DESCRIPTION OF ORC MICROTURBINE FLOW

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A promising technology for small scale cogeneration systems is Organic Rankine Cycle (ORC) where electricity is produced by a generator driven by a turbine operating on vapours of special low-boiling liquids. A new 100 kW ORC facility is built at IFFM with a multistage axial turbine working on MDM (Octamethyltrisiloxane). Fig. 1 shows a diagram of the cycle and a model of the test rig. Main components of this cogeneration cycle are ecological boiler fit to combust different kinds of biomass or biofuels, intermediate heat cycle to extract heat from flue gases to thermal oil as a heat carrier, evaporator, turbine with a low boiling liquid as a working medium, recuperator, condenser and circulating pumps for the working medium and thermal oil. In the presented heat cycle, electric energy is a by-product and amounts to less than 20% of the total supplied heat. Behind the turbine, the remaining superheat and condensation heat of the working medium is used for heating water for the district heating network. The solution offers a possibility to apply low temperature heat sources, allows utilisation of different types of fuels and modular construction, which facilitates adaptation of the CHP unit to the required power range. One can think of micro CHP units dedicated for individual households of total heat capacity up to 20kWt and electric power up to 4kWe as well as small CHP modules dedicated for communal energy centres of total heat capacity 500kWt and electric power 100kWe (maximum up to 5 MWt and 1 MWe, respectively).

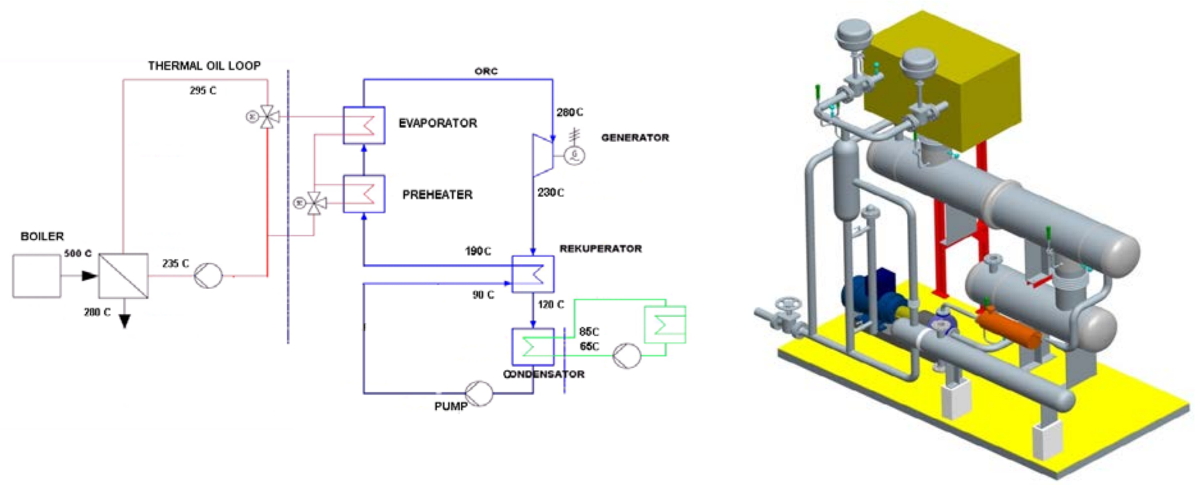

Fig. 1. The ORC cycle for MDM and the model test rig.

A number of turbine designs (multi-stage axial turbine and single stage radial/axial turbine) have been selected for 3000, 9000 and 14000 rpm generators. The turbine and generator are placed in a hermetical casing and are lubricated by the liquid of the working medium. The blading system for the 9000 rpm turbine design (mass flow rate 1.5 kg/s, inlet pressure 12 bar) consists of 7 stator/rotor stages (Fig. 2).

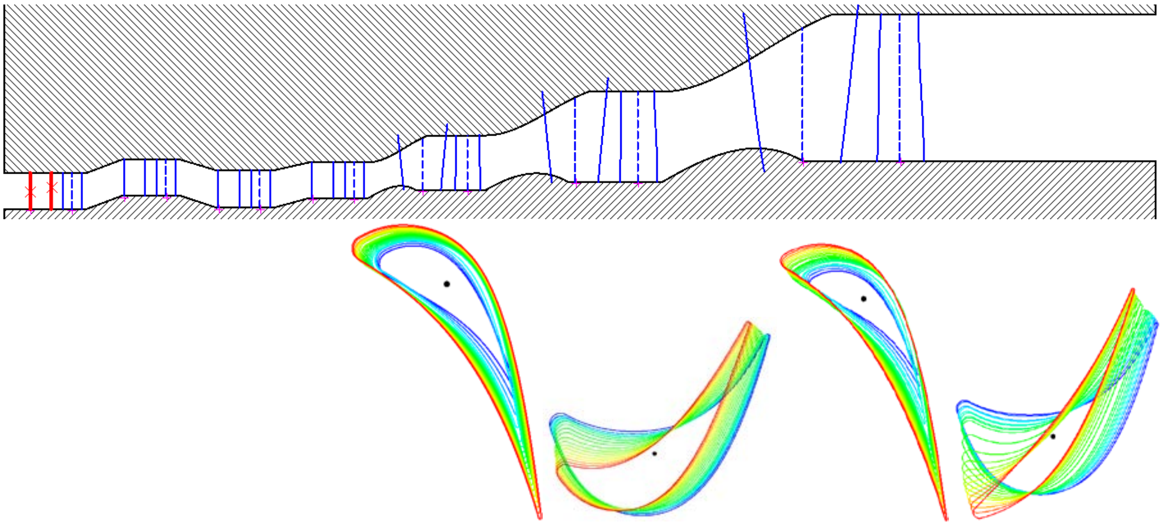

Fig. 2. A meridional view of the blading system for a 9000rpm ORC turbine (top) Hub-to-tip stator/rotor blade profile of stage 6 and 7 (bottom).

The first three stages (with cylindrical blades) are supplied in a partial admission mode with the admission arc increasing from 0.25 to 0.5. Partial admission is used here since the full-annulus admission design leads to a low blade height and rotor speed to meet the design value of velocity coefficient. Thus, the endwall and leakage losses are reduced and the performance (efficiency) of the turbine is improved. On the other hand, circumferential non-uniformity of flow patterns observed in the partial admission cascades give rise to high unsteady forces acting on the rotor blades connected with the cycle of admission. These effects are investigated in the present work with the help of the code Fluent.

The last three stages have blades with optimised profiles changing from hub to tip, optimised 3D stacking lines and endwall contours. They were obtained in the course of multi-disciplinary flow/structure optimisation. Results of heat and flow analysis of the blading system presented in the form of pressure, temperature and Mach number contours as well as enthalpy loss distributions exhibit regular flow patterns with relatively low effects of secondary flows and suction side or hub separation (Fig. 3).

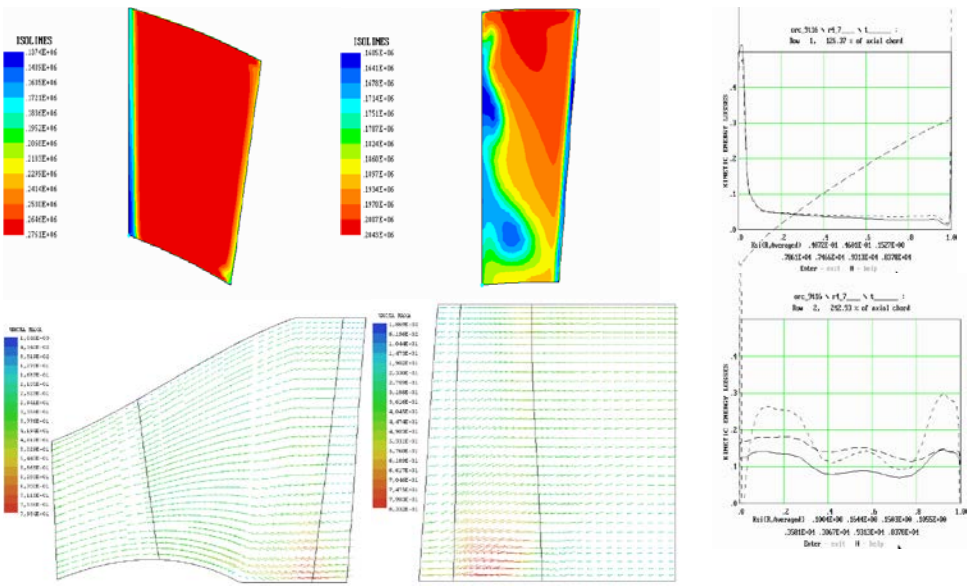

Fig. 3. Total pressure contours and enthalpy loss diagrams downstream of stage 4 (top, right); velocity vectors coloured by Mach number in stage 7 (bottom).