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C2Or2C-04: System-scale dynamic simulation of the 400W@1.8 K Test facility at CEA Grenoble: experimental validation on steady state and transient configurations (towards new applications)

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CEA Grenoble DSBT (Low Temperature System Department) commissioned in 2004 a test facility with a cooling capacity of 400W@1.8K (or 800W@4.5K). This system comprises a cold box with two centrifugal cold compressors, a cold turbine, a wet piston expander, counter flow heat exchangers and a phase separator at 4.5 K and a large Multi-Test Cryostat than can include a phase separator at 1.8 K. It has been designed to be modular in order to meet the needs of a wide range of studies: test of industrial components at 1.8 K, studies on thermal-hydraulics of two-phase superfluid helium, fundamental research on high Reynolds number turbulent flows. Recently, in the framework of the future High Luminosity upgrade of the Large Hadron Collider (HL-LHC) at CERN, the 400W@1.8K facility was used to characterize a specific compact heat exchanger between a He II pressurized bath and a He II saturated bath in order to cool the D2 magnet in different operating conditions at 1.8K and 2K.
At the same time, the Simcryogenics library was developed in the same CEA team to simulate and optimize cryoplant and its distribution to end-users. This homemade tool, based on Simscape, the modelling language extension of the Matlab/Simulink software, aims in particular to generate model-based control schemes for cryogenic plants that are subject to high disturbances (such as pulsed heat loads infusion reactors or particle accelerator). The library is validated on numerous experimental systems: warm compression station, cooling of superconducting magnets, cold boxes (JT-60SA Auxiliary cold box), RF cavities (SPIRAL 2 cryomodules), data from the 400W@1.8K test facility in the 800W@4.5K configuration.
Recently specific tests have been carried on the 400W@1.8K test facility to validate the simulation of systems including parts with superfluid Helium. The present paper aims to complete the Simcryogenics validation using these specific tests. The validation includes two parts: firstly, validation of each component and of the whole system based on steady-state tests with different flowrates and temperature between 1.8 K and 2 K; secondly, validation of the whole system model on transient configurations.
Anchoring the Simcryogenics library to the available data in superfluid helium will facilitate the running of the 400W@1.8K test facility (i.e. parameters optimization, model-based control tuning) and to explore new configurations. In particular, a System-modelling approach will be used to answer to the new challenges: to define the best architectures to provide several levels of cooling temperature at the same time or for managing load variations in the case of many end-users with varying cooling requirements for new applications such as the refrigeration of quantum cluster-like computer infrastructure.

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