THERMODYNAMIC ANALYSIS OF DIESEL REFORMING OPTIONS FOR SOFC SYSTEMS

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Development of a diesel reformer for solid oxide fuel cells widens the application of SOFC system by making it more fuel-flexible. While technologies for conversion of fuels containing these hydrocarbons are commercially available, the industrial scale processes and the composition of the reformed gas are not ideally suited to SOFC systems. The work is extremely challenging and will require some novel approaches to solving some of the technical problems. A key step in fuel processing is reforming of the fuel to a mixture containing hydrogen and methane. There are three routes for this conversion: steam reforming, autothermal reforming and partial oxidation. In this work we carried out a thermodynamic analysis of the three reforming routes. Minimum steam-to-carbon ratios for steam reforming and for autothermal reforming and minimum oxygen-to-carbon ratios for autothermal reforming and partial oxidation and their corresponding temperatures required for carbon-free operation were identified. Fuel processor efficiencies and reformer heat requirements were computed to identify practical operating conditions. SOFC stack efficiencies for 85% fuel utilisation were computed to identify the commercially viable options for the system. The calculations revealed that steam reforming of Diesel Grade-2 is thermodynamically feasible without carbon formation, at temperatures higher than 680°C with S/C=1.5, at temperatures higher than 580°C with S/C=1.8 and at all temperatures with S/C=2.

Thermodynamic potential for carbon formation is completely averted by autothermal reforming at S/C=1.8, O_2/C=0.25 and at S/C=1.5, O_2/C=0.5. Carbon formation is avoided by partial oxidation at O_2/C=1 at T>580°C but results in significant N_2 dilution. To operate at O_2/C=0.75, the temperature must be raised to 690°C to avoid carbon formation. To operate at O_2/C=0.5, the temperature must be raised to >800°C. However, the partial oxidation route becomes unattractive as it generates more waste heat in the system i.e. in addition to that generated from the fuel cell stack. Fuel processor efficiency and SOFC system efficiency are highest with the steam-reforming route and still in the acceptable range for the autothermal route at low O_2/C values. However, by utilising the waste-heat generated from the stack and that available from unutilized fuel in a thermally integrated system, low temperature steam reforming is the most attractive option for diesel reforming for SOFC systems. Fig. 1 below shows SOFC efficiencies calculated at 85% fuel utlisation for the various reforming options and conditions considered in this study.

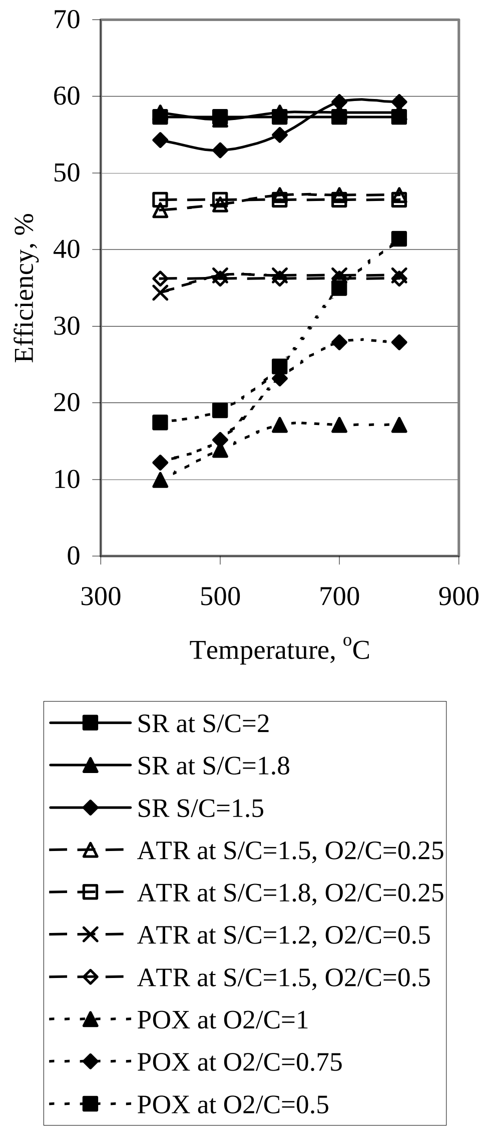

Fig.1 SOFC efficiencies for 85% fuel utilisation for various diesel reforming conditions