PULSE-DETONATION STEAM SUPERHEATER

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In [1], we patented the innovative pulse-detonation steam superheater (PDSS) for deep oxygen-free and pollutant-free gasification of organic municipal and industrial wastes to produce a gas mixture of H_2 and CO. The PDSS is essentially the pulse-detonation engine operating on the ternary fuel–oxygen–steam mixture with fuel represented, e. g., by a gas mixture of H_2 and CO (energy gas or syngas). The low-temperature steam (375–380 K) is produced by a standard steam generator. Pulsed detonations in the PDSS are achieved due to intermittent spark ignition of the fuel–oxygen mixture followed by fast deflagration-to-detonation transition and transmission of the detonation wave to the ternary fuel–oxygen–steam mixture. It is implied that the PDSS is directly connected to the waste gasification flow reactor and normally operates on the H_2–CO energy gas. However, for starting the plant, the PDSS initially operates on any available hydrocarbon fuel or hydrogen.

The objective of the present study is to experimentally obtain the concentration limits of detonation of ternary propane–oxygen–steam mixtures at normal atmospheric pressure implying that the starting fuel is propane. The PDSS is a stainless-steel tube 50 mm in diameter and 1.5 m long with one closed end and one open end

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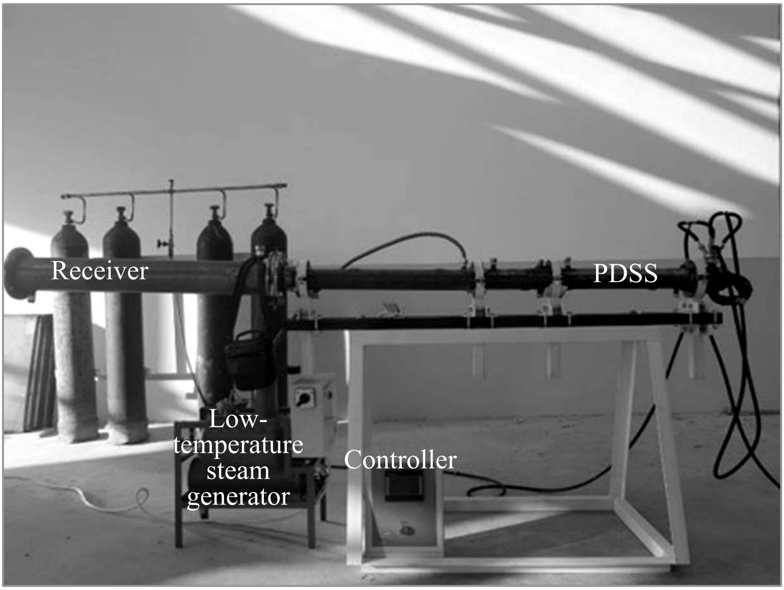

Figure 1 Pulse-detonation steam superheater

connected to a large 1-meter long receiver communicating with the atmosphere (Fig. 1). The experiments are performed by varying the fuel-to-oxygen equivalence ratio (from 0.3 to 1.7) and the steam volume fraction (from 0 to 0.7). In addition to experiments, thermodynamic and computational fluid dynamics (CFD) calculations with a detailed chemistry are performed.

Figure 2 shows the domain of cyclic detonation existence in the ternary mixture on the parametric steam volume fraction (X) – fuel-to-oxygen equivalence ratio (ER) plane obtained experimentally. Curve *1* separating the region "detonation" from the region "no detonation" is drawn between the experimental points corresponding to the normal and limiting/decaying detonation modes. It follows from Fig. 2 that detonation of fuel-rich mixtures with ER > 1 is significantly less sensitive to dilution with steam than the detonation of fuel-lean mixtures with ER < 1. The detonation limit of fuel-lean

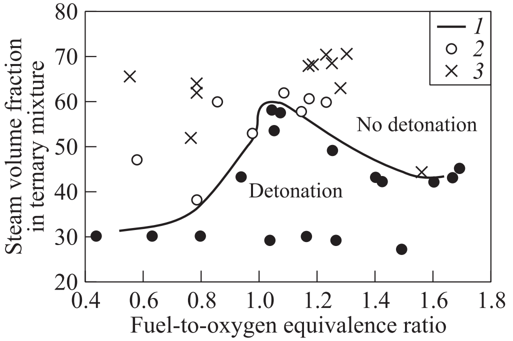

Figure 2 The domain of cyclic detonation existence in the ternary propane–oxygen–steam mixture: *1* — normal detonation mode; *2* — limiting detonation mode; and *3* — decaying detonation mode

ternary mixtures with ER = 0.4–0.8 is achieved with addition of 30%–35% steam, whereas the detonation limit of fuel-rich ternary mixtures with ER = 1.2–1.7 is achieved by adding ~ 45% steam. The maximum steam content (60%), at which detonation of the ternary mixture is still possible, is achieved at ER = 1.0–1.1.

It is shown based on the experimental results, thermodynamic and CFD calculations that pulsed detonations of ternary propane–oxygen–steam mixtures allow the generation of a high-temperature gas environment containing up to 80% H_2O (highly superheated steam) and up to 20% CO_2 with trace amounts of CO, O_2, and H_2 with a temperature exceeding 2250 K at atmospheric pressure. Due to the periodic filling of the PDSS with a low-temperature ternary gas mixture, the temperature of its walls and internal elements rises insignificantly (up to 400 K only), so that conventional (non-heat-resistant) structural materials can be used for its manufacturing.

Acknowledgments

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