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Research on Developing DPF Blowback Heating Regeneration Device

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Abstract

Development of human society faces two important subjects—energy crisis and environmental pollution. In this paper, Carbon smoke particulate materials (PM)—one of the main pollutants discharged by diesel were studied, and the characteristics, together with the actual state of diesel in China were introduced. In the light of the high-sulfur content of domestic diesel fuel, compulsory regeneration heater with LPG as heating source was designed, using particulate filter DPF made from Silicon carbide fiber non-woven material, which provides a technical route for the design and use of DPF blowback regeneration heater.

Keywords: Diesel; Particulate materials; Diesel particulate filter; Regeneration device; LPG heater

1. Introduction

Diesel engine is widely used as motor transport driving force with its high fuel economy, good power, low maintenance cost and reliable performance. The main harmful diesel emissions are particulate materials (PM) and nitrogen oxides (NO_X), small particles of soot in exhaust are 30-100 times higher than gasoline. These tiny particles can cause cancer. In addition, it is directly inhaled into human body, causing a variety of chronic diseases such as emphysema, skin diseases and allergy skin diseases [1]. Therefore, the purification of diesel particulate emissions is to solve an important problem of emission pollution.

At present, in order to reduce PM and NO_X, the DPNR device contained catalyst is internationally used, which is considered as an effective post-processing tool meeting increasingly stringent emission regulations. The sulfur content of diesel fuel is generally below 50ppm in Europe and Japan, which is suitable to use catalyst. However, in most parts of our country, the sulfur content of diesel fuel is more than 1000ppm at present, and SO_2 will generate in combustion, which is the main reason of catalyst

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poisoning [2]. Therefore, reducing the sulfur content of diesel fuel has become the prerequisite of China's using the above foreign DPNR device. More than 90% diesel engines still use mechanical control diesel fuel injection system, in view of which and the high sulfur content of diesel fuel, it is necessary to develop a diesel engine exhaust purification device suitable for our condition.

In order to reduce diesel's PM emissions, purification methods such as purifying outside machine, inside machine, or a combination of both are proposed. The major routes to reduce engine's PM emissions of purifying inside machine are high-voltage electrical controlling injection, the cooling technology, a variable swirl intake technology, high swirl ratio for rapid air/fuel mixture, the optimal design of combustion chamber, oil consumption control technology, reasonable optimization of diesel electrical controlling procedures and controlling reasonable amount of fuel injection. Purifying outside machine post-processing technology is an important way of automobile exhaust purification. It mainly uses the particulate filter DPF or plasma to reduce PM. SCR, SNCR, NSCR, NSR, DPNR and other technologies are used to reduce NO_X emissions [3-5].

Diesel particulate filter (DPF) can largely reduce particulate emissions as a post-processing device to reduce emissions. At present, some achievements have been made in introducing DPF into diesel post-processing in Europe, and in China, the use of DPF will be an effective and simple method with increasingly stringent emission regulations.

2. DPF regeneration

DPF is a device installed in the diesel vehicle exhaust system, using filter to reduce PM of the exhaust. The collection efficiency is mainly decided by filter structure parameters, diesel operating conditions, running time and other factors. With the accumulation of particulate in filter body, exhaust back pressure increases and engine performance deteriorates. Therefore, the particles deposited in filter must be timely cleared, so that the exhaust resistance can return to or near the original level and the regeneration of filter body can be finally realized. Filter regeneration technology is a key technology of particulate filter.

There must be four points of filter materials: (1) high efficiency of particulate filtering; (2) low exhaust resistance; (3) high mechanical strength and resistance to vibration performance; (4) be of anti-high temperature oxidation with heat and corrosion resistance, among which, high efficiency of filtering and low exhaust resistance are a pair of contradictory, and the two performances must be considered when choosing materials. At present, the commonly used filter materials are wall-flow honeycomb ceramic, foam ceramic, woven ceramic fiber, metal mesh and metal fiber felt and so on. Metal wire mesh is used in filter material selection of the design. Increasing soot's capture distance through the wire mesh, reducing the gap between metal mesh wires, changing weaving method of metal mesh and other programs [6, 7] are proposed in order to improve soot capture rate of DPF. Cartridge filter core rolled by high-density ribbon barbed wire is used in the design.

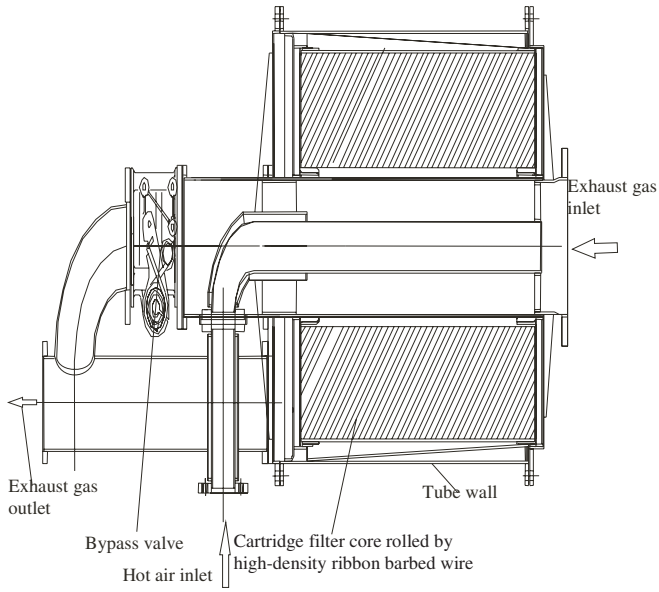

Fig. 1. Schematic diagram of DPF

Regeneration technology is the key point whether DPF can work normally in diesel, and it is also the technical difficulty of particulate filter at present. The regeneration of particulate filter generally improves the temperature inside the filter using outside energy to make particulates burn; or reduces particulate's ignition temperature using certain catalysts so that it can burn and decompose in a normal diesel exhaust temperature. It can be divided into passive regeneration and active regeneration according to different regeneration principles. Passive regeneration reduces the particulate ignition temperature using fuel additives to make particulates regenerate when burning in a normal diesel exhaust temperature. At present, there are fuel additive regeneration and regeneration of the catalyst coating. Active regeneration regenerates using external energy to make exhaust temperature reach the ignition temperature of particulates (500-600℃), there are mainly fuel injection or gushing gas helping combustion regeneration, electric heating regeneration, microwave heating regeneration, infrared heating regeneration, regeneration of reverse jet [8, 9] and so on. The design process uses LPG heating to achieve blowback regeneration.

3. Work process

The design uses LPG heating regeneration. The high-performance regeneration device with LPG as heating source is composed of LPG burner, combustion controller, the auxiliary fan for burners, the blower for air mixture, the frequency converter, electronic control unit (ECU) and so on.

Limiting and interlocking are used in combustion control system to restrict the range of safe motion, and it monitors burning state by flame detector used to check flame of combustion device. The signal from the flame monitor translates into the necessary operating signal after going through burner controller to start the safety shut-off valve. In the case that burner cannot burn or fire stops due to the fault of combustion device, flame monitor sends signal to burner controller to close the safety shut-off valve and to prevent the fuel into combustion chamber when detecting combustion flame abnormal. When flame

detector or burner controller breaks down, fuel shut-off valve acts, but there is a safety circuit function which does not start burner. The function of combustion controller is to make fuel burn safely.

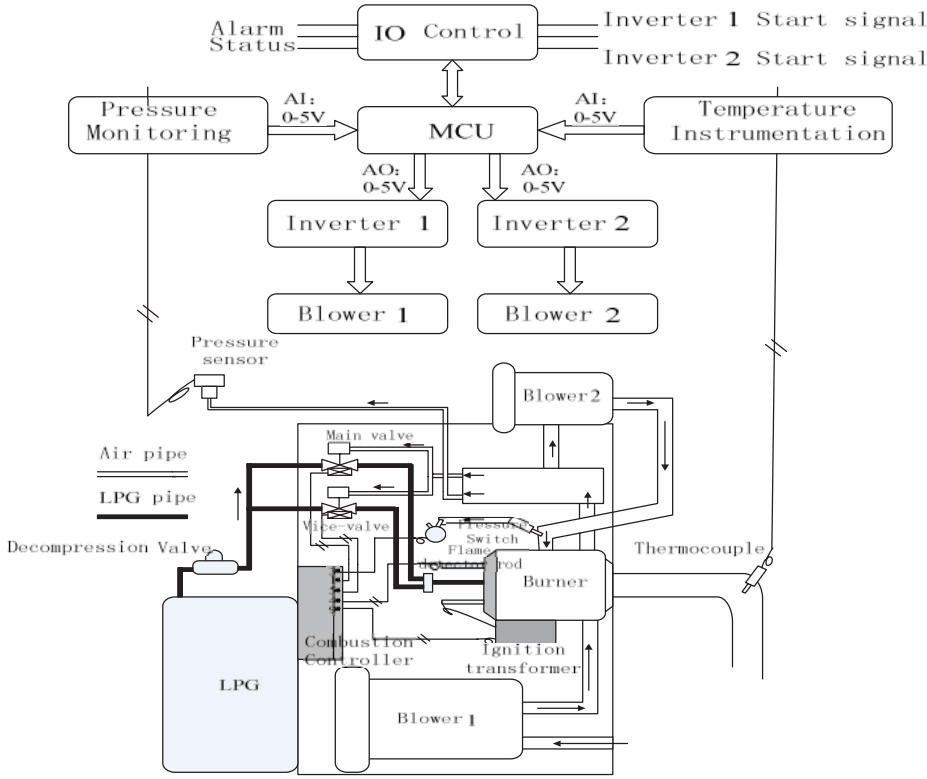

Fig. 2. Schematic diagram of the system.

With chief switch turning on, blower 1 and 2 come into work at 30Hz and 50Hz respectively when MCU starts timing at t_1. Combustion controller is activated by the control signal produced by MCU when the plenum pressure measured by pressure sensor rises above P_1 (setting minimum work pressure 1 atm). Presetting i as 1, blower working frequency as 40Hz, target temperature as 400℃, the temperature T detected by outlet thermocouple is sent as analogue signal to temperature control instrument which translates the signal into digital signal to MCU. As the temperature detected by thermocouple reaches400 ℃, the parameters i adds 1, blower working frequency, target temperature is set as 45Hz, 500℃ respectively. The loop continues if the requirement is met, and the blower 1 working frequency is set 60Hz when i is 4. The thermocouple checks whether the outlet temperature T is less than the maximum allowable temperature T_{max}, when T is less than T_{max}, checks again. If T is still less than T_{max}, calculates the difference value between T and the target temperature T_g (setting at 800 ℃), when the value is greater than T_z (setting at 50 ℃), sets A as 5, and when the value is less than T_z (setting at 50 ℃), gives A 1. Set blower 1's working frequency F according to the frequency correction formula. Check the time t_2, when the difference value between t_2 and t_1 is greater than work time t_s (setting at 20 min), stop working and the regeneration finishes. During work, it may be air leakage if the measured pressure $P < P_1$, and at this time fan alarms, the error counter adds 1 and work stops. It illustrates that the combustion temperature is too

high if the measured temperature T is greater than T_{max}, it may damage the equipment, and at this time fan closes, combustion stops, alarm is given because of overheating, the error counter adds 1 and work stops.

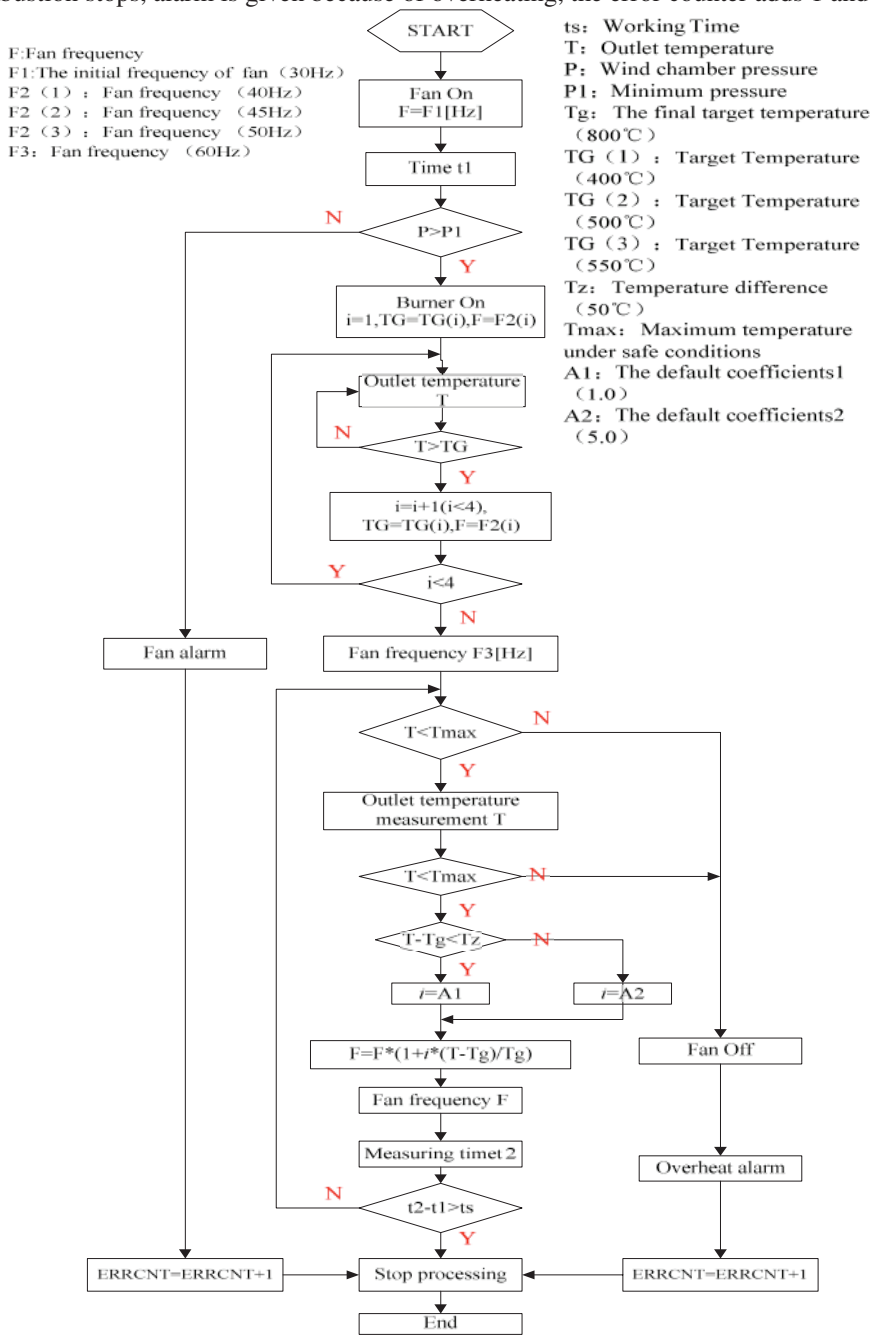

Fig. 3. Program flowchart.

The whole device is controlled by MCU, and combustion controller controls combustion. In order to achieve DPF regeneration, the hot air from LPG combustion enters DPF through the hole at the bottom of the DPF shown in Figure 1 and heats PM in DPF to burn it.

4. Conclusions

The study uses hot air from combustion to realize active regeneration to DPF with LPG as fuel source. Compared with electric heating and infrared heating, using LPG as fuel source can save energy consumption. The fixed DPF heater designed in the paper can not only reduce vehicle load, but also provide hot air with a stable temperature. A method is found for the device which needs constant temperature heat source. At the same time, a new economic and convenient application method is proposed for the development of DPF regeneration heater.

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