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Experimental study on the effect of coal to liquid on combustion and emission of heavy-duty diesel engine with exhaust gas recirculation

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ABSTRACT

The work aims not only to exploit the petroleum alternative fuel for relieving the energy crisis, but also to realize the ultra-low emissions of diesel engines fueled with this alternative fuel. The effects of direct coal liquefaction (DCL) on combustion and emissions have been studied in a heavy-duty engine fueled with exhaust gas recirculation (EGR). Two cases of the diesel engine operating condition were studied: 1000 r/min, 110 N m (referred to as Case A) and 1400 r/min, 473 N m (referred to as Case B). The experimental results showed that with the increase of EGR, the maximum in-cylinder pressure, rate of heat release and mean gas temperature decrease; the brake fuel conversion efficiency (BFCE) first increases slightly then decreases; brake specific fuel consumption (BSFC) has the opposite variation trend to BFCE. As the increase of EGR, the nitrogen oxides (NOx) emissions decrease monotonically, the soot emissions increase slightly, the hydrocarbon (HC) and carbon monoxide (CO) emissions increase, and the carbon dioxide (CO_2) and oxygen (O_2) concentration of the exhaust products increases and decreases respectively. The trade-off relationship between NOx and soot emissions can be improved when diesel engines are fueled with DCL instead of diesel.

1. Introduction

With the increasing consumption of crude oil and the limited crude oil reserves in the world, the energy crisis has become more and more severe. The currently known reserves of coal exceed those of crude oil by a factor of 25 in the earth [1]. It is a feasible solution to the energy crisis by making full use of the coal resources and putting them into the petroleum alternative fuel. Coal to liquid technology is one of the most reasonable approaches for alternative liquid fuels, having already been technically and commercially established. Coal to liquid includes direct coal liquefaction (DCL) and indirect coal liquefaction (ICL). The properties and distillation temperature of diesel and DCL are shown in Table 1 and Fig. 1 respectively. The cetane number, aromatics and sulfur contents of the fuels are tested by the method of the ASTM D613-10a, EN 12916:2006 and ASTM D26622-10 respectively. The distillation temperature versus the distillation ratio is tested by the method of the ASTM D86-10a. The other properties of the fuels refer to the original measured results. Compared with diesel, the lower cetane number, the higher content of paraffins and naphthenes and the lower distillation temperature except the initial boiling point (IBP) of DCL are all beneficial for the homogeneous mixture formation [2]. Additionally, the lower sulfur content, lower nitrogen content and lower aromatics content are all beneficial for decreasing the nitrogen oxides (i.e. NOx) and soot emissions.

Diesel engines have been widely applied in modern transportation and power generation facilities, due to the high combustion efficiency, good fuel economy and low carbon dioxide emissions [3]. However, NOx and soot are contained in the combustion products from diesel engines and have adverse effects on the environment and human health [4]. Moreover, the permanent trade-off relationship between NOx and soot emissions exists in the conventional combustion mode. With the increasingly stringent emissions standard, it is imperative to search a way to settle the trade-off relationship between NOx and soot emissions.

Exhaust gas recirculation is a well-known effective in-cylinder method for reducing NOx emissions in diesel engine. This is mainly due to the reduction of flame temperature by means of the thermal effect (i.e. the increase of inlet heat capacity due to higher specific heat capacity of recirculated CO_2 and H_2O compared with O_2 and N_2 resulting in lower flame temperature), the dilution effect (i.e. the decrease of inlet O_2 concentration resulting in the reduction of reaction rate, rate of heat release and combustion temperature) and the chemical effect (i.e. the dissociation of the recirculated water

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