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OPTICAL STUDY ON SPRAY AND TWO-STAGE IGNITION CHARACTERISTICS FOR DIESEL SPRAY UNDER LOW AMBIENT TEMPERATURE AND DENSITY CONDITIONS

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ABSTRACT–Poor atomization and ignition difficulty due to the deterioration of environmental conditions restrict the cold-start performance of diesel engine. To investigate how the ambient and injection parameters affect diesel ignition characteristics at low temperature and density, liquid spray development was measured by back-illumination method; vapor spray and ignition process were visualized using high-speed shadowgraph method in constant volume combustion chamber. The results showed that liquid-vapor penetration and two-stage ignition delay have different sensitivities to variables: the variation of ambient density greatly affects the spray development while ambient temperature is the most significant parameter affecting ignition delay. Additionally, the change of injection pressure cannot cause significant change of both liquid penetration length and low temperature ignition, but increasing injection pressure promoted the vapor penetration length downstream development. Based on the data obtained, the empirical formulation in the form of power function was fitted for the stable stage of liquid penetration length, which proposed a reference for comparing the liquid phase development characteristics of diesel spray. Similarly, revise the Arrhenius-type ignition delay prediction formula and the correction coefficient K (K_{LTI} and K_{HTI}) was optimized quantitatively instead of fixed values, provides a preliminary theoretical basis for subsequent diesel spray model.

KEY WORDS : Low temperature, Spray characteristics, Two-stage ignition, Penetration length, Ignition delay, Formula optimization

NOMENCLATURE

LPL : liquid penetration length
LPLm: mean of the LPL stable stage
VPL : vapor penetration length
T_{am} : ambient temperature
LOL : lift-off length
ρ_{am} : ambient density
HTI : high temperature ignition delay
P_{inj} : injection pressure
LTI : low temperature ignition delay
T_f : fuel temperature
ID : ignition delay
t_{inj} : injection duration

1. INTRODUCTION

Diesel engine has been widely used in commercial and military fields because of its power performance, stability and reliability (Heywood, 1998). However, the cold start difficulty of diesel engines under low temperature (below 0 °C) and high altitude (above 3000 m) conditions is still an important issue to be solved (Broatch *et al*., 2010; Nabi *et al*., 2020). Under cold start conditions, poor spray fuel-air mixing and auto-ignition stability caused by low in-cylinder temperature are the main reasons for diesel engine start difficulty (Hwang *et al*., 2015; Park *et al*., 2015; Pastor *et al*., 2011; Roberts *et al*., 2014).

Up to now, extensive studies have been conducted on the spray and auto-ignition characteristics for diesel through experiments and simulations. Generally, liquid penetration length (LPL), vapor penetration length (VPL), Lift-off length (LOL), and high-temperature ignition delay (HTI) decreases with increasing ambient temperature (T_{am}) due to the enhanced evaporation and increased chemical reaction rate(Higgins *et al*., 2000; Siebers and Higgins, 2001; Li *et al*., 2021a). The LPL and VPL increases with decrease of ambient density (ρ_{am}) because of the reduced drag force, while the LOL and HTI increased due to the decreased chemical reaction rate(Ong *et al*., 2021; Pang *et al*., 2019). As for the fuel injection parameters, injection pressure (P_{inj})

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