

## COMPACT CATALYST-FREE LIQUID FUEL TO SYNGAS REFORMER WITH PLASMA-ASSISTED FLAME STABILIZATION

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The paper discusses the use of nonequilibrium plasma of pulsed high-voltage nanosecond discharge for enhancement of the reforming process in a partial oxidation reactor of a catalyst-free liquid fuel reformer with 10 kW of full burning power. Addition of 5–10% of syngas, a mixture of CO and H<sub>2</sub>, can be used to decrease emission levels to internal combustion engines [1]. The main problem is on-board production of syngas. There are several industrial-scale technologies which are very efficient on a large scale, but are hardly scaled down. A number of new approaches aimed at scaling down reforming processes have been introduced recently, including small-scale catalytic steam reformers of various designs, partial oxidation process, auto-thermal reforming, thermo-catalytic cracking, sorbent-enhanced reforming, auto-thermal cyclic reformer, and some other approaches [2]. This paper considers partial oxidation (POx) with the use of a plasmatron to stabilize the oxidation processes in extremely rich fuel-air mixtures. Electrical discharge in the form of repetitive nanosecond sparks develops in the nozzle of the plasmatron serving as the inlet for the premixed reagents.

The reformer prototype testing scheme is shown in Fig. 1 with indicative general dimensions. The reformer is essentially a cylindrical reaction chamber (1) with ceramic walls (2) surrounded by layers of thermal insulation (3). The fuel and air flows are supplied into a preheater/evaporator (4) which is a stainless steel coil wrapped into heating tapes and thermal insulation. The temperature of the coil wall is measured by a thermocouple and maintained at a preset level through a feedback circuit. The preheated premixed fuel vapour-air flow enters the reaction chamber through a plasmatron (5). The plasmatron is a burner with a nozzle (6) at the outlet with plasma channels inside it. The plasma is formed by high-voltage repetitive nanosecond discharge in this prototype. The high-voltage pulses are formed by an external pulse generator (7). The high-voltage electrode in this plasmatron is the swirler (8) in the centre of the nozzle. The ground electrode is the body of the plasmatron. Further downstream in the reaction chamber a stack of ceramic foam filters (9) is installed in order to capture the produced particulate matter. The conditions inside the reaction chamber are monitored with a K-type ungrounded thermocouple (10). The composition of the products (H<sub>2</sub>, CO, CO<sub>2</sub>, and CH<sub>4</sub>) is registered in real time with a Nova gas analyzer. The sampler location is shown in the scheme as (11).

The results of diesel reforming are presented in Fig. 2 in terms of products concentrations and of the temperature inside the reaction chamber. It is seen that the products are mostly H<sub>2</sub> (20%) and CO (22%), though some CO<sub>2</sub> and H<sub>2</sub>O are also present, apart from N<sub>2</sub>. The curves show clearly the stability of the reformer output parameters. The maximum thermal power calculated as full burning power of the reagents is 10.7 kW in the current reformer prototype, which corresponds to 30 kW/l of specific power. The reformer was successfully tested for 6 hours of continuous operation. The air flow in the tests was kept constant at 60 slpm, whereas the diesel mass flow was varied from 11 to 15 g/min, which corresponded to ERs from 2 to 3.3.

The results demonstrate that the discharge is required for transient modes, including cold startup and self-cleaning phase. During normal operation with rich mixture it initiates the first, oxygenfuel stage of the conversion process. The second stage of the fuel conversion via partial oxidation is the reaction of water vapour with hydrocarbons, when plasma-assisted oxidation is

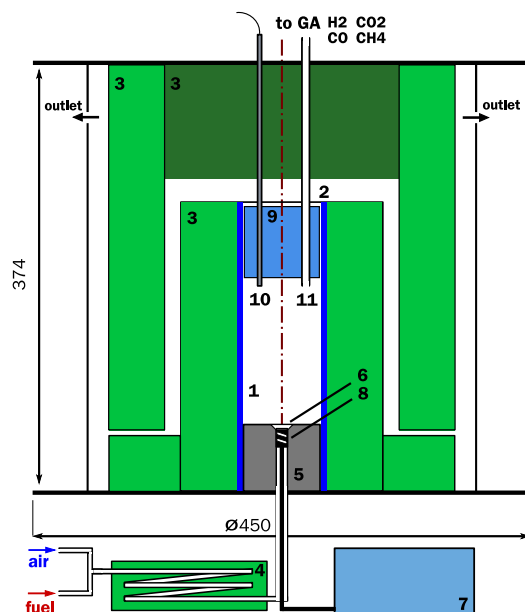


Fig. 1: Reformer scheme: 1 — reaction chamber, 2 — ceramic tube, 3 — thermal insulation, 4 — preheater/evaporator, 5 — plasmatron, 6 — plasmatron nozzle, 7 — high-voltage pulse generator, 8 — swirler/high-voltage electrode, 9 — ceramic foam filters, 10 — thermocouple, 11 — gas sampler.

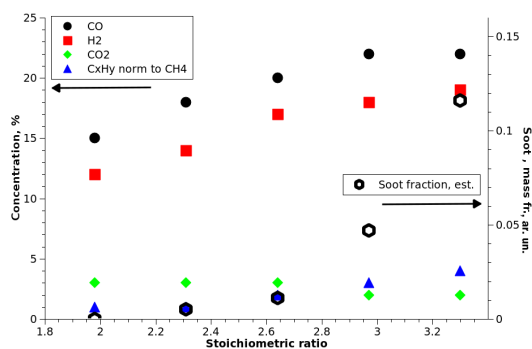


Fig. 2: Time-averaged components concentrations in reforming products and temperature in the reaction chamber. Diesel fuel reforming.

inefficient due to nonchain mechanism of the process. Thus, the thermal mechanism of chemical processes is shown to be the most important. High hydrogen yield can be achieved by optimal burner and reaction chamber geometry and by efficient thermal insulation. The current prototype yields syngas with 20% of H<sub>2</sub> and 22% of CO with both gasoline and diesel fuel. Such hydrogen production corresponds to 80% of the theoretical maximum.

## Reference

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