ENERGICO

Assessing Lean Blow Off

Ultra-low NO_x emission combustors utilize reduced peak flame temperatures within the burner to limit the formation of thermal NO_x through staging strategies such as Lean Premixed combustion. The low NO_x limit is often bounded by the onset of combustion instability in the form of Lean Blow Off (LBO). Lean Blow Off occurs when the thermal energy generated by the burning fuel/air mixture is no longer sufficient to heat the incoming fuel to the ignition point. Lean Blow Off is also often preceded by a sharp increase in CO emissions.

Assessing LBO requires an analysis of the combined effects of fluid dynamic mixing and fuel reaction rates. An assessment of the ratio of the characteristic chemical reaction time scale to the characteristic mixing or transport time scale, called the Damköhler Number (Da), has been used to predict LBO in experimental and commercial combustion systems. Often, this analysis is conducted using global estimates for the chemical and mixing time scales. However, it is more appropriate to use a local assessment of the chemical and mixing/transport time scales for proper understanding of when the chemistry of the fuel reaction is dominant and when it is slowed to the point that it can be limited by the fluid dynamics.

How to Assess LBO

ENERGICO's LBO analysis tool provides an innovative way to address the issue of defining Damköhler numbers for a combustor by taking advantage of the local flow and thermochemical properties extracted from a CFD solution and the detailed combustion kinetics available in the CHEMKIN chemistry set. Rather than trying to find and work with a pair of “global” chemical and flow residence times of a combustor, the LBO analysis tool defines both chemical and residence times locally to account for the spatial variation of mean flow, turbulence, and gas-mixture properties.

ENERGICO captures regions in the CFD flow field that represent the flame and then calculates the local Damköhler Number using the turbulence parameters from the CFD case for the mixing time scale and detailed kinetics for the chemistry time scale. The LBO tool verifies the integrity of the flame locally and provides an indication of the overall soundness of the flame zone visually as contours of the local Damköhler number. The Damköhler number distribution exposes the location and the size of the stable flame core in the combustor. By examining the structure and topology of the flame core and the integrity of the flame, the likeliness of blow-off can be determined.

What Do the Results Look Like?

ENERGICO captures the CFD cells associated with the flame through an algorithm that looks at temperature and fuel concentration gradients. The local Damköhler Number is then calculated for those cells associated with the flame. Figure 1 shows the results of the local Damköhler calculations on a simple can combustor. The image represents three-fourths of the flame in the dome of the combustor. The values of the Damköhler number below unity are cells where chemistry is faster than mixing and are therefore stable. The cells where the Damköhler number is above unity are regions where mixing is faster than chemistry and the flame is blown out.

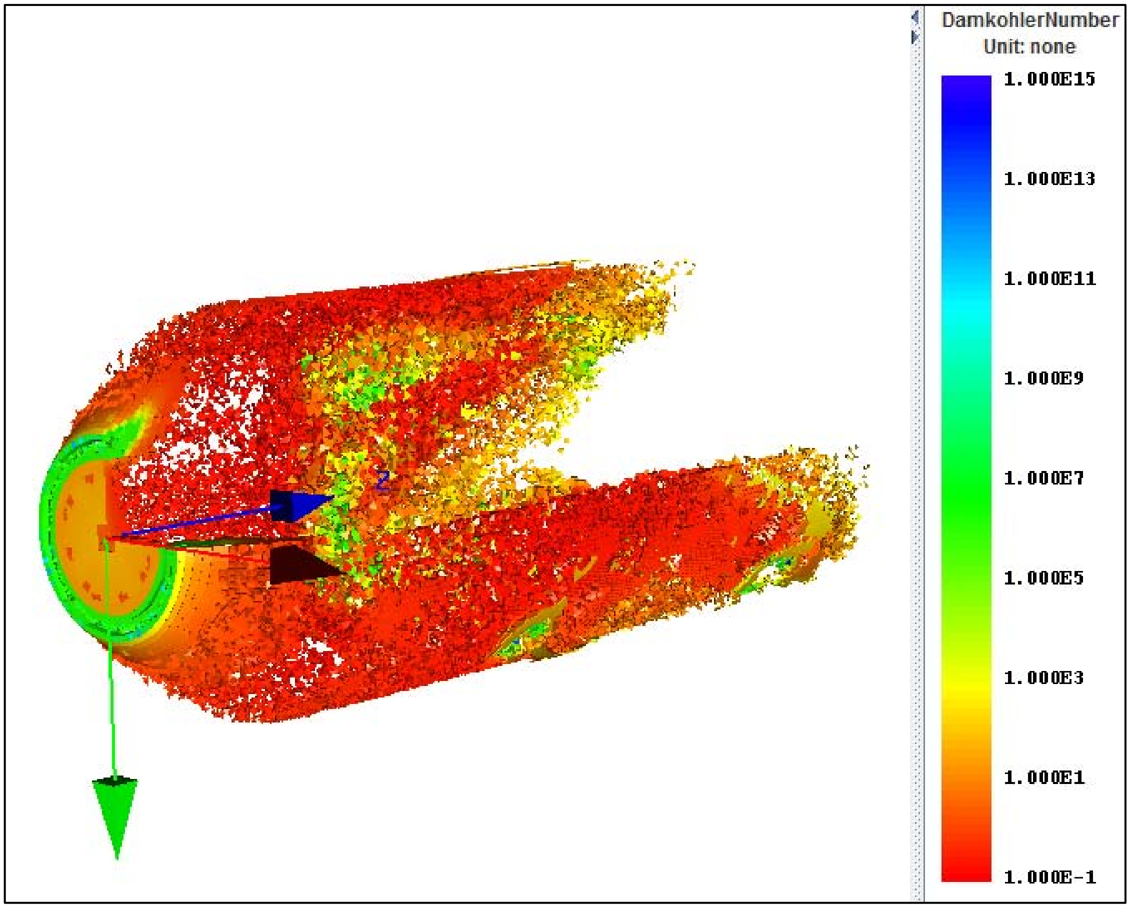

Figure 1. Local Damköhler Number identifies regions where flame is least stable.

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