SIMULATION OF A HYDRAULIC CIRCUIT FOR A MAGNETIC REFRIGERATOR

Thiago R.V. Ebel, Jaime A. Lozano, Pedro O. Cardoso, Jader R. Barbosa Jr.*

POLO – Research Laboratories for Emerging Technologies in Cooling and Thermophysics, Department of Mechanical Engineering
Federal University of Santa Catarina, Florianópolis, SC, 88040-900, Brazil
*Corresponding author. E-mail: jrb@polo.ufsc.br

Introduction

In the open literature, the flow management (or hydraulic) sub-system has been the least investigated of the magnetic refrigerator sub-systems. Nevertheless, it can be responsible for a significant fraction of the total losses in magnetic cooling devices [1,2]. The present study advances a computational simulation in a commercial software package of the time-dependent behavior of the hydraulic sub-system of a magnetic refrigerator. The focus is to understand the most important characteristics of the hydraulic sub-system that should be considered in the design of new prototypes.

Computational simulation

A simplified hydraulic circuit model of the magnetic refrigerator prototype developed by Lozano et al. [3] was carried out in this work. The model was implemented using the Computer-Aided-Engineering (CAE) software package Flowmaster [4]. A schematic diagram of the simplified flow management system implemented in the software is shown in Fig. 1, with the appropriate measurements (reference) points. The most important discussions on the flow behavior are related to Node 1 (upstream the high pressure rotary valve) and Node 5 (downstream the low pressure rotary valve). In the computational simulation each rotary valve [5] is modeled as two gate valves with the opening times synchronized. The regenerators were modeled as packed-sphere beds, for which the pressure drop can be determined by the Ergun correlation [6].

Results and Discussions

The analysis has been carried out for different mass flow rates and opening ramps. Figure 2 shows the behavior of the time-dependent absolute pressure behavior at Node 1 for different volumetric flow rates. It is observed a sharp decrease followed by severe oscillations (water hammer) when the rotary valves switch direction. This effect may harm the hydraulic system or the device structure.

![Figure 2 - Transient pressure at Node 1 for different volumetric flow rates](image)

To prevent the transient effects, the use of a proportional return valve with a low trigger pressure is proposed. Additional simulations indicated that this device can absorb the transient effects. Figure 3 shows the comparison between the transient absolute pressures associated with the original and the proposed layout.

![Figure 3 - Pressure at Node 1 for the original circuit and the proposed new layout](image)

Conclusions

A commercial CAE software package was used to simulate different operating scenarios of the fluid flow management system of a magnetic refrigerator to better understand its dynamic behavior. Different flow rates and valve opening ramps were evaluated in order to better understand the hydraulic circuit of a rotary magnetic refrigerator. It was inferred that the magnitude of the water hammer effects was proportional to the mass flow rate and the duration of the opening ramps played a key role in the hydraulic circuit behavior. Based on the obtained results, a proportional returning valve upstream the high pressure valves and after the low pressure valves is proposed in order to decrease the transient effects.

Acknowledgments

Financial support from CNPq, Embraco and the EMBRAPPI Unit Polo/UFSC is duly acknowledged.

References