
ELASTOCALORICS2025

CONTENT

PLENARIES

Towards Efficient and Fatigue-Resistant Elastocaloric Cooling and Heating

Jaka Tušek, University of Ljubljana

In the first part of the talk, we will discuss the development of tube-based elastocaloric regenerators and a cam-disc-based driving system that enables efficient loading and unloading with force recovery. In the second part of the talk, we will address existing challenges that limit the efficiency of elastocaloric regenerators, such as the improved design of these regenerators and the optimization of elastocaloric materials.

Recent Advances in Elastocaloric Materials, Refrigerant Structures and Devices

Qingping Sun, Hong Kong University of Science and Technology

In this talk, recent progress at HKUST in (1) developing high performance SMA materials, (2) design and fabrication of reliable and cost-effective refrigerant structures, and (3) enhancing energy efficiency at device level are reported. Challenges and opportunities for future R&D are also outlined.

High Throughput Development of Elastocaloric Materials

Jun Cui, Iowa State University

Elastocaloric cooling is emerging as a promising solid-state refrigeration technology, notable for its high efficiency and minimal environmental impact. This technology leverages diffusionless reversible martensitic phase transformations—the same thermodynamic phenomenon underlying shape memory alloys. Despite its potential, elastocaloric cooling technology currently faces a significant challenge: the absence of suitable working materials that simultaneously exhibit low critical stress, high power density, extended fatigue life, and cost-effectiveness. For instance, nitinol-based alloys, the current state-of-the-art elastocaloric materials, deliver outstanding thermomechanical performance but are expensive to manufacture and require substantial stresses (>600 MPa) to trigger phase transformations. In contrast, copper-based SMAs have emerged as promising alternatives, offering competitive properties at lower costs and with less energy-intensive manufacturing processes. However, these copper-based alloys exhibit certain drawbacks, including low latent heat, elevated austenite-finish transformation temperatures, and inherent brittleness. To address these limitations, the exploration of compositional space encompasses elements such as Cu, Mn, Al, Ni, Sn, Ag, and potentially other metallic or metalloid constituents. Additionally, the final performance of these materials is directly influenced by thermomechanical processing parameters—including annealing temperature and duration, quenching medium, aging conditions, and rolling or extrusion processes. At Iowa State University, our group has spent the past three years focused on high-throughput development of novel copper-based elastocaloric materials. In this presentation, we will discuss our experimental design rationale, methodology, data analysis techniques, and highlight some preliminary findings.

ELASTOCALORIC DEVICES AND APPLICATIONS

Elastocaloric Microcooling (Invited)

Jingyuan Xu, KIT

Elastocaloric cooling is an emerging solid-state cooling technology that promises environmentally friendly and energy-efficient alternatives to traditional vapor-compression systems. This talk presents recent advancements in miniature-scale elastocaloric cooling devices at Karlsruhe Institute of Technology.
At the miniature scale, we utilize superelastic SMA films, which combine a high elastocaloric effect with efficient heat transfer due to their large surface-to-volume ratios. We conduct thorough thermomechanical characterization of these SMA films and assess device performance in terms of temperature span, cooling power, and coefficient of performance (COP). Different configurations are benchmarked, including single-device systems, parallel architectures for enhanced cooling power, and cascade architectures to increase the achievable temperature span.
We further report the development of an ultra-high-lifetime elastocaloric microcooling device employing ultra-low-fatigue TiNiCuCo films. These devices exhibit durability exceeding 107 cycles, achieved through the use of ultra-low-fatigue films, optimized mechanical fixation strategies, refined film designs, and adaptable loading mechanisms.

Elastocaloric Cooling for Lab-Size Life-Science Equipment

Philipp Molitor, Saarland University

Elastocaloric cooling represents a promising solid-state technology for use in compact life science equipment, particularly where sustainable temperature control is essential. By repeatedly reconditioning the same air volume in a closed-loop system, high thermal efficiency is achieved without the use of environmentally harmful refrigerants. For significantly reducing maintenance time and minimizing operational downtime, the central elastocaloric module is designed as an easily replaceable unit. This technology thus offers a compact, modular solution for highly sensitive applications in the life sciences field.

Recent Elastocaloric Research Progress at XJTU (Invited)

Suxin Qian, Xi'an Jiaotong University

In the previous Elastocalorics conference, I presented the numerical modeling of elastocaloric cooling systems. In this presentation, I will introduce the recent experimental research progress at XJTU, including the solid thermal-contact prototype, the heat-driven elastocaloric cooling system, and the tubular elastocaloric regenerator.

Constant Power Approach for Efficient Driving of Elastocaloric Technology

Andrej Žerovnik, University of Ljubljana

Elastocaloric cooling and heat pump technology presents considerable potential as an environmentally sustainable alternative for heating and cooling. Despite this promising outlook, several critical challenges must be addressed to enable successful market implementation. Among these challenges, the driving system is one of the crucial parts of technology. Effective work recovery and minimized size of the drive system are key to the competitiveness of elastocaloric technology. Energy recovery during the unloading phase of the elastocaloric material's transformation is essential for achieving a high coefficient of performance (COP). Proper work recovery allows previously invested mechanical work (during loading) to be returned and reused, significantly enhancing efficiency.
Additionally, maintaining a constant power during the operation ensures minimizing system size, lower production and operational costs. This study presents the development of innovative laboratory-scale drive system for elastocaloric technology, utilizing a novel cam-based mechanism that introduces a constant power approach driving. The developed system employs analytical and numerical equations to precisely determine cam disc profiles based on mechanical response of elastocaloric material, which in turn provide a constant torque during the operation. A detailed conceptual and geometric model of the drive mechanism was established and validated through multi body dynamics simulations. The drive was subsequently manufactured, and experimental tests confirmed its operational effectiveness and importance of the constant power approach.

Overcoming Market Challenges to enable Elastocalorics to compete with Vapour Compression in next-generation Cooling and Heating (Invited)

Kevin O'Toole, exergyn Ltd.

The push for next-generation heating and cooling technologies has long positioned elastocalorics as a promising alternative to vapour compression, particularly due to its zero-global-warming-potential (GWP) advantage. However, the emergence of low-GWP refrigerants, such as propane, which offer strong thermodynamic performance despite certain drawbacks, has introduced new competitive challenges. This shift reduces the inherent environmental edge of elastocalorics, making it imperative to compete on efficiency, size, cost, and weight while meeting the thermal performance demands of traditional vapour compression systems. This talk will examine these challenges, outline the progress made to date in addressing them, and highlight remaining hurdles from both material and system perspectives. Additionally, the importance of standardized performance reporting to build credibility with OEMs will be discussed. By tackling these barriers through targeted innovation and industry collaboration, elastocalorics can establish itself as a viable, scalable solution for global adoption while minimizing environmental impact.

SIMULATION

Efficient Elastocaloric Systems: Models, Materials, and Regenerators (Invited)

Julie Slaughter, Ames Laboratory Of US DOE

To advance elastocaloric technology, accurate models of material behavior are needed to support the design of thermal devices and to guide material development efforts for improved performance. A Debye-based model has been demonstrated to predict elastocaloric material behavior with good accuracy with a relatively small number of fit parameters.1 Material properties that will improve elastocaloric performance are identified and cast in terms of model parameters (e.g., hysteresis width, transition width, and transition strains) that will guide future material development. To accurately fit the Debye model to experiments and use it for performance predictions, the best data sets include either isostress strain vs. temperature or isothermal strain vs. stress curves, with both heating and cooling or loading and unloading respectively. However, these types of data sets are not widely available for all materials, and researchers must rely on existing, less-than-ideal data. The best methods to use DSC data and a single, room-temperature stress-strain curve to estimate parameters will be discussed as well as active regenerator performance estimated using material models fitted to sparse data sets. Preliminary comparisons of models and experiments for two different device configurations will be presented.

This work was supported by the U.S. Department of Energy (DOE) and the U.S. Department of Defense. The research was performed at Ames National Laboratory, which is operated for the U.S. DOE by Iowa State University under contract # DE-AC02-07CH11358.

Modeling Moist Air Effects in Elastocaloric Devices

David Zimmermann, Saarland University

Elastocaloric systems, which leverage shape memory alloys (SMAs) to achieve efficient, eco-friendly thermal management, offer a promising alternative to conventional air conditioning technologies. This study presents a simulation-based approach to modeling the effects of moist air and condensation phenomena within these systems. Here, we examine key factors affecting SMA performance, including mechanical behavior and the material's latent heat characteristics. Moist air, particularly under conditions where temperatures fall below the dew point, introduces condensation and latent heat release, which can influence thermal output in elastocaloric systems. This work develops a comprehensive model that couples the thermomechanical behavior of SMAs with the thermodynamics of moist air, incorporating condensation heat transfer, mass balance, and moisture transport. Through simulations, we quantify the impact of condensation on device level and assess how ambient moisture conditions affect overall heat exchange. The findings enhance our understanding of elastocaloric system performance under real-world conditions, contributing to the advancement of sustainable and modern technologies.

From Concept to Simulation: Development of the preliminary 2D/3D SMACOOL Elastocaloric Heat Pump Model

Adriana Greco, University of Naples Federico II

The objective of the SMACool project is to develop a rotative heat pump based on elastocalorics, an emerging technology which uses Shape Memory Alloys (SMAs) as solid-state refrigerants to constitute a more efficient and ecofriendly solution for heating and air conditioning. In the SMACool project advanced NiTi-based structures are shaped in different geometries studied for optimizing the design of the elastocaloric regenerator that is the core of the elastocaloric heat pump. The regenerator is made of a binary NiTi alloy and it is crossed by water as an auxiliary fluid that regulates the heat transfer between the hot and cold sources; the structures are forced in compression. Once the potential geometries are identified, customized computational models are developed and applied to study and optimize the cooling performances in different operating conditions (different applied forces, auxiliary fluid mass flow rate, operating frequency, utilization factor etc.) and geometry aspects (different fluid channel thickness, different plates length...). The device was considered both in active regeneration and heat recovery modes. The numerical models, implemented in COMSOL Multiphysics 6.3 using a Finite Element Method (FEM) framework, evaluated over 80 parameter combinations, including variations in applied force (30–70 kN), operating frequency (0.3–2.0 Hz), regenerator length (100–700 mm), and fluid channel thickness (0.15–0.30 mm). The analyses carried out so far have been aimed at finding an optimal conformation of a single regenerator to be used in the rotating device. Also, the influence of buckling prevention material on energy performance has been studied. The analyses have been carried out to evaluate the energy performance in cooling and specifically the following have been evaluated: the temperature variations of the water in cooling, the cooling power, the Specific Cooling power and the Coefficient of Performance (COP). From the analyses carried out it was therefore decided to build a compression-based regenerator with buckling prevention material shaped outside and stressed not up to 1000MPa to guarantee a useful life for commercial applications. Many investigations have been done on compression-solution and the results of the optimization in terms of energy performances are shown.

Numerical Modeling Tutorial of an Elastocaloric Regenerator

Luca Cirillo, University of Naples Federico II

This contribution presents a tutorial model developed to simulate the thermal and fluid-dynamic behavior of a parallel-plate elastocaloric regenerator, employing water as the heat transfer fluid. The aim is to provide a practical and adaptable tool to support the design and analysis of elastocaloric cooling systems. The system consists of a series of elastocaloric plates arranged in a stack, with water flowing through the channels between the plates. The active material undergoes cyclic loading and unloading, inducing temperature changes that drive the heat exchange with the fluid. The numerical model is implemented in COMSOL Multiphysics® (6.3), coupling the Heat Transfer in Solids and Fluids and Laminar Flow interfaces. This allows the simultaneous solution of transient heat conduction in the solid and convective heat transfer in the fluid, along with the associated flow field. The tutorial guides the user step-by-step through the model setup: geometry, mesh, physics interfaces, boundary conditions, and solver settings. The model is designed to be modular and easy to modify, making it suitable for evaluating different geometries, materials, and operating conditions. Simulation results are discussed to highlight key performance parameters, such as the temperature span across the regenerator, the evolution of the temperature field over time, and the heat flux exchanged during a typical operating cycle. The model is intended as a shared starting point for researchers working on elastocaloric systems, facilitating comparison, validation, and further development.

Early-Stage Numerical Simulation Approach for the Optimization of the SMACOOL regenerator

Claudia Masselli, University of Naples Federico II

The SMACOOL project explores an innovative elastocaloric cooling approach based on NiTi Shape Memory Alloys (SMAs) undergoing a regenerative Active elastocaloric (AeR) cycle. Comparative analyses between tensile and compressive configurations demonstrated a consistent advantage for compression, with the spiral cross-section enabling enhanced ΔTcold and Specific Cooling Power (SCP). This work presents the results of an early-stage numerical optimization of the regenerator unit, focusing on the implementation of a spiral geometry under compression mode—selected for its superior energy performance and structural resilience against buckling. Using COMSOL Multiphysics and a Finite Element Method-based framework, 3D models were developed to simulate the thermo-fluid dynamics of the regenerator. Comparative analyses on compressive configurations of the regenerator with the spiral cross-section enabling enhanced ΔTcold and Specific Cooling Power (SCP). The optimization campaign examined geometric parameters (length, channel and spiral windings thickness) and operating conditions (force, frequency, dimensionless volume ratio, ratio between time duration of different steps of the AeR cycles), leading to a configuration that achieves a temperature jumps on cold exceeding 7 K and SCP values up to 2500 W/kg. These findings validate the spiral-compression design as a promising candidate for compact, high-efficiency elastocaloric devices, and lay the groundwork for the next stages of prototype development within SMACOOL. These simulation results now serve as the baseline for the development and experimental validation of a first-generation SMACOOL prototype.

SHAPE MEMORY ALLOY MATERIALS

New Generation of SMA Materials for Elastocaloric Solid-State Heat Pumps

Jan Pilch, exergyn ltd.

Heat pumps (HP) are an integral part of modern society, ensuring both industrial processes and a comfortable working and living environment. With over a century of history, vapor compression technology is used, including various types of refrigerants, which are currently regulated to meet stringent environmental criteria. Regulations lead to the selection of refrigerants that reduce the efficiency of HP and that are, for example, flammable. Alternative technology using elastocalorics instead of refrigerants has recently attracted considerable attention.

This new technology uses solid-state medium, an alloy, which undergoes a first-order reversible phase transformation under the influence of an external force. Elastocaloric materials belong to the group of shape memory materials – SMAs and offer the following key advantages. There is no risk of the medium leaking into the atmosphere, which allows easy recyclability, and it can compete with or even outperform established vapour compression systems in terms of efficiency. On the other hand, these elastocaloric materials face multiple challenges.

The key selection criteria are fatigue resistance - structural stability and efficiency degradation resistance - functional stability. State-of-the-art commercial elastocalorics, mostly based on nanocrystalline structures, offer sufficient stability and good fatigue properties under compressive loading, however, are generally limited to expensive thin structures such as filaments, thin wires and tubes. In the case of cheaper commercial bulk SMA materials, e.g. thick plates, rods, etc., we face massive instability and degradation of properties within several dozens of load cycles.

This work presents a new generation of SMA alloys produced in large-format volumes, exhibiting excellent structural and functional stability in compression, giant superelastic window greater than 80°C, temperature operational scalability in the range from -50°C to 140°C, high latent heat greater than 15 J/g available for energy transfer in each cycle within the whole superelastic window, extraordinal cyclic overload capacity above 2GPa and a small hysteresis response (~100 MPa, Fig. 1). A major advantage of these new generation SMA materials is the elimination of the need to "train" them to achieve a stabilized latent heat output under superelastic cycling. In this work, the thermomechanical response of this new generation SMA material after 1 million fatigue cycles is presented for various operational conditions.

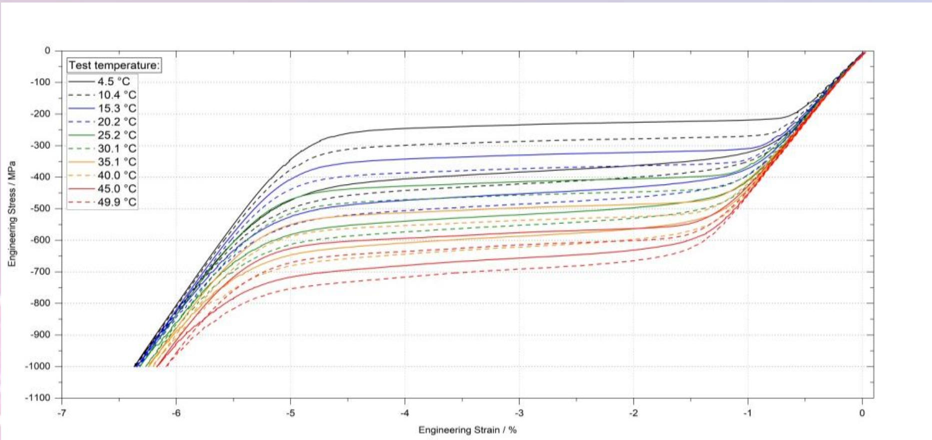

Fig. 1: The stress-strain isothermal behavior under compression loading of the new generation SMA purposely developed for efficient elastocaloric solid-state heat pumps.

Customization of NiTi(X,Y) Shape Memory Alloys for Elastocaloric Applications

Burkhard Maaß, Ingpuls GmbH

Today, Shape Memory Alloys based on Nickel Titanium are mostly used for superelastic applications in medical devices. Another known area of applications are actuator systems, using the shape memory effect. The emerging field of elastocalorics combines many of the requirements of both existing technologies. With the potential of both helping to make cooling and heating more sustainable and at the same time multiplying the world's market of Shape Memory alloy production, it is a very interesting field to be active in as an SMA producer. While tube and wire are the most used semi-finished products in medical devices, wire and compression springs represent a major part of actuator components. For elastocalorics, it is not yet clear which geometry will prevail.
Systems based on tension, compression and torsion have been presented by the community, each with its own merits but also disadvantages. What all have in common is that most prototype systems are built with available, off-the-shelf material for medical applications. What all also have in common is that this material is not really the best fit for Elastocalorics, and thus, the need of customized Shape Memory Alloys. Hysteresis, material's COP (Coefficient of performance) and cyclic stability are among the most important requirements. For cascaded systems, also precisely controlled alloy variations with close sequences of changing Af-temperatures.
In this work, we present our recent results on the processing, training and characterization of binary and quaternary alloys, wire, and sheet/ribbon for elastocaloric applications.

Direct Thermal Method to Characterize the Material Efficiency of Elastocaloric NiTi Tubes

Sabrina Unmüßig, Fraunhofer IPM

In this talk, we show a novel method for determining the efficiency of elastocaloric materials using a self-heating approach through cyclic loading. Originally developed for magnetocaloric materials by Schipper et al. and later adapted for electrocaloric materials by Unmüßig et al., we now extend this methodology to elastocaloric materials by characterizing commercially available Nickel-Titanium tubes. The primary requirements for this method are temperature measurements and the capability to cycle the caloric material.
A Figure of Merit (FOM), defined as the ratio of the adiabatic temperature change to the thermal hysteresis, is utilized to evaluate the efficiency of elastocaloric materials within cascaded or regenerator systems. By determining the heat loss of the material using this new approach, it is therefore possible to quantify the maximum possible efficiency of an elastocaloric cooling system with this material.

NiTi-based Alloy Design for Elastocaloric Applications

Jannis Lemke, BioActiveMetals S.r.l.

NiTi-based superelastic alloys are promising candidates for solid-state refrigeration since the martensitic transformation (MT) is associated with latent heat, causing a temperature rise or drop in the material when stress is applied or removed adiabatically—an effect known as the elastocaloric effect. To achieve high elastocaloric performance that remains stable over many cycles, alloys must be designed with stable superelasticity, narrow transformation hysteresis, high fatigue resistance, large latent heat, and low stress thresholds for transformation.

Although many studies have focused on improving the superelasticity, fatigue properties, and thermal properties of NiTi alloys, further optimization for elastocaloric applications remains a challenge. This difficulty arises in part because alloy development requires trade-offs, as several key parameters, such as high latent heat and low hysteresis—are inversely correlated, meaning that optimizing one often comes at the expense of the other. Alloy design and selection become even more complex considering that most literature data have been obtained from cast materials, which behave very differently from final processed NiTi components or materials subjected to prolonged cycling under stress.

In this work, we present an approach for alloy assessment and development for elastocaloric applications. The tested alloys are evaluated based on their thermal transformation behavior, microstructure, mechanical performance, and functional degradation upon cycling. Data on various binary NiTi and ternary NiTiCu alloys in cast and processed states have been collected, highlighting key considerations for tailoring the properties of both commercial and novel alloys. The results presented here provide valuable insights for designing tailor-made materials to meet the requirements of elastocaloric heat engines.

ADDITIVE MANUFACTURING

Enhancing Elastocaloric Regenerator Performance Through Tailored Functionally Graded Thin-Walled Tube Structures

Shiva Mohajerani, University of Toledo

Existing elastocaloric (eC) regenerator prototypes, which use commercially available geometries such as wires, tubes, or plates, face a significant limitation: nonuniform phase transformations along the length of eC regenerator caused by axial temperature gradients between the heat source and sink. This inefficiency, inherent in current designs, makes it challenging to align transformation temperatures (TT) with the thermal profile, especially at elevated temperatures, due to inadequate TT distribution.

Thin-walled tubes, known for their relatively good buckling stability, present a promising solution. To overcome this challenge, we propose a new approach that utilizes functionally graded thin-walled tube structures designed explicitly for eC regenerators. By precisely engineering TT variations along the length of the tube, our innovative designs align phase transformations with the local thermal environment, significantly enhancing the overall elastocaloric effect (eCE). This strategy reduces the critical stress required for initiating and achieving a complete phase transformation at elevated temperatures and increases the COP of the material by decreasing the overall hysteresis losses. Additionally, by designing a non-trivial tube geometry, our second optimized tube configuration achieves complete phase transformation across the active region, maximizing thermal exchange and material efficiency.

By directly addressing the problem of nonuniform phase transformation found in existing prototypes, our work could establish a transformative framework for next-generation eC regenerators, delivering superior efficiency, reliability, and performance for sustainable cooling applications.

Developing and Modeling 3D-Printed Active Elastocalorics Regenerators

Kun Wang, KIT

Heating and cooling in Europe account for 40% of continental energy demand, with conventional systems relying on volatile, high global-warming-potential refrigerants. Elastocaloric cooling, a solid-state technology leveraging the latent heat of phase-transforming shape-memory alloys (SMAs), offers an eco-friendly alternative by eliminating volatile refrigerants. Regenerative elastocaloric systems, employing oscillating fluid flows and active elastocaloric regenerators (AERs), enhance temperature spans 2-4 times beyond material adiabatic limits by recycling heat and improving heat exchange efficiency. Recent studies in regenerator design—such as tubular, microchannel, and foam structures with improved specific surface areas (up to 12.5 cm^2/g) to maximize cooling power (e.g., 260 W at 22 K spans for tubular regenerators). However, scalability and manufacturability remain challenging. In this work, we introduce a novel AER design using porous woven structures—interlaced weft/warp threads with customizable mesh geometries, which achieve a specific heat transfer area 4.3 times higher than foam regenerators (50% porosity, in plain weaves). A 1-D numerical model, validated by parallel-plate regenerator studies, evaluates plain, twilled, and dutch weaves regenerators, as shown in Figure 1, under varying porosities and operation conditions. Results demonstrate that a 30% porosity plain weave regenerator achieves the best performance: 485 W cooling power, 11.3 W/g specific cooling power, and COP of 1.48 under a 20 K span, surpassing parallel plate AER by a factor of 3.3 in cooling power. Twilled weave regenerators show comparable performance, whereas dutch weave regenerators show significantly lower cooling capabilities. The study highlights the potential of woven-structure regenerators for high-performance elastocaloric cooling, offering insights into optimizing regenerator design and operational parameters while emphasizing their promise for efficient and sustainable solid-state cooling systems.

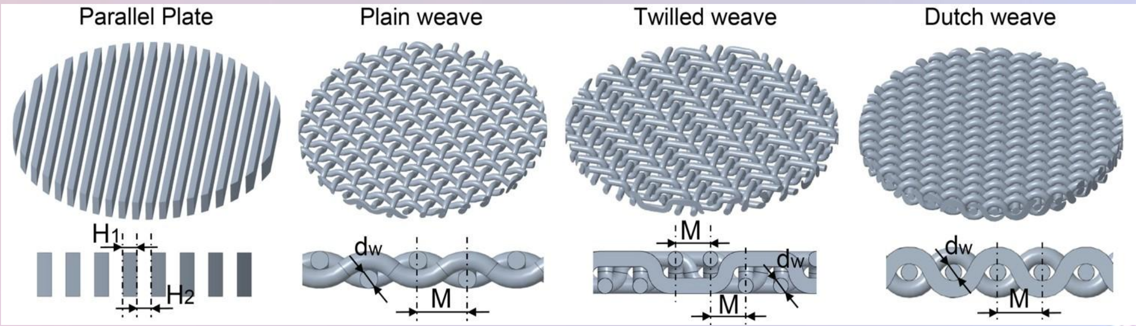

Figure 1: Four different regenerator bed units: parallel plate, plain weave, twilled weave, dutch weave.

POLYMERIC MATERIALS

Elastocaloric Effects in spin crossover Polymer Composite Films

Klara Lünser, University Duisburg-Essen

Spin crossover materials (SCO) can undergo a transition between low-spin and high-spin states, changing their magnetization, volume and optical properties during the transition. As the transition can be induced by external stimuli such as temperature, light and pressure, they can be applied for memory, switching and sensing devices. Many SCO transitions are first-order and involve a considerable latent heat, which can be used for thermal energy management and effects. Giant barocaloric effects as well as magnetocaloric effects have been reported for different SCO complexes in the past, but their powder nature so far prevented their use as elastocaloric materials.
Here, we report elastocaloric effects in the spin crossover complex $[Fe(L)_2](BF_4)_2$, [L = 2,6di(pyrazol-1 yl)pyridine], which was embedded into a polymeric matric of polyvinyl chloride (PVC) to form composite films. By studying films subjected to uniaxial tensile stresses, we demonstrate remarkable elastocaloric effects associated with the SCO transition: we measure isothermal entropy change of $\Delta S = 3.1\ Jkg^{-1}K^{-1}$ for stresses as low as $\sigma = 8$ MPa and very low strain values $\varepsilon = 0.3\%$. The elastocaloric performance characteristics of SCO compounds are more favourable than those of prototypical elastocaloric materials, such as shape memory alloys and elastomers: The required stresses are one order of magnitude lower than those required for shape memory alloys, and strains are several orders of magnitude lower than those of elastomers. This leads to a coefficient of performance of the SCO material being one order of magnitude larger compared to other elastocaloric materials. Therefore, SCO compounds are interesting candidates for elastocaloric-based cooling technologies, especially in applications requiring low applied stresses.

TwistER: Prototype of Twistocaloric Cooling Device with Energy Recovery Based on Natural Rubber

Enric Stern-Taulats, University of Barcelona

Elastocaloric cooling is a cutting-edge technology with the potential to advance cooling methods by replacing harmful refrigerants, improving energy efficiency, and addressing global warming. Recently, natural rubber has been identified as a promising solid-state refrigerant. This material demonstrates exceptional elastocaloric performance because of its ability to crystallize under strain, and initial prototypes made from natural rubber have already been developed. Recent findings indicate that twisting these materials, rather than just stretching them uniaxially, significantly enhances the cooling effect.
We present TwistER, a novel gas-free cooling technology that uses natural rubber refrigerants. TwistER incorporates both uniaxial stretching and twisting to maximize cooling power, cooling a closed heat exchanger water circuit. The design separates hot and cold sinks, simplifying heat exchanger design and boosting efficiency. Energy consumption is minimized through energy recovery principles, with a secondary cycle operating in antiphase mode. TwistER demonstrates the feasibility of using natural rubber for twistocaloric cooling, achieving significant undercooling with minimal mechanical stresses, all through low-cost and compact technology.
Financial support from 2023 PROD 00071, AGAUR (Catalonia). E.S.-T. acknowledges support from grant RYC2023-043444-I, funded by MICIU/AEI/10.13039/501100011033 and by ESF+.

Multicaloric Effects in P(VDF-TrFe-CTFE)terpolymers

Aleix Abadia-Huguet, University of Barcelona

PVDF-based polymers demonstrate a significant electrocaloric effect. Their combination of electroactivity, piezoelectricity, malleability, low cost, and chemical tunability makes them highly attractive for caloric applications. In particular, P(VDF-TrFE-CTFE) exhibits a relaxor-ferroelectric behaviour. This polymer consists of small alpha-phase crystals and an amorphous component. At room temperature, it shows a pronounced electrocaloric effect. When stretched 12 times its initial length, P(VDF-TrFE-CTFE) displays an elastic performance and elastocaloric effect. The thin film geometry of this material allows an excellent conditions for applying electric and uniaxial stress at the same time. We have studied the synergistic potential of combined electric and mechanical stresses with direct characterization of the multicaloric effects in P(VDF-TrFE-CTFE) terpolymers using thermometry data. Our study seeks to improve the comprehension of the physical causes of caloric effects in the terpolymer and pave the way for more investigation and improvement of multicaloric systems.

Bistability-Driven Elastocaloric Cooling: Utilizing Natural Rubber Foils

Carina Ludwig, KIT

We present a miniature-scale elastocaloric cooling (eC) device that employs a bistable actuation mechanism to cyclically load a natural rubber (NR) foil refrigerant with dimensions of 9 × 26.5 mm². The rubber foils large surface-to-volume ratio aids in efficient heat transfer to the planar heat sink and heat source through solid-to-solid contact. The device features a single-stage design with a rotating lever arm that maintains stable positions while ensuring effective thermal contact, leading to substantial energy savings. We examine how operating parameters and NR foil thickness influence key performance indicators, including cooling power, temperature span, and coefficient of performance (COP).

Cooling technologies are responsible for almost 17% of global electricity consumption, with most systems dependent on vapor-compression technology that have a high global warming potential (GWP). As an alternative, elastocaloric cooling based on superelastic shape memory alloys (SMAs) has gained attention due to its efficient phase transformation capabilities. However, factors such as high stress requirements, limited material availability, and cost constraints pose a challenge. As an alternative, natural rubber (NR) elastomers present an environmentally friendly and cost-effective alternative, offering advantages such as low actuation forces, exceptional fatigue resistance, and an adiabatic temperature change of around 20 K. Some studies have focused on NR foil refrigerants with a high surface-to-volume ratio to facilitate the separation of heat and cold through solid-to-solid heat transfer. In this work, we introduce a novel bistable actuation approach for load cycling and evaluate its impact on the eC performance.

In Fig. 1a) the bistable actuation mechanism of the eC device is depicted. The operation is based on an inverse Brayton cycle and requires only one actuator to load the NR foil refrigerant. A rotating lever arm is used to enable bistable actuation. The eC cycle can be divided in four steps: Starting with mechanical loading of the NR foil under quasi-adiabatic conditions (I), heat transfer to the heat sink (II), rapid quasi-adiabatic unloading (III), and resulting in cooling of the heat source (IV).

The loading and unloading durations are modified, with heat transfer taking place at the stable end positions, corresponding to 300% and 700% strain. Typical temperature profiles for various frequencies of the bistable device using a NR foil with a thickness of 290 μm are shown in Fig. 1b). Once the initial temperature change occurs, saturation is reached after about 75 seconds, with the device attaining a maximum temperature span ΔT_{device} of approximately 4.2 K.

The effects of varying maximum strain levels, strain rates, and pre-strain on the refrigerants temperature output are examined under uniaxial tensile loading. Strain ranges of 300% to 700% are found to be optimal due to strain-induced crystallization (SIC), which results in a material temperature change of +6/−8 K at a strain rate of 9.3 s^{-1}. The high strain rate is crucial for attaining adiabatic conditions in thin foils. The NR foil thicknesses in their undeformed state are 290 μm and 650 μm. Owing to the bistable mechanism, the actuator only needs to provide the tangential force component for load cycling, reducing the maximum required actuation force by a factor of 2.8 (650 μm) and 2.5 (290 μm). No power input is not needed while the actuator remains in the stable end positions, making contact between the refrigerant and either the heat sink or source. With a decrease in thickness from 650 to 290 μm, the optimal operating frequency increases from 350 to 424 mHz. As a result, the cooling power increases from 158 to 214 mW, corresponding to maximum specific cooling power values of 1.1 and 3.4 W g^{-1}, respectively. Lumped-element model (LEM) simulations indicate that optimization of heat transfer offers significant potential for further enhancing cooling power.

a) **b)**

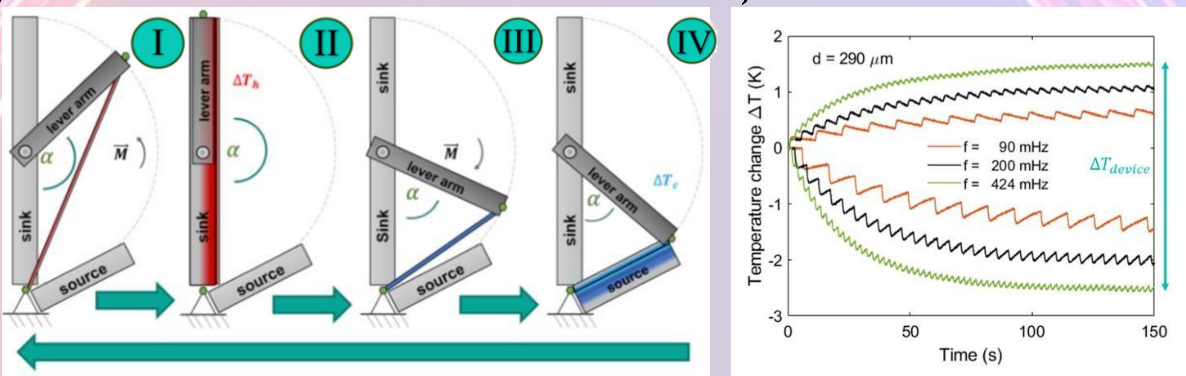

Figure 1: a) Schematic illustrating the EC cycle in four steps employing bistable actuation with a rotating lever arm. b) The temperature evolution of heat sink and source at different frequencies as indicted. Reproduced from C. Ludwig et al., doi: 10.1063/5.0231213, licensed under CC BY.

POSTERCONTRIBUTIONS

SMACool: Universal Testing Field for Elastocaloric Machines
Rawan Barakat, Saarland University

Pioneering Elastocaloric Refrigeration: The First Continuous Usecase Application in a Miniature CanCooler
Lukas Ehl, Saarland University

Simulative Evaluation of TPMS Structures for an Elastocaloric Application
Michael Fries, Saarland University

Initial Numerical Framework for Simulating Rotative Elastocaloric SMACOOL Heat Pumps
Sabrina Gargiulo, University of Naples Federico II

Enhancing Efficiency of Elastocaloric Devices Through CFD-Assisted Airflow Design
Ivan Trofimenko, Saarland University

Thermography of thin NiTi Wires during Operation in an Actuator based on Accurate Emissivity Measurements
Daniel Zipplies, Chemnitz University of Technology

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