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Publication date:
2014

Citation (APA):
Gabrielli, P., Andreasen, J. G., Pierobon, L., & Haglind, F. (2014). Performance of ORC turbogenerators using zeotropic mixtures. Poster session presented at ASME Turbo Expo 2014, Düsseldorf, Germany.

DTU Mechanical Engineering
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Performance of ORC turbogenerators using zeotropic mixtures

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1 MOTIVATION

The performance of organic Rankine cycle (ORC) power units (see Figures 1 and 2) strongly relates with the working fluid selection and the expander design. Binary zeotropic mixtures have the potential to enhance the system performance. However, the effects of the mixture composition on the expander efficiency need to be calculated so as to realistically assess the benefits of the aforementioned fluids.

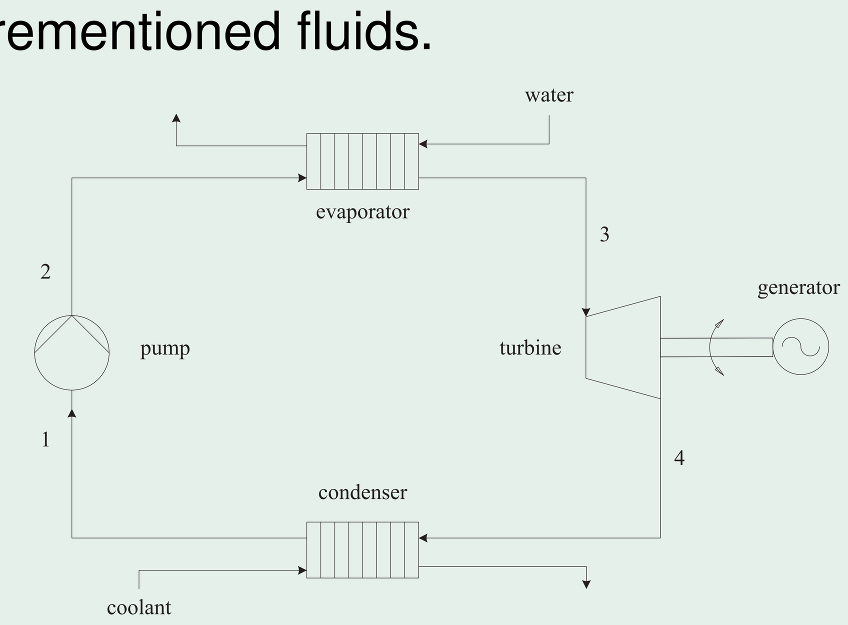

Figure 1: Layout of the ORC turbogenerator. The heat source is geothermal water at 120 °C.

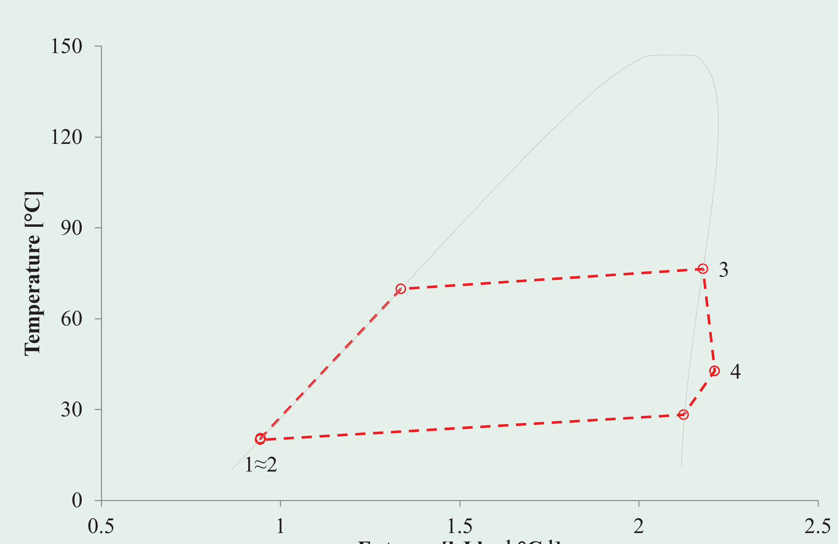

Figure 2: Saturation curve of an isobutane/isopentane mixture in a $T-s$ diagram, showing the thermodynamic cycle state points for the ORC unit.

2 METHOD

The study aims at assessing the impact of the composition of an isobutane/isopentane mixture on both the thermodynamic cycle performance and the expander efficiency.
Such task is accomplished by coupling an ORC simulator with a one-dimensional computational tool capable of designing multi-stage axial turbines. The case study is a geothermal heat source providing liquid water at 120°C [1].

3 RESULTS

The results suggest a certain influence of the mixture composition on the turbine performance.

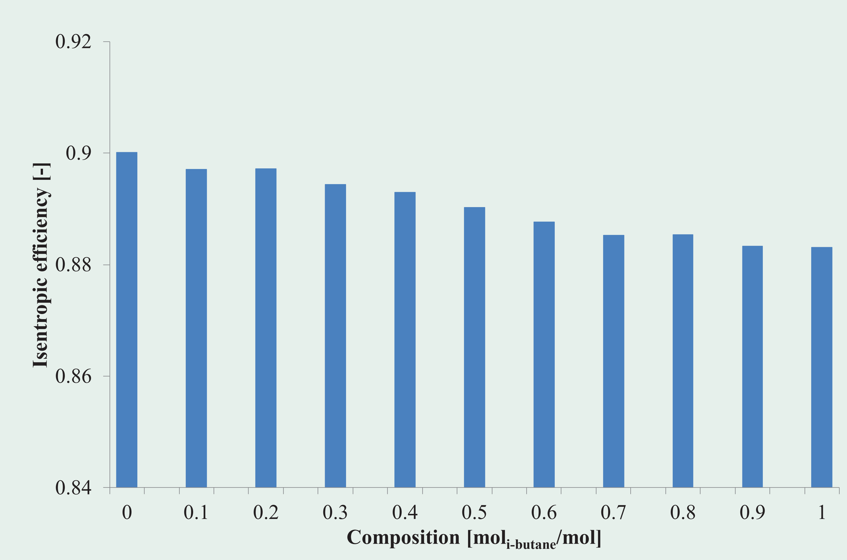

Figure 3: Isentropic efficiency at different mixture compositions.

Figure 3 shows the optimized isentropic efficiency profile which exhibits one absolute maximum and minimum at the extremes of the plot (90.0% for pure isopentane and 88.3% for pure isobutane).

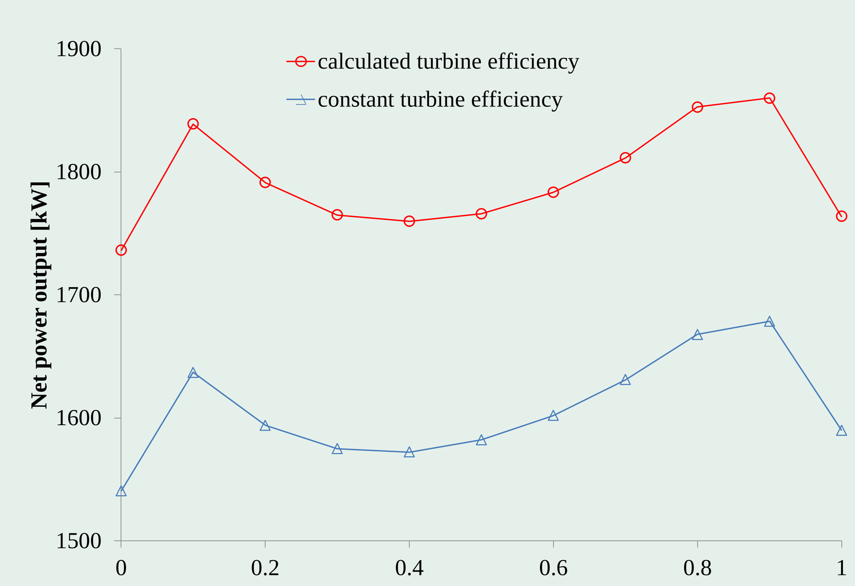

Figure 4: Organic Rankine cycle net power output at different mixture compositions.

Figure 4 connects the net power output of the ORC power module with the mixture composition for calculated (red line) and constant (blue line) turbine efficiency ($\eta_{is} = 0.8$). The difference in the power output maxima decreases owing to the tendency of the expander performance. The trend can be explained by analysing the losses within the turbine [2]. The profile losses are the major responsible for the efficiency drop. The profile loss in the rotor presents a minimum at a molar composition equal to 0.0 and a maximum with pure isobutane, see Figure 5.

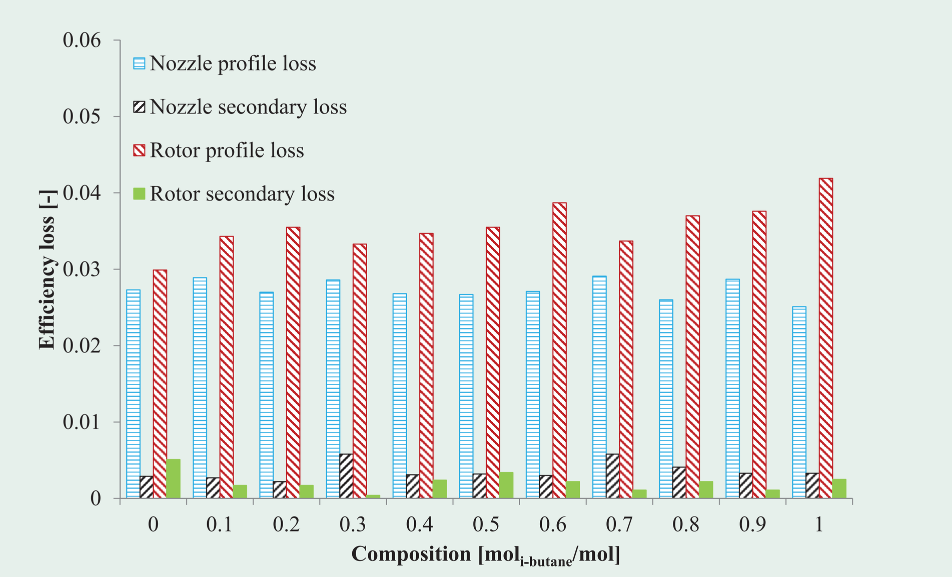

Figure 5: Profile and secondary losses at different mixture compositions.

4 CONCLUSIONS

This work demonstrates the importance of embedding simulation tools for turbine design in the thermodynamic cycle calculation when using binary mixtures as working fluids in ORC power units. Results unveil a deviation in the ORC net power output for different mixture compositions when employing the constant and the calculated turbine efficiency.

5 REFERENCES

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[2] Craig, H. R. M., & Cox, H. (1971). *Performance estimation of axial flow turbines.* Proceedings Institution of Mechanical Engineers, 71, 185 - 232.