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Increasing Efficiency and Cycle Frequency of Thermoelastic Harvesting for low-grade Waste Heat with Shape Memory Wires

The conversion of low-grade waste heat (<100 °C) from industrial processes can contribute significantly to the achievement of the ambitious climate goals, yet the construction of efficient, powerful and inexpensive systems remains a challenge. Especially martensitic materials are experiencing a renaissance as active materials for harvesting of waste heat, due to their high actuation energy and high conversion efficiency.
Here, we focus on thermoelastic harvesting, which employs shape-memory alloy (SMA) wires in a reciprocating heat engine. In the first part of this talk we use coupled finite element simulations to analyze the intimate connection between the functional properties of shape memory alloys and a thermodynamic cycle, which converts thermal to mechanical energy. [1] Our approach allows for a systematic optimization of efficiency by varying design and operation parameters, which include fluid pressure, tube diameter, temperature, prestrain, spring constant and damping. We obtain an efficiency of 8.6%, which is equivalent to 51% with respect to Carnot — an outstanding value for low-grade waste heat of just 55 °C. In the second part of the talk, we demonstrate that the cycle frequency and thus output power of a thermodynamic harvesting system can be increased by replacing the common fluid flow axial to the wire by a transverse flow. This allows to use long wires at high frequencies, which both contribute to an increase of output power, as we demonstrate by in-operando experiments up to 11 Hz.

[1] B. Neumann, S. Fähler, Energy Conversion and Management: X 27 (2025) 101099, https://doi.org/10.1016/j.ecmx.2025.101099