Diesel Engines Emissions Reduction

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Compression ignition engines play a significant role in the development of a country. They are widely used due to their innate properties such as high efficiency, high power output, and durability. However, they are considered one of the key contributors to transport-related emissions and have recently been identified as carcinogenic. Thus, it is important to modify the designs and processes before, during, and after combustion to reduce the emissions to meet the strict emission regulations.

diesel emission | air quality improvement | renewable energy | biodiesel

1. Introduction

The development of a country greatly depends upon its transportation, mining, and power generation sectors. Diesel engines, also known as compression ignition (CI) engines, have become a source of power for these sectors due to their having high innate efficiency, durability, and better power output. Hence, it shares a large portion of the passenger car and heavy machinery market [1]. However, with rapid growth in demand, the diesel engine has also become one of the key sources of pollutants. Both the environment and human health are adversely affected by the pollutants resulting from petroleum-derived fuel combustion. United Nations Intergovernmental Panel on Climate Change has reported a rapid surge of global warming due to increased greenhouse gas emissions, including methane, nitrogen oxides, and carbon dioxide. It is predicted that more than a hundred million lives will be in danger if the average global temperature increases by more than 2 °C [2].

The main constituents of emission resulted from the combustion of diesel fuel are carbon monoxide (CO), nitrogen oxides (NO_X), hydrocarbons (HC), and particulate matter (PM)—these are considered as regulated emission and Polycyclic aromatic hydrocarbon, benzene, toluene, xylene, soot—these are considered as unregulated emission. Diesel engines emit hydrocarbon as the by-product of incomplete or partial combustion [3]. Sneezing, coughing, drowsiness, eye irritation, symptoms akin to drunkenness, several lung diseases- these are the problems that can be caused by HC emission [4]. The incomplete oxidation product of hydrocarbon fuel results in CO emission [5]. Excessive inhaling of CO disrupts the proper functionality of several vital organs such as the brain, nervous tissue, and heart by reducing the oxygen-carrying capacity of blood [6][7]. CO emission also can cause morbidity in people who have respiratory or circulatory complications [4]. NO_X formation is a complex mechanism, which can be divided into three parts, thermal, prompt, and fuel. At first, the high combustion temperature breaks the triple bonds of “Nitrogen molecules.” Then, these nitrogen molecules dissociate into their atomic states and produce NO_X while reacting with oxygen. The development of free radicals in the flame front of hydrocarbon flames leads to rapid production of NO_X [8]. During combustion of fuel, oxygen reacts with nitrogen bound in the fuel and forms NO_X.

Irritation of the lungs, lowering respiratory infection resistance, edema, bronchitis, and pneumonia—these are the problems caused by NO_X emission [4]. Exposure to heavy metals causes adverse health effects, including toxicity, severe respiratory, and cardiovascular problems, and shorten life expectancy [9][10].

The acute effect of polycyclic aromatic hydrocarbon (PAH) on human health depends upon several factors, such as concentration, extent, the process of exposure, etc. [11]. Exposure to PAH may result in nausea, diarrhea, vomiting, skin irritation, etc. [12]. Long-time exposure increases the chances of lung, skin, bladder, and gastrointestinal cancers [13][14]. The most prominent aldehydes have carcinogenic effects, which are harmful to human health. Aldehyde over-exposure results in sore throat, nausea, headache, irritation of eyes, nose, skin, and throat, and difficulty in breathing and can cause chronic diseases at higher concentrations. Studies have shown that hematological, immune, neurological, and reproductive systems are each affected by N_2O emissions [15]. Furthermore, human exposure to benzene may cause adverse health effects and diseases, including cancer and aplastic anemia [16]. Toluene is a respiratory irritant that can affect the central nervous system. Inhalation of high levels of toluene vapors for a short period may cause headache, drowsiness, visual changes, nausea, dizziness, muscle spasm, and loss of coordination. Long time exposure to high-level toluene may result in attention and concentration and motor performance deficits [17]. To reduce the health effects of the combustion of diesel in internal combustion engines, regulators have imposed more and more stringent regulations on manufacturers.

The increased effect of global warming, limited efficiency of diesel engines, and stringent anti-pollution laws (especially NO_X and PM emissions) enforced by the governments have generated a spur to develop efficient engines with the acceptable emission level [18][19]. This development can be divided into three categories:

- Pre-combustion engine configuration modifications
- In-combustion fuel modification
- Post-combustion treatment techniques

2. State-of-the-Art of Strategies to Reduce Exhaust Emissions from Diesel Engine Vehicles

The summary of pre-, in-, and post-combustion techniques to reduce exhaust emissions are as follows:

- Retardation of injection timing can reduce NO_X emissions, whereas advancement reduces EGT, BSFC, HC, and CO emissions, and smoke opacity. However, the advancement of injection timing results in an increase in NO_X emission. Contrary, some researchers reported an increase in PM emission and BSFC and reduced BTE when injection timing is advanced and an increase of NO_X emission when injection timing is retarded. Furthermore, some studies reported that any change of injection timing, advanced or retarded, results in an increase of BSFC and reduction of BTE.

- Increasing the injection pressure improves BTE and reduces BSFC. However, some researchers had reported an increase of BSFC when the injection pressure was reduced or increased. An increase in injection pressure reduces CO, HC emission, and particulate number concentration. Contrary, some researchers reported an increase in NO_X and CO emission with an increase in injection pressure.
- An increase in compression ratio reduces BSFC, EGT, CO emission, and smoke opacity and improves BTE; however, it increases NO_X and HC emission.
- LTC techniques and EGR can reduce NO_X and PM emissions simultaneously; however, they generally increase HC and CO emissions.
- Multiple or split injection strategies also reduce PM and NO_X emission but increases BSFC.
- Biodiesel can be used with diesel fuel, as it has better lubricity, higher flash point, emits less CO, HC, and PM emission. However, they reduce efficiency and increases fuel consumption, and also emit higher NO_X compared to diesel fuel. Biodiesel lacks oxidation stability. If stored for a prolonged time, stability deteriorates rapidly. Furthermore, the biodiesel production cost is still higher.
- The oxidation stability of biodiesel can be improved by using antioxidants but will result in an increase in CO and HC emission.
- Algal biodiesel can solve some of the problems of first-generation biodiesels, such as the food vs. fuel debate. There are a lot of researches going on which aims to find an economical production process.
- Metal-based additives improve fuel economy; reduce HC, CO, and smoke emission, on the other hand, increase NO_X emission.
- Oxygenated additives improve combustion by increasing oxygen contents. The use of additives increases the maximum heat release rate and in-cylinder pressure. In contrast, these additives have some disadvantages: the high heat of vapourization, low cetane number, high auto-ignition temperature, an increase of NO_X emission, and inadequate lubricating behaviors.
- Cetane improvers reduce NO_X emission significantly; however, from the literature reviewed, there is a lack of studies, which focused on the effect of these additives on PM emission.
- DOC can reduce HC, CO emissions, and SOF. However, it has little/no effect on NO_X emission and sometimes can increase PM emission by producing more sulfates.

There are a robust debate and widespread demand for shifting away from combustion engines due to the harmful emissions. The use of hybrid and electric vehicles is getting popular day by day. Thus, it is imperative to continue research on combustion engines to improve their performance and limit their emission levels to a minimum. Shifting from petroleum fuels to bio-sustainable fuels is one of the options. Biodiesel is considered one of the

popular alternatives. Biodiesel has some disadvantages, which can be eliminated by using additives. Thus, research on suitable additives should also be carried out. Algal biodiesel and biodiesel from waste products (such as waste cooking oil) can solve sustainability-related problems. However, extensive research should be carried out to find a way to reduce the production cost to make it economically feasible, minimize by-product generation and improve biodiesel yield. Further research on engine modification can pave the way for the construction of engines suitable for pure biodiesel utilization.

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