FMCSA Contact: Albert Alvarez (MC-RRR) 202-385-2387

Improving Heavy-Duty Diesel Truck Ergonomics to Reduce Fatigue and Improve Driver Health and Performance

Background

The purpose of this study was to measure several factors inside the cab of heavy-duty diesel trucks (HDDVs) that may affect the health and performance of long-haul freight truck drivers. The evaluated factors were noise level, vibration from driver and passenger seats, and in-cab air quality. The data collected for this study are intended to serve as a baseline for future similar studies that may determine whether new truck designs impact these factors for the drivers.

The project also sought to develop a computer model to compare the dynamic trucks behavior without the expense of road testing and to investigate the relationship between specific vehicle components and vibration levels in the cab. Very few studies have been conducted in the United States on vibration from heavy-duty diesel truck seats.

The focus of the study was the Class 8b category HDDV, defined by the U.S. Environmental Protection Agency (EPA) as vehicles with gross vehicle weight rating greater than 27,216 kg (60,000 lb).

Method

The sample was comprised of 27 Class 8b category HDDVs of the latest-model-year vehicles available at the time of the study from four truck manufacturers. All measurements were conducted while the trucks were parked with the engines idling at a truck-stop rest area and during an actual on-road driving episode that included interstate and State highway driving over moderately steep and relatively flat terrain. The parked engine-idling test involved measuring in-cab air quality under several engine/heating, ventilation, and air-conditioning (HVAC) modes of operation.

The evaluated factors were noise level, whole-body vibration (WBV) from driver and passenger seats, and the air quality inside the cabin. Noise data were collected continuously during the on-road driving test by an integrating, averaging sound-level meter that was attached to the right-hand arm-rest of the driver seat. WBV data was collected by vibration transducer pads installed on the driver and passenger seats, and on the cab and truck body frame. In-cab air quality was evaluated by analyzing concentrations of carbon monoxide (CO), oxides of nitrogen (NOX), and particulate matter less than 2.5-µm in aerodynamic diameter ($PM_{2.5}$). During the parked-idling test, instruments were located in the bedding or trough area of the sleeper berth. Vibration data for computer modeling purposes was collected by several vibration transducers placed on the cab and truck body.

Programs of the Federal Motor Carrier Safety Administration (FMCSA) encompass a range of issues and disciplines related to motor carrier safety and security. FMCSA's Office of Analysis, Research, and Technology defines a "research program" as any systematic study directed toward fuller scientific discovery, knowledge, or understanding that will improve safety, and reduce the number and severity of commercial motor vehicle crashes. Similarly, a "technology program" is a program that adopts, develops, tests, and/or deploys innovative driver and/or vehicle best safety practices and technologies that will improve safety and reduce the number and severity of commercial motor vehicle crashes. An "analysis program" is defined as economic and environmental analyses done for agency rulemakings, as well as program effectiveness studies, state-reported data quality initiatives, and special crash and other motor carrier safety performance-related analyses. A "large truck" is any truck with a Gross Vehicle Weight rating or Gross Combination Weight rating of more than 10,000 pounds.

Currently, the FMCSA Office of Analysis, Research, and Technology is conducting programs in order to produce safer drivers, improve safety of commercial motor vehicles, produce safer carriers, advance safety through information-based initiatives, and improve security through safety initiatives. The study described in this Tech Brief was designed and developed to support the strategic objective to produce safer drivers. The primary goals of this initiative are to ensure that commercial drivers are physically qualified, trained to perform safely, and mentally alert.

U.S. Department of Transportation
Federal Motor Carrier Safety Administration

Office of Analysis, Research, and Technology
1200 New Jersey Ave. SE
Washington, DC 20590

Findings

The noise levels inside the cab were reasonably low, most likely the result of insulation from wall padding and floor carpeting installed in the cabin and sleeper berth areas. The two main areas of concern are vibration from the seats and the high $PM_{2.5}$ levels that drivers may encounter while the trucks are parked with engines idling at truck-stop rest areas as the drivers sleep in the cabs.

Noise Level

Overall results indicated that the noise levels (measured in the trucks during the on-road test) were well below the Occupational Safety and Health Administration (OSHA) permissible exposure level (PEL)—90 dBA—and/or the National Institute for Occupational Safety and Health (NIOSH) recommended value—85 dBA for an 8-hour work day.* Additionally, the noise levels in the test trucks did not exceed the Action Level (AL), which was 50 percent of the maximum PEL. This study tended to show overall noise levels to be somewhat lower than those usually reported in the manufacturers' literature, which generally shows the noise levels greater than the AL. Slighter higher noise levels were measured during interstate travel relative to State highway travel. It is believed that noise from tires, engine revolutions per minute, and wind impacting the cab at higher road speeds contributed to the elevated noise levels during interstate driving because higher road speeds are generally permitted on the interstates. Basically, the noise levels were similar across the truck manufacturers, although some slight differences were observed.

Whole-body Vibration (WBV)

Differences between truck manufacturers with respect to vibration were somewhat more pronounced than the noise-level differences observed between truck manufacturers. Overall results in all cases indicated that vibration (in units of acceleration) from the seats was generally below the European Union exposure action level—0.5 m/s^2 for an 8-hour driving day. Exposure limits were exceeded in a few trucks, but for the most part these were isolated and occurred while the trucks were driven on pavements that were in poor condition. Significant differences in WBV existed between truck manufacturers, and between interstate and State highway driving, with the higher WBV occurring on the highway. The comfort index of the seats, in the majority, fell within the "a little uncomfortable" region, which is one step removed from the best rating possible (i.e., the "not uncomfortable" region). Comparison between floor and seat vibrations showed that the floor vibration was absorbed by the seats before it could be transmitted to the driver.

Air Quality

For the parked engine-idling tests, overall CO, NOX and $PM_{2.5}$ concentrations were relatively low inside the cab when the truck engine and the HVAC system were turned off. Highest CO and NOX concentrations occurred during engine-on and HVAC in recirculation modes. High $PM_{2.5}$ concentrations occurred during engine-on and HVAC in fresh-air mode and during engine-on and fan-off modes. These results suggest that long-haul trucks have a tendency to self-pollute the cab during extended periods of parked-idling. It is believed that the problem of self-pollution and the close proximity of many trucks idling at the same time in truck-stop rest areas create conditions for certain

*According to Federal Motor Carrier Safety Regulations (49 CFR part 393.94), the interior sound level at the driver's seating position must not exceed 90 dBA, as measured when the truck is parked with all doors, windows, and vents closed; all power-operated accessories turned off; and, with the transmission in neutral, the engine is accelerated to—and stabilized at—either its maximum governed engine speed if it is equipped with an engine governor, or its maximum rated horsepower. The regulation does not specify a maximum time-weighted-average dBA level for an 8-hour work day, which was the standard used in this study.

byproducts of engine combustion to enter the cab via the HVAC system or by air infiltration that occurs naturally from cracks between windows and doors. Self-pollution occurs when a percentage of the vehicle's own exhaust enters the cab. The measured concentrations of CO for all of the engine/HVAC modes of operation were well below the OSHA 8-hour time-weighted average (50 parts per million [ppm] by volume) and should not pose health problems for the drivers sleeping in cabs during rest periods. However, the measured diesel $PM_{2.5}$ concentrations, which are known to cause various respiratory and health problems, exceeded the EPA National Ambient Air Quality Standards (NAAQS), which are 35 $\mu g/m^3$ (the 24-hour average) and 15 $\mu g/m^3$ (the annual average). These results were in line with similar studies that measured in-cab concentrations during parked-engine idling conditions at truck-stop rest areas. It should be noted that the NAAQS for $PM_{2.5}$ for the 24-hour averaging time is not to be exceeded more than once per year on average over 3 years, and the 3-year average of the weighted annual mean $PM_{2.5}$ concentrations from single or multiple community-oriented monitors must not exceed the annual average.

For the on-road tests, the in-cab concentrations of CO, NOX, and $PM_{2.5}$ were much lower than the concentrations measured during the parked-idling tests. Average CO, NOX, and $PM_{2.5}$ concentrations during parked idling were approximately 1.3, 4.8, and 4.5 times greater, respectively, than the average on-road concentrations. This suggests that there is less chance of a truck self-polluting the cab while it is being driven than while it is parked and idling. In-cab concentrations were noticed to be slightly higher, however, while driving on the interstate, relative to driving on the State highway. This condition is thought to be caused by the higher vehicle densities normally present on the interstate—a larger number of vehicles producing a greater quantity of pollutants that enter trucks through their HVAC systems.

Computer Modeling

A computer model was created that can predict the vibration at any selected point on the tractor, and data collected for this study were used as input to the model. Although the feasibility of developing a method to validate a computer model of one of the test trucks was demonstrated, this objective was not achieved due to manufacturers declining to provide proprietary specifications.

Recommendations

Vibration

While the seats for these test trucks were adequate overall in reducing WBV based on the comfort index used in the study, there is still room for improvement. Also, it may be necessary to train drivers in the proper use of the seating adjustments, so that they use the seat controls to full effect.

The sample of test trucks was relatively small in this study and at least 90 percent of the seats were manufactured by a single company. Also, the vehicles were lease- or rental-trucks, so it was likely that the standard (not the optional) seats were installed in the trucks for reasons of cost. Since a wider range of seats was not adequately represented in this study, it is unknown if all seats perform identically in the ability to attenuate vibration exposures for the driver. Therefore, it is recommended that a broader range of trucks be tested in future studies which will include more seat models from several manufacturers.

Air Quality

Offering a recommendation in this area is somewhat complicated because the most straightforward solution for improving the air quality in the cabin during periods of parked idling would be simply to prohibit engine idling while a driver is resting in the sleeper berth. However, to do this would severely limit the driver's use of the vehicle's heat and air conditioning, or comfort appliances such as a microwave or television, that depend on the idling engine to operate. A solution might be an electric system that provides external current to the vehicle so that the on-board appliances can be operated without idling the truck engine.

The presence of numerous trucks parked and idling together in close proximity at a truck-stop rest area exacerbates the air-quality problem in the cabs for the other drivers. Since a possible $PM_{2.5}$ problem exists, it is also likely that other gaseous hydrocarbon emissions, such as formaldehyde or acetaldehyde, may be present in the cab during extended periods of parked idling. The authors recommend additional research to better define and identify whether any of these other diesel engine combustion byproducts are present in the cabin during periods of extended idling.

Full report title:
Improving Heavy-Duty Diesel Truck Ergonomics to Reduce Fatigue and Improve Driver Health and Performance (Document No. FMCSA-RRR-10-010)

Authored by:
Joshua S. Fu,
Jimmy Calcagno III,
Wayne T. Davis

Performing Organization:
The University of Tennessee
Dept. of Civil & Environmental Engineering
1506 Middle Drive;
223 Perkins Hall
Knoxville, TN 37996

Key Words:
CMV, comfort, ergonomics, HDDV, heavy duty diesel truck, in-cab air quality, noise level, vibration, whole-body vibration

Web Site:
All FMCSA Tech and Analysis Briefs may be accessed at www.fmcsa.dot.gov.

December 2010
Publication Number:
FMCSA-RRR-10-010-TB