NREL Highlights

SCIENCE

Basic Science Simulations Provide New Insights to Aid Hydrogen Gas Turbine Development

Massive first-principles simulation provides insight into flame anchoring in a hydrogen-rich jet in cross-flow.

When gas turbine designers want to use gasified biomass for stationary power generation, they are faced with a challenge: bio-derived syngas typically contains significant amounts of hydrogen, which is far more reactive than the methane that is the traditional gas turbine fuel. This reactivity leads to a safety design issue, because with hydrogen-rich fuels a flame may anchor in the fuel injection section of the combustor instead of the downstream design point.

In collaboration with Jacqueline Chen of Sandia National Laboratories and Andrea Gruber of SINTEF, a Norwegian energy think tank, the National Renewable Energy Laboratory (NREL) is carrying out fundamental simulations to provide new insight into the physics of flame anchoring in canonical "jet in cross-flow" configurations using hydrogen-rich fuels. To deal with the large amount and complexity of the data, the combustion scientists also teamed up with computer scientists from across the U.S. Department of Energy's laboratories to develop novel ways to analyze the data. These simulations have shown that fine-scale turbulence structures formed at the jet boundary provide particularly intense mixing between the fuel and air, which then enters a quiescent region formed downstream of the jet in a separate, larger turbulent structure. This insight explains the effect that reducing the wall-normal velocity of the fuel jet causes the flame to blow off; with the aid of the simulation, we now understand this counterintuitive result because reducing the wall-normal velocity would reduce the intensity of the mixing as well as move the quiescent region farther downstream.

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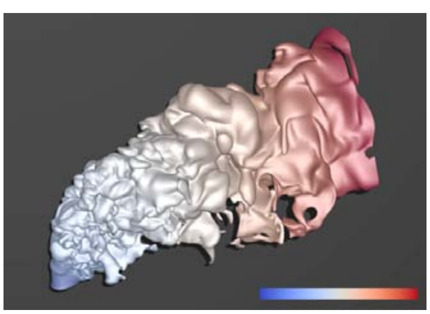

A mixture fraction surface, which reflects the boundary between the fuel jet and air cross-flow, from the simulation colored by a parameterization of the jet path developed and used by the team to analyze the dataset.

Key Research Results

Achievement

NREL and its research partners are conducting simulations that provide new insight into the physics of flame anchoring in canonical "jet in cross-flow" configurations using hydrogen-rich fuels.

Key Result

Simulation results explain the mechanism behind flame blow-off occurring when a component in the cross-flow direction is progressively added to the jet velocity vector, thereby reducing the relative impact of its wall-normal velocity component.

Potential Impact

Understanding the mechanism for flame anchoring aids the design of fuel injection nozzles that meet safety requirements when using hydrogen-rich fuels.

NREL
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