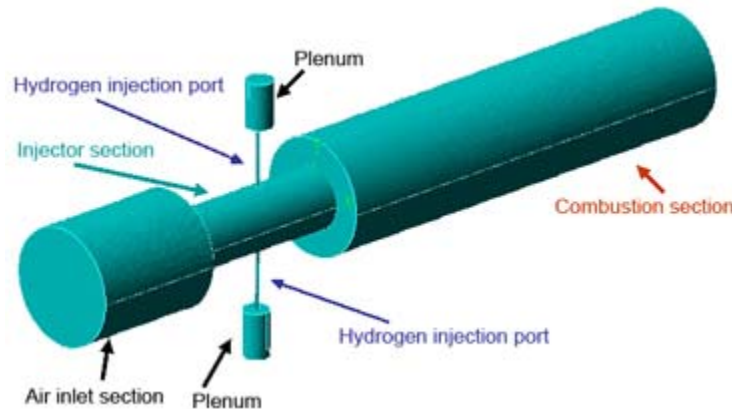# National Combustion Code Used To Study the Hydrogen Injector Design for Gas Turbines


Simplified computational model of a single hydrogen injector used with the NCC.
Long description of figure 1. Details of the single-injector computational model. The location of the air inlet, hydrogen injection ports, combustion section, injector, and exit are shown.

Hydrogen, in the gas state, has been proposed to replace Jet-A (the fuel used for commercial jet engines) as a fuel for gas turbine combustion. For the combustion of hydrogen and oxygen only, water is the only product and the main greenhouse gas, carbon dioxide, is not produced. This is an obvious benefit of using hydrogen as a fuel. The situation is not as simple when air replaces oxygen in the combustion process. (Air is mainly a mixture of oxygen, nitrogen, and argon. Other components comprise a very small part of air and will not be mentioned.) At the high temperatures found in the combustion process, oxygen reacts with nitrogen, and this produces nitrogen oxide compounds, or NO_x--the main component of atmospheric smog. The production of NO_x depends mainly on two variables: the temperature at which combustion occurs, and the length of time that the products of combustion stay, or reside, in the combustor. Starting from a lean (excess air) air-to-fuel ratio, the goal of this research was to minimize hot zones caused by incomplete premixing and to keep the residence time short while producing a stable flame. The minimization of these two parameters will result in low-NO_x hydrogen combustion.
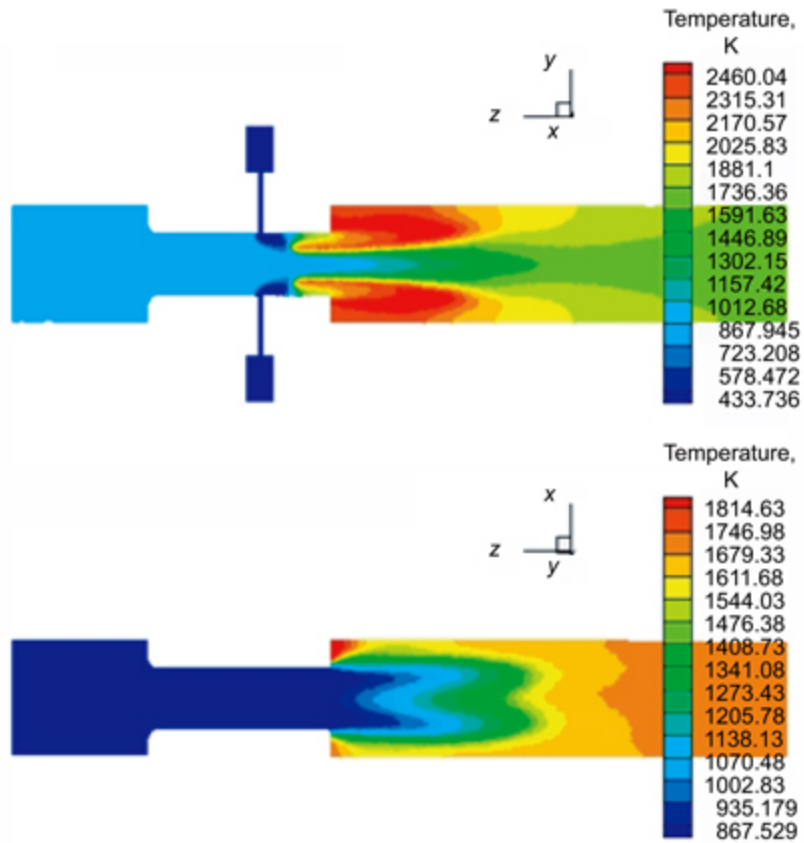
Temperature contours of the single injector model computed with the NCC. Top: Symmetry plane x. Bottom: Symmetry plane y.
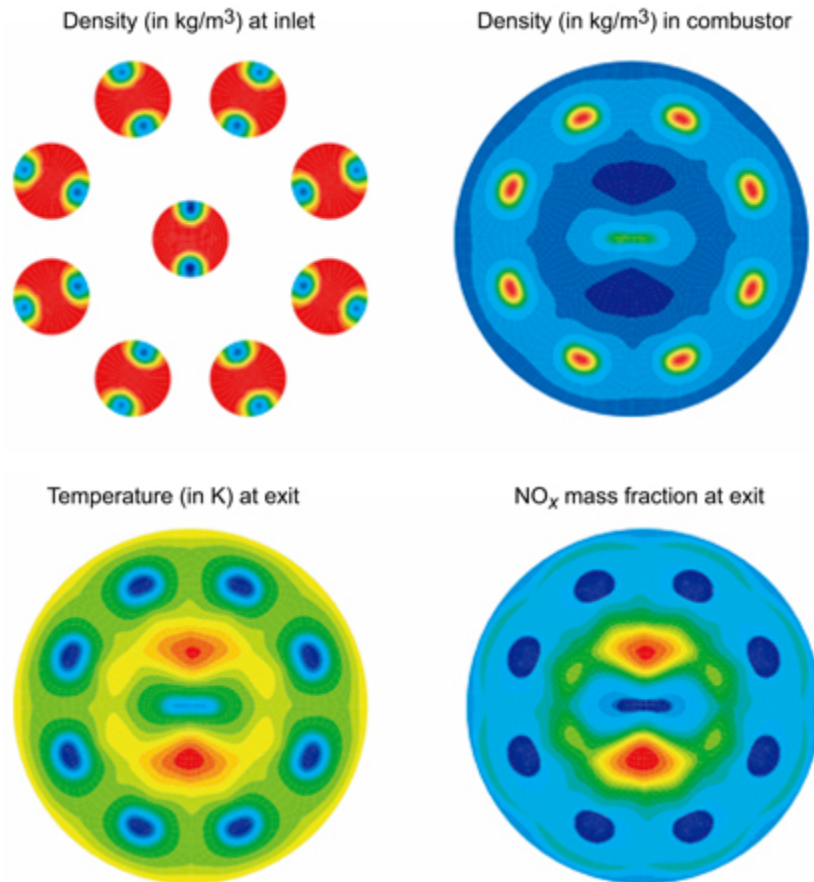
Long description of figure 2. Temperature contours (kelvin) indicate whether the flame is premixed or nonpremixed. In the x-plane, the flame is a premixed flame. In the y-plane, the flame is a nonpremixed flame. Nonpremixed flames produce large amounts of nitrogen oxides; therefore, the injector design needs to be improved. At this time, it is not known whether such a design is possible.
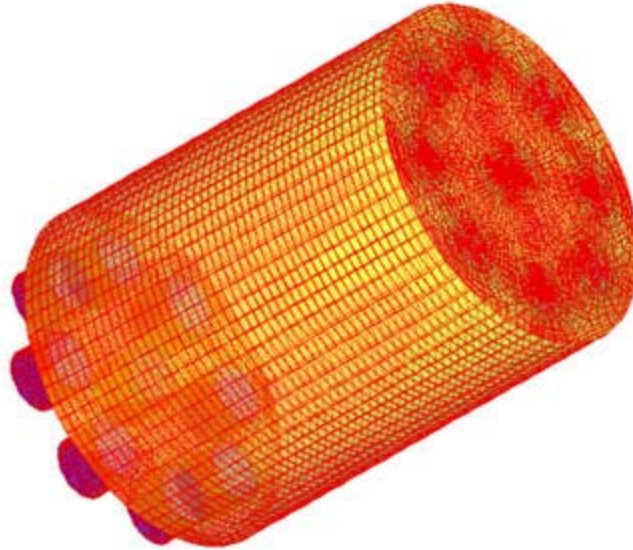
Computational grid of the multi-injector model used with the NCC.
Long description of figure 3. Hexahedral computational mesh of 282,624 elements that was used for the NCC calculations. The inlet conditions were taken from the single-injector model. This balanced computational requirements with design needs.

The hardware that actually creates the low-NO_x combustion process is the injector. The National Combustion Code (NCC, ref. 1) was used to conduct numerical studies of hydrogen combustion. The code was enhanced to include a generalized wall function (ref. 2), which represented the underlying injector flow physics better than the original wall function. This research was conducted in three stages: a validation stage (ref. 3), a detailed study of the mixing inside a single injector element (ref. 4), and the study of an array of injector elements. Detailed results were presented about the mixing of fuel and air, flame structures, and combustion species. This numerical information has assisted an ongoing experimental study of hydrogen/air injection concepts. This research effort was an in-house effort of NASA Glenn Research Center's Combustion Branch and the Ohio Aerospace Institute (OAI).

Temperature and NO_x contours computed with the NCC.

Long description of figure 4 The simulation was performed before experimental results were available and was intended as an aid to the design of the hardware. The mean exit temperature was 1328 kelvin, but there was significant variation of temperature seen over the exit plane. Poor mixing gives 180 parts per million of nitrogen oxides at the exit, mainly in the two central recirculation zones. In the simulation, the flame did not extend back up the inlet nozzles.

References

1. Stubbs, Robert M.; and Liu, Nan-Suey: Preview of the National Combustion Code. AIAA-1997-3114, 1997.
2. Shih, Tsan-Hsing, et al.: Generalized Wall Function for Complex Turbulent Flows. NASA/TM--2000-209936, 2000.
3. Shih, T.-H., et al.: A Study of Hydrogen/Air Combustor Using NCC. AIAA-2001-0808, 2001.
4. Shih, T.-H., et al.: Numerical Study of a Single Hydrogen/Air Gas Turbine Fuel Nozzle. AIAA-2003-4249, 2003.

Find out more about this research at http://www.grc.nasa.gov/WWW/combustion/

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