The experimental investigation of gas-coupled free piston Stirling generators

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Abstract

This paper presents an experimental investigation into the operation of gas-coupled free piston Stirling generators (FPEG), which are connected through a bypass pipeline between the compression cavities. The impact of different input power on the variation of parameters and the vibration characteristics of the generator shell were investigated. The results show that discrepancies between the two generators in terms of output power, phase and hot end temperature were insignificant as the input power increased. The two generators were found to be capable of cooperative operation through the action of gas coupling, with a maximum acceleration of the shell vibration being less than 0.2g, establishing a basis for further investigation into the vibration damping of FPSG has been established.

Structure of experimental apparatus and experimental process

The free piston Stirling generator has the advantages of high efficiency, low noise, few moving parts, long life. The structure diagram of FPSG is shown in Fig.1, including heater, expansion space, displacer, cooler, compression space, piston, alternator, flexural spring, bounce space, hall sensor and shell. The working process of Stirling generator can be simply summarized as that the hot end of the generator is heated by the heater, and the heat is transferred to the working medium. The working medium is heated and the pressure is raised. The displacer and the piston are pushed to reciprocate under the force of the blade spring to generate electricity.

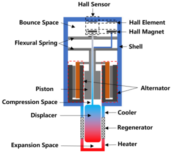

Figure 1. Stirling generator structure diagram

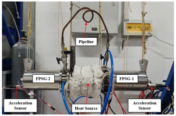

Figure 2. Physical diagram of gas-coupled opposed free piston Stirling generators

The two Stirling generators are placed in a coaxial direction, and the housing is connected as a whole with a connecting tool. The two compression chambers are connected by a gas pipe with a length of 950mm and an inner diameter of 5mm. The steps of this experiment can be summarized as follows: The hot end is heated through the heating rod. When the temperature of the hot end rises to the starting temperature, an instantaneous incentive is given to the generator, and the generator is started. After the generator runs steadily, various parameters are recorded. Then changing the input power and waiting for the generator to stabilize again, the operator observes its operation, and records data once more.

The physical diagram and Schematic diagram of gas-coupled opposed free piston Stirling generator are shown in Fig.2 and Fig.3.

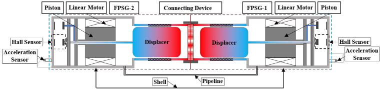

Figure 3. Schematic diagram of gas-coupled opposed free piston Stirling generators

Results and analysis

The amplitude change curve of the displacer piston and piston of FPSG-1 and FPSG-2 with input power of 1514W over time is shown in Fig.4. At this time, the two generators can work together, and the phase difference between the two displacers and the two pistons is very small. The phase difference between the displacer and the pistons is 8.37° and the phase difference between the pistons is 8.57° . Basically, it can be considered that the two displacers and pistons can maintain opposite movement.

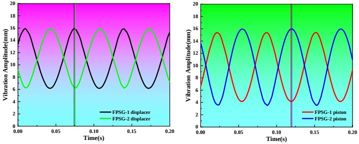

Figure 4. Variation curve of amplitude of displacer and piston with time

As can be seen from Fig.5, with the increase of input power, output power increases accordingly. With the input power increased from 995W to 2024W, the output power difference decreased from 1.33% to 0.05%. It can be clearly seen from the output power change curves of FPSG-1 and FPSG-2 that the power difference decreases with the increase of input power, and the temperature difference at the hot end also decreases with the increase of input power, with a maximum of less than 0.2°C, as shown in Fig.6. Under the action of gas coupling, the common heat source can control the reasonable distribution of input heat between the two FPSGs through feedback regulation, so that the output power is consistent and the difference between the output power of the two generators is reduced.

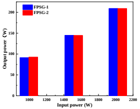

Figure 5. The change of two generators output power with the input power

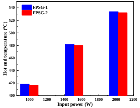

Figure 6. Temperature change of the hot end of two generators with input power

The amplitudes of the displacers and the pistons of the two generators both increase with the increase of input power. As shown in Fig.7, the amplitude difference of two displacers is relatively small, which is controlled within 3%. The amplitude difference of two pistons is relatively large and is controlled within 10%.

The change of shell vibration acceleration with input power is shown in Fig.8. Under cooperative operation conditions, the shell vibration acceleration can be controlled within 0.2g for the gas-coupled dual-engine opposition system with shared heat source. Compared with the 6.8g shell vibration acceleration generated by a single 250W free-piston Stirling generator, the gas-coupled dual-engine opposition system reduces the shell vibration acceleration by 97.06%, greatly reducing the vibration of the generator.

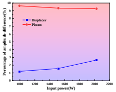

Figure 7. Percentage difference of amplitude with input power

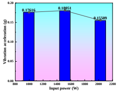

Figure 8. Change of shell vibration acceleration with input power

Conclusion

In this paper, two compression spaces of two generators are connected through the by bypass pipeline, and a gas-coupled dual-engine opposition experimental device is built. The output power, piston amplitude, phase and shell vibration acceleration parameters are analyzed and studied, and the conclusions are as follows:

(1) In the gas-coupled dual-engine opposition system, the two generators can achieve collaborative operation, at this time the difference of the piston phase, hot end temperature and output power of the two generators is small. And the phase difference between the displacers and the pistons is only 8.37° and 8.57° , and the temperature difference at the hot end is less than 0.2°C. And the output power difference is controlled within 1.33%.

(2) The gas-coupled opposition system can effectively reduce the vibration generated by the generator, in which the vibration of the shell mainly comes from the difference in the amplitude of the two generators' pistons. In this study, as the heating power of the system increases from 995W to 2024W, the maximum acceleration of the shell vibration is less than 0.2g under the action of gas coupling. Compared with the 6.8g shell vibration acceleration generated by a single generator, the gas-coupled dual-engine opposition system reduces the shell vibration acceleration by 97.06%.