Design of a total-pressure acquisition system for a small high-speed radial-inflow turbine for high-temperature organic Rankine cycle systems

Alice Maiello[1]
a.maiello-1@tudelft.nl

Matteo Majer[1]
m.majer@tudelft.nl

Piero Colonna[1]
p.colonna@tudelft.nl

[1] Propulsion and Power, Faculty of Aerospace Engineering, Delft University of Technology

ABSTRACT

Organic Rankine cycle (ORC) power systems are widely investigated for waste-heat recovery at temperatures ranging from ≈ 120°C to > 500°C [1]. In case of small-scale ORC power plants (up to hundreds kW), radial inflow turbines (RIT) are usually adopted because they are highly efficient, compact, and are suitable for high expansion ratio even with a single-stage configuration [2]. Accurate evaluation of their performance requires analysis accounting for fluid dynamic losses, which can be directly related to the total pressure of the flow downstream of the expander.

To address this need, this work documents the design of a total pressure measurement system for the ORCHID turbine, a 10kW high-speed RIT operating with siloxane MM as working fluid. This ORC turbine is installed at the Aerospace Propulsion and Power laboratory of Delft University of Technology.

At the design point, the turbine operates with a mass flow rate of 132 g s^{-1}, an inlet total temperature of 300 °C, a pressure ratio of 40.84, and a rotational speed of 98.1 krpm.

Mean total pressure measurements are planned at a cross-sectional plane located approximately five exducer blade heights from the rotor exit section, within a 41 mm diameter pipe.

The use of siloxane MM as working fluid imposes strict safety requirements on the instrumentation, which must comply with ATEX regulations [3].

Prior to probe selection, three-dimensional numerical analyses were carried out to characterize the mean flow field at the measurement plane. The results indicated the persistence of residual swirl and variations of the flow angle, which may lead to misalignment of the incoming flow with respect to the probe head and introduce errors in the measured total pressure.

As a result, a miniaturized Kiel-probe was selected due to its insensitivity to flow misalignment for a wide range of flow angles [4]. The head diameter of the chosen probe measures 1.65 mm, minimizing blockage and limiting disturbance of the local flow field.

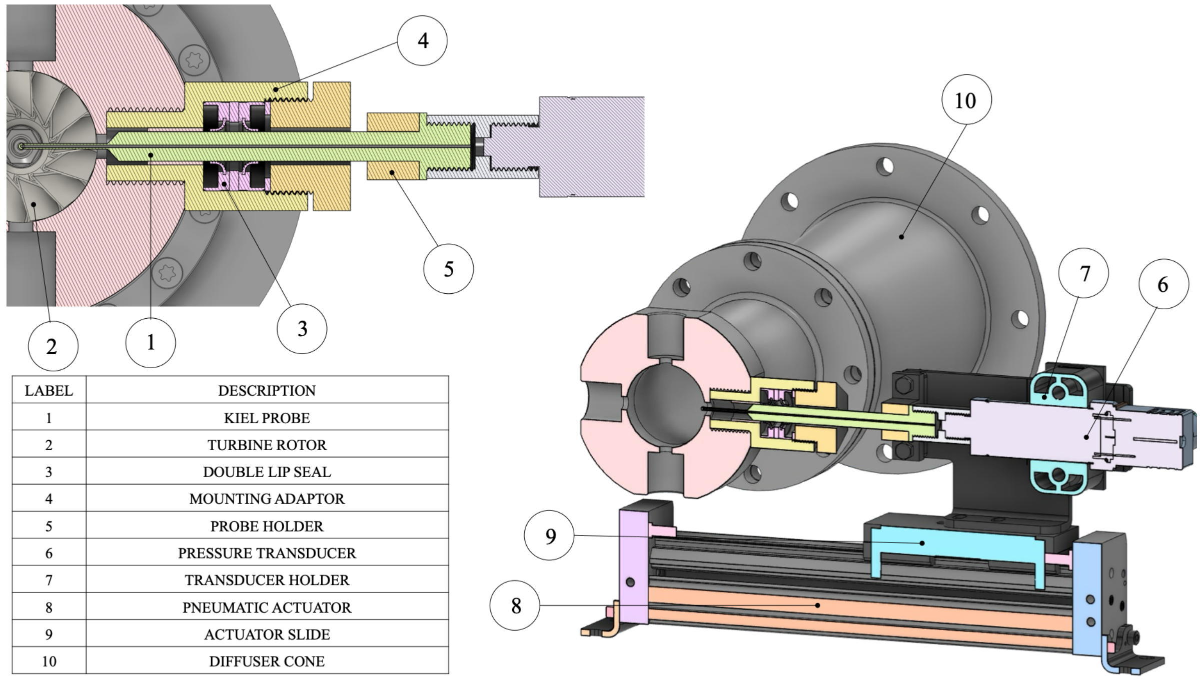
The pressure signal is acquired by an ATEX pressure transducer screwed to the opposite end of the probe stem, with a full-scale range of 0-1 bara to closely match the expected pressure and keep measurement uncertainty low.

A traversing system moves the probe from the wall to the pipe centerline in 1 mm steps, enabling adequate reconstruction of the radial pressure profile. Pneumatic actuation for this system is chosen as a more compact and cost effective ATEX-compliant alternative to a classical electric actuator.

At the current stage, the detailed design of the system has been completed (see Fig.1). The next steps are the characterization in a wind tunnel in which the flow conditions are those representative of the ORCHID turbine.

This is done to assess the response, repeatability, and angular sensitivity at different Mach numbers for the selected probe, prior to tests in the ORCHID.

The planned experimental campaigns will support the assessment of the ORCHID turbine efficiency and the validation of the previously performed CFD analyses.



LABEL	DESCRIPTION
1	KIEL PROBE
2	TURBINE ROTOR
3	DOUBLE LIP SEAL
4	MOUNTING ADAPTOR
5	PROBE HOLDER
6	PRESSURE TRANSDUCER
7	TRANSDUCER HOLDER
8	PNEUMATIC ACTUATOR
9	ACTUATOR SLIDE
10	DIFFUSER CONE

Figure 1. Cross-sectional view of the total-pressure measurement system integrated into the ORCHID turbine. The main view shows the complete assembly with the probe fully retracted, while the inset provides a detailed view of the probe–transducer assembly, sealing system and mounting interface with the probe fully inserted.

REFERENCES

[1] M. Astolfi et al. "Thermal Energy Harvesting: the Path to Tapping into a Large CO2-free European Power Source". Technical White Paper. Version 2.0. KCORC Knowledge Center on Organic Rankine Cycle Technology, 2025. doi: https://doi.org/10.17185/duepublico/82887

[2] P. Colonna, E. Casati, C. Trapp, T. Mathijssen, J. Larjola, T. Turunen-Saaresti, and A. Uusitalo. "Organic Rankine Cycle Power Systems: From the Concept to Current Technology, Applications, and an Outlook to the Future". In: Journal of Engineering for Gas Turbines and Power 137.10, 2015, p. 100801. doi: https://doi.org/10.1115/1.4029884

[3] Directive 2014/34/EU of the European Parliament and of the Council of 26 February 2014 on the harmonisation of the laws of the Member States relating to equipment and protective systems intended for use in potentially explosive atmospheres. Official Journal of the European Union, L 96. 2014

[4] S. H. Chue. "Pressure probes for fluid measurement". In: Progress in Aerospace Sciences 16, 1975, pp. 147–223. doi: https://doi.org/10.1016/0376-0421(75)90014-7