Conceptual Design of a Compressor Vane-HEX for LH_2 Aircraft Engine Applications

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Synergies with heat management

In order to meet the ambitious environmental targets set by the Paris Agreement, new sustainable carbon neutral aviation fuels need to be introduced. The high gravimetry energy density of hydrogen, makes it a prime candidate for a future aviation fuel. However, the associated poor volumetric energy density, requires an increased aircraft volume and associated penalty in aerodynamic performance. The required volume occupied by the hydrogen fuel can be decreased in half, if stored in its liquid form. This however requires that the liquid hydrogen (LH_2) is kept at cryogenic temperatures, requiring adequate tank insulation. Moreover, to increase the effective heating value of hydrogen, the fuel distribution system will include heat exchanger technology to increase the fuel temperature before injection in the combustion chamber. The present work provides an outlook of different heat exchanger technology for application in hydrogen fueled gas turbine aero engines. The heat exchangers can be placed in the vicinity of the engine to reject the heat generated by the gas core to the hydrogen fuel. Ideally, they are strategically located to use heat management to maximize the engine efficiency and ensuring sufficient component durability. Moreover, the combination of liquid hydrogen's high specific heat with cryogenic storage temperatures results in a formidable cooling capacity that can be explored by more compact heat exchanger solutions. Various heat exchanger (HEX) concepts to heat up the hydrogen fuel are illustrated in Figure 1.

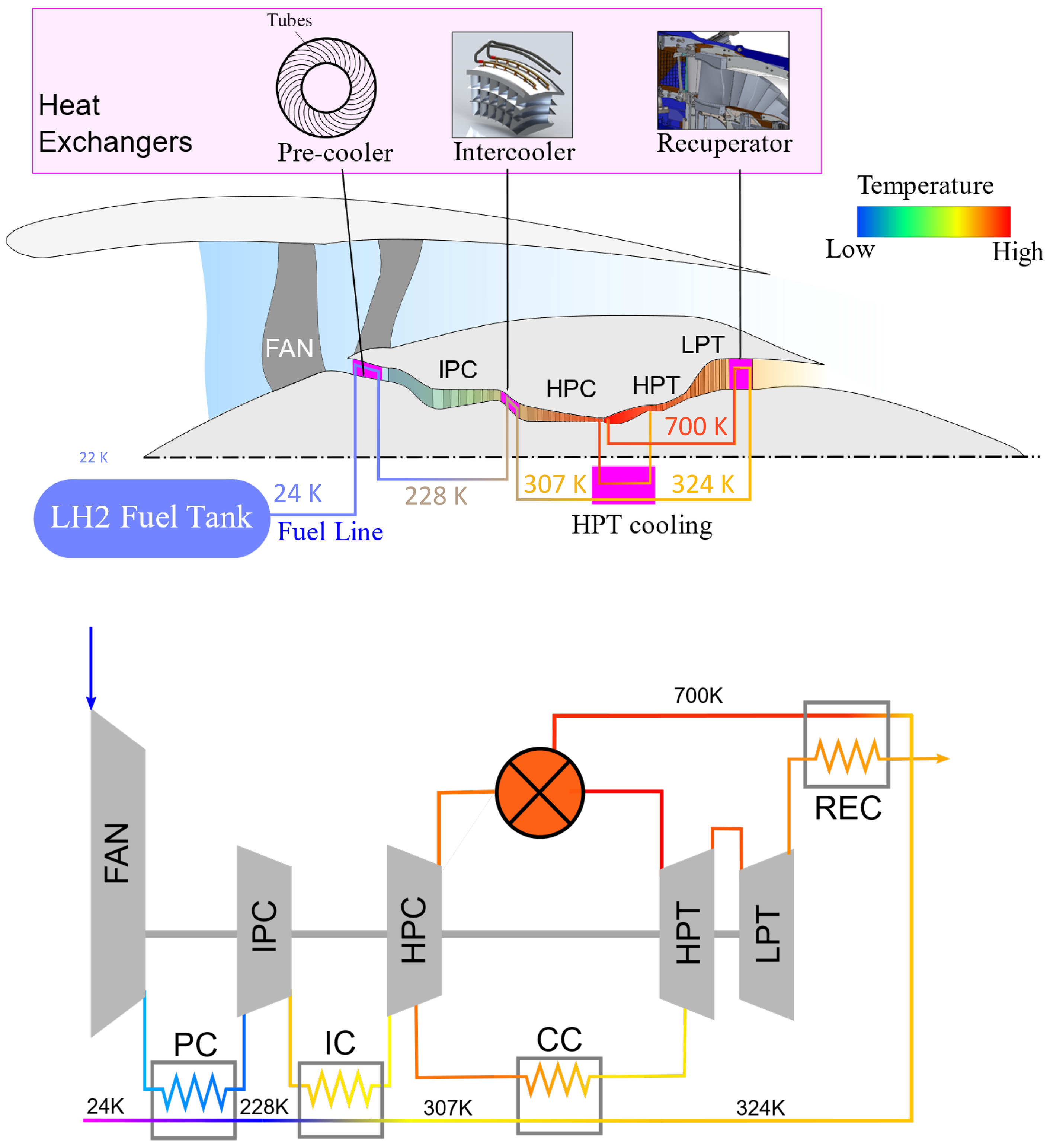


Figure 1: Cross-sectional meridional cut of a turbofan engine, including possible locations for core heat rejection to the hydrogen fuel. The fuel is stored at its boiling point in the LH2 tank. The temperature of the hydrogen in the fuel line is increased by the different core installed heat exchangers on its way to the combustion chamber. IPC: Intermediate-pressure compressor; HPC: High-pressure compressor; HPT: High-pressure turbine; LPT: Low-pressure turbine

Vane-integrated heat exchanger

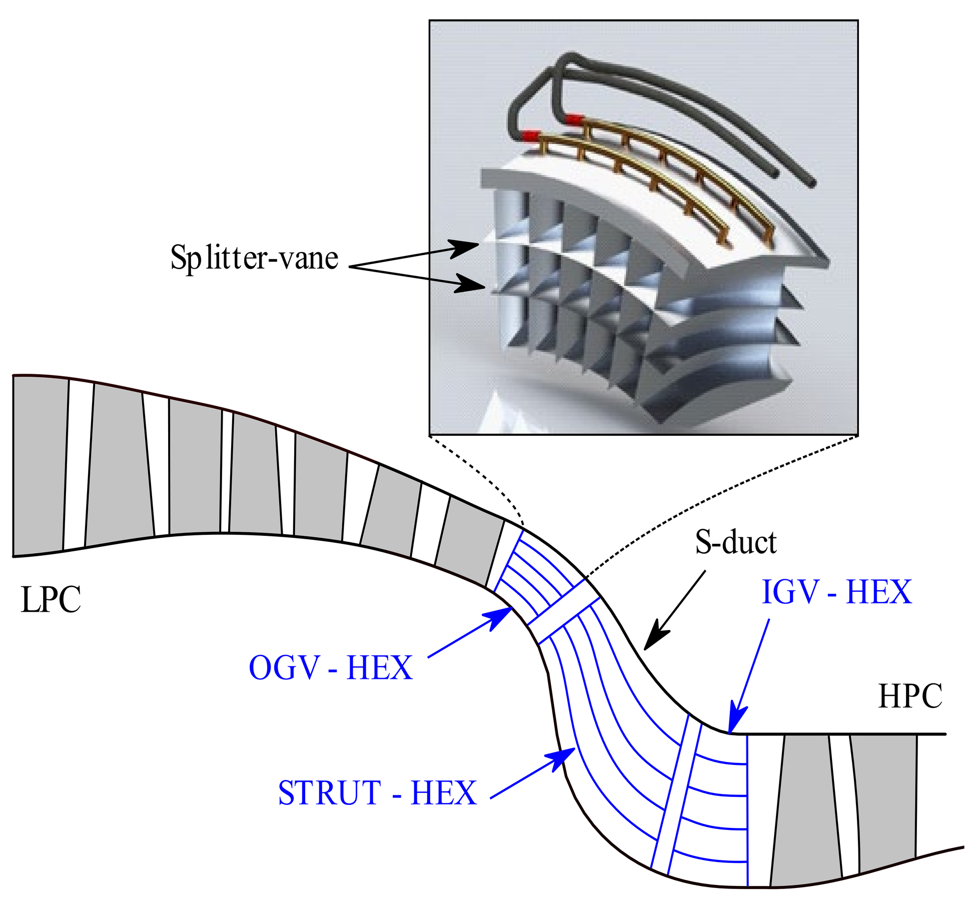


Figure 2: Possible arrangement of a compound heat exchanger, where the first HEX is placed at the low-pressure compressor outlet guide vane (OGV), a second HEX is integrated into the STRUT, and a third HEX is included in the high-pressure compressor inlet guide vane (IGV). Such an arrangement allows for the OGV-HEX to turn the flow radially downwards into the aggressive S-duct, and for the STRUT- and IGV-HEX to straighten the flow towards the high-pressure compressor first stage.

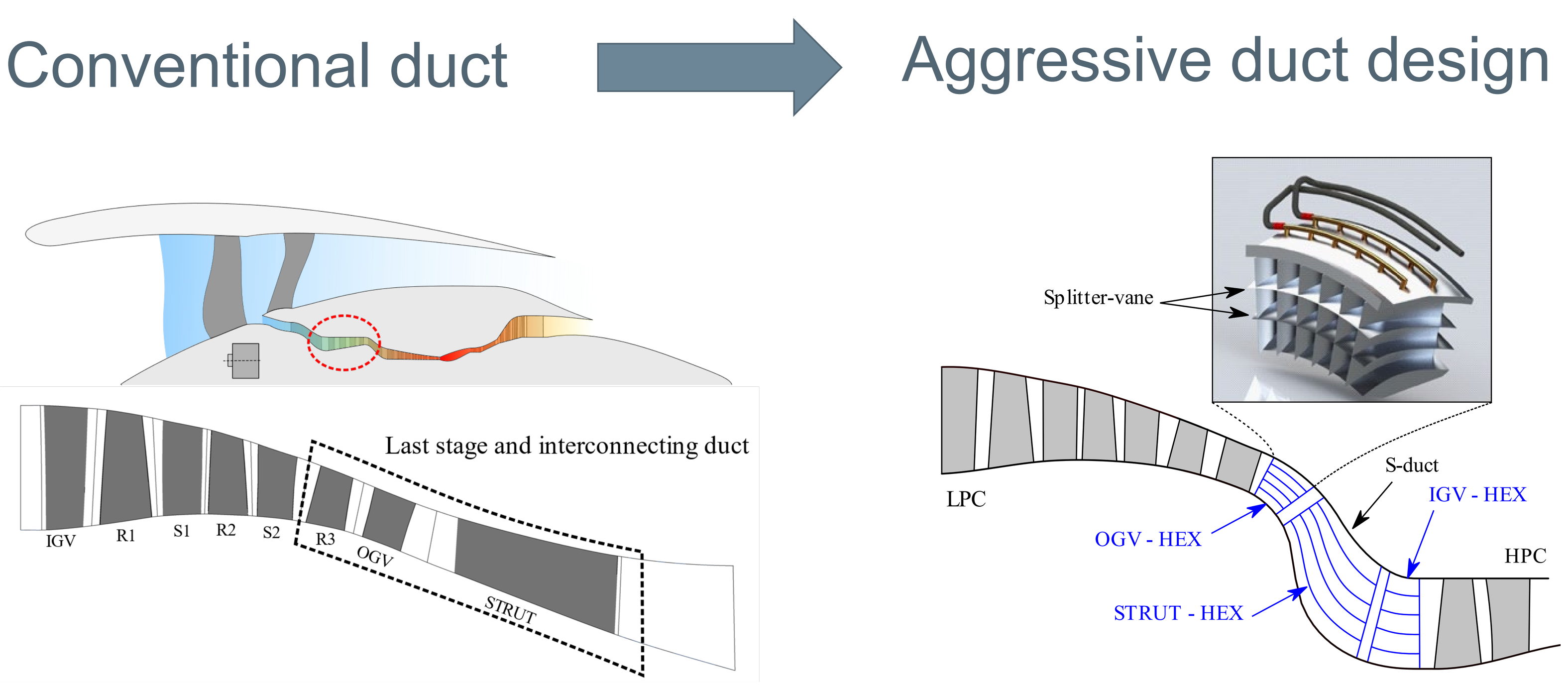
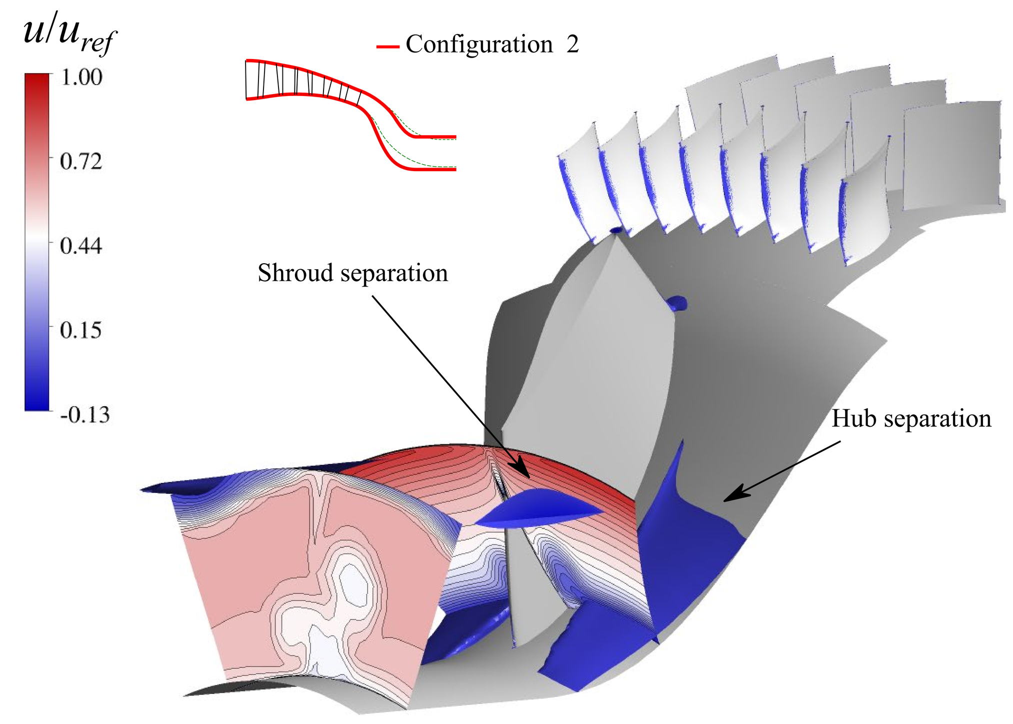
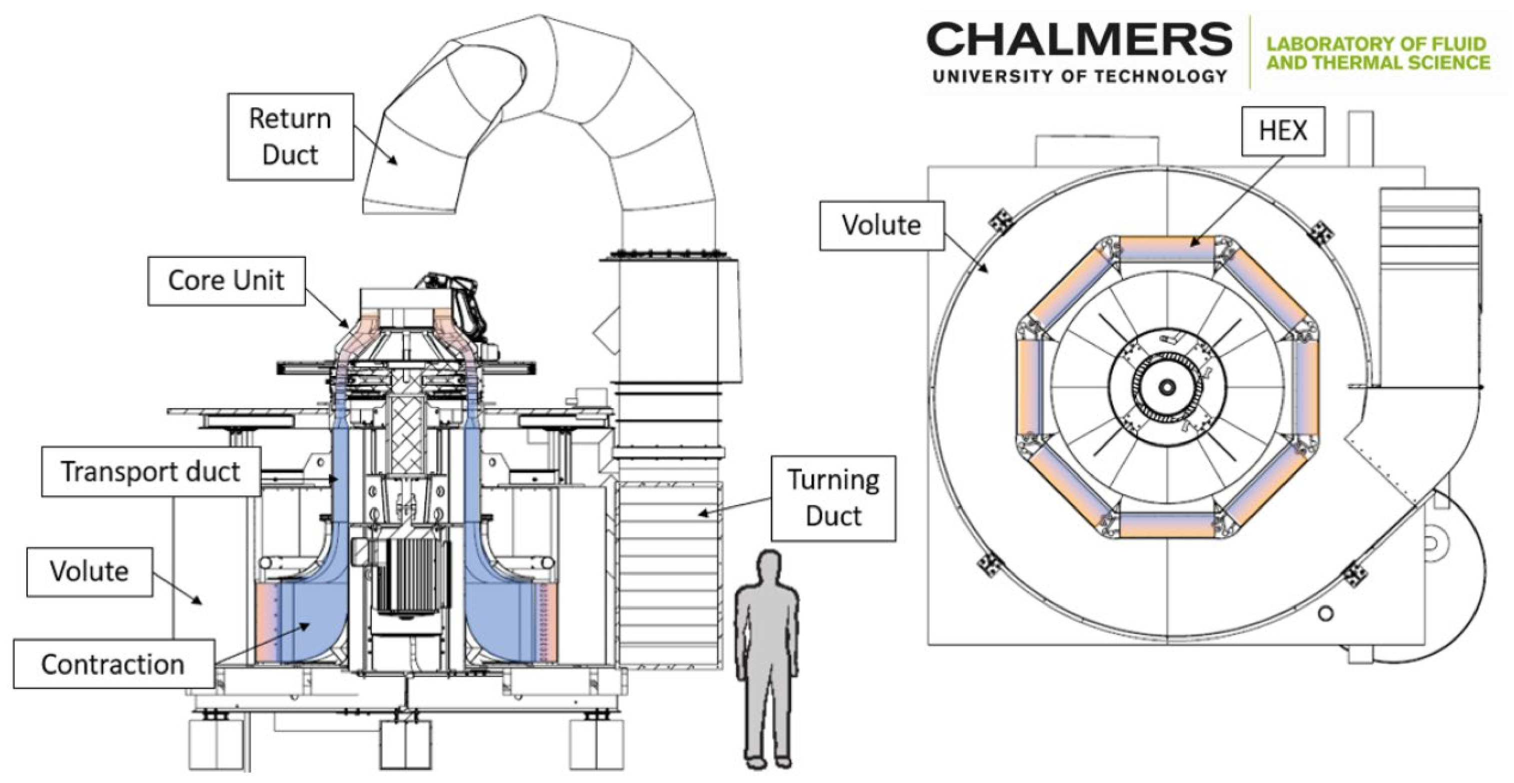


Figure 3: The additional spanwise distributed plates (splitter-vanes) will lead to additional pressure losses in the engine core but can also be designed to enhance the radial turning capability of the vane. The radial turning capability can allow for a reduction of engine length and weight by reducing the axial length of the transition S-duct between the low- and high-pressure compressors,

Figure 4: Aggressive ducts designs are more prone to flow separation leading to increased pressure losses and unacceptable levels of distortion at the high-pressure compressor inlet. The image shows normalized velocity contours and flow separation iso-surfaces at the hub and shroud.



Chalmers new experimental facility



Mass flow [kg/s]	17
Rotational speed [RPM]	1920
Rotor Re number [-]	6×10^5
Pressure ratio [-]	1.07
Axial velocity [m/s]	70
Tip speed [m/s]	100
Average tip radius [m]	0.620
Average hub radius [m]	0.540
Average aspect ratio	2.157
Average tip clearance [mm]	0.75
Average stage loading [-]	0.25
Average flow coef. [-]	0.50

Figure 5: Schematics of Chalmers low-speed 2.5 stage **heat management compressor facility**. The compressor facility is currently under construction at Chalmers University of Technology, Laboratory of Fluid and Thermal Sciences. It is designed to achieve an accurate low-speed representation of a state-of-the-art low-pressure compressor designed for a future geared turbofan engine. The facility and compressor are designed to accommodate for a diversity of instrumentation and ease of access. The compressor stages can be accessed at 28 locations, six of which have traverse capabilities of a full span 18-degree sector, to be used at the rotor-stator interfaces. The traverses can be replaced with windows for optical access when performing Particle Image Velocimetry (PIV) or flow visualization within the compressor. At the rotor outlet-guide-vane interface, four independent traverse systems provide a 360-degree access for more detailed studies. The open pressure recovery at the exit of the intermediate compressor duct allows for full volume traverse access by a robot arm

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