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EXERGOECONOMIC ANALYSIS OF TESLA TURBINE INTEGRATION IN CO2 HEAT PUMPS : OPTIMIZING SUSTAINABILITY VIA TRANSITING EXERGY

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ABSTRACT

Heat pump systems are widely recognized for their efficiency and sustainability in heating and cooling applications. Recent studies demonstrate that integrating a Tesla turbine into a transcritical CO_2 heat pump system can enhance performance by recovering work at the turbine stage. The compact design and low maintenance requirements of the Tesla turbine position it as a promising solution for optimizing such systems and advancing sustainable development.

This study introduces an innovative approach by applying the concept of "transiting exergy" to heat pump systems incorporating Tesla turbines. Transiting exergy is defined as the minimum exergy value determined by the intensive parameters at the inlet and outlet of a system or its components. Unlike traditional methods, this approach focuses on the portion of exergy that remains unchanged as it enters and exits the system, offering a clear and unambiguous distinction between consumed and produced exergy.

Furthermore, an exergoeconomic analysis is developed, integrating cost balances for each component based on consumed and produced exergies. The concept is evaluated across three transcritical CO_2 cycles integrated with Tesla turbines: basic transcritical, double-compression flash, and double-compression external intercooler cycles, which are compared to traditional transcritical CO_2 refrigeration cycles. This methodology delivers a more precise understanding of exergy and cost distribution at the component level, including compressors, heat exchangers, and the Tesla turbine.

Results reveal that the Tesla turbine achieves significant energy recovery of 26% in a basic transcritical CO_2 cycle, with a transiting exergy efficiency (produced exergy over consumed exergy) of 53%. In contrast, a typical expansion valve achieves only 37% transiting exergy efficiency. These findings highlight the Tesla turbine's potential to enhance energy systems with a new exergoeconomic approach, supporting advancements in energy sustainability and environmental impact reduction.