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C4Or1D-01: Vibration-Free 40-80K Turbo-Brayton cryocooler and its very high efficiency recuperator for Earth Observation instruments

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Several studies have demonstrated that Reverse Turbo-Brayton cryocoolers could be the next space cryogenic revolution, thanks to their capability to provide vibration-free remote cooling in the temperature range of 4 to 150K and for medium to high cooling powers. In this framework, Absolut System developed a Vibration-free 40-80K Reversed Turbo-Brayton cooler, work performed under contract N°XXXX and funded by ESA. The cooler is based on two turbo-compressor stages, a high efficiency recuperator and a cryogenic turbo-expander, for operation between 300 and 40K.

Following the fabrication of the cooler, we performed tests on both individual components, compressors, expander and recuperator as well as on the complete cooler. The turbomachines use aerodynamic bearings and generate very little vibrations and are extremely resilient. The characterizations performed during the project concern exported micro-vibration behaviors of the compressors and the expander, operating respectively up to 250,000RPM and 150,000RPM, and thermodynamic performances of the different elements. The cooler was tested down to its minimum temperature and required the development of specific operating procedures with regards to the conditioning of the circuit.

We report here in a first part the main results and observations stemming out of the test campaigns carried out during the project.

This work showed the necessity of putting additional efforts on the recuperator, one of the most critical component of the cooler. Absolut System is thus also working in parallel on developing a very high efficiency and compact heat exchanger for the specific needs of Turbo-Brayton Coolers in response to the ESA Proposal ESA-TDE-TECMTT-SOW-023649.

The technology selected for this is based on the common tube and shell but using very thin tubes of small diameters (<1mm). The challenge of this exchanger is not only the manufacturing, but also the very strict requirements. Obtaining a >97.5% efficiency in a very small mass while maintaining very low pressure drops, makes for a very compelling project.

We have performed the design phase, tested, and validated different aspects of the assembly. The design for the first breadboard model has been validated numerically and is in the fabrication process. Testing the exchanger will then take place to characterize the performances of the recuperator and allow for a comparison between experimental results and analytical and CFD models.

All these tasks are participating in placing the Turbo-Brayton cryocoolers at the forefront of space coolers and this development is pushing Europe even further in State of Art advancements for space, and brings us all closer to fulfill future Space Explorations and Earth Observation missions.

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