Solution Brief | Gas Turbine Combustors

CHEMKIN-PRO

Flame Extinction Modeling in Gas Turbine Combustors

Flame extinction is a critical combustion performance factor in low emissions combustors, burners, rockets and many other combustion devices. The use of staged combustion, rich and lean, lowers peak flame temperatures and hence producing less NO_x. However, doing so also moves the flame closer to the extinction point. Combustion parameters such as Lean Blow Off (LBO) are flame-extinction events.

Fuels such as Liquefied Natural Gas (LNG) have higher concentrations of higher carbon number gaseous components, such as ethane and propane, than are present in natural gas. These higher carbon- number gases (C_2 to C_5) can impact the extinction characteristics and produce undesirable combustion effects. Flame extinction is characterized by the operating conditions, local fuel/air ratio and the reaction chemistry of the fuel.

Setting Up in CHEMKIN-PRO

The Flame Extinction Model in CHEMKIN-PRO calculates the extinction strain rate of a flame. As an example, we will review an extinction analysis conducted for a premixed stoichiometric methane-air flame at 1 atm pressure. A reduced (17 species) methane-air mechanism is used in this application. The stoichiometric methane-air mixture is assigned to inlet 1 while pure nitrogen (N_2) is assigned to inlet 2. The inlet gas temperature for both inlets is set to 296 K and the inlet velocities for both nozzles are set to 80 cm/s. Note that the first opposed-flow flame solution is thus calculated for these parameters.

Results

The output file generated by an extinction project contains the output from each opposed-flow flame simulation conducted along the path to the extinction point. The fuel and oxidizer nozzle velocities continuously increase to the value in the neighborhood of 200 cm s^{-1}. The "turning point" (Figure 1) is reached when the MethaneAir nozzle velocity reaches about 203 cm s^{-1}. The global strain rate at the turning point is (203 + 201)/1.4 = 289 s^{-1}. The extinction strain rate is 550 s^{-1}. The locations corresponding to various strain rates are shown in Figure 2.

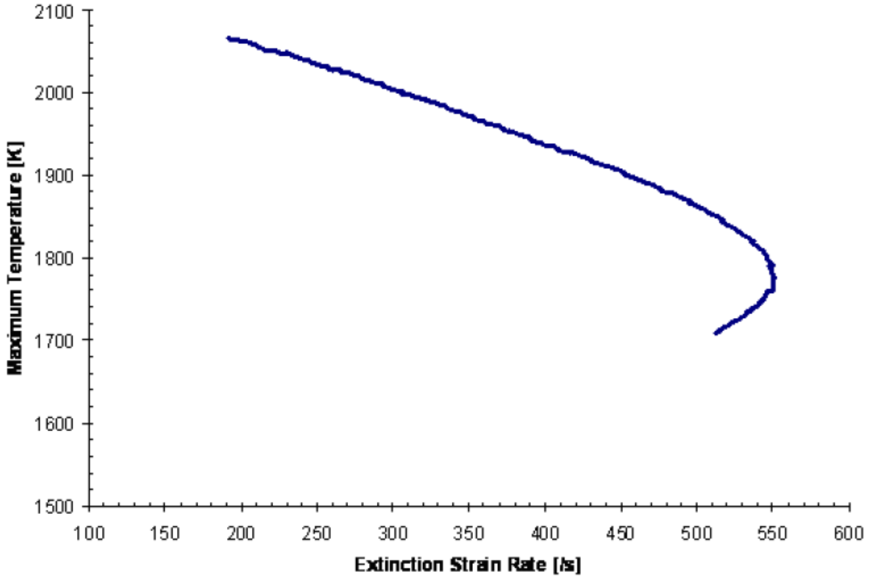

Figure 1. Flame response curve showing extinction (turning point) for premixed stoichiometric methane-air flame. The inlet temperature is 296 K and ambient pressure is 1 atm. The calculated extinction strain rate is 550 s^{-1}.

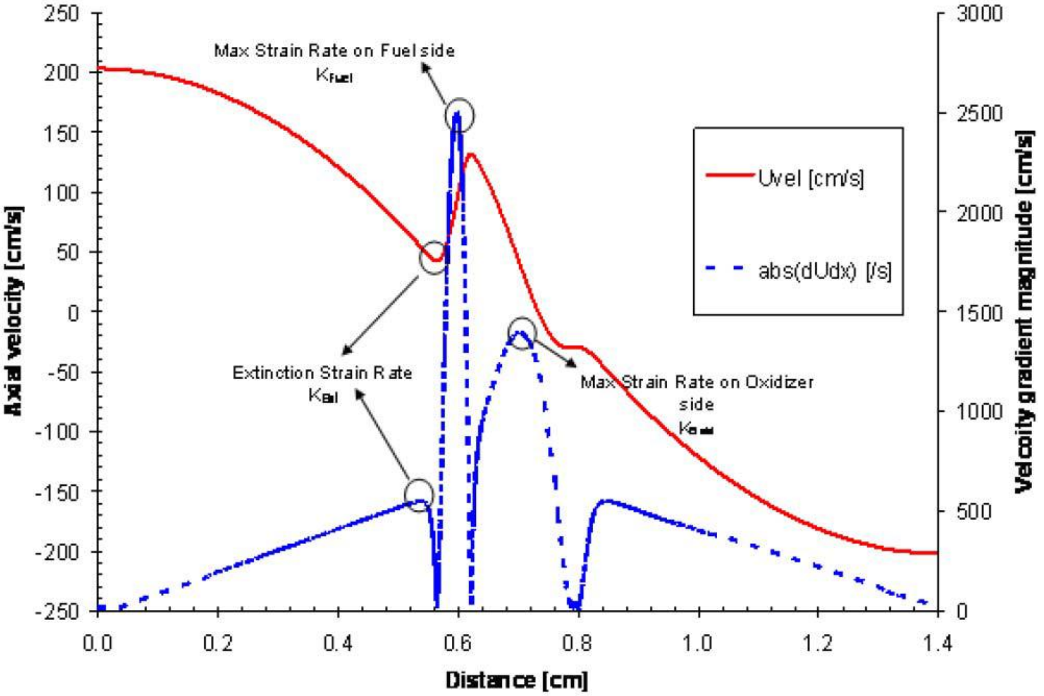

Figure 2. Axial velocity and velocity gradient magnitude for premixed stoichiometric methane-air flame at the extinction point. Also shown are the points corresponding to the definitions of various extinction strain rates.

This model can be used to investigate the impact of key operating conditions such as pressure, temperature, fuel-air ratio and oxidizer concentration on the extinction strain rate through the use of automated parameter studies. The flame extinction model can also be used to investigate the impact of fuel composition on the extinction strain rate. These simulations are valuable in the initial conceptual design phase, during experimental testing analysis, and in diagnosing field problems.