MODELING AND EXPERIMENTAL ANALYSIS OF A TESLA TURBINE FOR WASTE HEAT RECOVERY FROM SCREW AIR COMPRESSORS

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ABSTRACT

The recovery of low-grade waste heat from industrial processes asks for efficient and cost-effective solutions for both power cycle and equipment. While the organic Rankine cycle (ORC) is universally recognized as the most suitable power cycle for these applications, multiple options are available for the expander especially at small sizes (few kW to tens kW) where piston, scroll, screw expanders, etc., as well as radial inflow and partial admission axial flow turbines are found. Among them, the Tesla turbine has attracted much attention in the last decade due to the possibility of achieving a moderate efficiency with a simple and robust design. This work is about one-dimensional analysis, development of a test-rig and first experimental results obtained for a Tesla turbine operating with air and organic fluids. The one-dimensional analysis of the rotor is based on the simplification by a systematic order of magnitude analysis of the momentum equation proposed by Carey [1] and extended by Manfrida et al. [2] to relax the assumption of constant density and using real gas properties. The turbine model is embedded in the overall model of the ORC system in the search of a global optimization. The test-rig is built within a cutting-edge company in northeast Italy willing to apply the ORC technology with Tesla turbine for heat recovery from their series of screw air compressors having outlet temperature of 95°C and recoverable thermal power in the range 20-170 kW_t. The manufactured turbine has disks with an outer diameter of 0.225 m and an inner diameter of 0.076 m, and a convergent-divergent nozzle to allow for supersonic flow at rotor inlet. The first experimental tests on the Tesla turbine prototype conducted until now using compressed air at different pressures have provided useful indications to solve practical issues related to the leakage of air flow, improve the turbine efficiency and extend the operation to organic fluids. The outcome of the forthcoming experimental tests with enhanced equipment and using R134a will provide additional insights about the optimum operation of the system and enable to assess any difference compared to operation with air.

[1] Carey V.P. Assessment of Tesla Turbine Performance for Small Scale Rankine Combined Heat and Power Systems. Journal of Engineering for Gas Turbines and Power 2010;13:122301-8.

[2] Manfrida G., Pacini L., Talluri L. A revised Tesla turbine concept for ORC applications. In Proc. of the IV International Seminar on ORC Power Systems (ORC2017), 13-15 September 2017, Milan, Italy.