

Study of the Emissions in the Diesel Engines: A Review

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Abstract

Diesel engines are one of the main sources to supply the rapid growth of energy consumption worldwide. They have been widely used in the public and commercial transport sector due to their greater durability and efficiency. The current study in Diesel engines is focused on emissions from exhaust gases, as they are causing problems in human health and the ecosystem, because they contain dangerous substances, such as organic carbon, trace elements, elemental carbon and inorganic ions. In this paper, we study the different investigations on pollutant emissions in engines, focused on the mechanisms of formation of pollutants, the techniques to reduce these emissions and how they affect human health. With this, it will be possible to project the necessary improvements in this type of systems, to reduce the impact of these thermal machines on the environment.

Keywords: Diesel, Emissions, Formation, Health, Human

1. Introduction

The emissions generated by Diesel engines, which can be regulated or not regu-

lated, have been studied extensively by several authors [1]- [3]. The emissions regulated by law [4] are carbon monoxide (CO), unburned hydrocarbons (HC), nitrogen oxides (NO_x) and, for Diesel engines, particles (PM) [5]. There are several additional unregulated contaminants that have been found in engine exhaust gases, which may have potential health effects and, therefore, should be monitored and reduced in emissions. In the review of the literature by Ghadikolaei [6], a classification of these pollutants is established, among which are: alcohols, alkenes, alkyl nitrites, monoaromatics, particle emissions, nitrogen dioxide, among others. However, many of the pollutants from unregulated emissions are found in very low concentrations, which is why the study is focused on regulated emissions. The percentage of emissions depends on the type of emission control technology and the age of this technology, the operating conditions, the fuel formulations, the ambient temperature and the operation of the catalyst [7] - [10].

Researchers have suggested in recent studies that biodiesel [11], alcohols [12], natural gas [13], and dimethyl ether (DME) [14], could be used as alternative fuels to reduce harmful pollutants and greenhouse gases released from Diesel engines. Biodiesel is produced from renewable energy materials such as vegetable seeds and wheat, corn and sugar beet [15] – [17]. Biodiesel fuels can provide renewable and clean energy; Therefore, they renewable and environmentally friendly fuels [18], [19]. Another way to produce biodiesel is transesterification. This process allows to produce biodiesel that does not contain sulfur, it degrades quickly and is not toxic [20]. The United States Environmental Protection Agency (EPA) conducted an extensive survey of the results of 80 scientific studies to evaluate emissions from heavy diesel engines fueled by biodiesel [21].

2. Research into pollutant emissions from internal combustion engines

2.1. Mechanisms for the formation of emissions in diesel engines

In an internal combustion engine, some pollutants are generated that are emitted by the exhaust pipe, regardless of whether they are compression ignition or spark ignition because the combustion process is not completely carried out in any of the operating conditions of the engine. The emissions emitted by the exhaust pipe of the vehicles are the product of the combustion process that occurs inside the engine and comprises a series of pollutants such as CO, CO₂, HC, NO_x, SO₂, and PM. Also, certain contaminants present in the fuel, such as sulfur, are released to the environment also as a product of the combustion process. Vehicles with more powerful engines tend to generate higher pollutant emissions and these emissions emitted by the exhaust pipe not only depend on the temperature at which the combustion takes place, the pressure, the homogeneity of the mixture, the constructive characteristics of the engines and its emission control system, but also the maintenance status of the vehicle and operating factors such as speed, load and the frequency and intensity of accelerations and decelerations [23].

In compression ignition engines or diesel engines, the fuel is not distributed evenly inside the combustion chamber, which leads to the dosing inside the combustion chamber is not uniform, generating rich mixing zones, inside of the jet kernel and poor mixing zones, in the areas furthest from the center of the same. The mixing process is mainly controlled by parameters related to the injection, the turbulence of the air and the evaporation properties of the fuel.

On the other hand, the particles are formed in the diffusion flame by the dehydrogenation of the fuel in zones of high temperature and absence of O₂ and, therefore, in areas of excessively rich local dosing. The particles (PM) that are generated in diesel combustion are composed of soot (basically coal) and some hydrocarbons of very high molecular weight adhered to it, a soluble organic fraction (FOS, between 20 and 50% of the mass) and a fraction of other insoluble (ISF) composed of sulphates, water and a small amount of ash [24].

2.2. Techniques to reduce pollutant emissions in diesel engines

Among the different systems proposed for the control of emissions from diesel engines, most of the studies and research that have been carried out aim to reduce mainly NO_x emissions. This is because NO_x emissions correspond to a higher percentage compared to the rest of the emissions [25].

2.2.1 Technologies that affect engine design

The engine design techniques used to reduce polluting emissions, mainly NO_x and particulate matter, are:

- Combustion chamber

To reduce the emissions of CO, HC, and NO_x, the amount of fuel that goes into combustion in the pre-mixing and diffusion stages can be controlled. This is possible if the mechanism of mixing the fuel in the air is modified with the help of the position and shape of the combustion chamber that is carved on the piston [22].

- Low-temperature combustion

Low-temperature combustion is a technique that is based on increasing the amount of fuel that goes into combustion in the pre-mixing stage, which reduces the local temperature through the recirculation of exhaust gases (EGR), preventing the formation of emissions of NO_x and particulate material. As shown in the graph of Figure 5, the areas in which NO_x and particulate matter emissions occur must be taken into account, which is why it is important to regulate the engine to avoid these conditions inside the combustion chamber. The different phases [22].

Another technique based on low-temperature combustion is Combustion PCCI (Premixed Charge with Compression Ignition), in which NO_x and particulate matter emissions are minimal, but with a considerable increase in CO and hydrocarbon emissions. Also, this technique has the drawback that, by lowering the temperature of the exhaust gases, the efficiency of the catalysts is reduced.

- Injection air cooling

The use of an air cooler at the outlet of the turbo compressor, in the case of engines with supercharging, allows to achieve a low temperature in the combustion and therefore reduce NO_x emissions [22].

- Exhaust gas recirculation

At present, exhaust gas recirculation (EGR) is a NO_x emission reduction technique used with both diesel and biodiesel [4] [5] [26] - [31] EGR works by recirculating a portion of the exhaust gases from the engine to the engine cylinders. This dilutes the O₂ in the incoming air stream and provides inert gases to the combustion to act as absorbents of the combustion heat to reduce the peak temperatures in the cylinder. Therefore, NO_x formation can be drastically reduced [31] which is the main application of EGR technology. A flow path is established between the exhaust and intake manifolds and regulated by a throttle valve. However, given the reduction in cylinder temperature, this technology generates an increase in HC and CO emissions [25].

2.2.2 Gas post-treatment technologies

Exhaust post-treatment systems include DOC, DPF, and SCR. These systems are the most requested components especially for heavy-duty diesel engines and a combination of DOC, DPF and SCR has generally been used for the simultaneous elimination of the main emissions.

- Catalysts

When a catalyst comes in contact with the exhaust gases, the acceleration of the oxidation or reduction reactions takes place at a low temperature until reaching its equilibrium at the exhaust temperature. To carry out its function, the catalytic substance is deposited on a support by the interior in which the exhaust gases that have the greatest contact with the catalyst circulate. The support can be manufactured in a metallic matrix or ceramic monolith, and the catalyst substances can be Platinum, Palladium, Rhodium, and mixtures between them [22].

One of the gas post-treatment technologies that use catalysts is the LNT (Lean NO_x Trap). This technology, also called NO_x-storage-reduction (NSR) or NO_x adsorption catalyst (NAC), has been developed to reduce NO_x emissions, especially in conditions of scarcity. During poor motor conditions, LNT stores NO_x in the catalyst wash layer. Then, under the conditions of the fuel-rich engine, it releases and reacts with the NO_x by the usual three-way reactions. The LNT catalyst consists mainly of three key components. These components are an oxidation catalyst (Pt), a storage environment for NO_x (barium and other oxides) and a reduction catalyst [25].

Another type of technology is the Diesel Oxidation Catalyst or Diesel Oxidation Catalyst (DOC). The main function of the DOC is to oxidize HC and CO emissions. Also, DOCs play a role in decreasing the mass of particulate matter emissions by oxidizing some of the hydrocarbons that adsorb onto the carbon particles [34]. DOCs can also be used in conjunction with SCR catalysts to oxidize NO to NO₂ and increase the NO₂ [25].

- Reactors

The reactors are used to reduce the concentration of pollutants using chemical reactions in the exhaust gases. The chemical reactions that cause are oxidation, in the case of HC or soot, and reduction, for other compounds. The reactors can be thermal or chemical. In the first case, oxidation occurs at high temperature and, in the second case, a chemical reaction takes place through a reactant that allows the polluting substance to disappear. Among the technologies that use reactors to reduce emissions is the selective catalytic reduction (SCR - Selective Catalytic Reduction) system. In this system, which serves to reduce NO_x emissions, ammonia or urea is injected into the exhaust gases and allowed to pass through catalytic substances formed from mixtures of vanadium and titanium [22].

2.3. Environmental impact

In the first place, NO_x and SO₂ are the cause of the appearance of acid rain in the environment, causing damage to forests, aquatic systems, corrosion of metals, among others. Also, CO₂, in conjunction with other gases such as CH₄, CO, and NO_x, is a participant in the emergence of the greenhouse effect. On the other hand, the particulate material is suspended in the air and interferes with the transmission of light in the atmosphere, causing poor visibility [22].

3. Discussion

One of the main concerns is the impact of emissions from diesel engines to humans, since substances that alter the balance and the natural composition of air promote greater mortality and moderate or severe pathologies, which consider pollutants atmospheric and present a current risk to human health [22]. The proportion of pollutants that are expelled will depend on the type of vehicle, the fuel used, the emission control technology, among others; generating a great impact on health.

According to the Environmental Protection Agency (EPA) of the United States, emissions from diesel engines can contain more than 40 substances considered harmful, toxic and carcinogenic, which reach significant respiratory, cardiovascular and reproductive impacts on humans [22]. In the case of the respiratory system, there are pathologies such as greater difficulty in the recovery of people suffering from asthma, which makes their symptoms more serious; increase in lung diseases; loss of optimal functioning in the respiratory system of children; development of chronic respiratory diseases and even lung cancer. On the other hand, in the cardiovascular system, there is an increase in heart diseases such as embolism, hypertension, arrhythmia, thrombosis, etc. and an increase in the possibility of heart attacks. Finally, the reproductive system tend to generate disadvantages at the time of pregnancy, threatened abortion and infant mortality.

4. Conclusions

It is clear that a major source of environmental pollution and consequent impact on

human health, is combustion in internal combustion engines, because it generates emissions of carbon monoxide (CO), unburned hydrocarbons (HC), nitrogen oxides (NO_x), particulate matter (PM) and other products that depend on the composition of the fuel. The percentage of emissions will depend mainly on several factors such as the engine design, the operating conditions, the atmospheric conditions, the type of fuel and the gas post-treatment system used. However, although they are already identified, these factors are not fully improved in the new vehicles and machines; nor withdrawn in the already established engines. Given the above, and the importance of the consequences of this phenomenon, it is necessary to be able to develop strategies that facilitate the improvement of the factors that directly influence the high percentage of contamination.

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