Overview of Measures to Reduce Harmful Emissions for Internal Combustion Engines

Phan Trong Duc, Pham Van Lieu

***Abstract*— The birth of the internal combustion engine has opened a new era for human economic and technical development, but it also causes many negative impacts on human health and the ecological environment. toxic emissions. Pollution levels due to exhaust gases from internal combustion engines (car exhaust) include nitrogen oxides (NO x), carbon monoxide (CO), hydrocarbons (HCs), particulate matter - PM (Particulates Matter) and aldehyde has been at an alarming rate for many years. The article presents a synthesis of options to limit and minimize the impact of pollutant emissions from internal combustion engines through advanced production technologies and methods.**

***Index Terms*— Toxic emissions, pollution, environment, emissions, air**

I. INTRODUCTION

Currently, in the world, there have been many technical measures to reduce emissions applied on internal combustion engines [1]. To assess the influence of each emission component, people are divided into 2 groups:

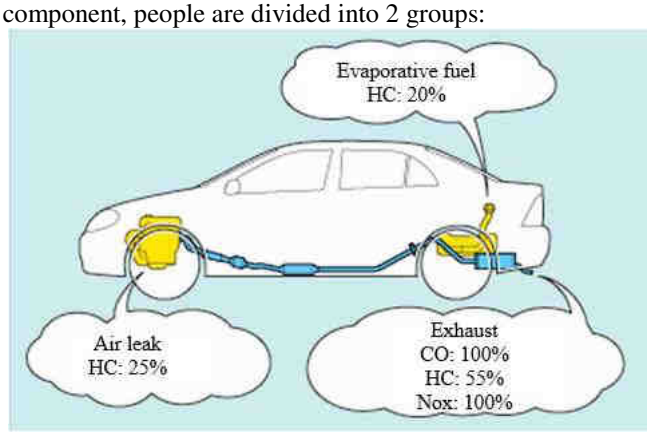

Figure 1.1. Automobile exhaust is released from the exhaust gas, evaporating fuel and exhaust gas

- ***Common pollutants:*** Including Hydrogen carbon (HC), carbon monoxide (CO), nitrogen oxides (NOx), particulate waste - PM (Particulates Matter). In some cases, carbon dioxide (CO2) is also included in this group because it is a gas formed under the influence of the greenhouse effect [2].

- ***Specific pollutants:*** Although these substances make up a relatively small percentage of emissions, they can be carcinogenic precursors or genetically modified. In developed countries, people are also interested in details of other components in the exhaust gas such as aldehydes, polynuclear aromatic hydrocarbons (PAHs) and some other toxic compounds (buta-l,3 -diene; formaldehyde...).

II. SOLUTIONS TO REDUCES EMISIONS FROM INTERNAL COMUSTION ENGINE

Emissions from vehicles such as automobile engines, passenger cars and boats are the source of many emissions causing serious air pollution. Strict compliance with emission standards such as CO, HC, NOx and particulate matter such as fine dust generated from internal combustion engines thanks to the following innovative exhaust gas treatment techniques

2.1. Particle filtration technology in engine exhaust treatment

- ***Structure of Diesel exhaust gas particulate filter***

Diesel Engine Exhaust Particle Filters (DPF) remove particles from Diesel engine exhaust through physical filtration. There are many types of filters, but the most common is the monolithic ceramic type (cordierite or silicon carbide) with a honeycomb structure. These include components such as:

- ***Component of the filter element***

(monolithic) is composed of small pores, which are carefully controlled during the manufacturing process. The total porosity of the material is typically 45 to 50% or more, while the average pore size is 10 to 20 µm .

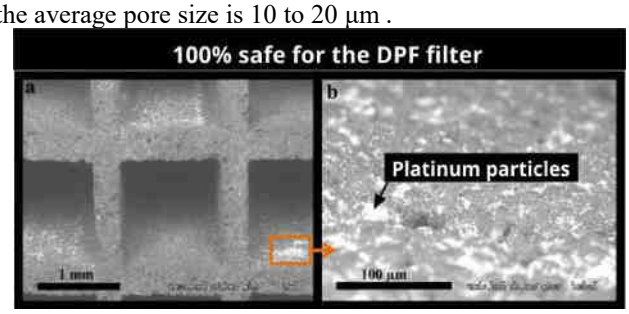

Figure 2.1. Filter core structure of Diesel exhaust gas particulate filter

- ***Catalytic Coating:***

The main function of a catalytic coating is to provide a substrate for the catalytic metals (precious metals). In addition, the catalytic coating also has the task of physically separating and preventing unwanted chemical reactions betweenthe components inside the complex catalyst. The catalytic coating material consists of non-metallic oxides which are inorganic chemical compounds such as alumina, silicon oxide, cerium oxide, titanium dioxide, zirconium oxide and zeolite.

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Phan Trong Duc, University of Economics - Technology for Industries
Pham Van Lieu, University of Economics - Technology for Industries

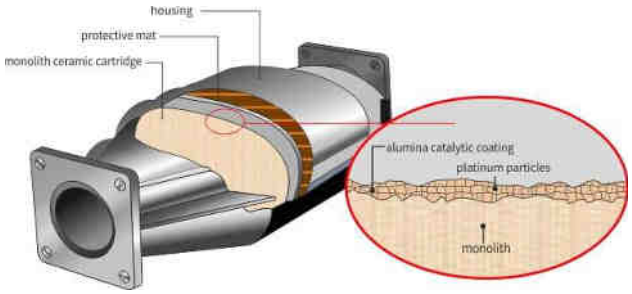

Figure 2.2. Structure of the catalytic coating [3]

➢ ***Catalytic metals:***

precious metal catalysts may be present in the catalyst slurry or they are used in a second step known as impregnation.

➢ ***Ceramic array (protection):***

it is enclosed around the filter element wall. Provides insulation, protection from mechanical shocks and vehicle vibrations.

➢ ***Working principle of diesel engine exhaust particulate filter***

The particulate filter is similar to the catalytic converter on a gasoline engine (cross section - honeycomb). However, the filter plates in diesel engine exhaust particulate filters are larger in diameter and have porous walls. In addition, they are coated with a catalytic coating that forms the basis for the metal particles to catalyze and heat.

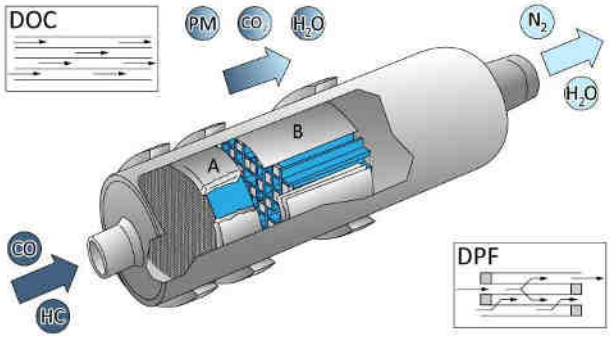

Figure 2.3. Working principle diagram of particulate filter in engine exhaust gas treatment

The exhaust gas passes through the diesel oxidation catalyst (DOC), then through the diesel engine exhaust gas particulate filter, the exhaust gas passes through the filter as if it has to pass through the porous walls and this filter will trap the particulates soot. The exhaust gas then exits to the line after the filter with cleaner exhaust.

To reduce emissions from diesel vehicles, diesel exhaust particulate filters capture and store soot, which must be burned periodically to regenerate the filter. The regeneration process ignites excess soot deposited in the filter, helping to prevent harmful emissions and black smoke that are characteristic of diesel engines when accelerating.

2.2. Engine exhaust gas recirculation (EGR) technology

➢ ***Structure of EGR Exhaust Gas Recirculation Technology***

The first generation EGR system had a very simple structure and was mainly used on carbureted engines. The opening and closing of the exhaust gas flow control valve depends mainly on the vacuum in the carburetor and this easily leads to problems when using.

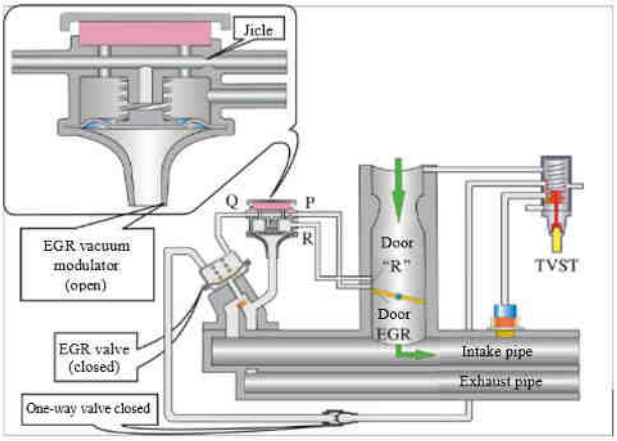

Figure 2.4. Structure diagram of exhaust gas treatment recirculating engine (EGR)[4]

When starting at low temperatures, the carburetor throttle valve is usually closed slightly to increase the vacuum and thicken the fuel-air mixture. Therefore, sometimes in this mode, the vacuum in the intake manifold is large enough to open the EGR system's exhaust flow control valve and adversely affect the engine's ability to start and accelerate.

To be able to control the operation of the EGR system, a number of features have been installed to control components in the EGR system such as temperature, pressure in the intake manifold, and the opening and closing of the exhaust control valve. cyclic….

➢ ***Working principle of EGR system***

The working principle of the EGR system is to use valves and pipes to bring a suitable amount of exhaust gas back to mix with fresh air in the intake manifold before entering the cylinder (Figure 2.5). The presence of exhaust gas in the fuel-air mixture in the combustion chamber has the following specific effects:

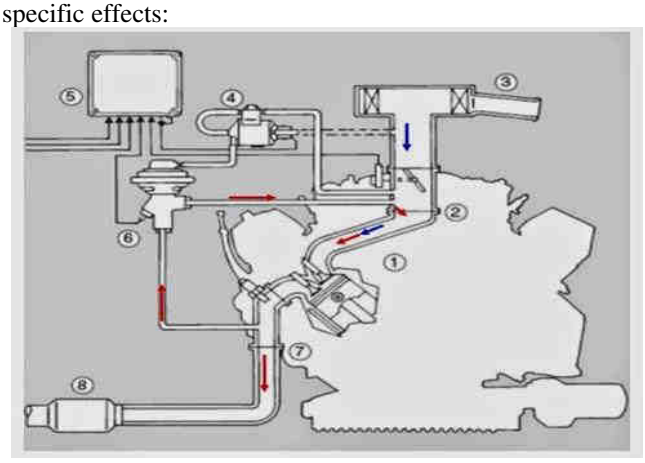

Figure 2.5. The principle of operation of the EGR system

1. Engine – 2. Intake pipe – 3. Air filter – 4. Vacuum valve – 5. Electronic control unit – 6. Recirculating exhaust gas control valve – 7. Exhaust pipe – 8. Catalytic processor.

Reduce the oxygen content in the same amount of mixture;
Reducing the combustion chamber temperature because the heat capacity of the exhaust gas is greater than the heat capacity of the air;

Obstructing and reducing the speed of spreading the flame film in the combustion chamber (reducing the burning rate).

All of these lead to a decrease in pressure and combustion temperature and thereby reduce the amount of NOx formed. Figure 2.6 shows the test results on the effect of recirculated emissions on NOx for BMW 3.0 engine, at 2500 rpm/min: in 72Nm working mode

When an exhaust gas equal to 8% of the mixture volume is introduced, compared with the case of no recirculating emissions (0%) the NOx content decreases from 2500 ppm to 900 ppm; In the working mode of 96 Nm, when the exhaust gas recirculated is 14.2% of the mixture volume, the NOx content decreases from 3200 ppm to 1000 ppm.

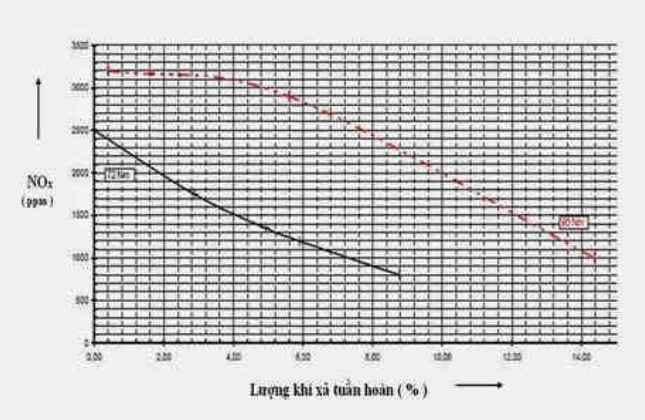

Figure 2.6. Effect of recirculating emissions on NOx

In addition to the main effect mentioned above, especially for gasoline engines, the use of the EGR system also has an effect in reducing fuel consumption. This can be explained as follows:

In gasoline engines, the power adjustment is made according to the principle of changing the amount of air-fuel mixture in the cylinder through controlling the opening and closing of the throttle valve (volume adjustment) and loss of fuel. on the recharge line depends on the opening and closing of the throttle.

When working in load mode, at the same working point, mixing exhaust gas with fresh air will allow people to open the throttle more than in the case of no exhaust gas mixing and thus will have the effect of reducing emissions. reduce losses caused by throttle resistance.
The test results of gasoline engines show that, in the load mode, the use of the automatic control EGR system can reduce fuel consumption by up to 5% compared to engines not equipped with this system.

2.3. Treatment of engine exhaust with a catalytic filter

➢ ***Structure of the exhaust gas catalytic converter***

Figure 2.7. Structure of the exhaust gas catalytic converter [5]

The catalytic converter is a metal box. Contains honeycomb filter elements made of Ceramic or metal. This filter core will be coated with a layer of catalyst. Helps create chemical reactions with harmful gases. This catalyst is usually rare metals such as gold, platinum (Platinum), Rhodium, Palladium ...

➢ ***Working principle of exhaust gas catalytic converter***

Usually after fuel combustion. The engine will emit major compounds such as CO2, N2, H2O. However, in practice, the combustion process can still produce small amounts of other very toxic compounds such as CO, NOx, HC

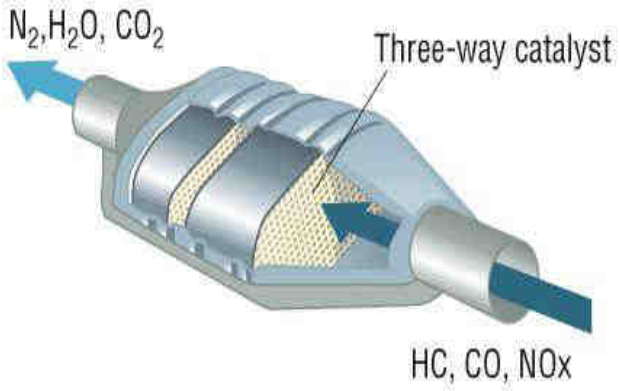

Figure 2.8. Working principle of the exhaust catalytic converter

The task of the catalytic converter is to convert toxic wastes such as CO, NOx, HC into compounds that are less toxic (CO2) or harmless to the environment (N2, H20). To do this, the catalytic converter must be equipped with a honeycomb filter. With a surface covered with a layer of rare metal. To catalyze the reduction and oxidation reactions taking place on the surface of the filter element. Therefore, the filter element surface must provide a large surface area. Make reactions easier. As well as less waste of precious metals.

Catalytic converters can only convert about 90% of environmentally harmful compounds into less toxic compounds.

III. RESULTS AND DISCUSSION

➢ ***Particle filtration technology in engine exhaust treatment***

Fine particulate matter from engine combustion is carcinogenic and particularly hazardous to the environment and human health. Therefore, the particulate filter allows to reduce fine particles from the engine exhaust very effectively and safely. This filter is usually used for diesel or gasoline engines in the form of a gasoline particulate filter (GPF). Features of the particulate filter include:

- Powerful filtration efficiency to separate extremely fine particles from exhaust gas
- Requires low back pressure at no load
- High heat resistance

Because of increasingly stringent emission standards, energy-saving vehicle equipment, particulate filters must be increasingly developed in the future. Accordingly, the scientists will focus on reducing back pressure and improving

the separation efficiency of the filter or combining particulate filtration with a catalyst. In order for the particulate filter to work effectively, it is necessary to rely on specific requirements such as back pressure, separation efficiency, ash deposition, strength, thermophysical properties, chemical composition and microscopic properties. In recent years, scientists have become more and more strict in choosing the process, choosing raw materials to heat treatment.

➢ ***Engine exhaust gas recirculation (EGR) technology***

This is a technology that has great potential to reduce NOx emissions from diesel engines. There are two different types of EGR, including:

High-pressure EGR: is the process of recirculating the exhaust gas between two high-pressure points, the exhaust pipe and the inlet pipe.

Low pressure EGR: is the process of recirculating the exhaust gas between two low pressure points, the tailpipe of the exhaust system and the inlet of the turbocharger.

As part of the exhaust gas returns to the intake air, the oxygen content dhe temperature increases, resulting in lower combustion heat and less nitrogen monoxide. However, reducing the oxygen content increases the amount of PM. The pressure differential on the EGR system is limited and achieving the flow rate is challenging. And the pressure differential alters turbocharger performance or feeds into many other subsystems. For high-pressure EGR recirculation unfiltered exhaust gas contaminates engine and lubricating oil. The low EGR recirculates particulate-free exhaust from downstream of the PM filter.

➢ ***Treatment of engine exhaust with a catalytic filter***

Catalytic converters are used in engines to reduce emissions of carbon monoxide, hydrocarbons and nitrous oxide. Most of these substances are especially dangerous to human health and the environment due to their toxicity. And the exhaust gas treatment by catalytic converter helps analyze the characteristics and remove many harmful emissions components. And among these solutions, diesel oxidation and DeNOx catalytic converters and functional particulate filters have high treatment efficiency. The catalyst aids have different filtration stages, high porosity and structure. And the application of this solution is affected by reactivity, back pressure. The design of this system makes it possible to test, analyze and optimize the catalytic converter and particulate filter. Speed catalytic conversion rate and SCR operating in static/dynamic environment. The system analysis depends on temperature, exhaust gas composition (CO, CO2, NOx, O2, HC, H2O, NH3, SOx) and volumetric flow.

IV. CONCLUSION

By analyzing the structural characteristics and operating principles of technologies to reduce harmful emissions for internal combustion engines, shows that measures to treat and reduce harmful emissions by modern new technologies have been and are being used. Each technology has different advantages and disadvantages, and at the same time, is capable of reducing harmful emissions for internal combustion engines, contributing to a significant reduction in the level of environmental pollution. In there, with the ability to easily replace, maintain and have a thorough effect, then a three-component catalyst is the optimal passivation method.

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