LARGE EDDY SIMULATION OF HOT JET IGNITION IN MODERATE AND HIGH-REACTIVITY MIXTURES

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Summary. The thermo-chemical dynamics of a hot jet in a reactive environment is computationally studied and the effective mechanisms in ignition event are investigated.

1 INTRODUCTION

Deflagration initiation by injection of hot gas into a fuel-air mixture is important in combustion engines, explosion protection and fire safety. Turbulent hot-jet ignition can be a reliable means of rapid ignition of lean-burn devices such as stratified IC engines and wave rotor combustors [1]. The penetrative hot jet which may contain chemically active radicals can act as a distributed source of ignition throughout the combustion chamber. In practice, due to the significant difference in pressure between the pre-chamber (deliverer of hot gas) and the main chamber, the incoming turbulent jet demonstrates complicated features stemmed in the temporal and spatial evolution of the transient jet. The occurrence of ignition via hot jet in a confined volume reveals more sophisticated features as the walls are interacting acoustically with the developing jet [2].

The following study aims to describe the underlying physics of the turbulent jet ignition in a confined volume containing CH$_4$-H$_2$ blend premixed with air by employing a well-resolved 3D simulation. The study sheds light on an ignition probability criterion, which can be used to predict the possibility of ignition development.

2 NUMERICAL METHODOLOGY

The numerical domain consists of a rectangular chamber which has a square cross section with 1.57” sides and it is 16” in length that contains H$_2$-CH$_4$ mixture at standard pressure and temperature. The hot products of a primary combustion are introduced to the main chamber through a 6mm nozzle at 2000 K and 316 m/s.

A block-structured grid is employed for the LES reported, and in combination with adaptive mesh refinement (AMR), the cell size distribution is chosen to provide adequate resolution for turbulent shear layer and reasonably sharp representation for pressure waves to model acoustic interactions. Using a preliminary estimation of Taylor and Kolmogorov length scales, the mesh refinement is adjusted to generate cells as small as 60μm depending on the first derivative of the velocity magnitude in adjacent cells. This refinement scheme provided the total number of cells equal to 46M to uniformly resolve velocity and pressure gradients. The target refinement criteria is believed to be able to resolve more than 90% of the turbulent kinetic energy according to the similar study by Nordin-Bates et al. [3]. The time scale opted for capturing the underlying physics varies between 1E-08 to 1E-05 seconds by employing a variable time scale algorithm that fits the chemical time scales prescribed by DRM 13. The transport equations are solved using the pressure implicit with splitting of operators (PISO) method of Issa. The computational facility used in this study is 180-node sector of BigRED II
supercomputer where each node contains two AMD Opteron 16-core x86_64 CPUs and 64 GB of memory.

3 RESULTS AND DISCUSSION

Figure 1. History of scalar changes in hot jet ignition
LES (Uj=316m/s, Tj=2000K)

Figure 1 depicts the measurements of various scalars with time for an injection event occurring at the conditions described in section 2. The ignition kernel is generally located at the jet tip vortex where high entrainment of reactants into the hot jet is expected. Subsequently, the reaction region spreads towards the lateral surfaces of the jet.

REFERENCES