הטכניון מכון טכנולוגי לישראל TECHNION Israel Institute of Technology

Faculty of Mechanical Engineering הפקולטה להנדסת מכונות

MECHANICAL ENGINEERING MSc SEMINAR (30 min.)

Thursday, January 15 2026 at 14:00-14:30, Lady Davis Building, Room 250

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Elasto-Caloric Phase Change In Thermodynamic Gas Cycles

Yoav Ben Chaim

Advisers: Prof. Amir Gat & Dr. Anna Zigelman

The thermodynamic properties of fluids are critical in determining the efficiency, range of operation, and environmental safety of heat engines and refrigeration cycles. Due to the ubiquitous nature of these thermodynamic cycles, it is essential for society to optimize them in terms of their efficiency and possible operating regimes. To pursue this goal, we apply ideas from the field of metamaterials and combine multiple thermodynamic processes in order to fabricate a 'metafluid' that exhibits unique thermodynamic properties.

My MSc research explores the thermodynamic interaction between an encapsulated gas and an elastocaloric (EC) material. Elastocaloric alloys (e.g., NiTi, CuZnAl) undergo a stress-induced Austenite to Martensite transformation that is analogous to the latent heat exchange of fluid phase changes. Unlike traditional fluids, however, EC materials facilitate this heat exchange while remaining in the solid state. We study capsules that combine gas and EC, where the geometry and properties of these capsules can be designed to achieve various forms of gas-EC interactions. The resulting thermodynamic properties are programmable and offer a non-toxic and emission-free alternative to current fluids.

Our modelling reduced the thermodynamic, elastic and elastocaloric equations to a coupled nonlinear system of partial differential equations (PDEs). By solving this problem, we were able to reveal the complex interplay between the thermodynamics of the encapsulated gas and the EC membrane. Specifically, we investigated two distinct geometric configurations: (1) The Regular Configuration: The gas and EC membrane expand simultaneously. Here, the cooling effect of the expanding gas is counteracted by the heating effect of the stressed EC material. This competition alters the thermodynamic path. (2) The Reverse Configuration: The capsule is designed so that the EC membrane compresses while the gas expands. Here the gas and the EC membrane heat simultaneously, thus mimicking the behavior of vapor-liquid phase changing fluids, effectively "stalling" temperature changes to create quasi-isothermal processes.

The thermodynamic properties that we computed were compared to standard Carnot, Brayton, and vapor-refrigeration cycles. Our results show that "Reverse Configuration" can significantly enhance cycle efficiency compared to pure gas cycles and the "Regular Configuration" yields properties beneficial for thermal energy storage applications. According to our results, this system offers a versatile, programmable, and environmentally sustainable alternative to traditional working fluids.

Note: the seminar will be given in English

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Seminars Coordinator: Assoc. Prof. Sefi Givli.