Emission Characteristics of Diesel Engine Fueled with Ethanol-diesel Blends in Different Altitude Regions

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Abstract: In order to investigate the effects ethanol-diesel blends and altitude on the emissions of diesel engine, the comparative experiments were carried out on the bench of turbo-charged diesel engine fueled with pure diesel (as prototype) and ethanol-diesel blends (E10, E15, E20 and E30) under different atmospheric pressures (81kPa, 90kPa and 100kPa). The experimental results indicate that all the parameters of emissions during 90~100kPa are superior to those of 81~90kPa. At 81kPa, both HC and CO emissions rise greatly with the increasing engine speeds and loads and addition of ethanol, while at 90kPa and 100kPa the effects of engine speeds and loads and usage of ethanol on HC and CO emissions are slightest. The changes of atmospheric pressure and mix proportion of ethanol have no obvious effect on NOx emissions and NOx emissions of ethanol-diesel blends have a slight drop in a small scale compared with prototype under most engine conditions.

Keywords: Atmospheric Pressure; Ethanol-Diesel Blend; Diesel Engine; Emission

I. INTRODUCTION

Recently, diesel engine has received considerable attention because of its high heat efficiency and low emission; however, with the stringent emission standard and limited petroleum reserve, alternative fuels for diesel engine have been used. As a renewable and oxygen-containing bio-fuel, ethanol is a prospective fuel for vehicle, which can be blended with diesel or be injected into cylinder directly. There are many studies on the application of ethanol on diesel engine, which focuses on the three aspects: application techniques of ethanol on diesel engine, fuel properties of ethanol-diesel blends and effects on the combustion and emission characteristics of ethanol-diesel blends[1-3].

The physical and chemical characteristics of ethanol-diesel blends are very important to its application on diesel engine. The stability, density, viscosity, surface tension, specific heat, heat value and cetane number of blends have great impact on the injection, atomization, ignition and combustion properties, as well as cold-start, power, fuel consumption and emission characteristics of engine. Additionally, the poking and leakage of conventional tank, fuel pipe and sealing part can be rendered. More stringent demands are necessary for the mixture, transportation, storage and usage of fuel because of low flash point of ethanol-diesel blends[4-6].

The atmospheric pressure and air density can affect the combustion process of engine, so the power performance, fuel consumption and emission characteristics of engine will be different when the engine was run at different altitudes. So far, the application researches of ethanol-diesel blends were almost carried out at low altitude. Therefore, in order to investigate the effects ethanol-diesel blends on the performance and emissions of diesel engine under different atmospheric pressures, the comparative experiments were done between the engine fueled with pure diesel (as prototype) and ethanol-diesel blends at different altitudes[7-9].

II. MATERIALS AND METHODS

A. Test engine

The test engine was a 3.298L, direct-injection, turbocharged diesel engine. The relevant characteristic of detailed engine configuration was given in Table 1. During experiment the engine was tested without any modification.
TABLE I. ENGINE CONFIGURATION

| Type                  | In-line, 4 cylinders |
|-----------------------|----------------------|
| Bore×stroke (mm)      | 100×105              |
| Displacement (L)      | 3.298                |
| Combustion chamber    | ω-type direct injection |
| Induction system      | Turbocharged and intercooler |
| Compression ratio     | 17.5 : 1             |
| Rated power (kW/(r·min⁻¹)) | 73/3200          |
| Maximum torque (N·m/(r·min⁻¹)) | 245/2200       |

B. Emission test apparatus and the realization of different atmospheric pressures

The emission test devices included an AC electric dynamometer (AVL AFA Drive 250/4-8), an exhaust analyzer (AVL CEB), a fuel consumption meter (AVL 733) and a smoke meter (AVL 415). The altitude of test bench is 1912m and the local atmospheric pressure is 81kPa. The relative humidity is 40~60% and temperature ranges from 18 to 21.

The different atmospheric pressures were produced by an engine condition system (AVL ACS1300/300), which can automatically control the atmospheric pressures and inlet gas temperatures. The inlet of turbocharger compressor was connected to the pressure output of engine condition system and the pressure sensor and temperature sensor were used. When the c was 81kPa, the exhaust back pressure was set at local environmental pressure. When the atmospheric pressure was 90kPa or 100kPa, the back pressure of engine was adjusted to inlet pressure.

C. Blend of ethanol and diesel

A hydraulic vibration emulsification device was developed, which was installed on the high-pressure pump of diesel engine. The ethanol and diesel were delivered to the emulsification device by two fuel delivery systems. The emulsified ethanol/diesel was injected into the cylinder by pump and injector. The emulsification device can provide different proportions of ethanol and diesel without modifying engine and stopping engine. The emulsification device can use the 95% ethanol without any emulsifier and surfactant. The test diesel is 0# diesel.

III. RESULTS AND DISCUSSIONS

A. Emission characteristics of HC

The HC emissions of diesel-ethanol blends under three atmospheric pressures were shown in figure 1, figure 2 and figure 3. It can be seen that the HC emissions under different atmospheric pressures show significant divergences when the mix proportions, engine speeds and loads change. With increasing speeds and loads, the effect of atmospheric pressure on HC emission was not significant. At 2200 r/min and 81kPa the mix proportions had great effects on the HC emissions, especially at light load (50N·m), which rendered the increase by 47%~293%. The increase of HC emissions of E30 was great. The HC emission increased with the increasing percentage of ethanol in blends, however the HC emissions of ethanol-diesel blends nearly reached the level of prototype at 3200 r/min.

Because the ethanol has higher latent heat of vaporization, which reduces the gas temperature and promotes the chilling of cylinder wall, the HC emission rises evidently with the increasing content of ethanol at low speed and load of engine. When engine speeds and loads go up, the temperature of gas and combustion chamber wall increases, which accelerates the formation of mixture gas and promotes the combustion of fuel, so the increasing blends of ethanol has litter influence on the HC emissions at higher engine speed and load. Thus, HC emission had slight increase and reached the level of diesel-fueled engine at some engine loads. Due to its higher latent heat of vaporization and lower cetane number, higher proportion of ethanol reduces the gas temperature and retards the ignition delay, which results in the significant rise of HC emissions of E30 at lower speed and load. Additionally, the limited emulsifiable ability of mixture device at higher proportion of ethanol may be another reason. Based on above analysis it can be said that HC emissions of ethanol-diesel blends are depended on the engine speed, load and the mix proportion of ethanol.
B. Emission characteristics of CO

The CO emissions of ethanol-diesel blends under three atmospheric pressures were shown in figure 4, figure 5 and figure 6. At 2200 r/min and low load (50N•m), E10, E20 and E30 augmented the CO emissions by 20%~250%, 33%~301% and 35%~210% respectively. With increasing engine speed and engine load atmospheric pressure had litter influence on the CO emission. At low and middle loads the higher proportion of ethanol increased the CO emission slightly. At full load CO emissions of ethanol-diesel blends were lower than those of pure diesel, especially at 81kPa. The experimental results indicated that the ethanol-diesel blends would not deteriorate the CO emissions except for 2200 r/min and low load.

The addition of ethanol causes the reduction of gas temperature, which restrains the oxidation of CO, so CO emission goes up at low load. With the increase of engine speed and load, the increase of gas temperature and wall temperature and oxygen content of ethanol promotes the oxidation condition of CO, which decreases the negative effect of addition of ethanol. At full load, the excess air ratio is comparatively low, so the increasing proportion of ethanol decreases the CO emission greatly. With the increase of atmospheric pressure, the excess air ratio increases, which decrease the effect of ethanol, so atmospheric pressure has little influence on the CO emission. Based on above analysis it can be said that CO emissions of ethanol-diesel blends are depended on the engine speed, load and the mix proportion of ethanol.
C. Emission characteristics of NOx

Figure 7, figure 8 and figure 9 showed the NOx emissions of ethanol-diesel blends under three atmospheric pressures. At different atmospheric pressures and mix proportions the NOx emissions showed the similar trend. The ethanol-diesel blends reduced the NOx emission at most modes. At 2200 r/min and low load the slight increase of NOx emission for E30 should be rendered by the bad emulsification at higher mix proportion. The increasing oxygen content can promote the formation of NOx; however, the maximum gas temperature is a most important factor of NOx formation, so the decreased gas temperature caused by higher latent heat of vaporization of ethanol can reduce the NOx emission.

IV. CONCLUSIONS

(1) At 81kPa the HC emission rises greatly with the decrease of speed and load and the increase of ethanol content, especially at low load. The increasing mix proportion of ethanol has little influence on the HC emission when atmospheric pressure ranges from 90kPa to 100kPa.

(2) At 81kPa the CO emission rises greatly with the decrease of speed and the increase of ethanol content, especially at low load. At 90kPa and 100kPa the CO emission increases slightly with the increasing mix proportion at low and middle load, while the CO emission is reduced at heavy load.
(3) Atmospheric pressure and mix proportion have no obvious influence on NOx emission. Under most working conditions NOx emission of ethanol-diesel blends has a slight drop compared to that of diesel.

![Figure 7](image7.png)  Comparison of NOx emission of different atmospheric pressure and mix proportion at speed 1400r/min

![Figure 8](image8.png)  Comparison of NOx emission of different atmospheric pressure and mix proportion at speed 2200r/min

![Figure 9](image9.png)  Comparison of NOx emission of different atmospheric pressure and mix proportion at speed 3200r/min

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