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Technical feasibility of supercritical CO_2 Brayton cycle in waste heat recovery applications

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1. Introduction

Industry is paying attention to waste heat recovery to produce electricity (cogeneration bottom cycles) as a technique to improve the efficiency of processes. The cement production industry is highly interested in such techniques [1]. Brayton cycles using CO_2 at supercritical pressure can be used to capture wasted heat from streams at mid temperatures (300ºC to 500ºC). This technology has been suggested for some designs of Generation IV fission reactors [2] especially in the re-compression configuration. Recent developments by Echogen [3] proposed recuperative cycles for waste heat recovery.

This paper is focused on the cascade design proposed by Echogen, suggesting a variation with two recuperators. Different arrangements are analysed under some design configurations in order to obtain a design criterion for each layout.

2. Methodology

A flue gases stream coming from a clinker furnace is assumed as thermal source. Two recuperative layouts (L1 and L2) have been analysed, according to Figure 1. The isentropic efficiencies have been taken as 88% in the compressor (C) and 92% in the turbines (MT and ST), which are assembled in a cascade arrangement. The minimum temperature approach has been assumed to be 10 K. The temperature and pressure at compressor inlet have been set to 35ºC and 85 bar. No pressure drops have been considered. A recovery efficiency has been defined to be used as a comparison number. Such efficiency is defined from the net power produced and the maximum available heat, that it, if flue gases were cooled down to the ambient temperature (15ºC).

Figure 1 shows the two analysed layouts (L1 and L2). In the layout L1 only one recuperator (HTR) is used, capturing the energy in the stream leaving MT. In the layout L2 a second recuperator (LTR) has been included in order to take into account the different values of specific heat of both streams at low temperatures. Two designs have been considered for L2: in the $L2_{HTR}$ the minimum temperature approach is forced at both sides of the HTR recuperator; in the $L2_{LTR}$ this requirement is forced in the LTR.

3. Results

Figure 2 shows the pressure at the turbine inlet that is required at L1 and $L2_{HTR}$ configurations in order to achieve the maximum recovery efficiency obtained at $L2_{LTR}$.configuration, for the same flue gases temperature. It is remarkable that L1 and $L2_{HTR}$ might achieve higher efficiencies that $L2_{HTR}$ for the same gases temperature but with higher pressure.

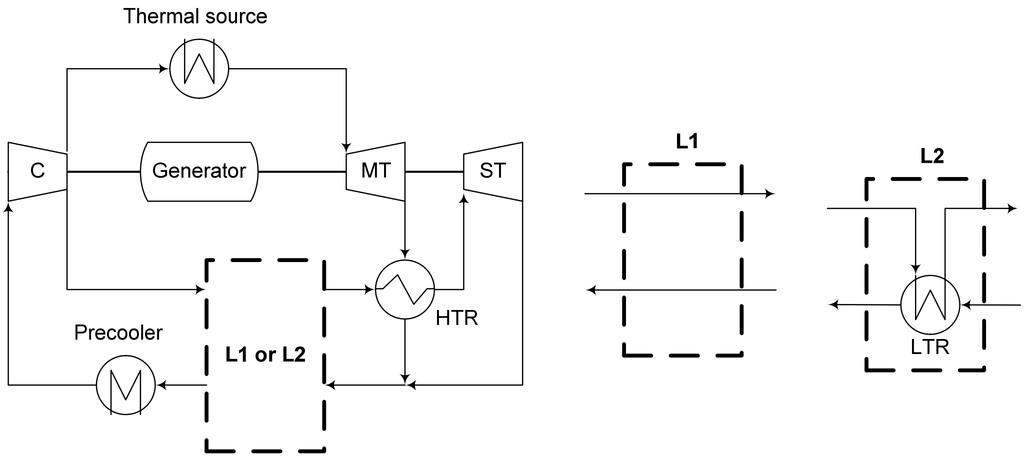

Figure 1. Proposed layouts

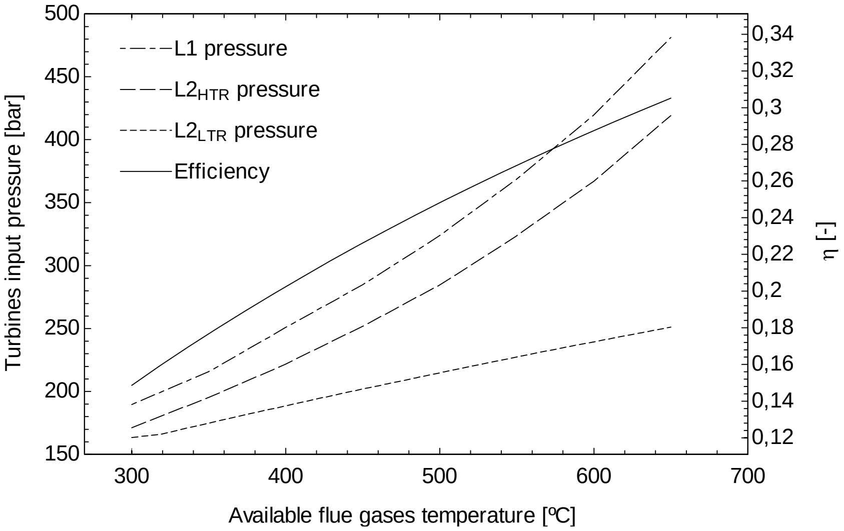

Figure 2. Turbine inlet pressure of proposed layouts to achieve the same efficiency.

4. Conclusions

From the obtained results it can be concluded that the simplest arrangement (L1) demands the highest pressure at turbine inlet whereas in the most complicated arrangement (L2) the best solution is found when the LTR is tuned, requiring the lowest pressures at turbines inlet.

5. References

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