Study of the influence of the plate-fin heat exchanger pressure drop on the performance of liquid air energy storage

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Introduction

Liquid air energy storage (LAES) is a very promising energy storage technology, which has the advantages of large capacity, long duration, long life and no geographical restrictions. In order to improve the efficiency and economy of the liquid air energy storage system, the optimization design of the heat exchanger is the focus of the research, especially the low-temperature plate-fin heat exchanger employed in the process of air liquefaction. The key design parameters of heat exchanger include heat transfer temperature difference and pressure drop. However, most of the current studies only focus on the heat transfer temperature difference of the heat exchanger. Reducing heat transfer temperature difference can improve the system efficiency, but significantly increase the cost of the heat exchanger. Therefore, the pressure drop research is the focus of this article.

Objectives

- ❖ Investigate the influence of the pressure drop of plate-fin heat exchanger on system performance.
- ❖ Obtain the best pressure drop for the heat exchanger with a high system efficiency and a relatively low cost.

Conclusions

- ❖ Thermodynamic analysis based on steady-state mathematical model was employed to evaluate the system electricity conversion efficiency.
- ❖ The results show that a moderate increase of the fluid channel pressure drop can significantly reduce the cost of the plate-fin heat exchanger, while the system efficiency decreases slightly.
- ❖ In engineering practice, the optimal pressure drop should be chosen rather than the minimum pressure drop.

Simulation model

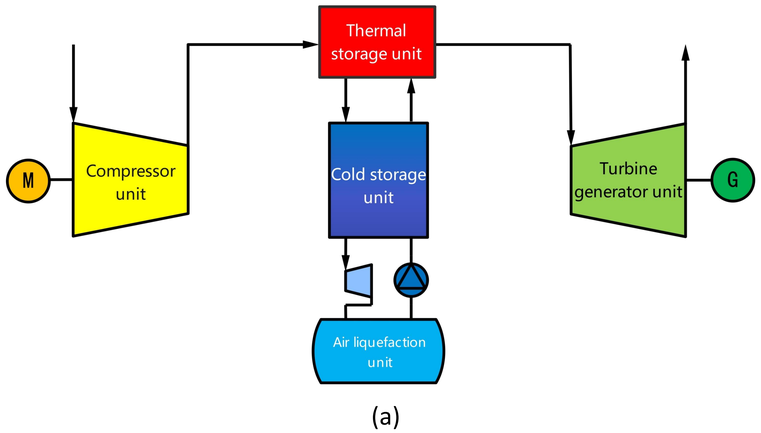

Figure 1. Schematic diagram of the LAES system (a) and the cold storage unit (b)

✓ The LAES system includes the compressor unit, the thermal storage unit, the cold storage unit , the air liquefaction unit, and the turbine generator unit.

✓ The multi flow plate fin heat exchanger includes the compressed air channels, the backflow air channels, and the cold storage medium channels.

Simulation parameters

Pressure drop configurations of different flow channels for three cases

		Case 1	Case 2	Case 3
Pressure drop/kPa	Compressed air channels	10	20	30
	Backflow air channels	10	10	10
	Cold storage medium channels	10	20	30
	Total	30	50	70

◆ The pressure drop of the backflow air channels remains constant of 10 kPa for it is limited by the gas phase pressure of the liquid air storage tank.

◆ The designed pressure drops of the compressed air and cold storage medium channels increase from 10 to 30 kPa respectively.

◆ The process simulation is conducted to obtain the corresponding electricity conversion efficiency.

Parametric analysis

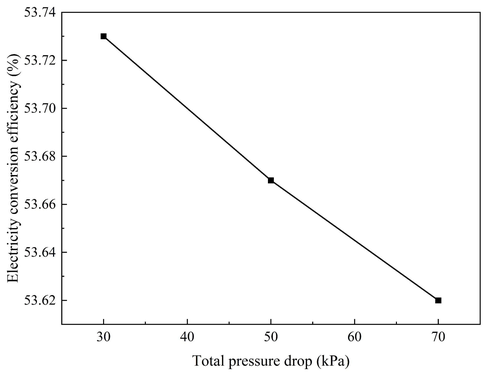

Figure 2. Influence of the pressure drop on the electricity conversion efficiency

➢ When the pressure drop of the plate fin heat exchanger increase, the power consumption of the compressor increases, while the expander output power decreases, leading to a decrease of the electricity conversion efficiency.

➢ As the pressure drop increase from 30 to 70 kPa, the electricity conversion efficiency decreases from 53.73% to 53.62%.

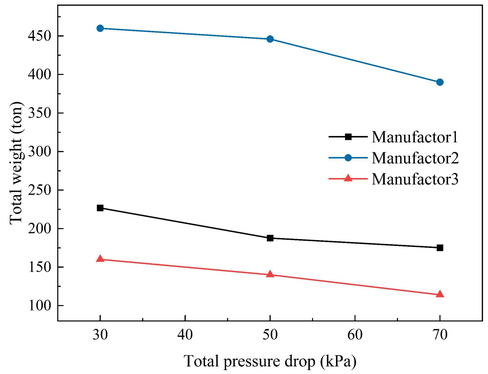

Figure 3. Influence of the pressure drop on the total weight

➢ As the flow area of the heat exchanger channel gradually decreases with the increase of pressure drop, the total weight of the heat exchangers of different manufacturers all decrease significantly when the pressure drop increase.

➢ When the pressure drop increases from 30 to 70 kPa, the weight reduction values of different manufacturers range from 46 to 70 ton.

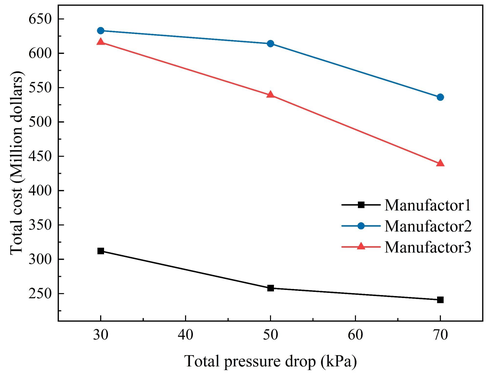

Figure 4. Influence of the pressure drop on the total cost

➢ Due to that the manufacturing cost of the heat exchanger is directly proportional to its total weight, the total cost of the heat exchangers of different manufacturers all achieve a significant decrease with the pressure drop increasing.

➢ As the pressure drop increase from 30 to 70 kPa, the cost reduction values of different manufacturers range from 71 to 177 million dollars.

If any questions, please contact me: ji-wei@cgdg.com