Contribution ID: **37** Type: **not specified**

3D printed pipes including sensors and heaters for thermal management systems in space and on earth

Wednesday 31 May 2023 14:45 (20 minutes)

The motivation for the development of 3D printed pipes including sensors and heaters for thermal management systems comes from the limitations and difficulties in directly monitoring and acting on fluid properties with existing methods. Sensing parameters such as pressure, temperature and flow rates of refrigerant are of utmost importance for the operation of thermal management systems, on earth and in space. Ideally, these measurements shall be performed directly in the fluid flow with sensors directly in contact with the fluid. In practice, this approach cannot always be applied due to hard-to-reach measurement areas, lack of space and limitations on the total mass of the system. Current systems use sensors either located on the outer surface of pipes or inside the pipe as additional elements, introducing additional volume, mass and cable management constraints.

CERN's thermal management systems rely on a transcritical CO2 refrigeration cycle in cascade with a CO2 mechanical pumped loop, and it involves a multi-branch system with complex distribution. Therefore, distributed sensing of local flow parameters is essential for optimizing heat exchange across the thermal circuit. However, the environments where silicon detectors are present are also characterized by strict mass and volume limitations. The use of AM-produced elements within these hydraulic systems provides the necessary freedom of design to answer these constraints, while the inclusion of embedded sensing capabilities allows for the precise monitoring of vital parameters throughout the thermal management system.

In this workshop the work of the project AHEAD: Advanced Heat Exchange Devices (part of the EC programme ATTRACT Phase 2) will be presented, which is targeting on the development of pipe segments including temperature sensors, heaters and energy harvesters directly integrated into the pipe thanks to a patented [1] design and manufacturing concept relying on advanced processes such as metal Laser Powder Bed Fusion (LPBF), Aerosol Jet Printing (AJP) of electrically conducting ink patterns as well as thin insulation layers.

1. Saudan H., Kiener L. Method for manufacturing a 3D electromechanical component having at least one embedded electrical conductor. European patent 3740382 B1, 2022-05-25.

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Session Classification: Plenary