NRC.CNRC

Motivation

- Support increased technical productivity by developing process technology to more effectively and efficiently estimate concentrations of particulate matter (PM) in Diesel engine exhaust
- This will enable the further development of emissions compliant engine products
 - -Develop efficient and effective soot management and dosing strategy for DPF's
- -Develop effective engine calibrations for reducing PM levels at different engine conditions
- -Facilitate further development of emissions compliant engine products

Background

- Currently "Gravimetric PM Sampling System" is used to measure PM, which is not real-time
- Laser Induced Incandescence (LII) is a real time, non-intrusive soot measurement techniques for rapid characterization of diesel particulate emissions
- The LII method has the advantage of being able to sample and report particulate emissions from either the direct exhaust or from a dilution tunnel facility

Approach

- In the present investigation, the LII instrument was evaluated extensively at the Constant Volume Sampling (CVS) emission laboratory at the Cummins Technical Center, where a Cummins' standard gravimetric PM measurement system is available as a comparative standard
- Collaborative efforts between Cummins Inc. and Artium Technologies are ongoing with the goal of advancing the LII capability for measuring real time soot at pre- and post DPF locations at transient and steady state engine operating conditions

Artium LII-200 Instrument

- LII technique evaluated was developed and patented by NRC Canada
- Artium Technologies Inc. commercialized LII-200
- LII-200 has 4 sub-systems:
- –LII power supply
 –Gas Flow Controller
- -LII Sensor Head
- -On-board computer with
- AIMS software (Advanced Instrument Management Software)

LII Advantages and Features

Measures real-time soot concentration (ppb & mg/m³)
 Sample dilution not required, can be used to estimate SVF in raw exhaust

Assessment of a Laser-Induced Incandescence Sensor for Real-Time Particulate Emissions Measurement

Ritesh C. Gujarathi^a, Virendra Kumar^a, Shirish A. Shimpi^a, William D. Bachalo^b, and Gregory J. Smallwood^c

· Short-term transient repeatability (COV)

-Gravimetric TPM: 2.1%

-SOF extracted PM: 5.3%

atest Results with Correct Calibration

· An issue was discovered with the neutral density

filters in the LII instrument; it was recalibrated on-site

-LII now is reporting lower SVF values than TPM

I E Sameline Dilute Exhaust

LII Sempling Day Exhau

· At high load, in both diluted and raw exhausts, LII

measured by the Cummins Gravimetric method

At low load, in raw exhausts, LII measures higher

measures about 95% of Dry PM from diluted exhaust

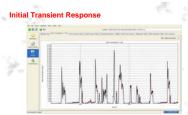
(ranging from 1.1 to 2 times), and in diluted exhaust

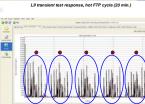
substantially lower, as compared to Dry PM from

diluted exhaust measured by the Cummins

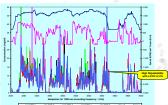
-LII: 3.5%

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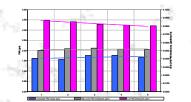




Five repeats of LII transient test response, hot FTP cycle (20 min.

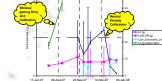


s of LII response vs. speed and torque for transient tests, hot FTP cycle (20 min.)



PM emissions (gm) from five repeats of transient testing • LII transient response higher by 1.6 * TPM and 2.0 * SOF extracted PM

Gravimetric method



Above graph shows the historical development of LII system at Cummins. This involved combined partnership to work with Artium and NRC to resolve sampling and instrument issues including: Leak in the system, software issues, improving sampling system, correcting Neutral Density filter issues
 There is still work in progress to further refine the system to expected traceability and accuracy

Critical Parameter Measurement



 Cummins, Artium, & NRC worked during the on-site visit at Cummins (13-15 Nov'07) to identify sources of uncertainty

Summary

LII current status:

- -The LII technique is capable of monitoring PM emissions by estimating soot concentration and primary particle size
- The currently implemented improvements to the LII resulted in repeatable measurements of soot volume fraction from the LII with a short term Coefficient of Variation (COV) of 3-7% for steady state cycles and a COV of 3-5% for FTP transient cycles for the equivalent gravimetric PM level ranging from 0.01 to 1.00 g/bhp-hr
- The correlation between time-integrated LII signals and the standard gravimetric PM measurement system was found to be robust with a correlation regression coefficient ranging from 96%-99.8%

-LII has been tested for Steady States, Transients, Raw Exhaust, PM Trap-out

- -LII reported similar readings compared to Dry PM measured using Cummins gravimetric method at higher load conditions, and much lower to about 0.9 to 2 times at low load conditions
- -LII-200 is nearing readiness for Prime Testing -Expected in the near future

• Work Ahead:

- –Reliable calibration of Neutral Density filters from 3rd party laboratory
- Determine most appropriate values of Soot Absorption Function $E(m\lambda)$ and relative absorption function
- Ongoing work to increase sensitivity through improved signal averaging and processing
- Packaging Feasibility of installing exhaust gas Sampling System to control volumetric flow and pressure in the sample cell

National Research Conseil national Council Canada de recherches Canada



18th CRC On-Road Vehicle Emissions Workshop San Diego, California, March 31 – April 2, 2008

LII steady-state response higher by ~ 1.7.2.5 * TPM.
 Short-term steady-state

Initial LII Steady State Response

Technologies In

· Insensitive to presence of other emission gas species

High resolution (0.01mg/m³) and high repeatability (2-

(counts vs. size): Below - validated mass

Data recording frequency: 1-20 Hz and connectivity

· Ease of operation, portable to transport and

Comparison Between Two LII-200 Instruments

LI Comparisor

LEA1 main?

with host data acquisition system

maintenance free working

5%)

Absolute intensity calibration

Example AIMS results from LII-200

-LII: 3-7% -Gravimetric TPM: 2-5% -SOF extracted PM: 3-25%

PM mass (gm) representation for 5 mode s/s tests (with 3 repeats)