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Turbulence Generator Integration for Enhanced Heat and Moisture Recovery in Quasi-Counter flow Membrane Heat Exchangers

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Abstract: Abstract: Heating, Ventilation, and Air Conditioning (HVAC) systems are essential for ensuring indoor thermal comfort, humidity regulation, and air quality, yet they remain one of the largest contributors to global energy consumption. Improving the efficiency of heat exchangers within HVAC systems is therefore a critical step toward sustainable energy use. Conventional turbulence generators (TGs) have been widely applied to enhance heat transfer in traditional exchangers; however, their potential in membrane-based systems for simultaneous heat and moisture recovery remains underexplored. This study evaluates the effect of TGs on the thermal and mass transfer performance of a membrane quasi-counterflow heat exchanger using both experimental measurements and computational simulations in ANSYS Fluent. Results indicate that TG integration with inline arrangements significantly improves exchanger performance compared to smooth-channel designs. Quarter-circle TGs with a 3 mm diameter and 4 mm height yielded maximum sensible, latent, and total effectiveness values of 81.05%, 73.94%, and 77.64%, respectively. At the highest tested mass flow rate (0.000615 kg/s), the spacer with TGs achieved improvements of 8.56% in sensible effectiveness, 2.33% in latent effectiveness, and 5.04% in total effectiveness over the baseline design, corresponding to a net recovered power gain of 12.5 W. These findings highlight the potential of TG-integrated membrane exchangers to advance next-generation energy-efficient HVAC systems.

Key Words: membrane heat exchanger, turbulence generator, sensible effectiveness, latent effectiveness

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