
Spray Hot-impingement System Optimization for Premixed Diesel Homogeneous Charge Preparation

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ABSTRACT

In this study, a spray hot-impingement system was set up to analyze the spray characteristics when spray impinged onto a flat hot surface by high-speed photography technology. The angle between spray axis and normal line of the flat surface could be changed, and the surface temperature could exceed 400°C. The influences of surface temperature and heating power on spray atomization were investigated too. At atmospheric pressure, when the wall temperature was 340~380°C, the impinging diesel spray was well atomized. In this experiment, the wall heating power could be set at 1~25 W/cm². When the heating power was about 1.6 W/cm², the impinging spray atomized well, and when it was about 10.1 W/cm² the spray atomized better though the heating power requirement should be high. The angle (α) between nozzle hole axis and wall normal line apparently affected wall jet velocity

Then a segment of steel tube was fixed between the intake manifold and cylinder head in a direct injection natural aspirated diesel engine. The tube wall could be heated to be over 400°C by the heater enwrapped outside. Diesel sprays would impinge onto the hot inner surface of the tube and atomize quickly when the tube wall temperature was high enough. Then the fuel-air mixture would be drawn into the cylinder in intake stroke, and HCCI combustion could be fulfilled. The tube, heater, and injector constituted a spray hot-impingement system used on engines. And a new method for diesel homogeneous charge preparation was realized.

Based on charge homogeneity and inducted fuel ratio, the nozzle hole number and α were optimized through comparison of 5 nozzle cases for premixed diesel homogeneous charge preparation by spray hot-impingement at intake manifold. The charge homogeneity was estimated by engine NO_x emission and exhaust opacity. When $\alpha = 15^\circ$, the hole number increase would reduce the exhaust opacity, but could not

effectively increase the inducted fuel ratio. But when $\alpha = 45^\circ$, it would effectively increase the inducted fuel ratio, whereas could not reduce the exhaust opacity. And NO_x emission would decrease when hole number increased. If α decreases, the inducted fuel ratio could be enhanced, but there was a best α for NO_x and exhaust opacity. For the 5 nozzle cases, the nozzle with 6 holes and $\alpha = 30^\circ$ was the optimized case.

INTRODUCTION

Homogeneous charge compression ignition (HCCI) is an attractive combustion process that substantially reduces both NO_x and PM emissions simultaneously, while still providing high diesel-like efficiencies [1]. Although the use of HCCI in transportation engines may be limited to engines with dual-mode combustion systems, its benefits are still tempting for diesel engines improvement [2].

The higher distillation temperatures of diesel fuel make the homogeneous charge preparation of diesel fuel more difficult, compared with gasoline fuel [1]. So preparation of diesel homogeneous charge is critical for fulfilling HCCI using diesel fuel. Then diesel is often injected into the preheated intake air upstream of the intake valve, and evaporates quickly to obtain the homogeneous fuel-air mixture. But the required air temperature is generally higher than 130 °C to prevent smoke emission [3] or at least be 90 °C [4], then the charge efficiency will be hugely reduced and the in-cylinder combustion will occur too early even though the compression ratio has been substantially reduced. Moreover, the intake air preheating needs much power and/or long time.

Arcoumanis et al. [5] investigated the characteristics of impinging transient diesel sprays on heated surface, and concluded that droplet sizes were generally reduced at the upstream side and at the front of the wall-jet with higher wall temperature, and the higher wall temperature would strengthen the wall-jet head vortex which would

result in higher air entrainment rates. Naber [6] observed that if the wall temperature increased to the transition regime where the wall temperature was between Nukiyama Point and Leindenfrost temperature, spray impingement atomization was observed to be affected by small changes in surface temperature. Nukiyama Point temperature is associated with the highest rate of droplet evaporation and that further increases in wall temperature will quickly transit to the Leindenfrost temperature with greatly reduced droplet evaporation rates. Liguang Li et al. [7] investigate the characteristics of droplet size and concentration distribution of diesel spray impinging on a heated flat plate vertically, and found that, when the wall temperature was high enough, the spray would be rebounded and vaporized, and the optimum surface temperature for rebounding and vaporization was about 300 °C.

And Liguang Li et al. [8] fixed a segment of steel tube between the intake manifold and cylinder head in a direct injection natural aspirated diesel engine. The tube surface could be heated to be above 400 °C by the heater enwrapped outside within several minutes under the power less than 600 W. The tip of an injector traditionally used for in-cylinder diesel direct injection was extended to the axis of the tube. The diesel sprays could impinge onto the hot inner surface of the tube and atomize quickly if the temperature of the tube was high enough. Then the fuel-air mixture would be drawn into the cylinder, and HCCI combustion could be fulfilled. The NO_x emission was always very low and exhaust opacity

(PM) was lower than 5% in the range of $\lambda = 4 \sim 5$ at the engine speed of 700 ~ 1000 r/min, when the hot surface temperature is higher than 370 °C.

In this study, the influences of surface temperature and heating power, tube geometry and nozzle parameters on the development of hot-impingement diesel spray were investigated with an isolated spray impingement system. Then, based on charge homogeneity and inducted fuel ratio, the tube wall temperature, nozzle hole number and α were investigated through comparison of 5 nozzle cases for premixed diesel homogeneous charge preparation by spray hot-impingement at intake manifold in a direct injection natural aspirated diesel engine.

HOT-IMPINGING SPRAY CHARACTERISTICS

TEST SYSTEM

Figure 1 shows the schematic of spray hot-impingement system in this investigation. It mainly consists of hot surface system (9, 12 in Figure 1), fuel injection system (1, 2, 3, 5, 7, 11, 13 in Figure 1) and high-speed photography system (4, 6, 8, 10 in Figure 1). Part of system parameters are list in Table 1. Figure 2 demonstrates the parameter definition of impinging spray structure. In Figure 1, the heating board is fastened with a fixedly bracket, the single-hole injector is assembled on a three-dimension movable bracket and also can be turned relative to the bracket. Then H and α

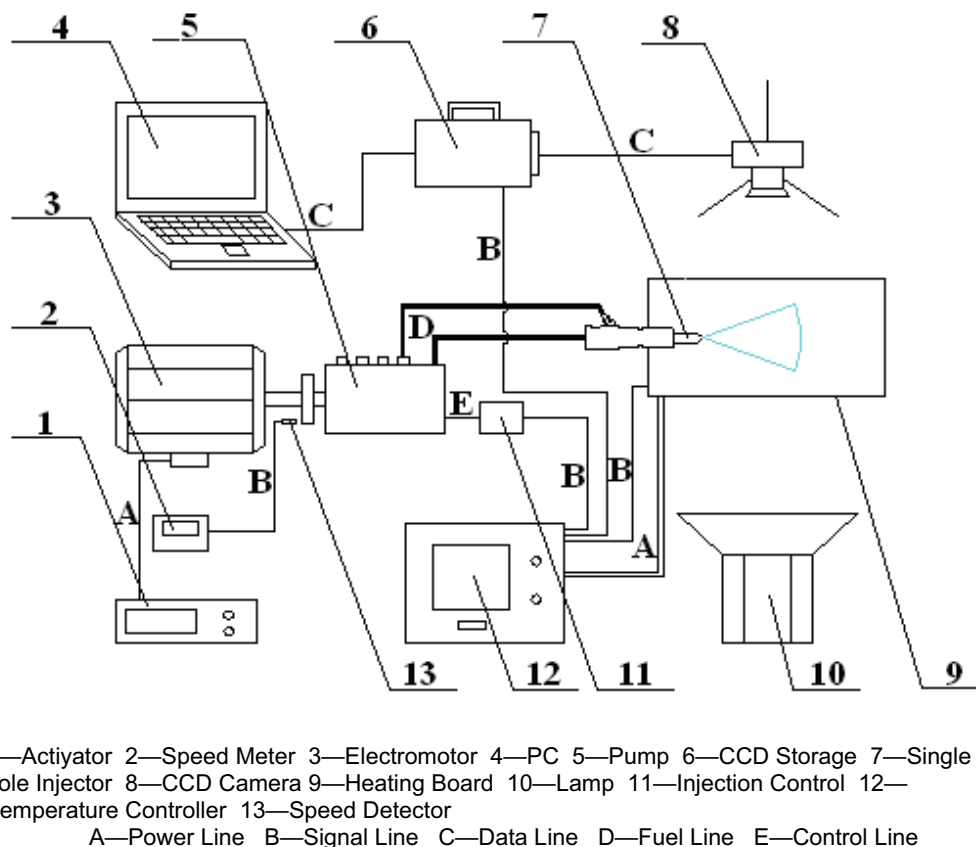


Figure 1 Schematic spray hot-impingement system