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# Experimental Study of a Coupled Stirling Generator-Pulse Tube Cryocooler System Driven by a Stirling Engine


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## Abstract

A coupled Stirling Generator-Pulse Tube Cryocooler(FPSG-PTC) system driven by a Stirling Engine was proposed in this work to solve the high temperature failure problem of the linear alternator for space usage. In the system, the Stirling Engine converts heat from hot source to PV power first. Then the PV power actuates the linear alternator for electricity generation and the Pulse Tube Cryocooler for refrigeration simultaneously, where the later one pumps heat from the former to cold end of the Stirling generator. The linear alternator temperature can be controlled by the PV power allocation between it and Pulse Tube Cryocooler system. A prototype was built to validate the feasibility of this proposal, where the Pulse Tube Cryocooler system was connected with the compression space of the Stirling Generator. It shows that, with 300 W heat input and 532℃ at hot end temperature, the Stirling Generator system can output 43.9 W electricity and Pulse Tube Cooler system can reach 61K without heating load.


## Experimental system

❖ Connection structure is a titanium tube with a diameter of 4 mm and a length of 150 mm.

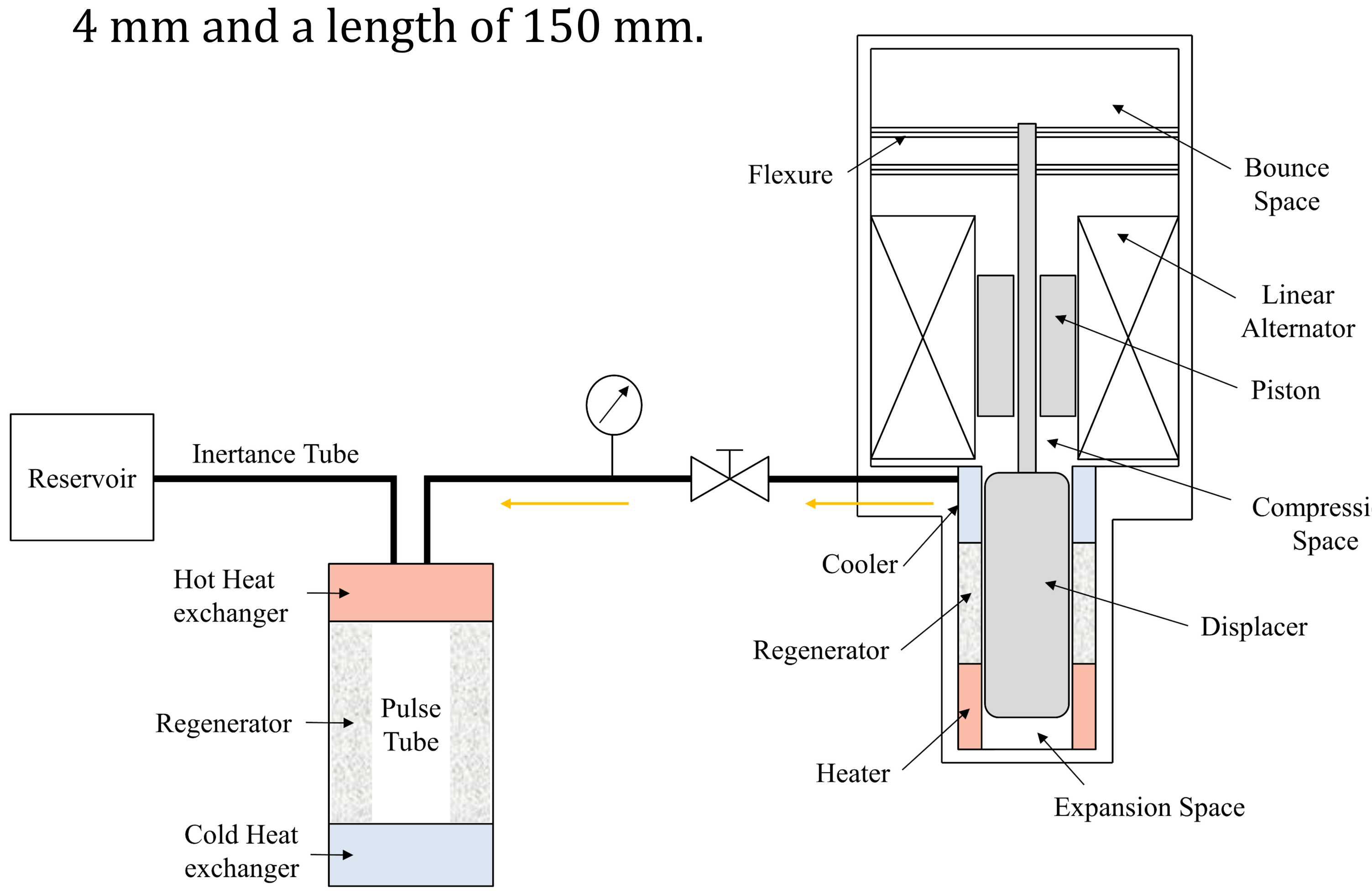



**Figure 1.** Schematic diagram of the coupled system

## Results

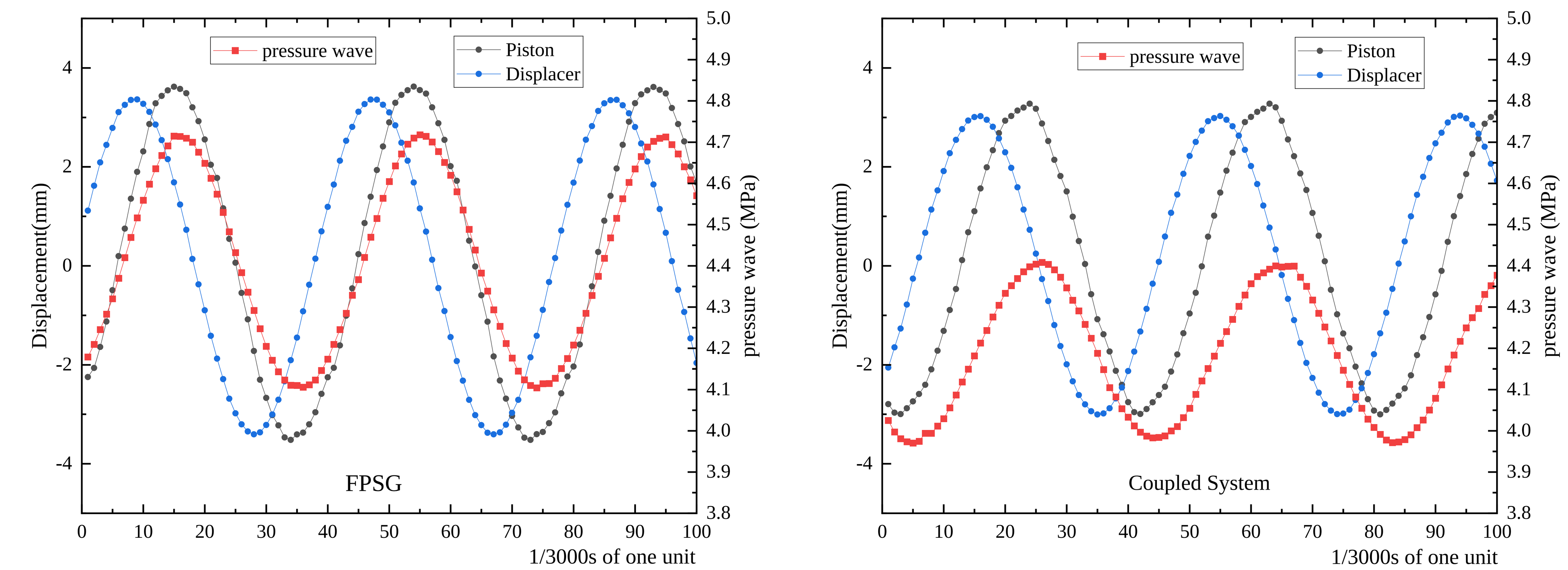
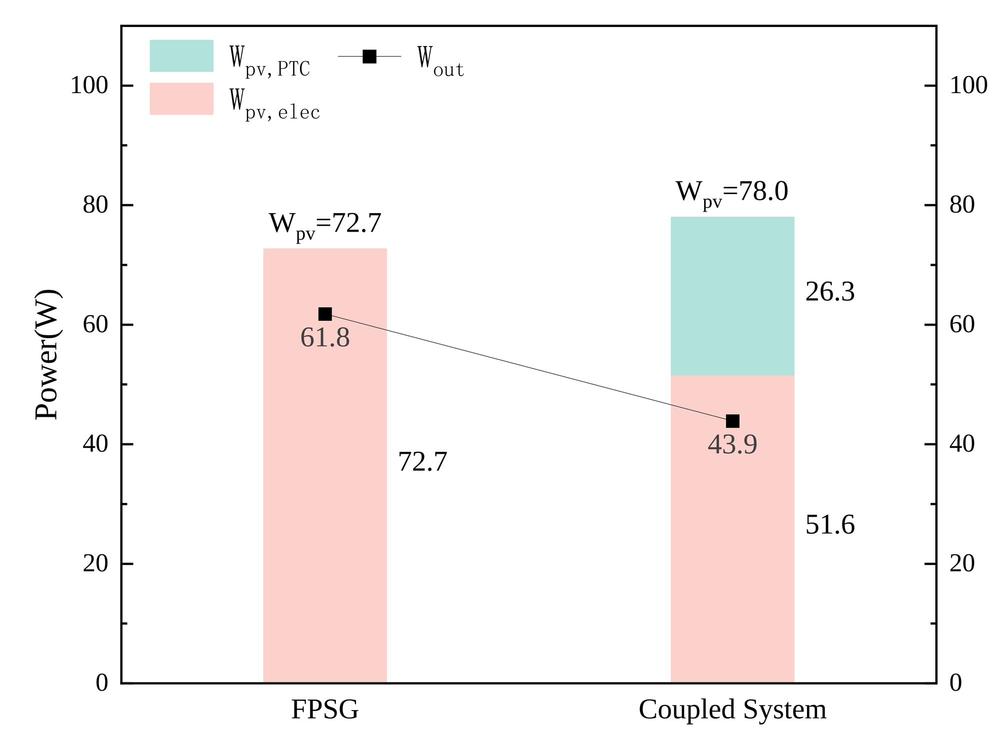



**Figure 2.** Comparison of the pressure waves and pistons displacements before and after coupling.

The amplitude of the pressure wave decreases from 0.3 MPa to 0.21 MPa. The reason is mainly due to the the pressure wave in the compression space doing work not only on the piston, but also on the PTC system.

The phase difference between the piston and pressure wave changed from 7.3° to 20° due to the phase adjustment function of the inertance tube in the PTC system.

For the Stirling single unit, the thermoelectric output efficiency changes from 20.5 % to 14.6 % with power generation and cooling simultaneously. The pulse tube system diverts approximately 33.8 % of the effective work generated by the Stirling engine to achieve a no-load cooling temperature of 61 K.




$$W_{pv} = W_{pv,elec} + W_{pv,PTC}$$

$$W_{pv,elec} = \frac{W_{out}}{\eta_{elec}}$$

**Figure 3.** Comparison of PV power consumed by Linear alternator and PTC system before and after coupling.

After coupling, both cold end and hot end temperatures rise, increasing the temperature difference. The heat absorbed by the gas micro-group at a fixed engine position is fully converted into work due to a constant average temperature. A decrease in pressure wave amplitude results in more significant changes in specific volume, causing a larger temperature gradient.

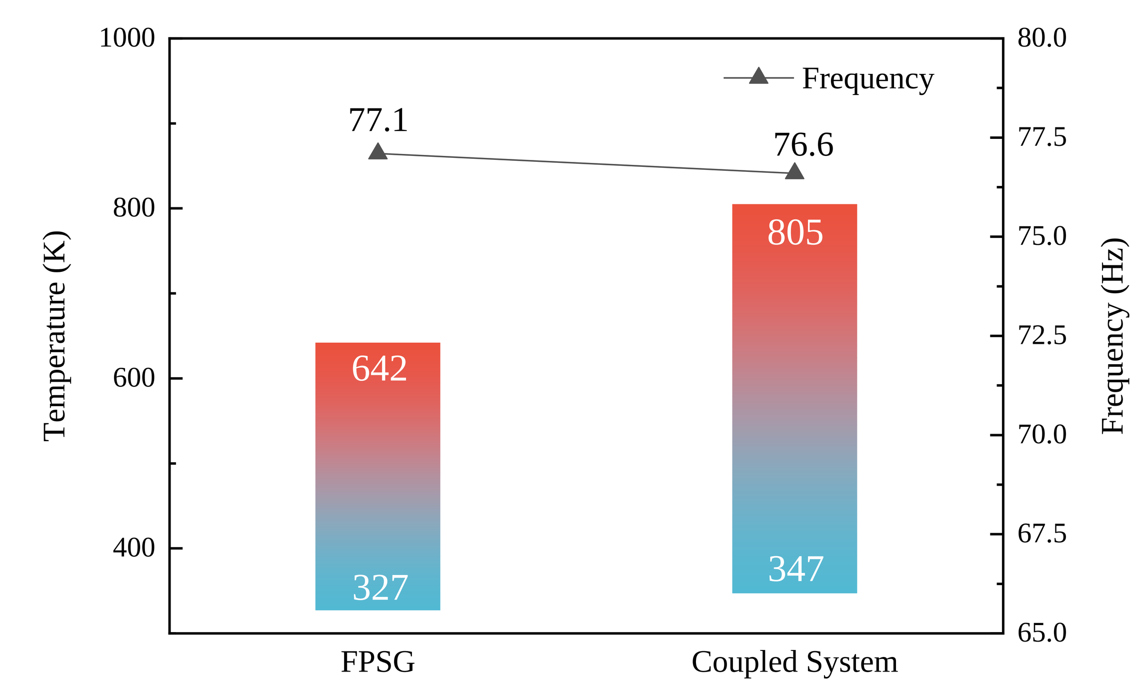



**Figure 4.** Comparison of the hot end temperature, cold end temperature of Stirling system and frequency before and after coupling.

## Conclusions

1. The experimental setup has achieved a lowest no-load temperature of **61 K** and output **43.9 W** electricity with **300 W** heat input.
2. The experimental results demonstrate that incorporating the pulse tube system has multifaceted effects. Reductions in amplitude and phase of pressure waves influence the displacement of the generator piston and the temperatures at the hot and cold ends, thereby affecting system output PV power.