8 Catalytic Combustion of Syngas

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8.1 INTRODUCTION TO CATALYTIC COMBUSTION

Heavy-duty natural gas–fired turbines based on the lean-premixed combustion technology currently attain NO_X emissions of 25 ppm (15% O_2) or less. The forthcoming emission legislation is likely to become more stringent, at least for power plants located in or near urban areas where the lowest achievable emissions rate (LAER) standards may be enforced. During the past two decades, heterogeneous (catalytic) combustion has been intensively investigated for gas turbines of power generation systems (Figure 8.1) as a means to reduce NO_X emissions and provide improved combustion stability.

Heterogeneous fuel conversion is accomplished in ceramic or metallic honeycomb reactors (Figure 8.1b) that are coated with an active catalyst and have suitably large surface-to-volume ratios. The underlying physicochemical processes within

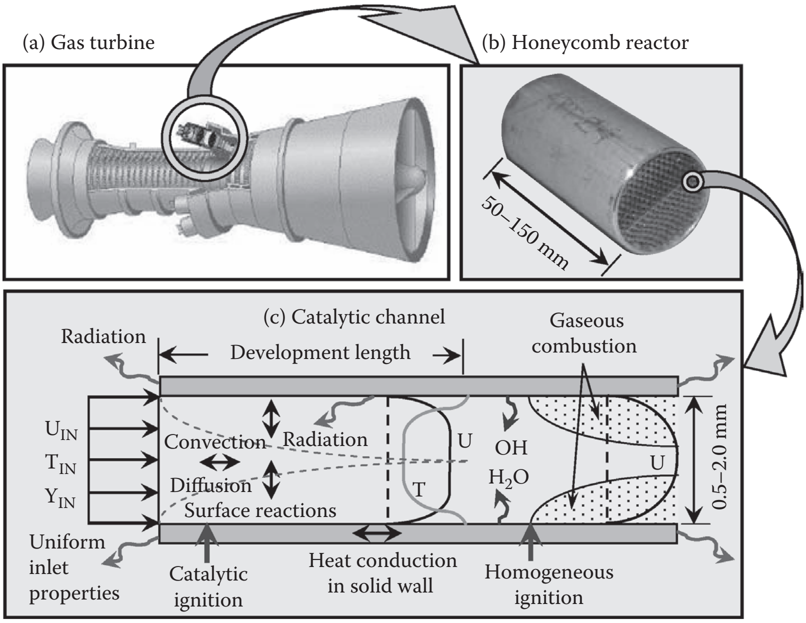

FIGURE 8.1 Catalytic combustion in power generation: (a) gas turbine using catalytic combustion technology, (b) honeycomb catalytic reactor, and (c) physicochemical processes within each catalytic channel.

each catalytic channel of the reactor, which ultimately determine the overall combustion performance, are depicted in Figure 8.1c. Preheated fuel/air premixtures are admitted in each catalytic channel at inflow velocities that guarantee, in most cases, laminar flows (Appel et al., 2005b). Fuel and oxidizer diffuse transversely to the catalytically active surface of the channel. Catalytic ignition (light-off) is attained at a certain distance from the entry, which depends not only on the operating conditions (inflow velocity and temperature, pressure, fuel-to-air stoichiometry, fuel type) and the catalytic reactivity, but also on key in-channel heat transfer mechanisms (heat conduction in the solid walls and surface radiation heat transfer). Therein, the surface temperature has reached a sufficiently high level such that the heterogeneous conversion shifts from the kinetically controlled to the transport-controlled regime (Pfefferle and Pfefferle, 1986). Following catalytic ignition, the fuel and oxidizer react vigorously at the catalyst surface forming a degenerate diffusion reaction sheet (Williams, 1985). This terminology reflects the fact that both reactants diffuse from the same side of the sheet and that the position of the reaction sheet is fixed in space. Heat and reaction products diffuse back to the main flow and a homogeneous (gas-phase) ignition is then established inside the channel (Figure 8.1c), if conditions are appropriate. Given the lower activation energy of the catalytic reaction pathway compared to that of the gaseous pathway (for example, in methane the catalyst reduces the apparent activation energy by a factor of about 2), homogenous ignition can be initiated downstream of the light-off position.