Proceedings of the 6th International Conference on Experimental and Numerical Flow and Heat Transfer (ENFHT'21)
London, England – March, 2020
DOI:

Using Advanced Carbon Dioxide Technologies in Refrigeration, Air Conditioning and Heat Pumping Systems: Exciting Thermodynamics in Action

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Global warming has motivated significant developments in the use of high-efficiency refrigeration, air conditioning and heat pump systems that also utilize environmentally-friendly refrigerants. One such refrigerant is carbon dioxide (CO_2), which has a negligible Global Warming Potential (GWP) among several other advantages, but often is associated with lower system energy efficiency due to the combination of its low critical temperature and high critical pressure. If a system utilizing CO_2 as the refrigerant cannot meet, if not exceed, the efficiency of systems utilizing hydrofluorocarbon (HFC) refrigerants, then much of the environmental benefit of using a natural refrigerant will be lost in the overall carbon equivalence. To address this, several modifications to CO_2 refrigeration, air conditioning and heat pump systems have been shown to increase the energy efficiency of such systems. One such modification with significant potential for performance improvement is expansion work recovery, which has been shown to be particularly advantageous in CO_2 systems due to the increased pressure differential available across the system. Another modification is multi-stage compression with economizing and/or intercooling. This talk will focus on multiple efforts that have been undertaken to efficiently recover the available expansion work and reduce the required compression power input. These efforts include the development of a combined turbomachine expander-phase separator, a variable-geometry ejector, and liquid-cooled compression among others. Numerical and experimental aspects of these research efforts will be discussed, as will lessons learned, results obtained, and perspectives for future work in this research area.