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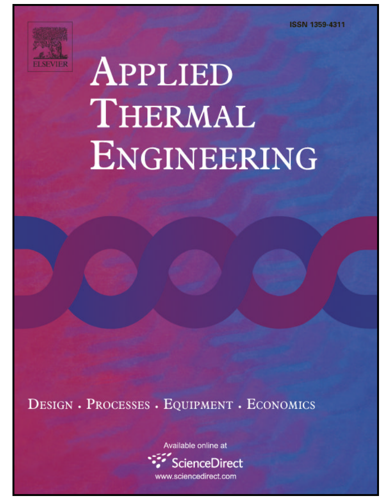


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# Experimental characterization and comparison of an axial and a cantilever micro-turbine for small-scale Organic Rankine Cycle

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**Abstract:** Electricity generation from waste heat by means of Organic Rankine Cycle is a promising method to increase the efficiency of industrial processes. However, due to special boundary conditions, such systems have to be robust, efficient in full load as well as in part load and scalable down to the power range of less than 15 kW. This study presents experimental results on the behaviour of two small-scale turbines, an axial impulse turbine and a radial cantilever turbine with a maximum power of about 12 kW. The turbine characteristics (isentropic efficiency and swallowing capacity) are given with respect to pressure ratio (ranging from 12 to 24) and rotational speed (ranging from 18,000 to 30,000 rotations per minute). For the axial turbine, a maximum isentropic efficiency of 73.4 % has been reached in the ORC test bed. The maximum isentropic efficiency of the cantilever turbine is even higher and reaches 76.8 %. The values are compared to volumetric expanders and it is shown that micro-turbines can compete even in the power range addressed in this study. As the turbine characteristics are given for full load and part load conditions, they can be implemented in simulation tools to allow for a more realistic calculation of ORCs with fluctuating heat sources.

**Keywords:** Organic Rankine Cycle, turbines, axial, cantilever, small-scale, turbine efficiency

## 1. Introduction

Organic Rankine Cycle has been widely applied in biomass-fired power plants and in geothermal applications. It is also discussed for waste heat recovery, as the working principle is known from large-scale applications at high temperatures. For example tremendous experience on steam power cycles downstream of gas turbine power plants is available from the last decades. Despite the high potential of industrial waste heat [1,2], only a few solutions in the electric power range of less than 100 kW are on the market [3,4]. One reason is the fact that boundary conditions of waste heat sources in terms of temperature, pressure and heat transfer medium vary widely for different industrial sectors. Hence, flexible and modular ORC systems are necessary. Manufacturers of such ORC plants must be able to adapt their plant design quickly and cost-efficiently to the requirements of their potential customers to reach economically feasible investment costs of less than 3000 €/kW [5]. As the expansion unit is probably the most critical component concerning plant efficiency and costs, we focus on affordable, small-scale and flexible turbines in comparison to volumetric expanders.

Many publications postulate that for small power output and/or small mass flow rate, piston, screw, scroll and rotating vane expanders are advantageous regarding efficiency, rotational speed, size and costs [6,7]. Branchini et al. [8] showed that volumetric expanders dominate the power range below 10 kW electric power and below a volume flow ratio of 10. The latter is due to the built-in volume ratio of volumetric expanders, which is generally < 10 for piston expanders [7] and even < 5 for scroll or screw types. However, in exhaust heat recovery of internal combustion engines high temperature differences and, therefore, high volume flow ratios in the order of 100 occur [9,10]. Compared to volumetric expanders, a turbine can handle this ratio in