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In-cylinder temperature field measurement with laser shearing interferometry for spark ignition engines

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Abstract

The temperature field in combustion chamber of spark ignition engine is measured using laser shearing interferometry and high-speed photography in this paper. A set of experimental facility is set up. The relationship equation between the interference fringe image and temperature distribution is deduced. Changing the shearing interferometry quantity, the two-dimensional temperature field of engine combustion chamber and flame propagation can be measured quantitatively by image processing. The test results indicate that the shearing interferometric method has a strong vibration resistance, and a simple and reliable optical path. The temperature distribution and the temperature gradient are different in different zones. The temperature is highest in the burning zone and the temperature gradient is large. The temperature is lower in the burned zone and the temperature gradient is smaller. The temperature is lowest in the unburned zone but the temperature gradient is large. At the initial period of combustion, the flame propagation velocity is low. In the combustion process, the flame front in the approximate spherical shape pushes toward the unburned zone, and the flame propagation velocity starts to decrease. It rapidly increases until it reaches the maximum value as the combustion process going on, and then it gradually decreases until it has burned in the entire combustion chamber.

Keywords: Shearing interferometry; High-speed photography; Temperature field; Combustion chamber; Spark ignition engine

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1. Introduction

The combustion temperature in the cylinder of an internal combustion engine is an important parameter to characterize the thermodynamic state of combustion process. Research of the combustion process and the pollutant formation mechanisms requires the knowledge of the change process of mixture temperature with space and time. For example, knock is an abnormal combustion phenomenon of spark ignition engine. A main reason of engine knock is that the end-gas temperature in combustion chamber of the engine is too high [1]. The realization of controlled auto-ignition (CAI) or homogeneous charge compression ignition (HCCI), which is widely researched lately, also has an important relationship with the distribution of temperature in the cylinder of engine [2–4]. However, the theoretical analysis and numerical simulation on temperature field in cylinder are difficult because of the complexity of the combustion process of engine. Experimental measurement is still the main way to investigate the change of temperature field in the combustion process of an engine.

With the development of computer, image processing, and laser technology, the optical measurement method has become a main way to measure the temperature. Especially, as the interferometric fringes can reflect the change of media density, it may be used to measure the temperature field quantitatively. Holographic interferometry is the earliest interferometric temperature measuring method [5]. However, the method is sensitive to vibration, its equipment is expensive, the optical path is complex, and the synchronization is difficult. Use of holographic interferometry on the combustion analysis of practical engine is difficult.

A plan of using shearing interferometry to analyze combustion process of spark ignition engine was put forward by the author [6]. It has achieved continuous measurement of combustion process in practical engine. There are several characteristics for using shearing interferometry to measure combustion temperature field. Shearing interferometry is not susceptible to vibration, which is very important for practical engine measurement. The interferometric image is countable fringes fit for high-speed camera. The interferometric fringes can be superposed and loaded wave, which is convenient for image auto-process. Using shearing interferometry and high-speed photography, many shearing interferometric photos in combustion chamber under different conditions are obtained in a practical spark ignition engine. The two-dimensional temperature field in the combustion chamber is obtained using the image analyzing software developed by author. Data of flame propagation rate have been calculated.

2. Basic principle of temperature field measurement with shearing interferometry

The basic principle of temperature field measurement with shearing interferometry is that: after the collimated light passes through the temperature field to be measured, the change in temperature brings about a change in refractive index and in the light wave front. The light wave front is sheared into two parts by the shear