Study on Pressure Loss of Inlet and Exhaust Flow in Single Screw Expander With Large Internal Volume Ratio

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Extend Abstract: Generally, the greater the difference between evaporation and condensation temperature of ORC(Organic Rankie Cycle) is, the higher system efficiency and the larger expansion ratio will be [1,2]. Fig. 1 shows that net efficiency of theoretical cycle and expansion ratio of ORC system changes with evaporation temperature when condensing temperature is 313 K (R123 and HFO-1336mzz (Z) are selected).

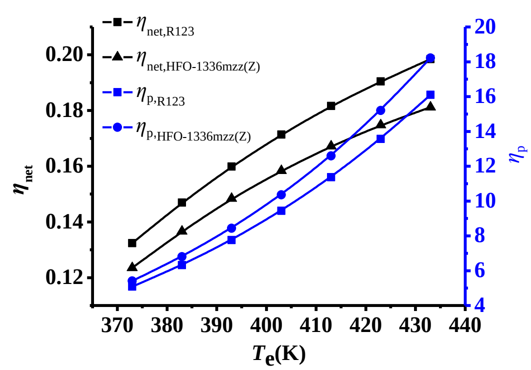

Figure 1: The expansion ratio and cycle net efficiency vary with evaporation temperature

The maximum internal volume ratio of single screw expander can reach 26.5. So in theory, it can meet the demand of large expansion ratio. However, the area of intake triangle hole (S_Δ) tends to be zero at this time(see Fig. 2(b)), and the performance of expander may be affected with the area decreases of intake triangle hole (see Fig. 2(a)) [3].

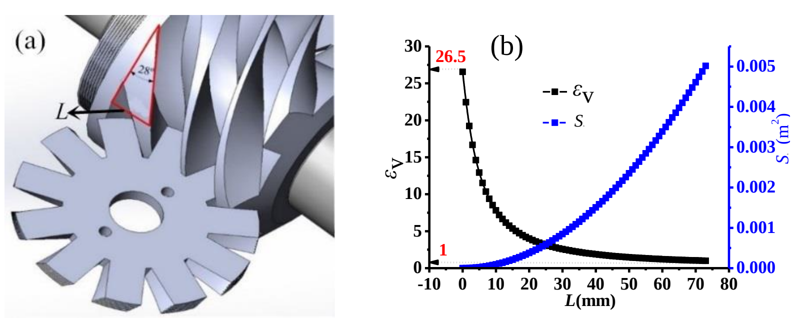

Figure 2: (a) Diagram of intake triangular hole of single screw expander, (b) internal volume and the area of triangular hole changes with the length of *L*

In order to study the key factors that affect the performance of single screw expander with large internal volume ratio. This paper established a new thermodynamic model (internal volume ratio from 3 to 8) of single screw expander that concerned intake throttling, leakage, heat-transfer and friction loss. And then it was calibrated and verified by our previous study [4] (R123 was selected as working fluid). As seen in Fig. 3, the calculated values of volume efficiency and shaft efficiency were in good agreement with the experimental values. And the maximum error was 2.1% and 2.3% respectively. So, compared with the semi-empirical model set up in reference [5] (the calculation error of shaft efficiency was 6.14%), and mathematic model established in reference [6] (the calculation error of volume efficiency was 6.2%), the model established in this paper was more accurate.

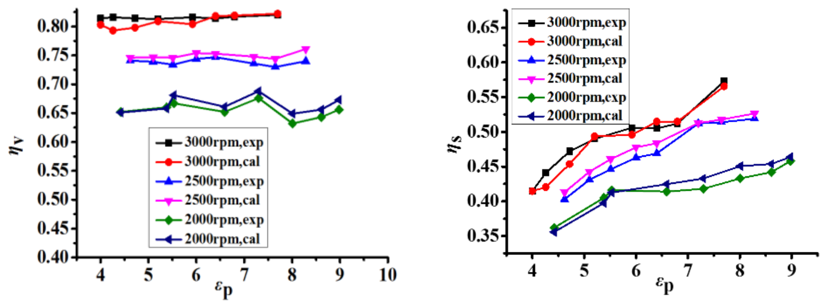

Figure 3: Volume efficiency and shaft efficiency comparison between experimental and calculated values

As indicated in Fig. 4, internal volume ratio had a great influence on shaft efficiency. Optimal shaft efficiency $\eta_{s,opt}$ was adopted in this paper, and $\varepsilon_{v,opt}$ was used for representing the optimal internal volume ratio corresponding to $\eta_{s,opt}$. it can be seen that $\varepsilon_{v,opt}$ was only about 5.50 when evaporation reach 423 K (pressure ratio was 10.45 at this time). That is to say, the $\varepsilon_{v,opt}$ is not the larger the better in the case of high pressure ratio. So it is necessary to analyze the potential reasons.

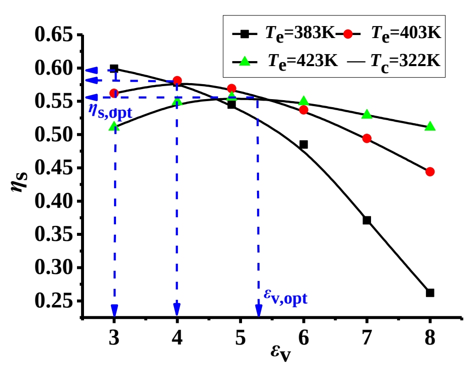

Figure 4: Shaft efficiency changes with internal volume ratio at different evaporation temperatures

As seen in Fig. 5, $\eta_{\Delta PL2}$ (Δ_{PL2} represents the exhaust pressure loss degree). The arrows refer to the $\varepsilon_{v,opt}$ under this condition. It can be seen that $\varepsilon_{v,opt}$ was always obtained at under-expansion condition ($\eta_{PL2} > 0$). Although the increase of internal volume ratio would reduce the degree of under-expansion, but the

$\varepsilon_{\mathrm{v,opt}}$ was not obtained at the moment of minimum under-expansion loss. From this point of view, η_{PL2} was not the key factor that restricted the further increase of shaft efficiency.

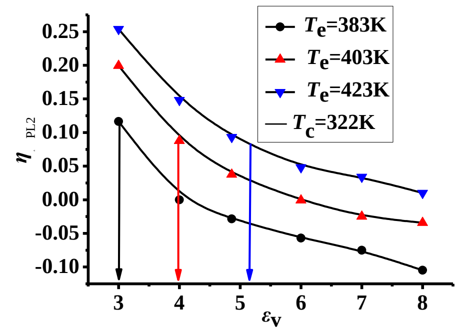

Figure 5: Exhaust pressure loss changes with internal volume ratio at different evaporation temperatures

In order to quantitatively evaluate the change of intake throttling degree with the increase of internal volume ratio. $\eta_{\Delta\mathrm{PL1}}$ (intake pressure loss coefficient) was defined. It can be seen in Fig. 6 that $\eta_{\Delta\mathrm{PL1}}$ increase rapidly with the increase of internal volume ratio. Therefore, in the case of large volume ratio, severe intake pressure loss would also reduce the exhaust pressure and produce suitable expansion, but this was not a good phenomenon. The result $\varepsilon_{\mathrm{v,opt}}$ was not obtained at suitable expansion condition) in Fig. 5 was an example.

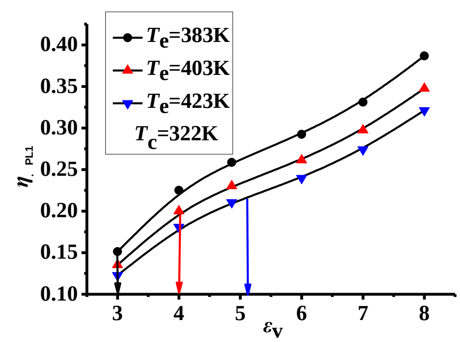

Figure 6: Intake pressure loss changes with internal volume ratio at different evaporation temperatures

We divided the intake pressure loss into 6 levels (100% $\eta_{\Delta\mathrm{PL1}}$, 80% $\eta_{\Delta\mathrm{PL1}}$, 60% $\eta_{\Delta\mathrm{PL1}}$, 40% $\eta_{\Delta\mathrm{PL1}}$, 20% $\eta_{\Delta\mathrm{PL1}}$, 0% $\eta_{\Delta\mathrm{PL1}}$) to study its effect on optimal internal volume ratio and shaft efficiency. The main results are shown in Fig. 7. It can be seen from the figure that optimal internal volume ratio and optimal shaft efficiency gradually increase with the intake pressure loss decreases, especially in large internal volume ratio condition. That is to say, intake pressure loss in the process of suction is the key factor that restricts the further increase of single screw expander performance.

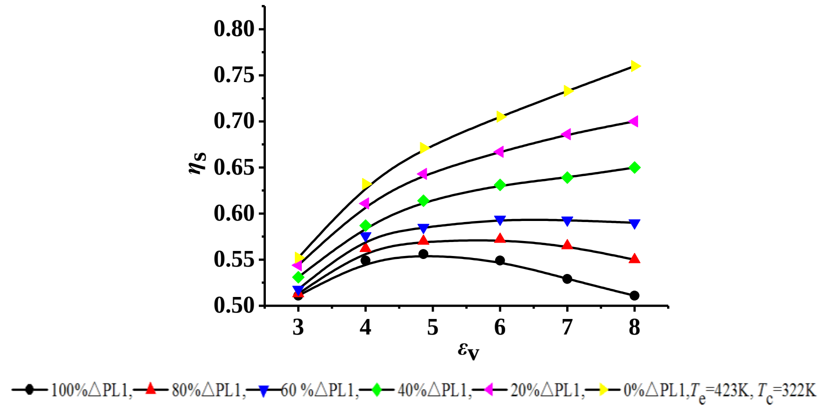

Figure 7: Influence of intake pressure loss on shaft efficiency of single screw expander

Conclusion: The optimum internal volume ratio and the optimum shaft efficiency will increase with the decrease of intake pressure loss, that is to say, the intake pressure loss is an important factor that restricts the performance improvement of single screw expander with large internal volume ratio under high pressure ratio. Optimizing intake process is a powerful method to improve the performance of single screw expander with large volume ratio.

References

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