Direct Integration of Carbon-free Fuels with Concentrated Solar Radiation

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The development of technologies to hybridise concentrating solar thermal energy and combustion technologies is driven by the potential to provide both cost-effective CO_2 mitigation and firm supply. In particular, hybrids between solar and combustion systems fed with carbon-free fuels (e.g. hydrogen) offer potential for low-cost carbon-neutral or carbon-negative energy (Nathan et al., 2017, 2018). However, all of the hybrid energy thermal systems employed commercially to date utilise a solar receiver designed solely to harvest the solar energy and a combustor designed solely to harvest the energy from the fuel (with the two devices designed to run in either series or parallel). This results in significant heat losses and inefficiency while increasing the capital cost of the combined system (Chinnici et al., 2018). These limitations can potentially be avoided by “direct hybrids”, which harness the solar and combustion processes within a single device (Nathan et al., 2018). However, while the potential benefits have been demonstrated by analysis and recently by experimental evidence (Chinnici et al., 2018), no data on the performance of direct hybrids fuelled with alternative fuels are presently available, so that a systematic investigation is needed to fully confirm these potential benefits.

To meet the aforementioned needs, this study describes the performance characteristics of a Hybrid Solar Receiver Combustor, in which the functions of a solar receiver and a combustor are integrated into a single device. The device was tested at a nominal capacity of 12-kW_{th} for the solar-only, combustion-only and mixed-mode (a combination of both solar and combustion simultaneously), using hydrogen (H_2) as fuel. A 5-kW_{el} xenon-arc lamp was used to simulate solar radiation into the device (Figure 1). The influence of the mode of operation on the thermal performance and pollutant emissions is analysed, for a range of values of the heat extraction. A CFD model of the device was also developed to assess the influence of the mode of operation on the heat transfer rates and heat flux distribution within the cavity. The thermal performance was found to be similar for all modes of operation, despite the different nature of the two energy sources. Overall, this study highlights that, if renewable H_2 (which can be produced by different renewable energy sources, including solar, wind and biomass) is used as fuel, the device can efficiently operate in all the modes of operation employing 100% renewable energy.

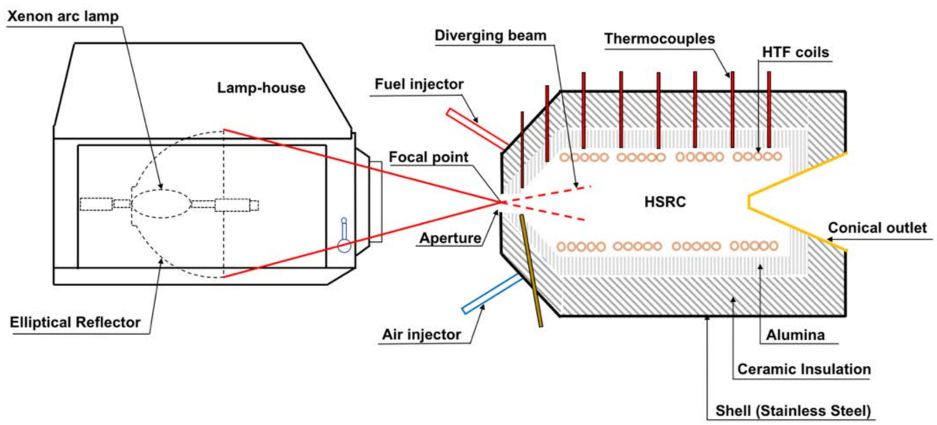

Figure 1. Schematic diagram of the experimental set-up, showing a side view of the laboratory scale HSRC and the 5-kW$_{el}$ short arc xenon lamp.

References

Nathan, G.J., et al., 2017, 'Research challenges in combustion and gasification arising from emerging technologies employing directly irradiated concentrating solar thermal radiation', *Proceeding of the Combustion Institute*, 36, p2055-2074.

Nathan, G.J., et al., 2018, 'Solar thermal hybrids for combustion power plant: A growing opportunity', *Progress in Energy and Combustion Science*, 64, p4-28.

Chinnici, A., Nathan, G.J., Dally, B.B., 2018, 'Experimental demonstration of the hybrid solar receiver combustor', *Applied Energy*, 224, p426-437.