Proceedings of the Virtual International Conference on Energy and Heat Transfer (V-ICEHT'26)
May, 2026 | Virtual Conference
DOI: 10.11159/iceht26.001

Advancements In Adsorption Refrigeration: Fundamentals and Prototype Evolutions Over the Last Two Decades

Salvatore Vasta
Senior Researcher
CNR, ISTITUTO DI TECNOLOGIE AVANZATE PER L'ENERGIA "NICOLA GIORDANO"
Via Salita Santa Lucia Sopra Contesse, 5, 98126 – Messina
www.cnr.it
Tel. +39 090 624404
salvatore.vasta@cnr.it

Extended Abstract

Adsorption refrigeration has emerged as a promising alternative to conventional cooling technologies, driven by the growing demand for sustainable and low-energy cooling solutions. This speech provides a comprehensive overview of the fundamental principles of adsorption processes and highlights key technological advancements achieved over the past two decades.

Adsorption systems exploit the reversible interaction between a refrigerant vapor and a solid adsorbent material, enabling thermally driven cooling cycles with minimal electricity consumption and reduced environmental impact. The core thermodynamic cycle (comprising adsorption, desorption, condensation, and evaporation) is discussed alongside the main performance metrics and energy balance considerations. Particular attention is given to adsorbent materials such as silica gel, zeolites, activated carbon, and metal-organic frameworks (MOFs), emphasizing their critical properties, including selectivity, thermal stability, and surface area. Despite their advantages, adsorption systems face persistent challenges, notably related to heat and mass transfer limitations within adsorbent beds, often caused by low thermal conductivity and inefficient contact between grains.

Recent research efforts have focused on improving system performance through advanced heat exchanger designs, including the use of coated surfaces and innovative materials such as polymers enabled by additive manufacturing. These approaches significantly enhance **heat transfer** (that still remain the main challenge) while reducing weight, cost, and corrosion issues. In parallel, optimized cycle configurations and heat recovery strategies have been developed to increase the coefficient of performance (COP) and reduce energy consumption. The speech also reviews the evolution from early commercial systems (1990–2000), which faced reliability and efficiency limitations, to modern prototypes and hybrid configurations. In particular, hybrid adsorption–compression chillers demonstrate the potential to combine the low electricity demand of sorption systems with the high responsiveness of conventional chillers, achieving improved overall performance. Additional applications, such as mobile air conditioning, thermal energy storage systems for maritime use, and solar-powered ice makers, illustrate the versatility and scalability of adsorption technologies.

Despite significant progress, adsorption refrigeration remains a developing technology. Future research directions include the development of novel adsorbent materials, further **enhancement of heat and mass transfer processes**, and system simplification: the widespread adoption of adsorption cooling will depend not only on performance improvements but also on achieving simple, robust, and cost-effective designs.