International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 8 Aug. 2022, pp: 794-798 www.ijaem.net ISSN: 2395-5252

Solutions to Reduce Environmental Pollution with EGR Exhaust Gas Recirculation System

Ngocnguyen Van[1], Hoai Cu Huy[2]
College of Technology II, Ho Chi Minh City, Vietnam[1]
Thu Duc College Of Technology, Ho Chi Minh City, Vietnam[2]

Submitted: 10-08-2022 Revised: 17-08-2022 Accepted: 20-08-2022

ABSTRACT: The Exhaust Gas Recirculation (EGR) system was invented in the early 1970s with the desire to minimize the harmful emissions that pollute the environment of cars. Today, although no longer as popular as catalytic exhaust gas neutralizers, the EGR system is still an effective technology to reduce the concentration of toxic NOx in automobile exhaust. When the temperature of the engine combustion process reaches above 1600 °C or 2912°F, nitrogen gas in the air will combine with oxygen to create different nitrogen oxides (NOx) such as NO, NO2, N2O, N2O5...To lower the combustion chamber temperature, this can be done by using a system to return a certain exhaust gas flow back to the combustion chamber, which is called the exhaust gas recirculation system (EGR).

Keywords: Exhaust Gas Recirculation, Exhaust Gas Recirculation, EGR, NOx toxic gas concentration reduction.

I. INTRODUCTION

Exhaust Gas Recirculation (EGR) is an emission control technology that allows to significantly reduce NOx emissions from most types of engines. Although the application of EGR to reduce NOx is the most common reason for adopting EGR to modern commercial engines, its potential application also extends to other purposes. Some of these include: creating detonation resistance and reducing the need for high load fuel enrichment in SI engines, supporting the vaporization of liquid fuels in SI engines[1], as a supporting factor for closed cycle diesel engines[2][3], to improve the ignition quality of hard-to-ignite fuels in diesel engines [4] or to improve the performance of SCR catalysis[5][6].

While reductions in NOx have been reported to EGR as early as 1940 [7], the first engine experiments to investigate the likelihood of reducing NOx of EGR appear to have been carried out in the late 1950s in SI engines [8]. In the 1970s, EGR was taken seriously as an NOx control measure for diesel engines[9][10].

From 1972 to the late 1980s, EGR was commonly used to control NOx in the engines of passenger cars and gasoline-powered light trucks in North America. After the early 1990s, some applications used gasoline fuels that could be dispensed with EGR. After the initial application of gasoline, EGR was also introduced for passenger cars powered by diesel engines and light trucks and later for heavy-duty diesel engines. Although there have been applications for heavy-duty diesel engines since the 1970s, it was not until the early 2000s that machine-cooled EGR became very popular among heavy-duty diesel engines in North America [11]. It was this heavy engine application that drew the most attention to EGR, due to its more difficult technical challenges than previous applications on light engines. After 2010, the application of EGR to gasoline engines was expanded – not for NOx control but for fuel economy purposes. It is applied not only to light gasoline engines but heavy gasoline, natural gas and propane-fueled engines. For SI engines, EGR can reduce pump losses, improve combustion efficiency, improve impact resistance, and reduce the need for fuel enrichment [12]. One potential application that does not reduce NOx EGR for modern diesel engines is to combine it with other engine control measures to increase exhaust gas temperatures and facilitate the regeneration of diesel particulate filters[13].

At higher rpm, more gas is needed, the recirculation valves will depend on the engine rpm and the load will be adjusted to bring the highest efficiency.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 8 Aug. 2022, pp: 738-741 www.ijaem.net ISSN: 2395-5252

In addition, such recirculation allows thorough combustion of the fuel to minimize environmental pollution.

In internal combustion engines, exhaust gas recirculation (EGR) is a nitrogen oxide (NOx) emission reduction technique used in gasoline, diesel and some hydrogen engines

II. SOLUTIONS TO REDUCE NOX ON THE ENGINE

2.1. REDUCE Nox

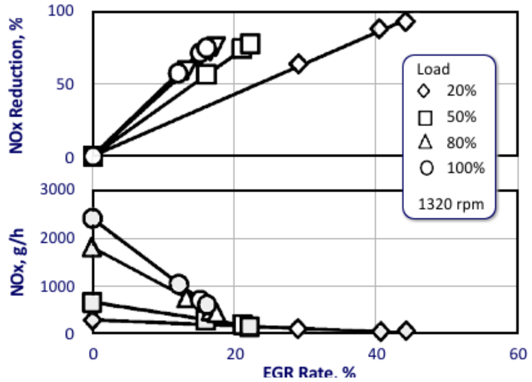

Fig. 1. Effect of EGR rate on NOx reduction at different motor loads

The effect of the EGR ratio on the reduction of NOx at different engine loads at medium speed conditions is illustrated in (Fig 1). Under all loads, the amount of NOx decreases as the EGR rate increases. The graph also shows that the efficiency of reducing NOx at a certain EGR rate increases as the motor load becomes higher [17].

This dependence on loads can largely be explained by different exhaust components and therefore differences in dilution effects at different loads. When NOx reductions for different loads are plotted based on the oxygen of the intake manifold (Fig. 1), all points are on the same curve.

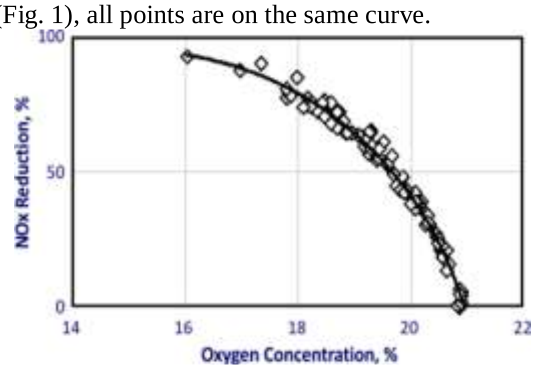

Fig. 2. Relationship between intake manifold oxygen and NOxreduction

The temperature of the EGR can affect the intake gas mixture temperature and therefore NOx emissions. Cooling the EGR will increase the temperature difference duration in the heat absorption equation for the EGR, Formula (1), increase heat absorption and further reduce NOx.

$\Delta Q = \Delta m_0 \cdot C_p \cdot \Delta T$ (1)

Inside:

ΔQ - Increased heat absorption of non-reactive gases;

Δm_0 - Mass gain in the cylinder;

Cp - Specific heat at constant pressure;

ΔT - Difference between the combustion temperature and the EGR temperature.

2.2. EGR SYSTEM SOLUTIONS FOR MOTORS

When the air conditioner, the J and M doors of the TVSV are connected so the gas can go from J to M through the TVSV. Thus atmospheric pressure is directed in from the J of the TVSV through the M door and the check valve to the upper part of the EGR valve, keeping the check valve still open.

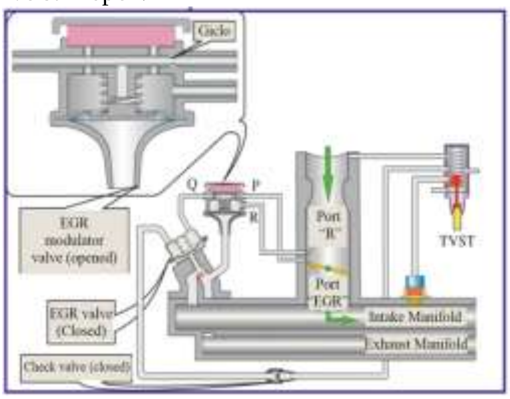

Fig. 3. EGR system at cold enginemode

Due to the warm engine (coolant temperature above 56^{o}C), the K and M doors of the TVSV communicate with each other, and the intake manifold vacuum acts on the check valve causing the check valve to close. At this time, because the B door and the EGR door are located on the throttle blade, the vacuum of the intake manifold does not pass through the EGR and the "R" door of the EGR so the valve remains closed and the exhaust gas is not recirculated.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 8 Aug. 2022, pp: 794-798 www.ijaem.net ISSN: 2395-5252

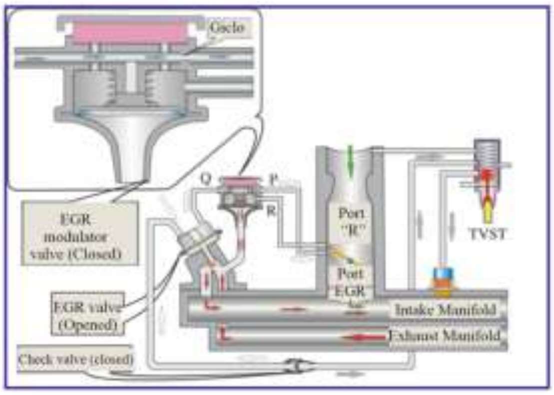

Fig. 4. EGR system in warm engine mode

III. EGR CONTROLSYSTEM

During the engine design phase, the EGR control strategy must be developed to not only meet NOx reduction targets but also to ensure PM emissions meet design objectives, so that fuel consumption does not increase excessively and vehicle performance meets customer expectations. In most modern diesel engines, it is not enough just to control the amount of EGR flowing to the combustion chamber; instead, the EGR control strategy must be consistent and work well with the entire engine management system. Since EGR can affect the availability of oxygen for combustion, EGR control strategies typically have tasks with two important objectives:
(1) Ensure that the air-to-fuel ratio (A/F) is appropriate across all engine operating conditions to meet performance and emissions targets;
(2) The volume of oxygen trapped in the cylinder is consistent with the amount of fuel injection. Therefore the EGR control system is an integral part of the air management system.

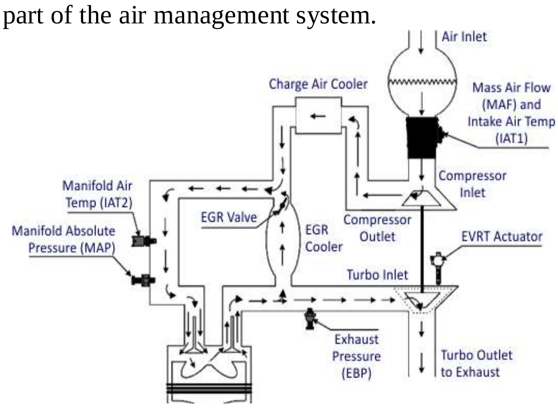

Fig. 4.HPL EGR system for medium power diesel engines [18]

Control of HPL EGR Systems. In this paper, we focus on typical control strategies for high pressure ring EGR systems. [Figure 1] shows the basic components of the air management system of modern diesel engines, including sensors, with the HPL EGR system [14]. This hardware arrangement will be typical for many modern light and midsize diesel engine applications. The inlet air passes through the air filter and mass air flow sensor before entering the turbocharged compressor. Then the compressed air is cooled with an air freshener and mixed with the cooled EGR gas. The state of this compressed and heated air/EGR mixture is sensed by the MAT (air temperature in the intake manifold) and MAP (intake manifold absolute pressure) sensors just before it enters the cylinder. Exhaust gas pressure is measured with an exhaust gas reverse pressure (EBP) sensor before escaping through the turbocharger. In this example, for heavy vehicles, the air management system for an engine with HPL EGR will be similar; the main difference is that an air flow sensor will not be used.

Sensors: In order to control the EGR with the required precision and precision, signals from a variety of sensors are required as shown in Figure 1. It is possible to use a real sensor that measures general parameters such as temperature, pressure and flow or a simulated sensor . Some common sensors used to control EGR include:

Temperature sensors: Intake manifold temperature and EGR temperature can be measured using commonly available temperature sensors. If the engine is equipped with a mass air flow meter, it usually incorporates a temperature sensor that can provide a measurement of the intake air temperature in front of the compressor. In the temperature range from -50°C to 150°C, silicon microchip sensors are commonly used while for temperatures up to 1000°C, the thermistor type sensor is available. Virtual sensors can also be used to estimate temperatures in particularly difficult locations such as at turbine inlets[15]

Pressure sensors: Many EGR control applications require intake and exhaust manifold pressure, atmospheric pressure, and EGR valve pressure drop. Piezoresistive micromechanical pressure sensors are very popular for these applications.

Flow sensors: Some flow parameters are important for EGR control.

The intake air flow at the compressor inlet can be measured with an air mass sensor (MAF)—these sensors can use a hot wire type, hot film, or thin film type sensor element. Modern designs can detect the flow direction to accurately calculate the flow reversal. These sensors are common for light and medium applications. However, there are challenges to using them in heavy-duty applications, including insufficient durability. Most MAF sensors also integrate an air temperature sensor.

EGR flow can be measured by flow sensor or simulator sensor using EGR valve position and pressure drop as input. Designs based on hot film wind measurement have also been developed[16]

The intake flow from the intake manifold to the cylinder can be determined by a virtual sensor based on the speed/density approach.

The EGR valve position sensor and the variable geometric turbine blade position sensor are also important system signals that may be required to control the EGR. EGR valve position sensors can be based on a variety of principles including potentiometers and Hall Effect sensors.

Gas Composition Sensors: Exhaust Oxygen (EGO) and NOx sensors can also serve a useful function in controlling EGR in diesel engines. Diesel engines operate with excess air so switch-type EGO sensors for molecular measurement gasoline applications are not commonly used. The wide-range EGO sensor uses ZrO_2 solid electrolyte and oxygen pump electrochemical titration to measure the air-fuel ratio over a wide range. The sensor for measuring NOx is similar but includes additional features to first remove excess O_2, then separate the NOx into N_2 and O_2 and then pump the obtained O_2.

IV. CONCLUSIONS

The paper summarizes the world's studies on the EGR emission control system, analyzes the basic operation of the system and the appropriate control system. Research is the basis for controller design and application on the actual model.

REFERENCES

[1]. McAdams, W.H., “Method Of Controlling Recycling Of Exhaust Gas In Internal Combustion Engines”,1933 US Patent 1,916,325, http://www.google.com/patents/US1916325.

[2]. Thwaites, H.L., “Method Of Fuel Combustion Control In Internal Combustion Engines”,1956 US Patent 2,742,885, http://www.google.com/patents/US2742885.

[3]. Campbell, L.F., “Closed Cycle Engine”, US Patent2,645,216, http://www.google.com/patents/US2645216

[4]. Mühlberg, E., “Recycled Exhaust Gas Regulation”,1964 US Patent 3,135,253, http://www.google.com/patents/US3135253

[5]. Zha, Y., et al., 2017. “Sustained Low Temperature Nox Reduction”, Oral-only presenation, 2017 SAE World Conference, https://www.osti.gov/scitech/biblio/1350595

[6]. Zha, Y., et al., “Cummins Sustained Low Temperature Nox Reduction (SLTNR)”, 2016 Annual Merit Review, US DOE, Washington, DC, June 9, 2016, https://energy.gov/sites/prod/files/2016/06/f33/pm068_zha_2016_o_web.pdf

[7]. Berger, L.B., et al, “Diesel engines underground – II. Effect of adding exhaust gas to intake air. Report of Investigations 3541”,1940, US Department of Interior, Bureau of Mines, November 1940

[8]. Kopa, R.D., H. Kimura, “Exhaust gas recirculation as a method of nitrogen oxides control in an internal combustion engine”, Proceedings of the APCA 53rd Annual Meeting, Cincinnati, Ohio, USA, 22–26 May 1960, (Air Pollution Control Association)., 1-54

[9]. Teshirogi, N., H. Nakahara, “Method For Controlling Noxious Components Of Exhaust Gas From Diesel Engine”, 1974, US Patent 3,851,632, http://www.google.com/patents/US3851632

[10]. Kern, R.A., et al., “Exhaust gas recirculation system for a diesel engine”, 1977, US Patent 4,020,809 (Caterpillar), http://www.google.com/patents/US4020809

[11]. Hawley, J.G., et al., “Reduction of Steady State NOx Levels from an Automotive Diesel Engine Using Optimized VGT/EGR Schedules”, SAE Technical Paper 1999-01-0835, doi:10.4271/1999-01-0835

[12]. Styles, D., “Cooled EGR for GTDI Engine CO2 Reduction – Benefits and Challenges”, 9th Annual CTI Forum – Exhaust Systems, Stuttgart, Germany, January 26, 2011

[13]. Lemaire, J., W. Mustel and P. Zelenka, “Fuel Additive Supported Particulate Trap Regeneration Possibilities by Engine Management System Measures”, 1994, SAE Technical Paper 942069, doi:10.4271/942069

[14]. Ford, “2003 MY OBD System Operation Summary for 6.0L Diesel Engine”, Ford Motor Company, Detroit, USA

[15]. Xin, Q, “Diesel Engine System Design”, Woodhead Publishing, 2011.

[16]. Grimm, K., Nigrin, S., Tönnesmann, A. and Dismon, H. “Exhaust Gas Mass Flow Sensor for Car and Commercial Vehicle

Applications", MTZ Extra: 100 Years of Kolbenschmidt Pierburg, March 2010, http://www.atzonline.com/Article/10912/Exhaust-Gas-Mass-Flow-Sensor-for-Car-and-Commercial-Vehicle-Applications.html

[17]. Yokomura, H., S. Kohketsu and K. Mori, "EGR System in a Turbocharged and Intercooled Heavy-Duty Diesel Engine: Expansion of EGR Area with Venturi EGR System", Mitsubishi Technical Review, 2003 No. 15

[18]. Ford, "2003 MY OBD System Operation Summary for 6.0L Diesel Engine", Ford Motor Company, Detroit, US.