

Preparing for Combustion in an IC Engine using Hydrogen

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Abstract

Hydrogen-fuelled spark-ignition engines (H_2 ICEs) offer near-zero carbon emissions and high efficiency, but their fast burning and wide flammability range create significant challenges for safe, stable combustion, particularly in confined chambers. This work develops a staged OpenFOAM-v2406 workflow for hydrogen combustion, starting from a minimal closed-chamber benchmark and progressing to a moving-mesh single-cylinder hydrogen SI engine case. A three-dimensional rigid chamber with premixed H_2 -air is first simulated using `reactingFoam`, a JANAF-based thermophysical model, Sutherland transport, and a global one-step H_2/O_2 Arrhenius mechanism, to validate chemistry, ignition behavior, and basic pressure-temperature evolution. The solver is then extended to `reactingDyMFoam` by coupling combustion to dynamic mesh motion via `dynamicFvMesh` and piston kinematics prescribed from a crank-slider law, implemented through a tabulated displacement input generated by a Python script. A hydrogen SI engine configuration based on Lee et al. (1995)—0.488 L single cylinder, 85×86 mm bore and stroke, compression ratio 8.5:1, speeds 1000 and 1500 rpm—provides operating points and validation trends for combustion phasing, peak pressure, volumetric efficiency, and abnormal-combustion onset. Particular attention is given to root-cause analysis of floating point exceptions arising from stiff H_2/O_2 chemistry on a moving mesh, and to stabilisation via ODE solver choice, adaptive time-stepping, Courant number control, and mesh-motion optimisation. The resulting framework provides a reproducible base case for future extension to detailed kinetics, turbulence, and quantitative validation of hydrogen SI engine simulations in OpenFOAM.

Keywords: Hydrogen combustion, SI engine, Dynamic Mesh, `reactingDyMFoam`