PHD thesis proposal

2021 to 2024

Title :

Design and optimization of Elastocaloric refrigeration systems : development of Proof of concept for near room temperature Cooling

Supervisors :
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Location : CETHIL(UMR CNRS 5008)
Support : Bourse fléchée ELyTaX / INSA

International context of the project :
he project falls in the framework of the cooperation with the Institute of Fluid Science of Tohoku University in Japan, laboratories in Lyon (CETHIL and LGEF) and IRL ELyTMaX, around the utilization of elastocaloric materials for refrigeration. It will strengthen and deepen the advances reached through ANR ECPOR project involving the same laboratories.

Project :
Caloric materials exhibit large entropy variations upon the application of an appropriate excitation, like electromagnetic field or mechanical stress. In recent years, several breakthroughs have been published in terms of performant materials, for example electrocaloric ceramics [Nair, Nature 2019 (doi :10.1038/s41586-019-1634-0)], and also in terms of refrigeration proof of concept using electrocaloric ceramics [Torello, Science 2020 (doi :10.1126/science.abb8045)] or elastocaloric shape memory alloys [Tusek, Nature Energy 2016 (doi :10.1038/NENERGY.2016.134)] and natural rubber [Greibich, Nature Energy 2021 (doi :10.1038/s41560-020-00770-w)]. Temperature span above 10K and specific cooling power reaching hundreds of W/kg were experimentally obtained. This research on alternatives to conventional refrigeration systems (vapor compression based) is driven by the need of reducing or suppressing the use of refrigerant gas known to exhibit environmental issues.

IRL ELyTMaX is focusing on the use of natural rubber for refrigeration, thanks to its large elastocaloric effect due to strain induced crystallization. In the framework of a collaborative project ANR ECPOR leaded by LGEF and involving among others CETHIL and ELyTMaX, it was obtained preliminary results both in terms of proof of concept and modelling of the complex heat transfer occurring in regenerative systems [Sebald, J. Appl. Phys. 2020 (doi :10.1063/1.5132361)].

In this framework, the PhD topic is devoted to further development of the elastocaloric refrigeration proof of concept, as well as the modelling of the heat transfer mechanisms at the origin of the generation of a net heat flux along a cooling line. More precisely, it is intended to work on so-called single stage systems, where the elastocaloric is mechanically driven cyclically, which induces time variations of temperature around room temperature. The material is then put in contact with hot and cold reservoir at specific times resulting in a net heat transfer from the cold reservoir to the hot reservoir.

The heat transfer in transient / periodic regime between elastocaloric material and moving fluid/reservoirs will require a dedicated thermal model in order to design performant systems and quantify the ultimate performance. The research plan includes material characterization and thermomechanical modelling, and proof of concept design, fabrication and testing. Several configurations will be developed and implemented first with a single pair of hot and cold reservoir, and later with intermediate reservoirs for higher temperature span. In addition, regenerator may be also utilized for further improving the temperature span. It is expected also that working with soft materials (elastomers) offers several additional degree of freedom compared to stiff materials like ceramics and metals.

The key scientific questions to be answered are (i) the quantification of the refrigeration capabilities of such systems and (ii) the material properties that has to be optimized through a quantitative analysis (e.g. thermal conductivity, elastocaloric properties, mechanical losses...) and their impact on system temperature span, cooling power and coefficient of performance.

Acronyms :
ELyTMax : International Research Laboratory (IRL) between Lyon and Tohoku University, Japan.
LGEF : Laboratoire de génie électrique et de Ferro-électricité
CETHIL : Centre d'énergétique et de thermique de Lyon

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