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Design & optimization of a compact heat exchanger for a micro gas turbine micro-chp application

Jojomon Joseph[1], Rabia Nacereddinea[2], Michel Delanaye[3], Juergen J. Brandner[4]
[1]joseph.jojomon@mitis.be, [2]rabia.nacereddine@mitis.be, [3]michel.delanaye@mitis.be,
[4]juergen.brandner@kit.edu

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Counter-flow, Printed plate fin heat ex-changers, Conjugate heat transfer, S-shaped, pins.

ABSTRACT

Mitis is developing a micro-CHP system based on a micro gas turbine for residential application. The system is based on a recuperated inverted Brayton cycle and makes use of a flameless combustor which produces very low NOx. A micro gas turbine consists of a compressor, turbine, combustor, generator and several heat exchangers. The advantage of the inverted Brayton cycle is the fact that the system works sub-atmospheric, hence does not require the compression of the fuel gas, and allows to use larger size turbomachinery components[1]. The target efficiency of the machine is ranked higher than 25% to fit at best the market expectations. According to the cycle analysis, the recuperator plays a major role to achieve that target. The recuperator retrieves thermal energy left into the exhaust gas of the turbine to pre-heat fresh incoming air entering the combustion chamber. This pre-heating reduces the amount of fuel required to achieve the target inlet turbine temperature and therefore enhance the electrical efficiency of the cycle[2]. Pressure losses also play a major role and affect the efficiency and should therefore be minimized. The targeted performance of the recuperator shall be a thermal efficiency greater than 90% with minimum pressure losses (less than 2%) for both fluid passages. The current configuration of the recuperator is based on the assembly of small passages separated by thin foils[3] and with a special configuration to obtain an efficient counter-flow heat exchange. The passage embeds a special mesh structure to sustain the pressure differences. This structure also seems to play a role in reaching the efficiency with less effect from varying mass flow. In practice, Reynolds number in the heat exchanger is close to 100 but the internal structure can create substantially larger velocities which can enhance heat exchange but also increase pressure losses.

The objective of the work is to improve the current design by enhancing the understanding of the fluid mechanics in the heat ex-changer, to understand the heat transfer and develop new internal structures which can maintain the high efficiency while decreasing pressure losses. The research is heavily supported by the use of advanced 3D CFD analysis with conjugated heat transfer[6] (ANSYS Fluent). Printed Plate-fin heat ex-changers (PPFHE) are found to be more effective to attain high area densities[4]. Several alternative configurations are currently analyzed including PPFHE with pins[8] [9](with an angle) and S-shapes[5]. Influence of longitudinal vortex (increase wall normal fluctuations) and reattachment length on heat transfer should be optimized. Smaller reattachment length (small dead zones) induce high heat transfer zones (due to high wall normal fluctuations) near the wake of pins[7] [10]. A detailed study of S-shaped configurations can be used to reduce separation and therefore increase heat transfer while ensuring minimum pressure losses[5]. Characteristic shape and spacing of pins/S-shaped should be optimized for different flow patterns.

In addition, collectors of the heat exchanger must also be characterized in terms of pressure losses. A detailed study including CFD of the overall heat exchanger with a model of pressures losses in the flow passages is performed.

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