Challenges for 100% hydrogen combustion in gas turbine applications

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Abstract: Challenges for 100% hydrogen combustion in gas turbine applications

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The continuing growth of renewable energy in the Netherlands and Europe provides challenge and opportunity. The cyclic nature of Solar and Wind renewable generation results in periods of substantial over capacity as well as periods of shortfall. The generation shortfall is typically addressed through the use of conventional fossil fuel generation such as gas turbines. Cost effective energy storage has the potential to support balancing load requirements while offsetting the need for fossil fuel. A high energy density media such as hydrogen is able to allow the capture of excess energy capacity in the off peak and release this energy during times of peak demand, with zero carbon emissions. Infrastructure is needed to support the generation, storage and use of hydrogen as a fuel.

Gas turbine based power generation and combined heat and power installations, due to their flexibility and high thermal efficiency, are the first candidates to use hydrogen as a fuel to generate power during periods of shortage of renewable energy. The Netherlands has a high number of high efficiency and high flexible gas turbine units, currently equipped with combustion systems for natural gas. These units should become capable to vary their operation smoothly between 100% natural gas and 100% hydrogen with low NOx emissions, while keeping the high efficiency and flexibility and with limited impact on maintenance.

This presentation will discuss the current developments in the gas turbine industry with respect to hydrogen combustion. The impact of the different challenges for combustion of hydrogen: high flash back risk, high flame temperature and high diffusivity will be discussed. The potential technological solutions to these challenges like microjet mixing burners, axial jet injection, low swirl burners and trapped vortex burners will be illustrated with examples from industry and academia.

TU Delft identified the risk on flash back as one of the main challenges to achieve low NOx and stable combustion of 100% hydrogen under gas turbine conditions. The research at the TU Delft on premixed hydrogen flashback modeling builds upon the flash back models developed at the TU Munich by Hoferichter et al.. The current research focuses on the improvement of these TU Munich models as they lack accuracy especially at low equivalence ratios and high inlet temperatures, very relevant conditions for gas turbine application. It shows that the low Lewis at the conditions is the main reason for these inaccuracies. TU Delft included the Lewis number effect on the turbulent flame speed into the flash back model. The first results of this improved model and the comparison with experiments will be shown. In the next steps TU Delft will also implement the model into a CFD code to be able to use it as a general tool for flash back risk analysis for premixed burners.