Numerical study of H_2-air turbulent mixing processes using a selective permeable injection technique

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Premixed combustion is receiving a raising attention in the last years as it has several advantages over non-premixed combustion: there are no local regions with high concentration of fuel, avoiding the formation of hot spots. This, together with the stoichiometry control can decrease drastically the formation of NO_x particles[1,2].

However, several major changes must be tackled: in this regime, fuel and oxidizer come into contact before combustion take place notably increasing the risk of undesired deflagrations or flashbacks. This risk is even higher when using H_2, given its high reactivity, diffusivity in air and flame speed. In the last years, several studies[3,4,5] have analyzed the H_2-air turbulent process using matrices of micro-injectors configured with jet in cross-flow. This configuration notably enhances the mixing process. However, diffusion flames are still formed.

The purpose of this work is to move one step forward, following the proposed concept by Gruber et al.[6], in which hydrogen is injected into the combustion chamber flowing through an H_2-selective permeable plate. This is achieved with a porous material that allows H_2 but not air penetration, provided that hydrogen molecular diameter is much smaller than the molecular diameters of oxygen and nitrogen.

The work aims to study the H_2-air turbulent mixing processes which takes place prior to the mixture being ignited, paying special attention to mixing timescales, degree of mixing achieved as well as H_2 molecular diffusion in air, in order to determine the theoretical feasibility of this novel injection technique, determining whether or not a premixed flame can be achieved and if this flame can be stable.

The problem is numerically approached by defining the canonical problem of a fully developed turbulent flow of air moving under the confinement of two infinitely wide parallel plates, while H_2 is injected through the bottom plate. Full time-dependent, three-dimensional, compressible Navier-Stokes equations are solved. In particular, turbulence is handled from a large eddy simulation (LES) approach using turbulent kinetic energy transport equation to model the subgrid scales.

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