Effects of Fuel Sulfur Content and Dilution Conditions on Engine PM Emissions under Transient Conditions

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INTRODUCTION

The U.S. has introduced ultra low sulfur diesel fuel in 2007 and by 2010 will completely replace the current low-sulfur diesel fuel which has a sulfur content of less than 500 ppm. As a result, most diesel engines, including new and aged ones, are currently implementing ULSD. Thus, it is important to understand how ULSD will affect these engines' emissions, especially under transient conditions when the load, speed, exhaust gas temperature, and primary dilution ratio change continuously.

This study is to assess the effects of fuel sulfur content and aging condition on PM emissions under transient conditions. Combinations of fuels and primary dilutions were used. The primary dilution was accomplished by a CFV-CVS, a system which maintains proportional sampling throughout temperature excursions and is designed for engine emission certification. Data were collected by a Scanning Mobility Particle Sizer and an Engine Exhaust Particle Sizer for steady-state and transient testing, respectively. Although the steady-state results show reasonable agreement with previous studies, the transient results display significant discrepancy when ULSD and LSD were used with the high primary dilution ratio.

EXPERIMENTAL METHODS

A 1992 International engine controlled by a General Electric direct current dynamometer rated at 149 kW (200 hp) was tested in this study. The engine was used to power a school bus for over 250,000 miles, typically under severe stop-and-go driving conditions. The engine exhaust was initially diluted in a CFV-CVS tunnel. A sample of the homogeneously-mixed exhaust stream was then taken iso-kinetically to an aging chamber with a 2:1 dilution ratio and a two-second residence time. The exhaust was then sampled and diluted further by two ejection-type micro-diluters. The diluted sample was then measured by particle sizing instrumentation.

Data were collected for LSD and ULSD fuels. The engine was run with each fuel for two CFV-CVS tunnel flow rates. ISO modes 1, 8 and 11 were run for steady-state data collection and FTP HD cycles were run for transient data collection.

RESULTS AND DISCUSSION

STEADY STATE TESTS

Steady state tests were conducted to observe the effects of fuel sulfur content and primary dilution on PM number emissions, and compare the results to findings from previous studies.

Figure 1 shows the dilution-corrected, normalized particle distribution of ULSD and LSD for the three ISO Modes tested. ISO Modes 1 and 8 led to the formation of only accumulation mode particles with no distinct nuclei mode formation. Therefore, no fuel sulfur effects were evident under these operating conditions, consistent with the results of previous studies.

Figure 2 shows particle size distributions with LSD from a CFV-CVS tunnel with different flow rates. The only visible variance due to dilution ratio in Figure 2 was in the size distribution of ISO Mode 1.

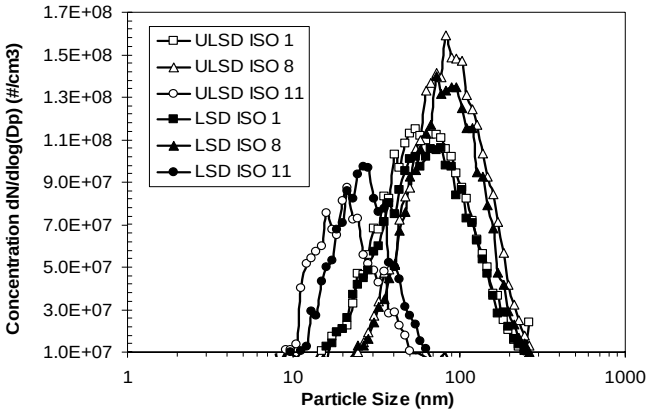

Figure 1. Particle size distributions as a function of fuel sulfur content

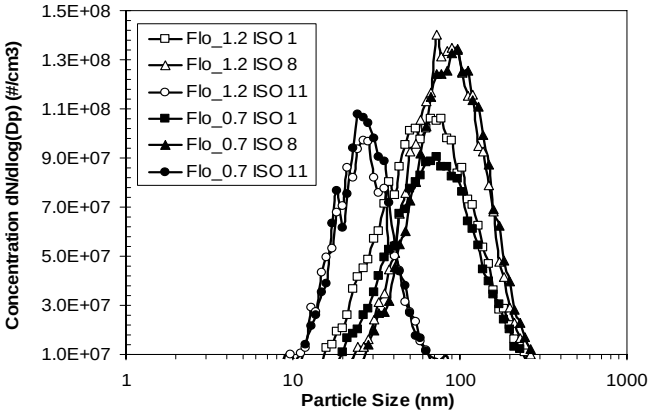

Figure 2. Particle size distributions as a function of dilution ratio

TRANSIENT TESTS

In order to characterize the emissions pattern during transient operation of the engine, instantaneous data of a deceleration and an acceleration during the FTP cycle were analyzed. The particle size distributions from the deceleration and acceleration are represented by three single-second curves: the beginning, middle and end of each event.

Figure 3 shows the particle size distributions during deceleration. The nuclei mode PM emissions for LSD are significantly higher than for ULSD for the duration of the event. It is evident that the conditions of deceleration promote nuclei mode particle formation.

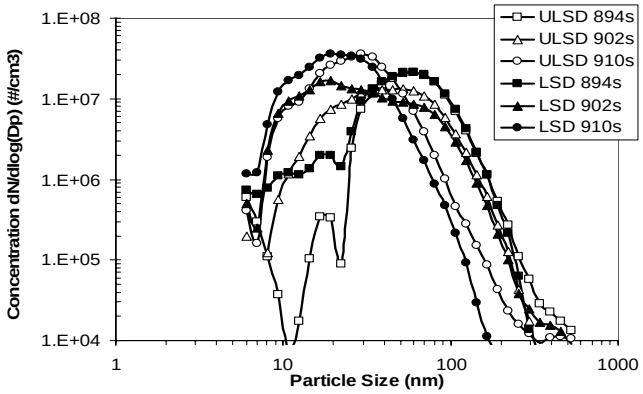

Figure 3. Particle size distributions as measured by the EEPS during deceleration.

The single-second PM data for the acceleration are shown in Figure 4. The distributions show little difference between the use of LSD and ULSD until the end of acceleration. At that time, the nuclei mode peak from the use of LSD is higher than the peak from the use of ULSD. This is consistent with the previous findings that nuclei-mode particle formation is strongly affected by fuel sulfur content and engine load.

Figure 5 displays the total number of all particles emitted for each testing configuration. The total number of PM emissions during an FTP cycle is higher when LSD is used at the higher primary dilution ratio. No statistical difference is observed, however, when the lower dilution ratio was used.

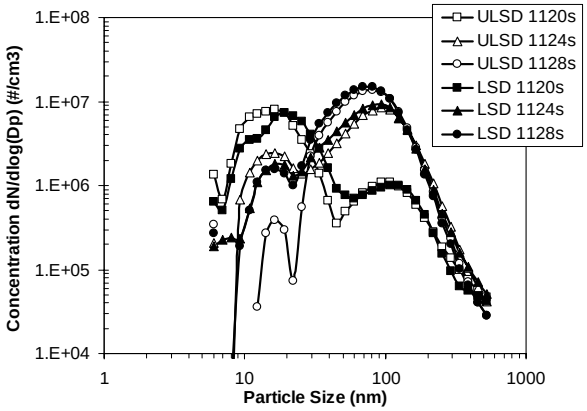

Figure 4. Particle size distributions as measured by the EEPS during acceleration.

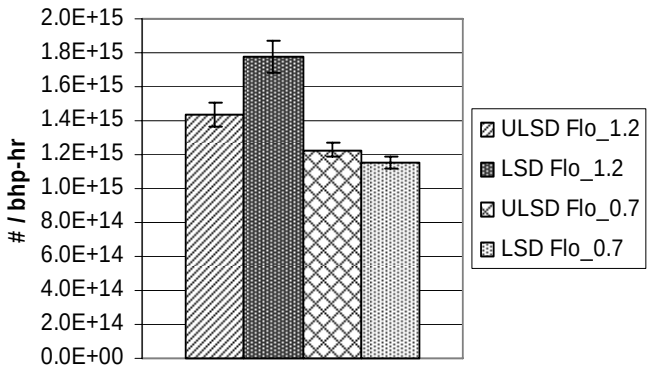

Figure 5. Average total PM number emissions as measured by the EEPS.

CONCLUSIONS

The effects of fuel sulfur content and primary dilution ratio on heavily-used diesel engine emissions observed during transient operations differ from those observed during steady state operations, though further research is required to gain a full understanding of the discrepancies.

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