Energy Conversion and Management 88 (2014) 794–807

Contents lists available at ScienceDirect

Energy Conversion and Management

journal homepage: www.elsevier.com/locate/enconman

Review

A review on idling reduction strategies to improve fuel economy and reduce exhaust emissions of transport vehicles

I. Shancita *, H.H. Masjuki, M.A. Kalam *, I.M. Rizwanul Fattah, M.M. Rashed, H.K. Rashedul

Centre for Energy Sciences, Department of Mechanical Engineering, Faculty of Engineering, University of Malaya, 50603 Kuala Lumpur, Malaysia

ARTICLE INFO

Article history:
Received 28 May 2014
Accepted 13 September 2014
Available online 29 September 2014

Keywords:
Idling reduction devices
Fuel economy
Exhaust emission
Diesel and gasoline vehicles

ABSTRACT

To achieve reductions in vehicle idling, strategies and actions must be taken to minimize the time spent by drivers idling their engines. A number of benefits can be obtained in limiting the idling time. These benefits include savings in fuel use and maintenance costs, vehicle life extension, and reduction in exhaust emissions. The main objective of idling reduction (IR) devices is to reduce the amount of energy wasted by idling trucks, rail locomotives, and automobiles. During idling, gasoline vehicles emit a minimum amount of nitrogen oxides (NO_x) and negligible particulate matter (PM). However, generally a large amount of carbon monoxide (CO) and hydrocarbons (HC) are produced from these vehicles. Gasoline vehicles consume far more fuel at an hourly rate than their diesel counterparts during idling. Higher NOx and comparatively larger PM are produced by diesel vehicles than gasoline vehicles on the average during idling. Auxiliary power unit (APU), direct-fired heaters, fuel cells, thermal storage system, truck stop electrification, battery-based systems, engine idle management (shutdown) systems, electrical (shore power) solutions, cab comfort system, and hybridization are some of the available IR technologies whose performances for reducing fuel consumption and exhaust emissions have been compared. This paper analyzes the availability and capability of most efficient technologies to reduce fuel consumption and exhaust emissions from diesel and gasoline vehicles by comparing the findings of previous studies. The analysis reveals that among all the options direct fired heaters, APUs and electrified parking spaces exhibit better reduction of fuel consumption and exhaust emissions than others.

1. Introduction

Vehicle idling occurs when the engine of a vehicle is running but is not engaged with the transmission or is simply not in gear. Vehicle idling could be due to various reasons. One is to warm up the engine or to supply heat or air conditioning to the cab or sleeper compartments for comfort. The engines of heavy-duty trucks normally become idle during rest periods at overnight stops to control the temperature and to supply electricity for devices such as television, heater, lamps, refrigerator, and microwave oven. Public vehicles may also idle their engines to provide power for auxiliary equipment, including aerial lifts and safety lights. Places where idling usually occurs include bus terminals, truck stops and rest areas, roadways, restaurant drive-through, tourist attractions, border crossings, and schools, among others.

Vehicle idling affects health, environment, and vehicle performance adversely and is an escapable source of air pollution and of pollutants such as particulate matter (PM) and NO_X, which affect respiratory and cardiovascular health. The idling of vehicles also emits carbon dioxide (CO_2) and volatile organic compounds (VOC). Previous studies had shown that the amount of pollutants obtained from vehicles is higher in places where idling is frequent, such as bus stops, rest stops, and near schools. The sound of idle combustion is considered as an unwelcomed source of noise pollution to some people [1–3]. During idle operation, the engine consumes a highly rich fuel–air mixture compared with that during normal operation and does not operate at peak temperatures, resulting in high brake-specific fuel consumption and incomplete fuel combustion. Idle operation leads to high emissions formation as well as fuel residue in the exhaust [2,3]. Extended idling can also affect the engine oil because as the amount of unburned fuel and soot mix with the oil, resulting in its dilution, the life of the lubricating oil is decreased. Idling hampers the efficiency of the lubricants, leading to an increase in the frequency of oil change. In addition, idling causes excess engine wear and tear. During idle operations, vehicles produce zero (0) miles per gallon (MPG) and fuel is unnecessarily expended. This wastage can be expensive, especially for fleets, over the course of a year. The amount of fuel

* Corresponding authors. Tel.: +60 379674448; fax: +60 379675317 (I. Shancita).
E-mail addresses: shancitaislam@gmail.com (I. Shancita), kalam@um.edu.my (M.A. Kalam), rizwanul.buet@gmail.com (I.M. Rizwanul Fattah).

http://dx.doi.org/10.1016/j.enconman.2014.09.036
0196-8904/

wasted varies from vehicle to vehicle; the larger the engine, the more fuel is wasted while idling [4,5].

Khan et al. [6] provided a dataset of tailpipe emissions from 75 heavy-duty diesel engines and trucks that have electronic fuel ignition (EFI) and mechanical fuel ignition (MFI) systems. They reported that vehicles with EFI emit 20 g/h of CO, 6 g/h of HC, 86 g/h of NO_X, 1 g/h of PM and 4636 g/h of CO_2, on the average, while idling, and MFI vehicles emit 35 g/h of CO, 23 g/h of HC, 48 g/h of NO_X, 4 g/h of PM and 4484 g/h of CO_2 on the average. Thus, EFI vehicles emit less idle CO, HC, and PM because of the enhancement of combustion efficiency and fuel atomization. In addition, EFI vehicles produce higher idle-NO_X than MFI vehicles because of advanced injection timing that improves idle combustion. The study also reported that the injection management system had no effect on CO_2 emission and, hence, fuel consumption. The study also mentioned that idle CO_2 emission allowed the projection of fuel consumption during idling. They concluded that the use of air conditioning without increasing engine speed resulted in an average increase in idle CO_2, NO_X, PM, HC and fuel consumption by 25%.

Variations in idling exhaust emissions were observed to be the effect of engine speed, accessory loads, humidity and ambient conditions. The negative effect on air quality, general health issues, fuel wastage and gradual increase in cost of the fleet during the idling raises the necessity of utilizing idling reduction (IR) technologies [7–10]. "Idling Reduction Technology" refers to devices that allow engine operators to prevent unnecessary main engine idling by the provision of an alternative source of power to provide heat, air conditioning and/or electricity, while the vehicle is temporarily parked or remains stationary. Several alternative technologies are available to reduce or eliminate idling, save fuel and reduce emissions [6,11]. The IR technologies available for light, medium, and heavy-duty diesel and gasoline vehicles include on-board equipment (auxiliary power systems, direct-fired heater, thermal storage, engine idle management (shutdown) systems, shorepower solutions, direct heat with thermal storage cooling and energy recovery systems), fuel cells, truck-stop electrification, battery based systems, and cab comfort system [12–14]. The United States National Energy Policy 2001 restated the significance of "wise energy use" by enforcing alternatives to idling at truck stops and emphasized the necessity to reduce emissions and fuel consumption of long-haul trucks. Most of these trucks distribute essential materials throughout the country and rest overnight at truck stops in idling condition. Long-haul truck drivers often place their vehicle engines on idle to maintain the warmth inside the compartment as well as to maintain battery voltage or for safety and habitual purposes [15,16].

IR options are available for stand-alone installation aboard the vehicle or use at wayside installations. On-board devices can be used wherever and whenever the truck is stopped, but they add weight to the vehicle. In electrified parking spaces, greater PM was observed, although these emissions generally occurred in places with low population density [7,17]. Variations in climate of different states control the full fuel-cycle effect from IR techniques. Studies had observed that the most suitable option for a particular place can be less suitable for other places. Changes in time spent for heating or cooling also result in varied corresponding effects. A regulation on idling by the California Air Resources Board (CARB) bans idling during nighttime and imposes new requirements regarding idling alternative techniques within the state. Continued vehicle idling contributes to high fuel wastage, greenhouse gas emissions, pollutant emissions and negative environmental and health effects. One of the most suitable methods for reducing fuel consumption and exhaust emissions is to shorten idling time. Various feasible IR technologies with different functions, configurations, and capabilities to work on the IR option have been proposed [7,12]. In this paper, a literature review of idling fuel usage and emissions of different pollutants is provided. A comparison of the performances of various IR devices is also detailed to understand their benefits and shortcomings for future development.

Table 1
Leeds experiment on idling fuel consumption rate [21].

Sets of data	Observations number	Fuel use rate (gal/h)	
		Mean	Standard deviation
Complete stops	158	0.328	0.573
Stops for 20 s or more	78	0.346	0.182

2. Fuel consumption during idling

Extended idling of transport vehicles causes large amounts of fuel to be wasted. According to the Argonne National Laboratory (Argonne), 800 million gallons of diesel fuel are used by overnight trucks or sleeper idling per year. The rate of fuel consumption varies with vehicle size and for every 10 min of idling, a maximum of 1/10–4/10 of a liter of fuel can be used. The relevant fact is that more than 10 s of idling burns more fuel than starting up or shutting down the engine [12,18,19]. Around one gallon of diesel fuel is consumed for each hour of truck idling, or up to 1800 gallons of fuel usage if the truck operates 6 h per day at 300 days per year. This wastage is equivalent to the annual monetary value of US$2250.00 per truck. Fuel consumption during idling is not dependent on driving behaviors or road conditions. However, different variables may affect the idling fuel consumption rate for the same vehicles, such as engine temperature, combustion efficiency, idling speed and ignition timing. The age of a vehicle can also affect the idling fuel consumption rate. For example, in a Leeds experiment, idling fuel consumption rate was observed at 158 stops for two cases, namely, vehicles performing complete stops and those that stop for 20 s or more. The mean and standard deviation were calculated for these two sets of data. The results of this experiment are presented in Table 1 [20,21].

3. Emissions from transport vehicles

A considerable number of gaseous hazardous compounds are present in diesel and gasoline exhaust. A vehicle emits gases, such as NO_X, CO and VOCs, from its tailpipe during idling. These gases are called criteria air contaminants (CACs). Emissions of CACs are responsible for air pollution and smog. Meanwhile, an unavoidable by-product of burning gasoline is CO_2, which is primarily a greenhouse gas. Therefore, every time an engine starts, CO_2 contributes to climate change [22,23].

Pollutants emitted from diesel and gasoline engines can be divided into three major elements: NO_X, CO and HCs and particulate matters (PM) [23,24]. NO_X is composed mostly of nitrogen oxide (NO) and nitrogen dioxide (NO_2). In diesel exhaust, NO has a larger quantity than that of NO_2, though NO_2 is more contagious than NO [23,25]. Recently, N_2O has received considerable attention because of its environmental impact that is 200 times than CO_2, specifically in causing global warming [23,26].

Though NO, NO_2, and N_2O have different impacts on the atmosphere, most studies on exhaust from diesel engines consider these emissions to be under the same species called NO_X. CO and HCs are formed both in diesel and gasoline engines. HCs are composed of various species, such as alkanes, alkenes and aromatics, and are generally considered as total hydrocarbons (THC). Generally, each component has individual toxicity, carcinogenicity and impact on the formation of oxidants [23,26–28].