



Research on Effect of EGR and SCR on NO_x Emission from a Heavy Duty Diesel Engine

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Abstract: Experimental study was conducted on NO_x emissions law of a heavy diesel engine with EGR and SCR. Opening of EGR valve (OEV) was adjusted by INCA, and ammonia nitrogen ratio (ANR) was changed by controlling urea injection quantity with control unit DCU of SCR. Under low, medium and high speed and 50%, 75% and 100% load conditions, the effect of EGR (exhaust gas recirculation) and SCR (selective catalytic reduction) on diesel engine NO_x emission was studied by test. The results show that when a heavy diesel engine use EGR and SCR, the conversion magnitude and conversion ratio of NO increased significantly, NO_x emissions rule is similar to that of NO, and when opening of EGR valve is more than 25%, the effects of OEV increasing on NO and NO_x are smaller than the effect of SCR. Only under the conditions of high emissions concentrations of NO₂, EGR and SCR significantly reduce NO₂ emission concentration.

Keywords: Diesel Engine, Exhaust Gas Recirculation (EGR), (SCR), Nitrogen Oxides (NO_x)

1. Introduction

Since diesel engine has the advantages of low fuel consumption, high torque output and high reliability, it has been widely used in the field of transportation, agricultural machinery, construction machinery, and etc [1]. But compared with gasoline engines, NO_x and PM emissions from diesel engines are more. According to the annals of China's motor vehicle pollution prevention in 2014, the national NO_x emission from diesel engines is close to 68.8% of the total emissions from cars, and PM is more than 99%, so the NO_x and PM emissions have become one of the important factors restricting the development of diesel engines. At present, two different emission control technical routes for diesel engines are adopted: one is SCR + DOC + DPF/POC technical route; another is EGR + DOC + DPF technical route [2], the former mainly decrease NO_x emission by redox reactions, the latter mainly control internal NO_x production. Considering the trade-off relations of NO_x and PM from diesel engines, the approach of diesel engines emission reaching VI standards is to research and develop post-processing technology (SCR) for diesel engines on the basis of controlling NO_x production in

the cylinder by EGR [3]. Foreign scholars have researched the diesel engine using EGR and SCR technologies from the aspects of theory, test and control [4-7]. While domestic scholars have studied diesel engines using EGR technology or SCR technology by experiments or simulation [8-13], and they put forward it is necessary for diesel engines to use EGR combined with SCR technology [3, 14], but experimental study on using EGR and SCR technology on diesel engine is relatively little. Therefore in this paper, a heavy diesel engine is used as the test prototype. Under different working conditions, the influence of EGR and SCR on NO_x emission from a heavy duty diesel engine is studied by test, and the experimental results are analyzed.

2. Test Equipment and Program

2.1. Test Diesel Engine

The test diesel engine is an electronically controlled high pressure common rail heavy duty diesel engine, which is equipped with EGR and SCR, and its main technical parameters are shown in Table 1. Opening of EGR valve (OEV) is adjusted by INCA. SCR catalyst is TiO₂-WO₃-V₂O₅,

and urea injection regulation is realized by urea calibration unit DCU.

Table 1. Specifications of the test engine.

Item	Parameter
Displacement/L	11.6
Compression Ratio	17:1
Air intake Mode	Turbo Charging with Inter-cooling
Diesel Supply System	High Pressure Common Rail
Cylinder Form	Inline 6 cylinder, 4 valve / cylinder
Bore/mm×Stroke/mm	126×155
Calibration Power/kW	295
Calibration Speed /r/min	2100
Maximum Torque /N·m	1549
Maximum Speed/r/min	1500

2.2. Test Instruments

The schematic diagram of the test bench is shown in Figure 1.

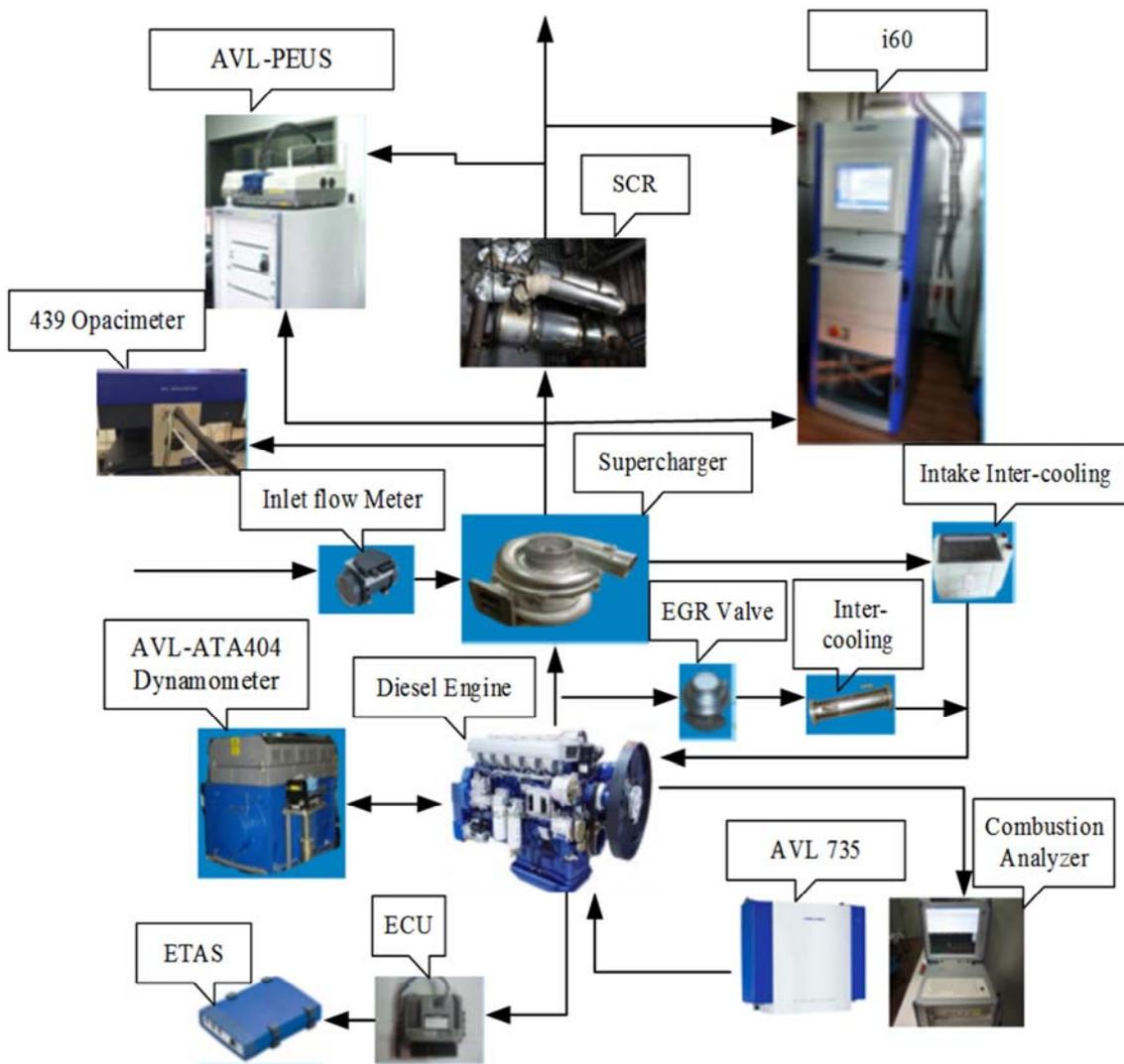


Figure 1. Schematic diagram of the test bench.

Engine test bench is AVL-PUMA fully automatic engine test bench control system, and the system controls the engine speed and torque with AVL APA 4F4 dynamometer, NO, NO₂ and NO_x emissions are measured by AVL-PEUS multiple

component emission instrument.

2.3. Test Program

Specific test conditions are as follow: ESC three speed 1295

r/min, 1590 r/min and 1885 r/min, 50%, 75% and 100% load. EGR ratio is adjusted by changing opening of EGR valve (OEV), ANR is changed by controlling urea injection quantity with DCU. First of all, under different working conditions, opening of EGR is controlled at 25% and 50%, then ANR is changed from 0.5 to 1.0 on the basis of EGR, the NO_x emission trend is researched by test.

3. Experimental results and Analysis

3.1. NO Emission Analysis

Under different OEV and ANR, variation of NO volume concentration and conversion ratio with engine loads is shown as Figure 2. The figure shows that the NO volume emission concentration from a diesel engine without EGR and SCR increases with the increase of load. When the diesel engine using EGR and SCR at the same time, SCR further reduce NO volume emission concentration on the basis of the EGR reducing NO produce. The effect of EGR and SCR on reducing NO is more significant with the diesel engine load increasing. When the engine load increases, the results of SCR reducing NO volume emission concentration by increasing urea injection amount are more significant. At the same condition, EGR and SCR reduce the NO volume emission concentration to a certain extent. Once the limit is exceeded, the effect of the increase of both on the reduction of NO volume emission concentration is no longer significant. When diesel engine operate at the condition of 1295 r/min and 50% load, the decrease of NO volume emission concentration corresponded by OEV 25% and ANR 0.5, OEV 25% and ANR 1, OEV50% and ANR 0.5, OEV 50% and ANR 1 are individually 100.12×10^{-6} , 173.23×10^{-6} , 115.81×10^{-6} , 202.47×10^{-6} . When diesel engine operate at the condition of 1295 r/min and 100% load, the decrease of NO volume emission concentration corresponded by OEV 25% and ANR 0.5, OEV 25% and ANR 1, OEV 50% and ANR 0.5, OEV 50% and ANR 1 are individually 218.81×10^{-6} , 327.62×10^{-6} , 268.39×10^{-6} , 382.72×10^{-6} . It can be seen that the high load operation of diesel engine, regardless of the size of the diesel engine EGR valve opening, the effect of SCR on decreasing NO volume emission concentration is significant. When EGR and SCR are combined by diesel engine, the conversion ratio of NO was significantly higher than that of EGR or SCR alone, especially the use of EGR could further improve the conversion ratio of SCR. With the opening of the EGR valve increasing, the induce amount of NO volume emission concentration is becoming bigger at the same ANR, and the change trend is similar to other two speeds. Under the condition of 1295 r/min and 50% load, when OEV is 25%, the NO conversion ratios corresponded by ANR 0.5 and ANR 1.0 are individually 46.9% and 81.3%, when OEV is 50%, the NO conversion ratios corresponded by ANR 0.5 and ANR 1.0 are individually 54.1% and 94.8%. 1885 r/min diesel engine, 50% load operation.

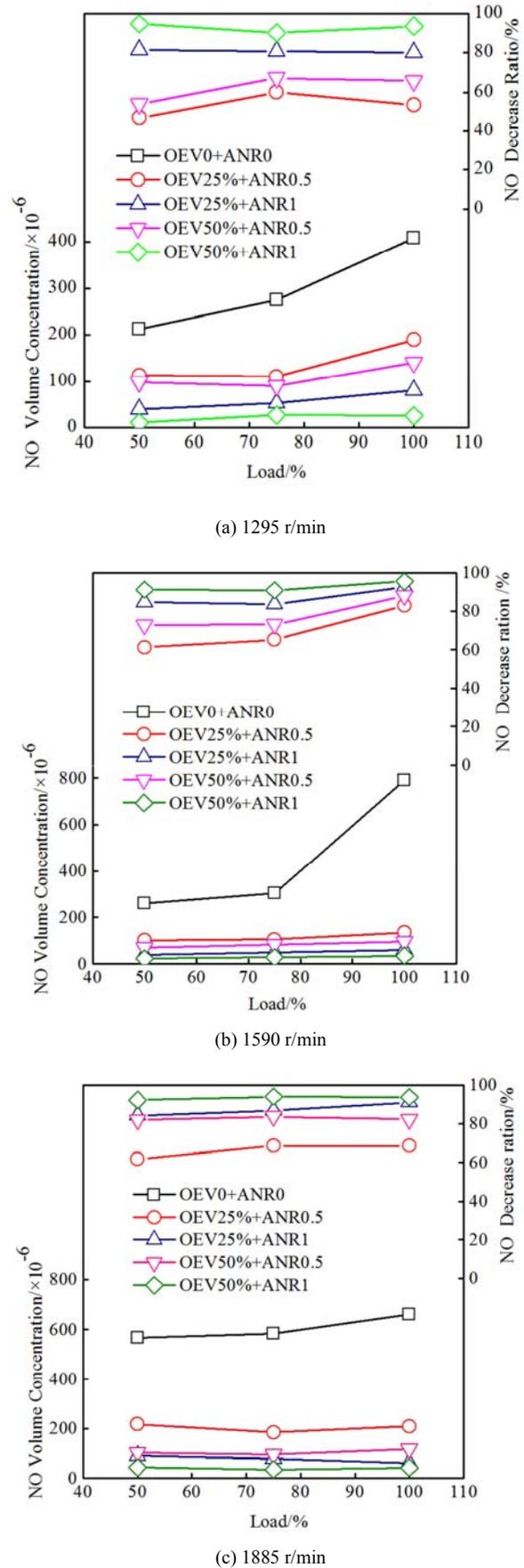
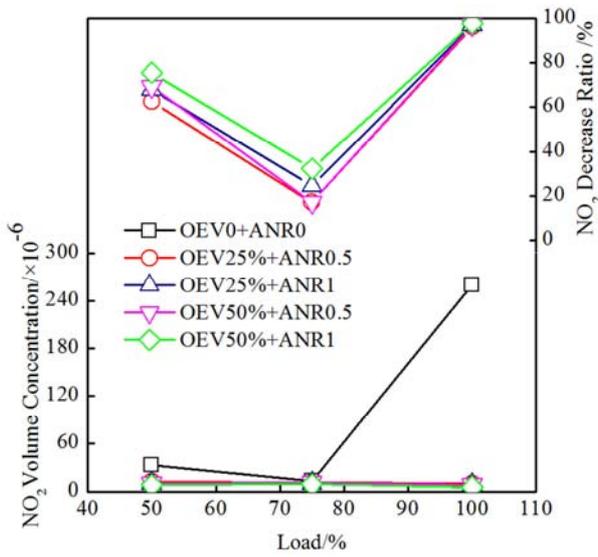


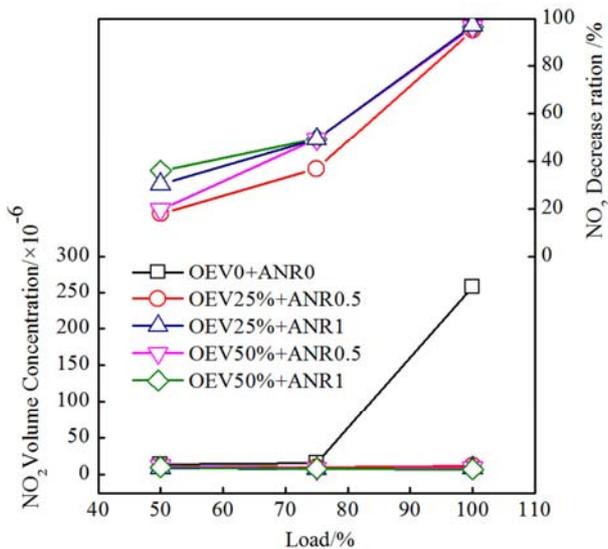
Figure 2. Variation of NO volume concentration and conversion ratio with engine loads.

3.2. NO₂ Emission Analysis

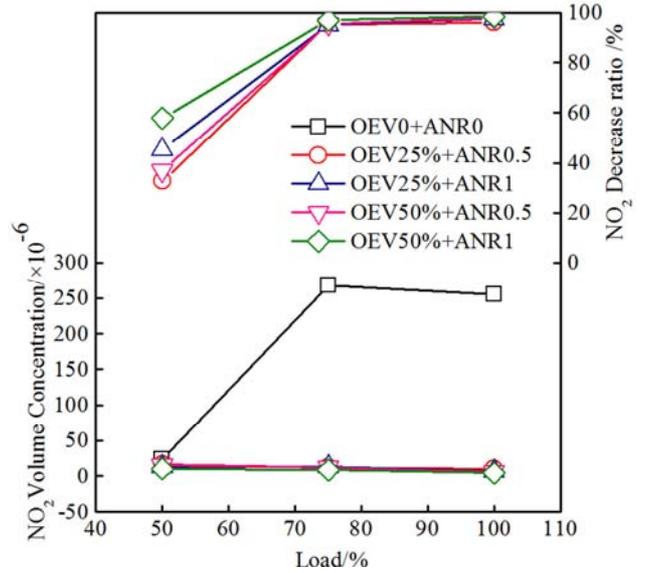
Under different OEV and ANR, variation of NO₂ volume concentration and conversion ratio with engine loads is shown as Figure 3. The figure shows that when the diesel engine runs at low loads, the NO₂ volume concentration is low, and the combined effect of EGR and SCR has little effect on NO₂ volume concentration. At high loads, NO₂ emission volume concentration is greatly decreased by the combined use of EGR and SCR. When OEV is 25%, NO₂ emission volume concentration is decreased obviously, and once OEV is bigger than 25%, the downward trend of NO₂ is no longer evident. As we can see, using a combination of EGR and SCR greatly reduces the NO₂ volume concentration at 100% load. At 100% load, when the speed is 1295 r/min, 1590 r/min and 1885 r/min, the maximum decrease of NO₂ volume emission concentration are 253.49×10^{-6} , 250.43×10^{-6} and 257.16×10^{-6} .



(a) 1295 r/min



(b) 1590 r/min

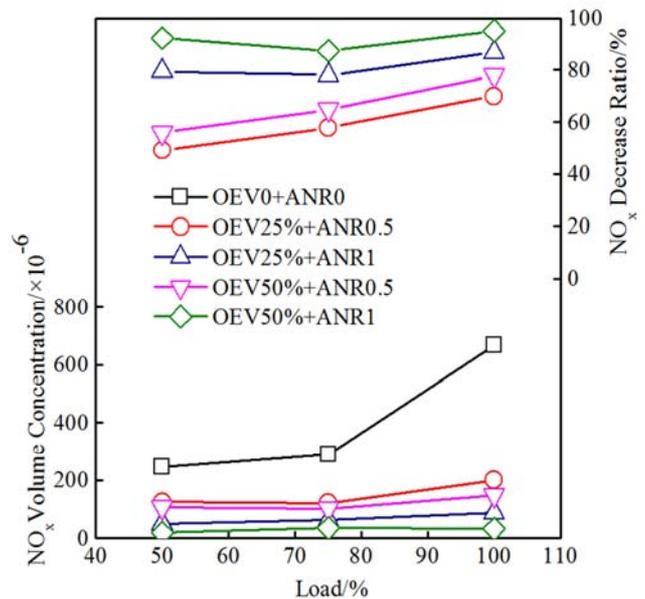


(c) 1885 r/min

Figure 3. Variation of NO₂ volume concentration and conversion ratio with engine loads.

3.3. NO_x Emission Analysis

Under different OEV and ANR, variation of NO_x volume concentration and conversion ratio with engine loads is shown as Figure 4. From the figure, we can see the conversion trend of NO_x is similar to that of NO, which is because most of the NO_x emissions from diesel engines are NO emissions. The effect of OEV25%+ANR0.5 on the NO_x volume concentration is great, especially at high loads. When OEV and ANR increase further, the effect is not evident.



(a) 1295 r/min

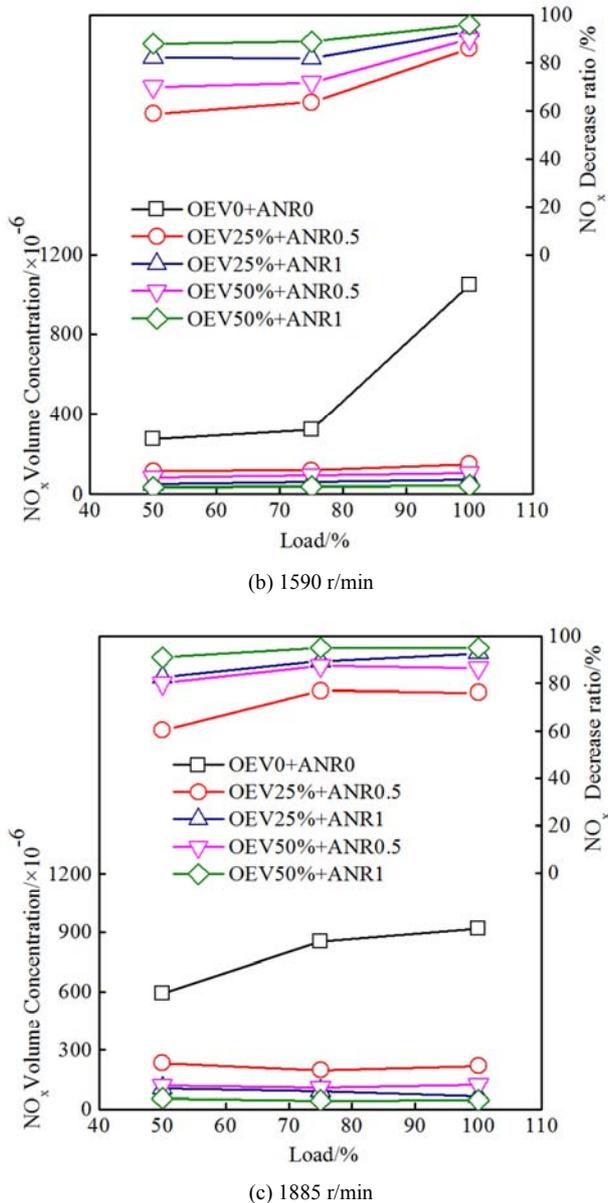


Figure 4. Variation of NO_x volume concentration and conversion ratio with engine loads.

4. Conclusion

When the heavy diesel engine use EGR and SCR at the same time, OEV25%+ANR0.5 reduce the NO volume concentration significantly. While OEV is bigger than 25%, NO volume concentration can further be reduced, but the effect is no longer significant.

Only at high loads of the diesel engine, NO_2 emission concentration is higher, under these conditions, EGR and SCR reduce NO_2 emission concentration significantly.

EGR and SCR can effectively reduce the NO_x volume concentration, and the trend of NO_x volume concentration reduction and conversion ratio is similar to that of NO emission.

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