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THE EFFECT OF PRESSURE OSCILLATIONS ON FUEL DROPLET IGNITION

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Combustion-driven instabilities have an important influence on the performance and noise characteristics of gas turbines. Thermo-acoustic oscillations can increase not only emissions of noise or pollutants such as unburnt hydrocarbons or nitric oxides, but can also lead to very high levels of pressure pulsations, resulting in structural damage of the machine. Identified mechanisms capable of driving combustion instabilities include complex flow and flame interactions: fuel feed line – acoustic coupling, equivalence-ratio oscillations, oscillatory vaporization and mixing, oscillatory flame-area variation, vortex shedding. In order to clarify different aspects of acoustics - combustion interference it is necessary to study the simplified models. At ZARM, Bremen the effect of acoustic oscillation on single droplet ignition was studied experimentally and numerically.

The experimental facility allows to investigate the ignition of a single droplet under spherical conditions (absence of natural convection) and variable pressure and temperature of the ambient gas. The suspended fuel droplet with initial diameter of 0.7 mm is placed in a furnace, two opposite walls of which are motor-driven pistons. The scale of the oscillation of gas parameters in the furnace corresponds to that in real gas-turbines under condition of a thermo-acoustic resonance. In the present work parameters of the ignition of a single n-heptane droplet under mean pressure (p0) up to 5 bar and temperature 700 K was examined.

The computational model is 1-dimensional and includes processes of vaporization, multi-component diffusion and extended chemical reactions including the low-temperature branch. The model was firstly validated through the single droplet experiments achieving good agreement. Then the physical parameters were varied in order to match conditions of real gas-turbines. In this case droplet diameter was about 0.04-0.1 mm, initial pressure of the gas up to 20 bar and temperature up to 700 K, respectively.

It was found that the acoustic-scale changes of the pressure and temperature result in significant changes of the ignition delay. Applying numerical calculations to micro-sized droplets enabled

to study the thermo-acoustic effects under conditions approximating real gas-turbines.

The findings of investigation show the importance of thermo-acoustic effects on ignition processes in the instability-driving mechanisms of combustion and indicate that “acoustics-ignition”-interactions must be taken into account for low-frequency as well as for high-frequency dynamics. This in addition to the flow and mixture perturbations which are well known to drive combustion instabilities in gas-turbines.