DLR Deutsches Zentrum für Luft- und Raumfahrt

Influence of Solidification Rate on the Solid Properties of Eutectic $NaNO_3$-KNO_3

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Nitrate salts are widely used as a thermal energy storage medium, particularly in molten salt technologies. Due to their suitable phase change transition, DLR has used these salts for latent heat thermal energy storage (LHTES) at 306°C and 222°C to supply process steam. Depending on the specific use case, operating conditions – and thus, especially solidification rates – can vary significantly. The thermal history of the phase change material (PCM) directly affects its resulting microstructure, porosity, and solid-state properties. Investigating these properties enables us to design LHTES on a large scale and develop a safe operational strategy for long-term service. Therefore, this study systematically investigates the influence of the solidification rate on the pore fraction, density, thermal expansion, and creep behavior of eutectic $NaNO_3$-KNO_3. The material used was technical-grade $NaNO_3$-KNO_3, which had previously undergone several cycles. PCM samples are produced that are solidified at four different cooling rates ranging from 1K/h to approximately 15K/min and tailored to the test method.

A microstructural analysis was performed to determine density using a quasi-fluid pycnometer, while computed tomography (CT) was employed to examine the pores. Partial results of the density measurements showed an inverse relationship between density and solidification rates: the faster the solidification rate, the lower the density of the sample. CT scanning revealed that the pores do not appear as circular structures, but rather as elongated voids resembling fractures, as shown in Figure 1.

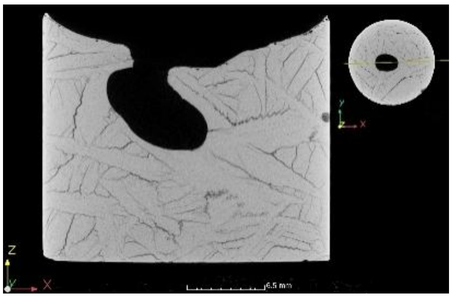

Figure 1: CT scan of cylindrical, fast solidified, eutectic $NaNO_3$-KNO_3 sample

Push-rod dilatometry is used to measure the thermal expansion behavior at different solidification rates. It was observed that samples that solidified more quickly exhibited lower thermal expansion. Indentation penetration testing is employed to evaluate PCM creep behavior under varying mechanical loads and temperatures using a flat-faced indenter. It was determined that creep intensifies with both increasing temperature and higher mechanical loads.

The next step will be to investigate whether creep also depends on the solidification rate. In addition, experiments will be conducted using the nitrates as single materials of a high purity grade, to investigate their behavior as a mixture, as well as the influence of impurities in the mixture.