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Experimental study of single screw expander used in low-medium temperature geothermal power system

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Abstract

Research and development of renewable energy is one solution to energy crisis and its related environmental problem. Among all kinds of renewable energy, geothermal energy has good development feasibility due to its low investment and operation costs, independence to weather and climate change, and stable power generation. In China, high-temperature geothermal resource is rare; however, low-medium temperature geothermal resource is widely distributed. Therefore, small and medium sized geothermal power system based on low-medium temperature organic Rankine cycle (ORC) is a good choice for geothermal exploitation. Expander is the key device in such system. Single screw expander has proper size and good output performance. Therefore, in order to test the application of single screw expander in geothermal exploitation, compressed air was used as working fluid to conduct experimental study at different temperature. The results show that at the same rotational speed, the single screw expander at a higher air temperature has a bigger output power, a smaller gas consumption rate, a bigger expansion ratio, a bigger temperature drop, a higher thermal efficiency, and a smaller irreversible loss. Moreover, if a lubricant circle is added in the experimental system, the single screw expander with lubricant at a lower air temperature will have the same performance as the expander without lubricant at a higher air temperature. Therefore, the performance of single screw expander can be improved by adding a lubricant circle and raising compressed air temperature.

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Keywords: Single screw expander; Geothermal power generation; Organic Rankine cycle; Compressed air; Lubricant circle

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1. Introduction

With industrial development in recent years, a lot of problems caused by energy consumption are become more and more serious. Therefore, development and utilization of new energy and renewable energy is great significance. Among all kinds of renewable energy, geothermal energy has an average capacity factor of 70% and capacity factors up to 90% are considered possible[1]. Moreover, geothermal energy has good development feasibility due to its low investment and operation costs, independence to weather and climate change, and stable power generation. In China, high-temperature geothermal resource is rare; however, low-medium temperature geothermal resource is widely distributed. Therefore, small and medium sized geothermal power system based on low-medium temperature organic Rankine cycle(ORC) is a good choice for geothermal exploitation. Expander is the key device in such system. The rapid development of compressor technology makes a possible breakthrough in the manufacture of small size expander. Single screw technology has many advantages such as a good force balance, a long life, a high pressure ratio, a high volumetric efficiency, a high efficiency at part load, a simple structure, a low noise, and so on. Therefore, single screw expander becomes a promising technology in small size expander. In this paper in order to test the application of single screw expander in geothermal exploitation, compressed air was used as working fluid to conduct experimental study at different temperature.

2. Establishment of Experimental System

The single screw expander used in experimental system was developed and manufactured by the lab where the authors work. Some previous research work has been conducted on single screw expander by the members in author's research team[2-4]. In this study, expander inlet flow is $1.1 \text{ Nm}^3/\text{min}$ and power output is 10kW. Fig 1 depicts the single screw expander experimental system with heated compressed air as the working fluid. The main device consists of a single screw expander, a compressed air heating system, a lubricant system, a data acquisition system, and a dynamometer machine.



Fig. 1. single screw expander experimental system

3. Experimental Result and Discussion

Due to the length limitation of paper, only the performances of single screw expander with and without lubricant when inlet temperature is 80°C are reported. Fig 2 to Fig 7 depict the relation between the

performances of single screw expander and its rotational speed. These performances includes power, gas consumption rate, expansion ratio, temperature drop, thermal efficiency, and irreversible loss.

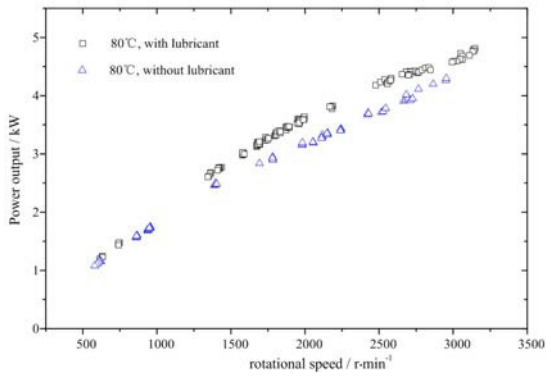


Fig. 2. relation between power and rotational speed

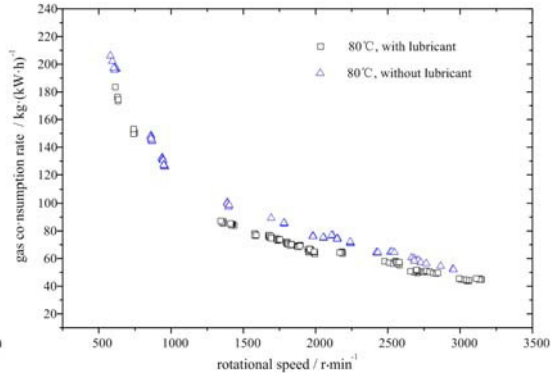


Fig. 3. relation between gas consumption rate and rotational speed

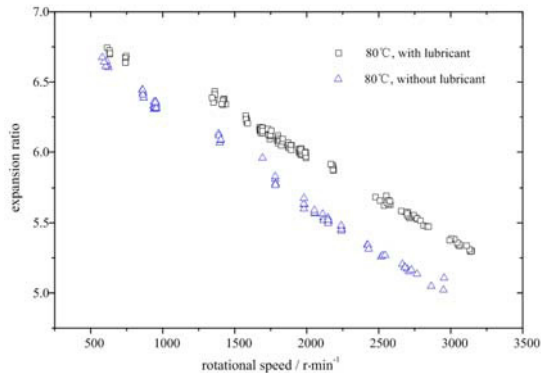


Fig. 4. relation between expansion ratio and rotational speed

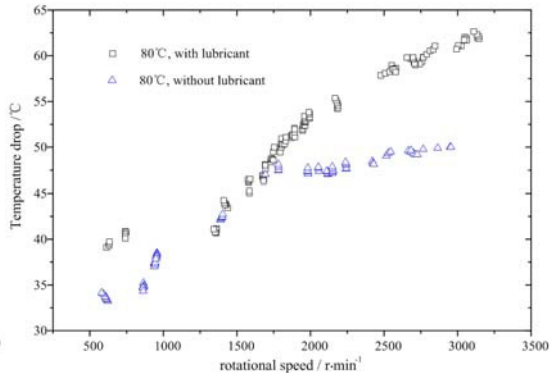


Fig. 5. relation between temperature drop and rotational speed

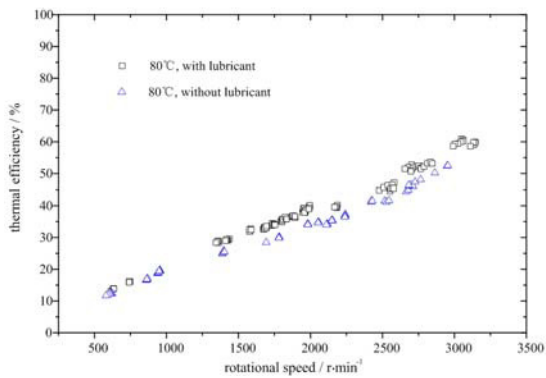


Fig. 6. relation between thermal efficiency and rotational speed

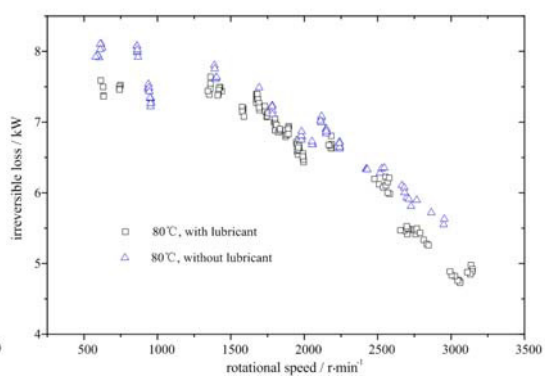


Fig. 7. relation between irreversible loss and rotational speed

From the above figures, it can be seen that because of the sealing and lubricating of lubricant,

- At the same rotational speed, the single screw expander with lubricant has a bigger power output.
- At the same rotational speed, the single screw expander with lubricant has a smaller gas consumption rate.
- The expansion ratio of expander decreases with the increase of rotational speed. The expander with lubricant has a bigger expansion ratio at the same rotational speed.
- At the same rotational speed, the expander with lubricant has a bigger temperature drop.
- At the same rotational speed, the expander with lubricant has a bigger thermal efficiency, but the efficiency increase is not very significant.
- At the same rotational speed, the expander with lubricant has a smaller irreversible loss.

4. Conclusion

In order to test the application of single screw expander in geothermal exploitation, compressed air was used as working fluid to conduct experimental study at different temperature. The results show that at the same rotational speed, the single screw expander at a higher air temperature has a bigger output power, a smaller gas consumption rate, a bigger expansion ratio, a bigger temperature drop, a higher thermal efficiency, and a smaller irreversible loss. Moreover, if a lubricant circle is added in the experimental system, the single screw expander with lubricant at a lower air temperature will have the same performance as the expander without lubricant at a higher air temperature. Therefore, the performance of single screw expander can be improved by adding a lubricant circle and raising compressed air temperature.

Acknowledgements

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Biography

Prof. Jingfu Wang got this doctor degree from Tohoku University, Japan. Now he works in Beijing University of Technology and his research interest is utilization technology of renewable energy and basic theory of combustion and pollution control mechanism.