Investigation of the soot growth process in a flame by the 2D-LII method

A.V. Eremin, E.S. Khodyko@, R.N. Kolotushkin

Joint Institute for High Temperatures of the Russian Academy of Sciences,
Izhorskaya 13 Bldg 2, Moscow, Russia, 125412
@ egor.hodyko@ihed.ras.ru

Knowledge about the mechanisms of formation and properties of polycyclic aromatic hydrocarbons (PAHs) and ultrafine (≤ 5 nm) carbon nanoparticles or precursors of soot particles with sizes smaller than ordinary soot (10-50 nm) contained in the exhaust of internal combustion and jet engines is necessary for reducing harmful emissions during combustion processes. Taking into account the absorption and emission of radiation by such particles allows to determine their contribution to the thermal balance of the atmosphere, which affects climate change. Monitoring the number of such compounds per unit volume of air allows to assess the danger to human health due to their carcinogenic properties. Also, to predict the properties and environmental influence of "mature" soot particles, it is necessary to understand the process of their formation and, in particular, to investigate its early stages, the key participants of which are ultrafine carbon nanoparticles which are practically transparent to visible radiation.

One of the useful methods in this field is the well-known and widely used laser-induced incandescence (LII) method. Two-dimensional laser-induced incandescence (2D-LII) and time-resolved laser-induced incandescence (TiRe-LII) methods are the promising laser-optical methods for studying the soot precursors formed below the soot formation flame region. In this study the results of 2D-LII and TiRE-LII methods implementation for the investigation of the early stages of the soot particles formation and growth during the hydrocarbons combustion are presented.

The laminar flat premixed flame was stabilized with a kinetic McKenna type burner, which allows to form a flame with horizontally uniform parameters. To verify this fact, vertical and radial temperature measurements were carried out using ultrathin type B thermocouples. The combustion of ethylene – air (φ = 2.1, C/O = 0.7) and acetylene – air (φ = 1.8, C/O = 0.72) mixtures was investigated.

Using a composition of cylindrical lenses the beam of a nanosecond Nd:YAG laser at the first harmonic (1064 nm) was deployed in a vertical laser plane along the height of the burner to heat the entire central section of the flame and obtain a height- and width-distributed incandescence signals from laser-heated carbon particles on the nanosecond ICCD camera K018UV. The camera shot was synchronized with the laser pulse using a pulse/delay generator. The laser beam size was 0.7 mm x 15 mm, energy density was maintained at ~ 0.15 – 0.2 J/cm^2. Laser beam profiles were obtained using BEAMAGE-4M beam profiler. A comprehensive camera setup was carried out to register the emission of ultrafine soot particles and their precursors in the flame in the visible spectrum. Using narrowband filters, diagnostics was configured in the wavelength ranges corresponding to the most intense radiation of ultrafine carbon nanoparticles in accordance with the Swan bands.

As a result of the conducted research, vertical and radial temperature profiles of the studied flames were obtained. Spatially and time resolved flame particles incandescence signals were carried out using 2D-LII and TiRe-LII methods. The profiles of the volume fraction of the studied particles were calculated from the obtained ICCD images of the flame using a LII mathematical model. The calculations of the sizes of the studied particles based on the attenuation of the incandescence signals were started.

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