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Evaporation of CO2 in microchannels : CFD simulations with Fluent and microfabrication process

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Thanks to its good thermo-physical properties, in particular its high latent heat, CO2 is considered as a good choice for two-phase cooling devices [1]. The next generation of tracking detectors at LHC (CERN) will be cooled at temperatures between 10℃ and -40℃, by evaporating the liquid CO2 flow circulating in titanium mini-channels attached to the pixel silicon sensors of 4 cm². For the next eneration of pixel detectors installed on the Future Circular Collider (2045) , a new option, studied by the LEGI-LAPP team (Laboratoire d'Ecoulements Géophysiques et Industriels & Laboratoire d'Annecy de Physique des Particules) is to **circulate the CO2 within micro-channels integrated in the silicon covering the whole surface of the sensors**. Within the current decade, their thermal performances will have to be evaluated to validate this option. For this deadline, the **numerical simulation** of two-phase flows should help us to **predict the cooling performances** of CO2 in microchannels over a wide range of operating conditions (saturation temperature, cooling power, hydraulic diameter and materials of the channels, mass flow rates, etc. . .). Until now, 2D simulations have been carried out on ANSYS Fluent 2020 for an isolated static bubble, with the Volume Of Fluid (VOF) method. This work has two main objectives which are discussed here: 1/ control and reduce the spurious currents induced by the low viscosity of CO2 caused by the modeling of the surface tension force, 2/ set up a boiling model able to guess the correct bubble's growth rate for a given temperature field in the frame of VOF and VOF/Level Set approaches. With this work, we intend to simulate a CO2 two-phase flow in a microchannel. In parallel, the fabrication in a clean room of silicon microchannels, sealed with pyrex, has begun. The primary objective is to measure the pressure resistance of prototypes of different dimensions, and to compare the results with the measurements done at CERN in 2020 [2]. Several challenges have to be overcome, in particular regarding the robustness of the connectors. The ultimate goal is to **manufacture prototypes of single and multi-microchannels**, in order to measure the dynamic and thermal behavior of CO2 convective boiling on a test bench in the LAPP laboratory (Annecy, France), and to **compare experimental results with the numerical simulations**.

References

[1] BARROCA Pierre, Modeling CO2 cooling of the ATLAS ITk Pixel Detector, Th'ese, Laboratoire d'Annecy de Physique des Particules, 2019. https://hal.univ-smb.fr/tel-02956226.

[2] MAPELLI & al., Micro-channel cooling for collider experiments : review and recommendations,2020. https://cds.cern.ch/record/2712079?ln=fr

Primary author: VACHER, Maxime (Laboratoire d'Ecoulements Géophysiques et Industriels (Grenoble) & Laboratoire d'Annecy de Physique des Particules)

Co-authors: COLOMBET, Damien (Laboratoire d'Ecoulements Géophysiques et Industriels (Grenoble)); AYELA, Frédéric (Laboratoire d'Ecoulements Géophysiques et Industriels (Grenoble)); DELEBECQUE, Pierre (Centre National de la Recherche Scientifique (FR)); JEZEQUEL, Stephane (LAPP-Annecy CNRS/USMB (FR)); KOSSAKOWSKI, Roman (Laboratoire d'Annecy-le-Vieux de Physique des Particules (LAPP)); LEVEQUE, Jessica (LAPP (Annecy-Le-Vieux))

Presenter: VACHER, Maxime (Laboratoire d'Ecoulements Géophysiques et Industriels (Grenoble) & Laboratoire d'Annecy de Physique des Particules)