A NEW CONFIGURATION FOR ORGANIC RANKINE CYCLE POWER SYSTEMS

Claudio Spadacini, Lorenzo Centemeri, Luca G. Xodo*, Marco Astolfi, Matteo C. Romano, Ennio Macchi†

*Exergy,
Via Cremona, 1, 20125 Legnano (MI), Italy
e-mail: l.xodo@exergy.it
Web page : www.exergy-orc.com
†Politecnico di Milano – Dipartimento di Energia,
Via Lambruschini, 4, 20156 Milano, Italy
e-mail: matteo.romano@polimi.it
Web page : http://www.energia.polimi.it/

In the large spectrum of organic fluids suitable for Rankine cycles, a fluid that is already well-known and available on industrial scale but currently excluded from this kind of application has been selected.
This choice is due to the remarkable characteristics of the fluid, such as its high molecular weight, good thermal stability, non-flammability, and atoxicity.

Compared to those fluids nowadays common in the ORC market, its thermodynamic properties and fluid dynamic behavior lead to a peculiar configuration of the cycle:

- Supercritical cycle, when heat input is at medium-high temperature;
- Massive regeneration, to obtain higher efficiency;
- Low specific work of the turbine;
- Relatively high volumetric expansion ratio and relatively low absolute inlet volumetric flow;

Accordingly, an innovative cycle design has been developed, including a once-through Hairpin primary heat exchanger and a multi-stage radial outflow expander.
This last innovative component has been designed to get the best performance with the chosen fluid:

- The high inlet/outlet volumetric flow ratio is well combined with the change in cross section across the radius;
- Compared to an axial turbine, the lower inlet volumetric flow is compensated by higher blades at the first stage. It is feasible thanks to the change in section available along the radius, so that there is no need for partial admission;
- The prismatic blade leads to constant velocity diagrams across the blade span;
- It minimizes tip leakages and disk friction losses, due to the single disk / multi-stage configuration;
- The intrinsical limit of a radial outflow expander to develop high enthalpy drop is not relevant for this cycle, presenting itself a very low enthalpy drop. Moreover the tip speed is limited by the low speed of sound and consequently this kind of expander suits well with this cycle arrangement.

The results of this study, conducted through thermodynamic simulations, CFD, stress analysis and economic optimization show an ORC system that reaches high efficiencies, comparable to those typical of existing systems.