MEASURED vs. MODELED BIODIESEL EXHAUST

Deriving Model Estimates from the EPA’s MOtor Vehicle Emission Simulator for Comparison to Measured Biodiesel Exhaust: A MOVES2010b Evaluation

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MOTIVATION

The EPA’s MOVes Vehicle Emission Simulator (MOVES) utilizes second-by-second model (i.e., acceleration/cruise, braking, and idle) vehicle activity patterns to estimate mobile source emissions rates. MOVES estimates emissions rates on the basis of vehicle operating modes (OpModes), which are defined by vehicle specific power (VSP) and vehicle speed. OpMode specific emissions rates in the MOVES relational database are based on statistical and physical relationships between available data from existing emissions researches on a wide range of vehicle types and ages operating on different fuels [1]. Certain real-world conditions are not currently well-represented in the MOVES database. This is a growing issue as new vehicle technologies and emissions regulations continue to develop. In particular, MOVES estimated emissions from modern light-duty vehicles fueled by biodiesel blends are presently based on very limited data sources and assume overly simplistic relationships between operational variables and emission rates.

The overall aim of this work is to compare the accuracy of MOVES2010b emissions rates by OpMode for a passenger car running on various blends of biodiesel to real-time emissions data (gas and particle phase) collected from a 1.9L Volkswagen diesel engine coupled to an eddy current dynamometer (Amfield CM20 system). The engine was run on a transient drive-cycle developed from on-road data and fueled by waste cooking oil based biodiesel blends (B0, B10, B20, B50, and B100). In order to accomplish the overall goal, it was first necessary to generate suitable MOVES emissions rates estimates for comparison, as described in the following work.

OBJECTIVES

- Generate baseline modal emissions rates from MOVES for comparison to CM12 (light-duty diesel engine) data
- Determine what adjustments MOVES makes for different blends of biodiesel fuel
- Conduct a sensitivity analysis for temperature and humidity to determine how these factors affect MOVES results

METHODOLOGY

Sequences of MOVES runs were conducted at the project level (microscale) in order to simulate a single diesel passenger car operating under various conditions (changes in meteorology or biodiesel content). Inputs were used to generate emissions rates (g/hr) for individual road segments, each representing one hour of activity at a running exhaust OpMode (Table 1) [2]. Emissions rates by OpMode were then converted to g/kg for later comparison to second-by-second measured CM12 emissions rates. Emissions rates were generated for all pollutants modeled by MOVES, but only Particulate Matter (PM2.5), Carbon Monoxide (CO), Total Hydrocarbons (THCs), Oxides of Nitrogen (NOx), Acetaldehyde, Formaldehyde, and Azoene were analyzed for this study. These pollutants were chosen both for their recognized risk to health (EPA Criteria Pollutants and Mobile Source Air Toxics (MSATs)), as well as their comparability to CM12 emissions data.

Fuel formulation inputs were based on known fuel parameters from CM12 tests. Only biodiesel content was adjusted in each run of a sequence (0, 10, 20, 30, 50, and 100% biodiesel) in order to examine the effect of parameter on emission rates. Diesel (DB) was used as the baseline condition.

A sensitivity analysis was conducted for meteorological conditions (temperature and humidity). Preliminary tests indicated increased conditions of 20°C (68°F) and 50% relative humidity (RH) to be a suitable baseline, both because MOVES makes no adjustments to emissions rates based on air conditioning (AC) at this point, and also because it is within the range of meteorological conditions for CM12 tests. From this baseline, a temperature sensitivity analysis was conducted by changing only temperature in increments of 5°C from 0°C to 50°C for each MOVES run. A humidity sensitivity analysis was conducted by changing only RH in increments of 10% from 0% to 100% for each MOVES run.

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REFERENCES


RESULTS & CONCLUSIONS

Tables 1-4 show MOVES emissions rates generated for the baseline condition. Results for NOx (Acetaldehyde, Formaldehyde, and Azoene) are not shown because they exhibited constant ratios to THC across all conditions and for all OpModes (0.056, 0.0685, and 0.0667 respectively).

Figure 3-5 shows the results of the temperature sensitivity analysis for each pollutant. The negligible change in PM2.5 suggests insensitivity to changes in temperature. CO, THCs, and NOx exhibited sensitivity between 20°C and 40°C, with general increases in emissions rates. A review of the EPA technical literature suggests that these changes are primarily a result of the model assuming increased usage of air conditioning (AC) under these conditions. MOVES utilizes heat index (a factor combining both temperature and humidity) to estimate a percentage of air conditioning use [4]. Accessories such as AC place additional load on the engine, thereby affecting emissions. Approximate points at which AC use begins and when it reaches 100% are shown in the temperature sensitivity plots.

Only NOx exhibited sensitivity to changes in RH, the results of which are shown in Figure 6. MOVES utilizes a NOx humidity correction factor based on coefficients for gasoline (0.00038) and diesel (0.00020), which decreases NOx emissions rates for increases in specific humidity [4]. This effect can also be observed in the temperature sensitivity plots of NOx emissions, because specific humidity increases with temperature (assuming RH is held constant). The humidity correction factor dampens the NOx AC adjustment factor for the Idle OpMode, outweighing it for braking (thus the overall decrease), and cancels out this factor for all other OpModes.

SUMMARY

- MOVES utilizes simple emissions rates adjustment factors for biodiesel content and MSATs
- MOVES light-duty diesel exhaust running emissions rates are generally insensitive to changes in temperature and humidity
- Adjustment primarily based on assumed AC usage at certain heat index values
- NOx demonstrates sensitivity to specific humidity, through both changes to RH and temperature

FUTURE WORK

CM12 second-by-second emissions rates will be binned based on engine power output for comparison to MOVES OpMode bins. The work described here suggests that MOVES estimated emissions rates from a diesel passenger car at 20°C and 50% RH (before adjustments are made for AC usage) are a suitable baseline for comparison to CM12 measured emissions rates. Comparison of NOx emissions rates (MOVES vs. CM12) may need to take humidity sensitivity into consideration. Finally, the possibility of developing an algorithm for implementation of Particle Number (PN) emissions rates into MOVES based on current MOVES PM2.5 estimates and relationships between CM12 PM2.5 and PN data will be explored.