Parametric Analysis and Optimization of an Elastocaloric Heating and Cooling Cycle

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INTRODUCTION: Elastocaloric heating/cooling systems take advantage of structural changes in shape memory alloys (SMAs) that release and absorb heat when a critical strain is applied. Technology using this method of heating and cooling have the potential to improve issues associated with the use of ozone-depleting refrigerants used in common heat pump/refrigeration cycles. This study explores the design of a well-tested cycle built at Army Research Lab (ARL), which strains the SMA (NiTi) in a continuous flow loop that releases and absorbs heat at the curved sections of wire. This study aims to uncover the physical mechanisms that govern this cycle's behavior, with the goal of finding the system parameters that will maximize cooling potential and temperature change.

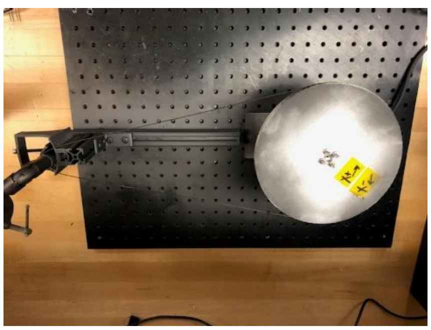

Figure 1. Army Research Lab Elastocaloric Refrigeration Loop

COMPUTATIONAL METHODS: We perform a parametric study that varies the wire radius, disk radius, its rotational speed, and its contact area with the primary heat sink. In order to simulate the continuous flowing of the wire over the disk, and appropriately capture the loss of heat to its surroundings, the wire and disk are modeled as fluids rather than solids. We use the Creeping Flow and Heat Transfer in Solids and Fluids modules to maintain a uniform flow, and adjust the thermal contact resistance between the disk and wire to reflect the temperatures measured by experiment across a range of parameters.

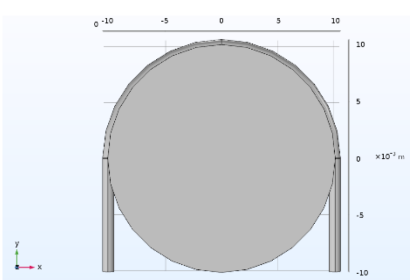

Figure 2.: Wire and Disc Geometry

The Creeping Flow Module was used to simulate the movement of the wire as a rigid body solid rotating around the disk, while also providing flexibility to map specific thermal and mechanical behaviors of NiTi over the wire.

The Heat Transfer in Solids and Fluids module was used to apply a volumetric heat sink and source at the bend of the wire. Two assumptions were made to model how heat enters the system: 1) Transformation in the NiTi takes place instantaneously, thus the sink and source are localized to only the regions entering and exiting the bend. After which, heat conducts through the wire and into the disk. 2) The heat transfer is modeled uniform throughout the selected volume [1].

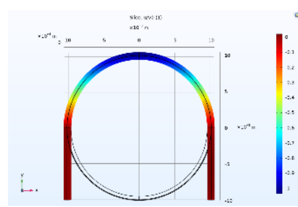

Figure 3. X –Dir Velocity Plot (xy slice)

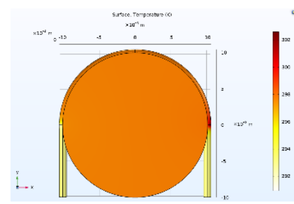

Figure 4. Steady State Surface Temperature Plot of System

RESULTS: Using a wire feed rate to simulate the strain rate and corresponding heat generation in the material, the model was able to reach a steady state temperature difference between source (the curvature inlet) and sink (the curvature outlet) of ~10° C. This temperature is consistent with what was produced by the physical model at ARL.

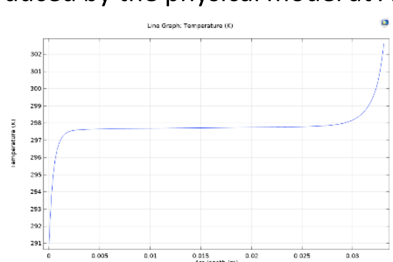

Figure 5. Steady State Wire Temperature Around the Disk

CONCLUSIONS: As we build confidence and continue to improve the COMSOL model by validating results with the physical system's performance, we will be able to vary parameters that will allow us to find the specifications to improve this cycle.

REFERENCES:

1. D. Sharar, J. Radice, R. Warzoha, B.Hanrahan and B. Chang, " First Demonstration of a Bending-Mode Elastocaloric Cooling 'Loop'," Proceedings of the Intersociety Conference on Thermal and Thermomechanical Phenomena in Electronic Systems, 2018.