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Using shape memory alloys for low temperature waste heat conversion - material properties, requirements, and challenges

Close to 60% of the primary energy loss in conversion processes comes from domestic systems, which operate in a temperature range below 100 °C. This waste heat cannot be utilized in technical applications. Recovering it offers a path to reduce energy loss and to improve overall efficiency. While industrial waste heat recovery is well-established for high-temperature processes, there is a major technical gap in the utilization of low-grade (temperature) thermal energy. Shape memory alloys (SMAs) represent a promising solution to tackle this challenge. In particular, shape memory driven thermoelastic generators (TEGs) can be used to convert thermal energy into a mechanical work output. Different thermal engine designs have been proposed since the 1970's. However, they all utilize commercial NiTi wires which were not optimized for this type of application. Our research focuses on identifying and developing SMA materials suited for good TEG performance. We adopted the Ashby material selection framework to define key property targets such as work output, latent heat, specific heat, hysteresis width, transformation temperatures, and fatigue resistance (etc.) to screen potential alloys. We consider SMAs based on NiTi, Cu, Ti, as well as other less-common systems. Our property maps were generated using selected data from literature, materials databases and thermomechanical cycling experiments. The data provide a good overview on the potential performance of different types of SMAs in TEGs. We also discuss strategies related to multi-parameter optimization, which help to identify compositions with good compromise property profiles.

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