled lasers can be operated in current control mode and the power can be increased beyond 300 mW. In this case, and for water-cooled lasers, one can use at least 500 mW laser power.

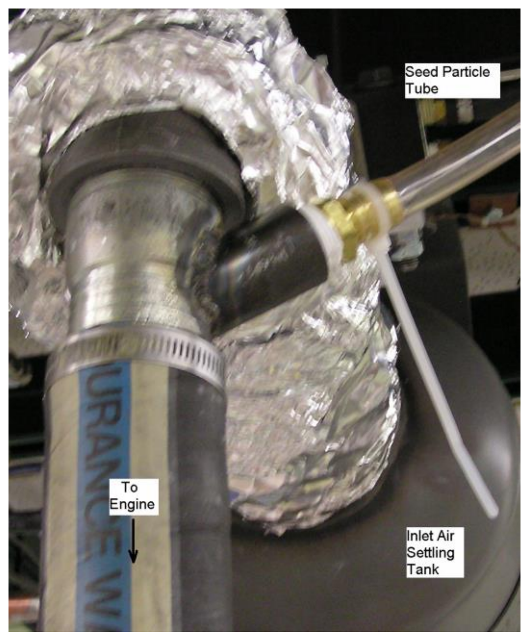

Figure 1. Example seed particle introduction

Software Settings

Initial software setup involves entering the parameters for the TR110 or TR210 fiber probe. These values and complete instructions are found in the LDV/PDPA Operations Manual, PN 1990048.

Software setup for IC Engine measurements involves enabling the "Once per Rev" (OPR) capability of FlowSizer™ software to synchronize the data capture with the engine. This is accessed by pressing **CNTL-R**, clicking the RMR tab, and selecting Encoder Parameters Mode = "Once per Rev." The "Degrees per Cycle" setting can be selected (usually 720 for four-stroke engines) and "Direction" selected. Then click the "**Windows**" button and create one window with the full number of degrees chosen above (0-359 or 0-719) so as not to gate out any data. If the shaft encoder marker pulse ("Z" pulse) is not at top dead center (TDC) enter the offset in the "Absolute Offset" field to make TDC correspond to the start of intake or power stroke. Apply these settings and close the window. Figure 2 shows settings for a four stroke engine with 90 degree "V" arrangement with the trigger pulse phased to the opposite cylinder bank (-90 degree Absolute Offset). Additional details are given in the LDV/PDPA Operations Manual, chapter 12.

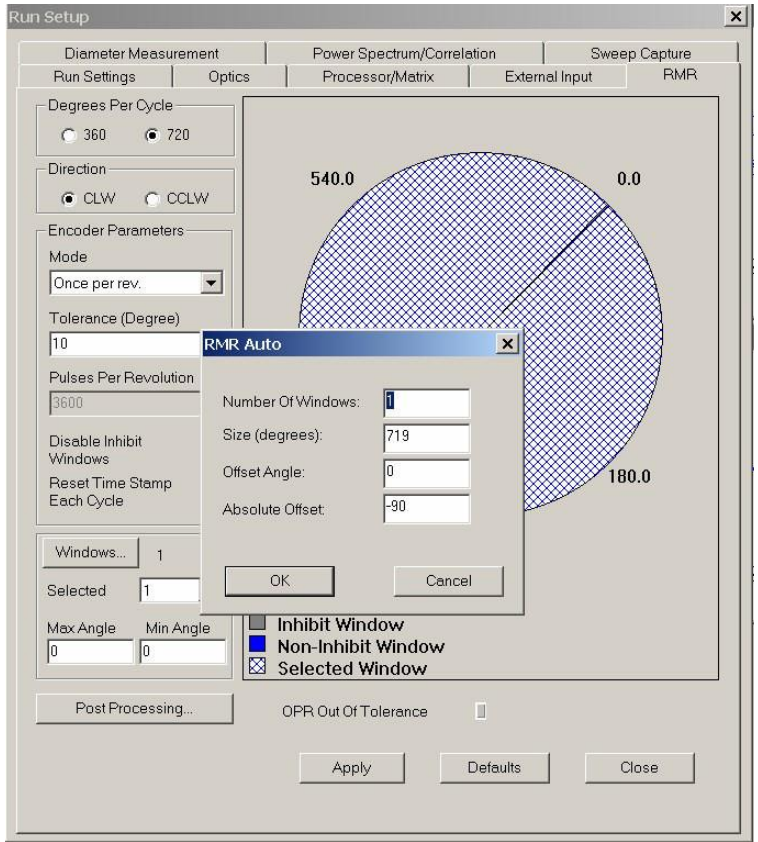

Figure 2. Software setup for engine synchronization

Once the system is set up and the engine operating, data collection can begin. One may start with the 2 to 20 MHz frequency band, and 35 MHz down mixing. Examine frequency histograms and look for clipping as discussed in chapter 2 of the LDV/PDPA Operations Manual. It may be necessary to move to a larger frequency band, like the 5 to 40MHz band. If there are significant negative velocities and minimal positive velocities, you may want to insert the probe in the EP-12 or EP-14 IC Engine Adaptor 180 degrees to its current orientation.

Once the frequency band and downmix values are selected, you optimize the PMT voltage (gain) to maximize data rate but minimize noise. If the laser power can be increased, it is preferable to increase the laser power rather than increase the PMT voltage (400V is a good starting point). Noise is indicated by a low "Burst Efficiency" reading (lower right corner of FlowSizer software) and by certain consistent velocities present in the data. Figure 3 shows an example of this, with the noise appearing at a velocity of 0 m/s. This type of noise can be eliminated by increasing the burst threshold. Typical values are 100 to 150 mV. Compare to Figure 4.

Other Parameters

Window fouling is often an issue to contend with when using any type of optical window in an IC engine. TSI does not recommend continuous firing when using the IC Engine Adaptor because of temperature limitations. Still, oil and other deposits can cause window fouling. One indicator of fouling is a lowering of the data rate. Another indicator is the appearance of data at 0 m/s velocity as shown in Figure 3, even after optimization of laser power, PMT voltage, and burst threshold. When this happens, the special TSI optical wipes in the TR110/210 accessory kit can be used to clean the window on the EP-12 or EP-14. Acetone, ethanol, or a commercially available glass cleaner can be used if necessary to remove stubborn deposits.

Image and data courtesy of Victor Salazar, Engine Research Center, University of Wisconsin-Madison

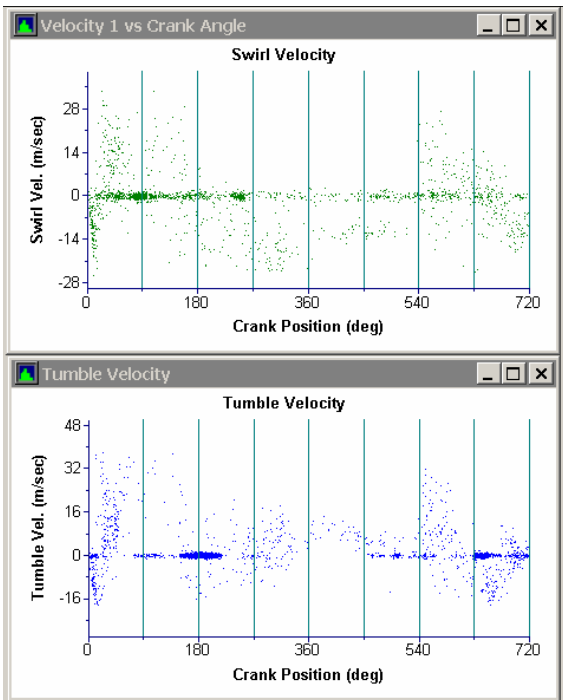

Figure 3. Noise in IC engine data

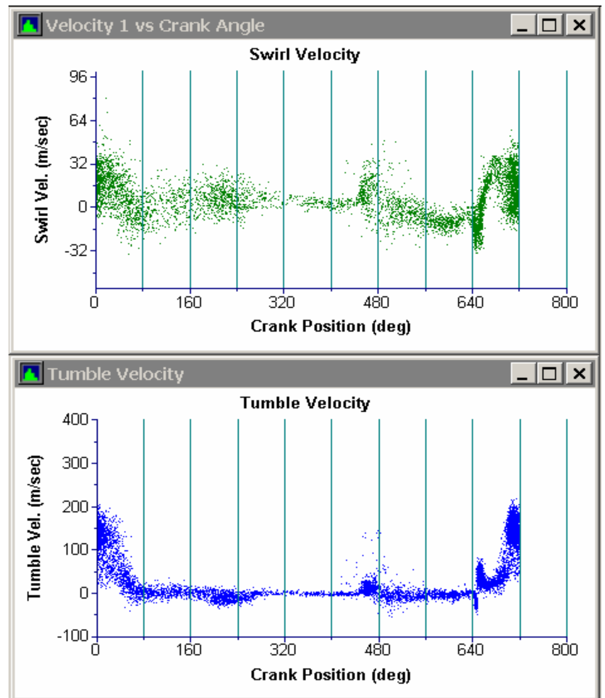

Figure 4. Typical IC engine data for 3000 RPM

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