IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 12, Issue 1 Ver. III (Jan- Feb. 2015), PP 29-34
www.iosrjournals.org

Practical Investigation of the Environmental Hazards of Idle Time and Speed of Compression Ignition Engine Fueled With Iraqi Diesel Fuel

Miqdam Tariq Chaichan [1], Sajda Sabri Faris [1]
[1]*(Mechanical Engineering Dept., University of Technology, Baghdad, Iraq)*

Abstract: *Idle emissions of unburnt hydrocarbon (HC), CO, CO_2, NOx, particulate matter (PM) and noise measured from multi-cylinder direct injection diesel-fueled engine. The purpose was to evaluate the hazards collateral to operating the engine at idle speed for long periods. Experiments were conducted at various speeds (900, 1000, 1200 and 1500 rpm) and for 20 min period. The measurements obtained each 5 min.*
The results indicate that increasing idle time increased CO, HC, NOx, PM, and noise, at the same time reduced CO_2 concentration. Increasing idle time deteriorated combustion causing lower CO_2 while the other emissions increased profoundly. Increasing idle speed improved the combustion and reduced CO, HC, PM and noise while increased CO_2 and NOx.
Keywords: *Engine idling, idle time, NOx, PM, HC, CO, noise. .*

I. Introduction

Climate change is an essential issue of concern for the last two decades. Climate change tied to energy usage and the emissions emitted from fossil fuels combustion. Huge efforts are made to the use of that energy efficiently and to reduce the emitted carbon dioxide quantity from all the used energy sources [1]. The idle period for heavy-duty diesel vehicle consumes fuel and emitted emissions that reduce atmospheric quality. Idle engine operation is crucial to provide the cab heat or air-conditioning that supply the driver comfort. However, preventing this operation mode or period needs legislation, in addition to public edification for its importance to air quality [2].

Heavy-duty trucks have been subjected to many valuable improvements to achieve high efficiencies. In addition to reducing its fuel consumption, within the existing profiles of tractor and trailer operated all over the world [3, 4, 5 & 6].

One obstacle to defining idle operation impact on air quality and human health is the lack of a comprehensive tailpipe emissions database that describes these effects. A large number of studies investigated and quantified idle emissions of heavy-duty diesel vehicles. The primary target of these studies was to understand the impact of engine speed and load on idle emissions and to evaluate the idle reduction technologies performance. Mc-Cormick [7] tested the emissions of idle operation of 24 heavy duty diesel vehicles and four heavy-duty compressed natural gas vehicles. Diesel trucks emitted considerable quantities of HC, CO, NOx, and PM emissions during idling compared to compressed natural gas trucks. Brodrick [8] tested the engine speed and loaded impact on idle emissions on a 1999 model year Freightliner truck powered by a 450 horsepower engine. Increasing the engine speed with air conditioning operated; resulted in increasing emissions of CO, NOx, and CO_2. It also increased the consumed fuel by 70%.

Chaichan [9] reported an increment in idle emissions of CO, HC, NOx, PM, and CO_2 with adding EGR to the suction manifold. Idle NOx concentrations increased with time; also, fuel injection control did not have any effect on CO_2 concentrations. The study concluded that the usage of the air conditioning in the truck without increasing engine speed increased the emitted emissions. Increasing the engine speed increased the emissions of CO_2 and NOx highly, whereas PM and HC emissions increased by 100% and 70%, respectively.

Idle operation emitted emissions have serious impacts on human health, but truck drivers are specifically at risk. Their long-term exposure to diesel exhaust increases the hazards of lung cancer [10]. The recent studies of air pollution inside and outside of trucks at idling indicated an increase in fine particulates emissions [11, 12 & 13]. The studies verified that the pollutant exposure, when the driver is resting in a truck with the engine idling has a disruptive of sleep comfortably. Sleep intermittence causes driver exhaustion during waking hours [14].

Idle reduction includes methods and technologies needed to be provided. Alternatives for cabin heating and cooling must be taken into consideration. Maintaining the engine and reduce fuel sulfur content, improving system warming for easy startup. Also, the providing of electricity for other amenities activities can lessen the engine idle operation at stopping points. Many idle reduction technologies used including onboard direct-fired heaters. The off-board stops electrification equipment on the truck that supplies electric power for air conditioning, heating, and ventilation [15].

In this paper, the idle emissions quantity measurement was the one of primary targets. The examination of the effect of elevated engine speed and engine idle time on idle emissions was one of the targets. Iraqi conventional diesel fuel employed in the engine idle period evaluated, also.

II. Experimental Setup

2.1 Equipments

Fiat diesel engine used in the tests is direct injection, water-cooled, four cylinders in-line, and naturally aspirated. Table 1 represents the major specifications of the tested engine. A hydraulic dynamometer is coupled to the engine to control the applied load. An emissions analyzer type Multigas model 4880 was used to measure the concentration of regulated emissions (NOx, HC, CO_2, and CO).

Emitted PMs collected by a device type Sniffer L-30 (low volume air sampler). PMs obtained by means of Whatmann-glass micro-filters. These filters weighted before and after the end of sampling operation period that extend for half an hour every time. At the end of each sampling period, each filter was kept in a plastic bag provisionally until weighing and analyzing the outcomes.

Particulate matters (PMs) concentrations determined by the equation:

$$\text{PM in } \left(\frac{\mu g}{m^3}\right) = \frac{w_2 - w_1}{V_t} \times 10^6 \qquad (1)$$

Where: PM = the concentration of particulate matters in ($\mu g/m^3$).
w_1 = filter weight before the sampling period in (g).
w_2 = filter weight after the sampling period in (g).
Vt = the drawn air total volume (m^3)
The equation to evaluate Vt is:

$$Vt = Q_t \cdot t \qquad (2)$$

Where: Q_t= Elementary and final air flow rate through the device (m^3/sec).
t = sampling time in (min).

Table 1 Tested Engine Specifications

Engine type	4cyl., 4-stroke
Engine model	TD 313 Diesel engine rig
Combustion type	DI, water cooled, natural aspirated
Displacement	3.666 L
Valve per cylinder	Two
Bore	100 mm
Stroke	110 mm
Compression ratio	17
Fuel injection pump	Unit pump 26 mm diameter plunger
Fuel injection nozzle	Hole nozzle 10 nozzle holes Nozzle hole dia. (0.48mm) Spray angle= 160^o Nozzle opening pressure=40 Mpa

Precision sound level meter equipped with microphone type 4615 was used to measure overall sound pressure. A standard calibrator meter type pisto phone type 4220 used to calibrate the tests noise level meter.

1.2 The used fuel

The commercial Iraqi diesel used as engine fuel in this work. Iraqi diesel fuel is well known by its high sulfur content (it was 10000 ppm sulfur in the present tested fuel). Also, it has a moderate cetane number (49 in the present work).

2.3 Error analysis

The reliance potential of the tests outcomes is represented by measurement accuracy. The calibration of the used measuring equipments defined the error sources, and then the uncertainty in this study can be determined. Table 3 lists the measuring equipment and its accuracies. The uncertainty can be defined by the equation [16]:

$$e_R = \left[\left(\frac{\partial R}{\partial V_1} e_1\right)^2 + \left(\frac{\partial R}{\partial V_2} e_2\right)^2 + \cdots + \left(\frac{\partial R}{\partial V_n} e_n\right)^2\right]^{0.5} \qquad (3)$$

Where:
e_R: outcomes uncertainty.
R : function includes variables or R=R (V_1, V_2, …, V_n).
e_i : variable uncertainty range.

The partial derivative $\frac{\partial R}{\partial V_1}$ represents results sensitivity to a single variable. Then, the uncertainty for the recent investigation results was:

$$e_R = \begin{bmatrix} (0.045)^2 + (1)^2 + (0.07)^2 + (0.95)^2 + (0.98)^2 + (1.24)^2 + (0.7)^2 \\ +(0.022)^2 + (1.09)^2 \end{bmatrix}^{0.5} = \mp 2.366\ \%$$

The uncertainty result confirms the achieved accuracy in the measurement of more than 95% of the present study. All tests repeated three times at least to lessen random errors in the results. The results average for each test recorded along with more than 95% confidence.

2.4 Tests Procedure

The engine was left to run about 10 minutes without any load until the cooling water, and lubricant oil reached 75°C. After that, the engine was made to run at constant speeds of 800, 1000, 1200 &1500 rpm. Exhaust emissions CO_2, CO, HC, NOx, PM, and noise measured at intervals of 5 minutes each. The readings obtained for 20 minutes in each test. This time selected about the fact that this engine idling time is possible in practical life in Baghdad city and other Iraqi governorates due to checking points and traffic strangulations.

III. Results And Discussions

The effect of engine runs time with various idle speeds on the emitted emissions studied. CO, CO_2, HC, NOx, PM and noise emissions considered. Fig. 1 shows time effect on CO_2 concentrations for tested speeds. CO_2 concentrations increased until 10 min timing, and then it started to reduce till 20 min. At 1000 rpm, CO_2 concentration increased gradually to reach its maximum value at 10 min operation time, and then it began to decrease. The figure results indicate that after engine operation more than 10 min at idle speed the combustion deteriorates. CO_2 reduction means higher CO and HC concentrations resulted from this bad combustion. By comparing the emitted CO_2 for the studied engine speeds with that resulted by 900 rpm, it can be seen that an increment in these concentrations at 1000 rpm with about 29%. CO_2 decreased with about 22 and 10.7% for 1200 and 1500 rpm respectively.

Fig. 2 represents the time and idle speed effects on CO concentrations. CO emissions from diesel engine are low during normal operation but at idle its behavior changed. At 900 rpm, CO concentration started at high levels, and it declined until it reached its minimum values near 10 min timing. After 10 min operating, these concentrations began to increase. At 1000 and 1200 rpm, CO concentrations reduced to reach its minimum value around 5 min then it increased to 20 min. While at 1500 rpm, it reached its minimum value around 20 min operations. CO_2 deterioration means that the combustion is poor, so instead of complete combustion with no CO concentrations, CO increased. The CO increment is due to the following:

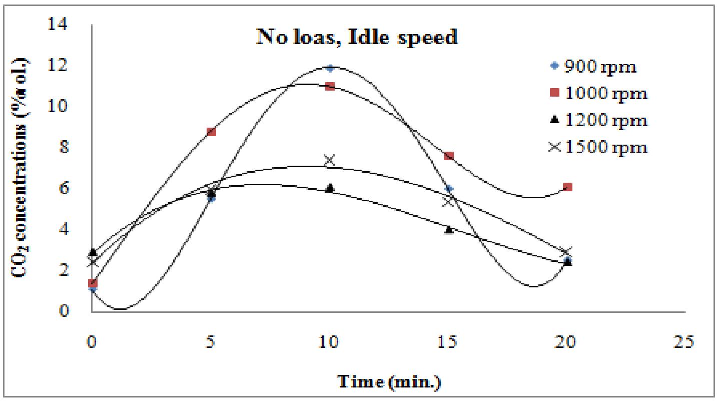

Fig. 1, the effect of time and engine idle speed on emitted CO_2 concentrations

1. At the beginning of combustion, the combustion chamber is cool causing fuel partial evaporation and uncompleted combustion.
2. With idle period continuing, combustion chamber temperature increased, and better engine combustion achieved.
3. With idle time and fuel injection continued, the quantity of partially burned fuel increased causing higher CO concentrations.

The results indicated that the increments in CO concentrations were -32, 2.7 and 22% for 1000, 1200 and 1500 rpm compared with that emitted at 900 rpm. At 1000 rpm the lowest CO concentration was achieved.

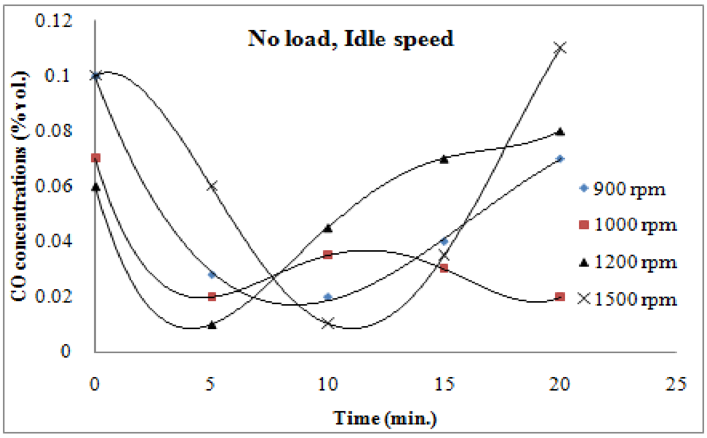

Fig. 2, the effect of time and engine idle speed on emitted CO concentrations

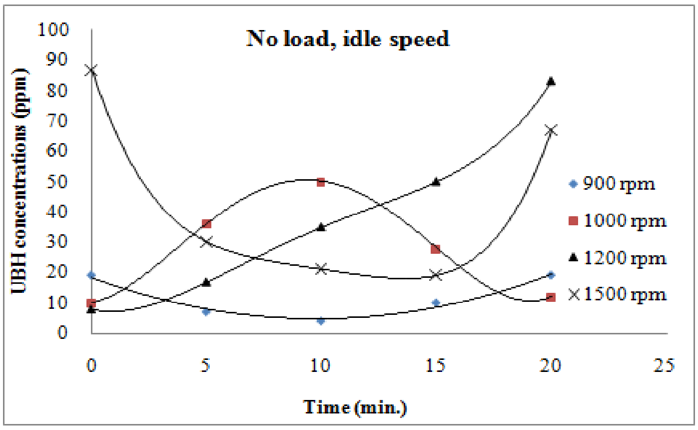

Fig. 3, the effect of time and engine idle speed on emitted HC concentrations

Fig. 3 declares the impact of idle time and engine idling speed on HC concentration. Idle HC emissions from diesel engines, in general are small in comparison to their gasoline counterparts because of high diesel engine combustion efficiency. Idle HC emissions, in some cases, were so small that they could not even detected accurately. HC concentrations reduced with time at 900 rpm till 10 min operation and then it increased gradually. Increasing idling period increased these concentrations. At 1000 rpm, HC concentrations increased till 10 min operation and then it reduced. For 1250 rpm the concentrations increased all the time. At 1500 rpm HC concentrations reduced to 15 min operation and then, it increased with a high rate. When the vehicle stopped, and no load subjected on the engine, the combustion chamber cooled, and uncompleted combustion take place increasing HC concentrations. The engine became warmer with idle period continued which reduced HC concentration. The emitted HC concentrations were increased by 130, 227 and 279% for engine idle speed 100, 1200 and 1500 respectively compared with 900 rpm emitted HC.

Idle NOx exhibited a total contrast to the idle CO and HC emissions behavior. NOx concentrations increased with time increasing as Fig. 4 represents. At 900 rpm, NOx concentrations are the lower rate of all other idling speeds. Increasing idle speed means increasing combustion chamber temperatures which result in higher NOx. The concentrations measured in the present tests are greater than any regulated legislation as Euro 3, 4 or 5 or American Tier 3 or 4. The emitted NOx concentrations were increased by 19, 33.9 and 54.98% for engine idle speed 100, 1200 and 1500 respectively compared with 900 rpm emitted HC.

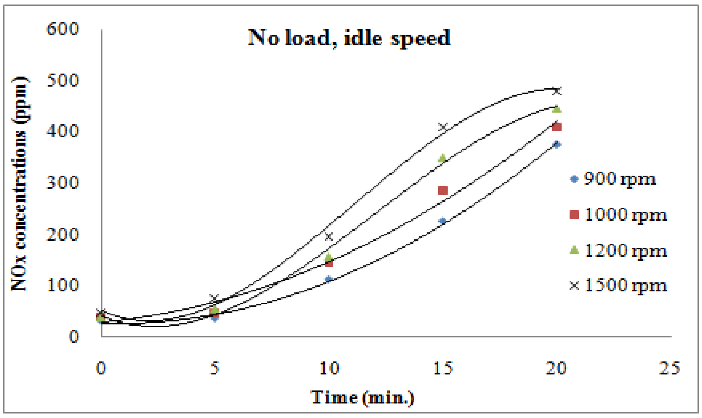

Fig. 4, the effect of time and engine idle speed on emitted NOx concentrations

Idle PM emissions from the diesel engines are minuscule, especially for the later model year vehicles. Fig. 5 clarifies the effect of idle time and speed on PM concentrations. PM concentrations increased at low speeds due small combustion chamber temperatures. Increasing idling speed increased combustion chamber temperatures causing lower PM. For idle period from 10 to 20 min, PM concentrations increased for all speeds indicating combustion deterioration. The maximum concentrations resulted at 900 rpm stating the hazards from operating the engine idle speed at low ones. The results showed that the decrements in PM concentrations were 25, 40 and 53% for 1000, 1200 and 1500 rpm compared with that emitted at 900 rpm. At 1500 rpm the lowest PM concentration was achieved.

Engine noise increased at low idle speeds and reduced at high ones as Fig. 6 illustrates. At low speeds, engine vibration increased causing higher noise accompanied with low lubrication for rotating parts. At high engine idle speed, the block vibration reduced as well as lubrication of moving parts increased. The results illustrate that the decrements in engine noise were 32, 33.5 and 33.6% for 1000, 1200 and 1500 rpm compared with the 900 rpm engine noise. At 1500 rpm the lowest engine noise was achieved.

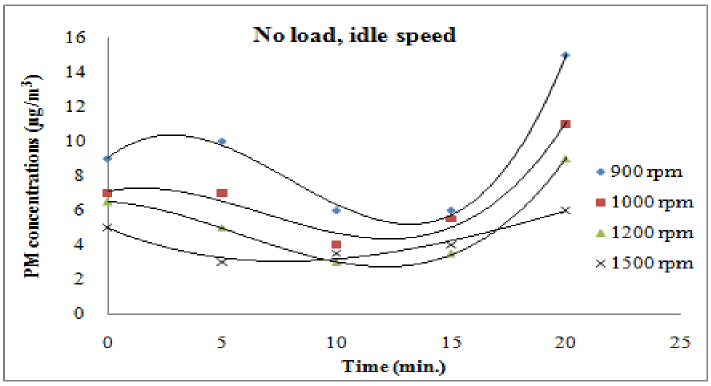

Fig. 5, the effect of time and engine idle speed on emitted PM concentrations

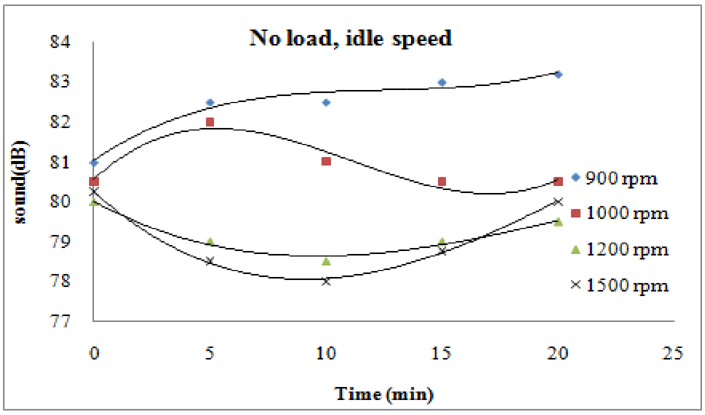

Fig. 6, the effect of time and engine idle speed on emitted noise

IV. Conclusions

The effect of idle time and engine idling speed were tested using multi-cylinder direct injection diesel engine. The results indicate that increasing idle time increased CO, HC and NOx, and reduced PM and noise. Increasing idle time deteriorated combustion causing lower CO_2 while the other emissions increased profoundly. Increasing idle speed improved the combustion and reduced CO, HC, PM and noise while increased CO_2 and NOx. Increasing engine speed enhanced combustion resulting in higher CO_2 concentration, but it also increases combustion temperature that led to higher NOx.

References

[1]. Downing K & Matthews S, Improving Truck Efficiency and Reducing Idling Submitted to: House Interim Committee on Environment and Water, October 1, 2010.

[2]. Khan A S, Clark N N, Thompson G J, Wayne W S, Gautam M, Lyons D W and Hawelti D, Idle Emissions from Heavy-Duty Diesel Vehicles: Review and recent Data, J. Air & Waste Manage. Assoc., vol. 56, pp: 1404–141, 2006.

[3]. National Academy of Sciences (NAS), Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles, Washington D.C., The National Academies Press, 2010.

[4]. Denning C and Kustin C, The Good Haul: Innovations that Improve Freight Transportation and Improve the Environment, Environmental Defense Fund, New York, NY 2010.

[5]. Cooper C, Kamakaté F, Reinhart T, Kromer M and Wilson R, Reducing Heavy-Duty Long Haul Combination Truck Fuel Consumption and CO_2 Emissions, Northeast States Center for a Clean Air Future, October 2009.

[6]. Rocky Mountain Institute, Transformational Trucking Initiative Report, 2009.

[7]. McCormick, R.L.; Graboski, M.S.; Alleman, T.L.; Yanowitz, J. Idling Emissions from Heavy-Duty Diesel and Natural Gas Vehicles at High Altitude; J. Air & Waste Manage. Assoc. 2000, 50, 1992-1998.

[8]. Brodrick, C.-J.; Dwyer, H.A.; Farshchi, M.; Harris, D.B.; King, F.G., Jr. Effects of Engine Speed and Accessory Load on Idling Emissions from Heavy-Duty Diesel Truck Engines, J. Air & Waste Manage. Assoc. vol. 52, pp: 1026-1031, 2002.

[9]. Chaichan M T, Exhaust gas recirculation (EGR) and injection timing effect on emitted emissions at idle period, Al-Khwarizmi Engineering Journal, vol.10, No. 4, pp:33-44, 2014.

[10]. Garshick E, Laden F, Hart J E, Rosner B, Davis M E, Eisen E A, Smith T J, Lung Cancer and Vehicle Exhaust in Trucking Industry Workers, Environmental Health Perspectives, vol. 116, pp: 1327-1332, 2008.

[11]. Miller T L, Fu J, Storey J and Parks J, Diesel Truck Idling Emissions: Measurements at a PM2.5 Hot Spot; Paper No. 07-2609 presented at the 86th Annual Meeting of the Transportation Research Board, Washington DC, 2007.

[12]. Doraiswamy P, Davis W T, Miller T L, Fu J S, Lam Y, Measuring Air Pollution Inside and Outside of Diesel Truck Cabs, Prepared for the U.S. Environmental Protection Agency by Department of Civil and Environmental Engineering, University of Tennessee, 2005.

[13]. Doraiswamy P, Davis W T, Miller T l, Lam N, Bubbosh P, Air Quality Measurements Inside Diesel Truck Cabs During Long-Term Idling, Transportation Research Record: Journal of the Transportation Research Board, Issue Number: 1987, 2006.

[14]. Gaines L L and Hartman C B, Energy Use and Emissions Comparison of Idling Reduction Options for Heavy-Duty Diesel Trucks, 88th Annual Meeting of the Transportation Research Board Washington, D.C., Paper No. 09-3395, January 11–15, 2009.

[15]. Proc K, Nitschke B, Wagner F, Anderson M, Slezak L, Idle Reduction Technology Demonstration Plan, National Renewable Energy Laboratory Report No. NREL/TP-540-34872, September, 2003.

[16]. ASHREA GIUDE LINE. Guide engineering analysis of experimental data, Guideline 2-1986.

Notation

IT	injection timing
CN	cetane number
DI	direct injection
HC	unburnt hydrocarbon
CO	carbon monoxide
CO_2	carbon dioxide
NOx	nitrogen oxides
dB	decibel
LCV	Lower calorific value