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Hetero-/Homogeneous Combustion

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8.1
Introduction

The fuel-lean and fuel-rich catalytic combustion of lower hydrocarbons, syngas, or hydrogen fuels has received increased attention in many industrial applications that include chemical synthesis and fuel reforming, exhaust gas aftertreatment, fuel cells, microreactors, industrial boilers, and power generation gas turbines. In the past two decades, technologies based on combined heterogeneous (catalytic) and homogeneous (gas-phase) combustion have been intensively investigated for power generation systems as a means to reduce NO_x emissions and improve combustion stability. The NO_x reduction is a result of the suppression of the prompt-NO_x formation route during heterogeneous fuel conversion [1] and as such it provides a direct combustion measure for emissions control, contrary to the conventional exhaust gas catalytic treatment techniques for pollutant abatement discussed in Vol. 2 Ch.11 [2].

The adopted strategies in gas turbines include either fuel-lean or fuel-rich combustion (Figure 8.1). In the former, referred to as catalytically stabilized thermal combustion (CST) [3, 4], nearly half of the fuel is converted heterogeneously, stabilizing with thermal and chemical interactions a post-catalyst homogeneous combustion zone (Figure 8.1a). In CST, both catalytic and gas-phase combustion modules operate under fuel-lean stoichiometry. A more recent approach, referred to as catalytic rich combustion (Figure 8.1b), entails catalytic partial oxidation (CPO) of the hydrocarbon fuel to synthesis gas [5, 6]. Therein, part of the air and fuel are mixed so as to provide a fuel-rich stoichiometry at the entry of the CPO reactor. The products, which are mainly hydrogen-rich syngas and unconverted reactants, create a pilot flame that in turn stabilizes the main fuel-lean homogeneous flame of the bypassed reactants. Both aforementioned hetero-/homogeneous combustion approaches provide the best available and most cost efficient low-NO_x technologies for gas-turbines [1, 7], with demonstrated emissions less than 3 ppm [4, 8]. Furthermore, the lower energetic barrier of the catalytic reaction pathway (compared to that of the gaseous reaction pathway) allows for stable combustion below the classical

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