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Experimental Study on Dynamic Characteristics of Gas Spring Resonant System

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Abstract

Using gas spring instead of planar spring in compressor or Stirling generator is an effective way to improve the reliability of engines. In this paper, rotation vector decomposition method and system resonance method to test the equivalent stiffness of a gas spring system are introduced and experimentally compared. The results show that the gas spring stiffness measured by the two methods is basically the same, with a maximum difference of less than 10%. In addition, the effects of initial pressure and piston amplitude on the stiffness and damping characteristics of the gas spring system are analysed, it is found that initial pressure is proportional to the stiffness of the gas spring and damping component of the gas force, while piston amplitude has little effect. The study provides a reference for the structural design of gas springs.

Methods of gas spring stiffness

1.System resonance method

$$W = \int F dx = \frac{1}{2} BL|I||dx|\cos\langle I, dx\rangle$$

Find f when $\cos\langle I, dx\rangle = 1$

$$k_g = m(2\pi f)^2 - k_m$$

2.Rotation vector decomposition method

$$\Delta \boldsymbol{p}A = \boldsymbol{F_{gas-x}} + \boldsymbol{F_{gas-v}}$$

$$k_g = \frac{dF_{gas-x}}{dx_p} = \frac{d(\Delta pA\cos\langle p, x\rangle)}{dx_p}$$

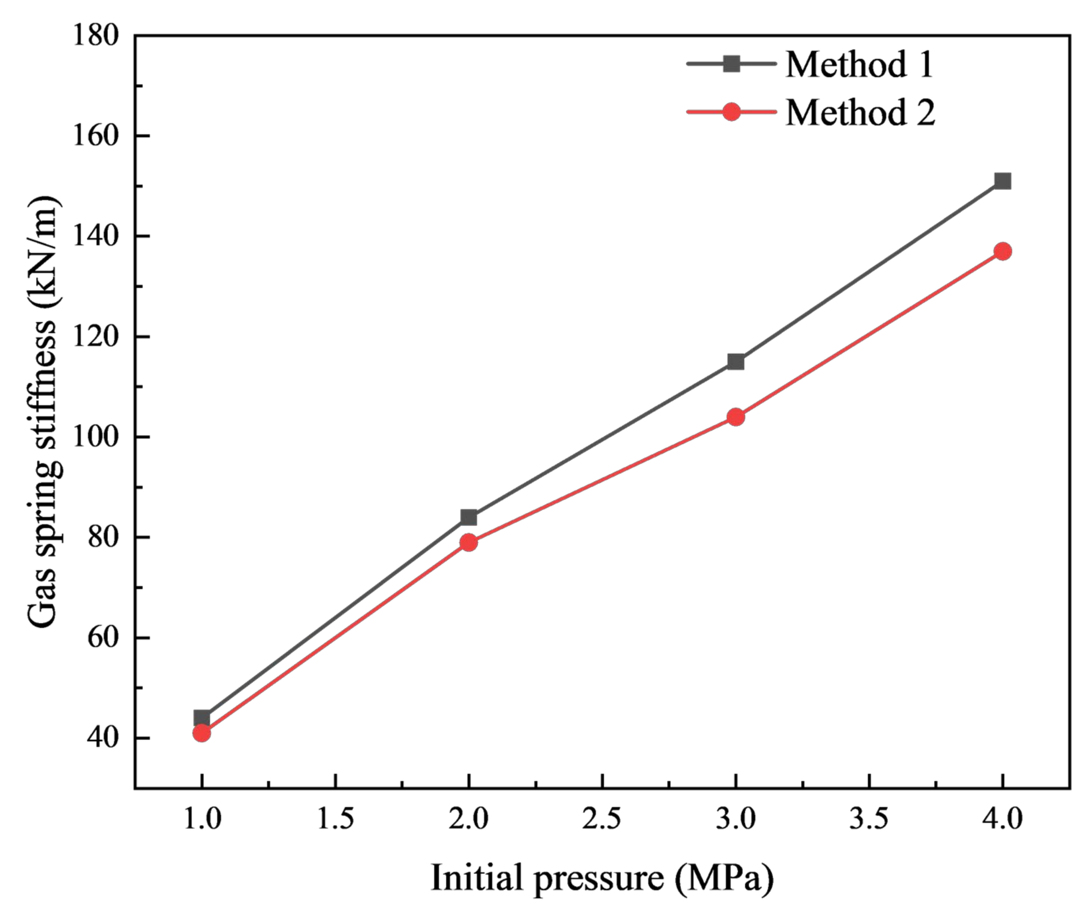

Figure 1. Comparison of two methods

- Both methods can be used to calculate the gas spring, and the maximum error is less than 10%. However, method 2 can not only measure the stiffness of the gas spring in the non-resonance state, but also obtain the dynamic stiffness of the gas spring in different motion states.

Establishment of experimental system

The AC power source supplies power to the linear motor, drives the reciprocating movement of the piston, and changes the volume and pressure of the gas spring space.
The pressure of the gas spring space is recorded by the pressure sensor, the laser displacement sensor records the displacement of the piston, and the dynamic change of the current is recorded by the current clamp.

Calculate: $F_{gas} = (p - p_0)A_p$

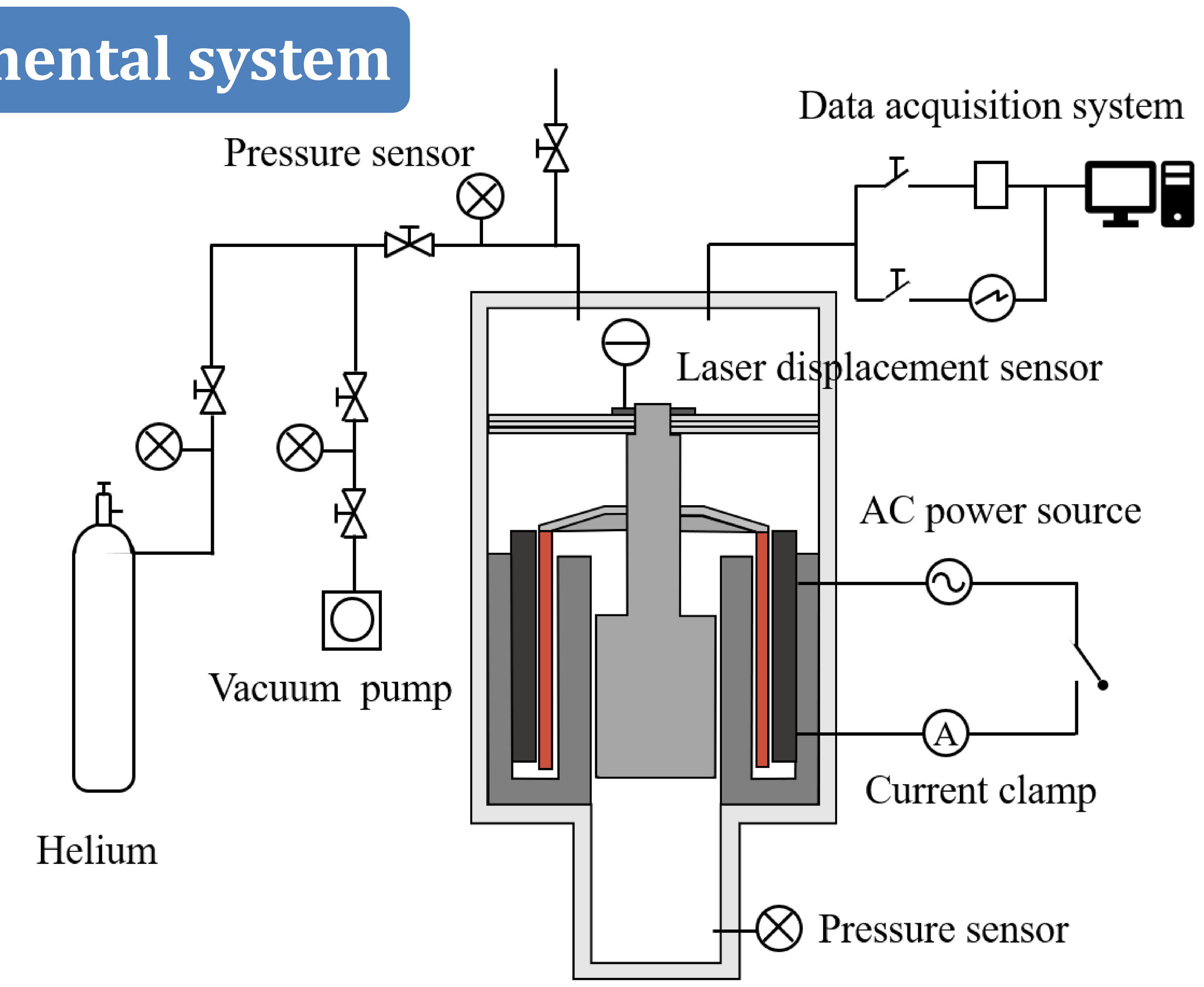

Figure 3. Experimental system diagram

Influence of initial pressure& piston amplitude

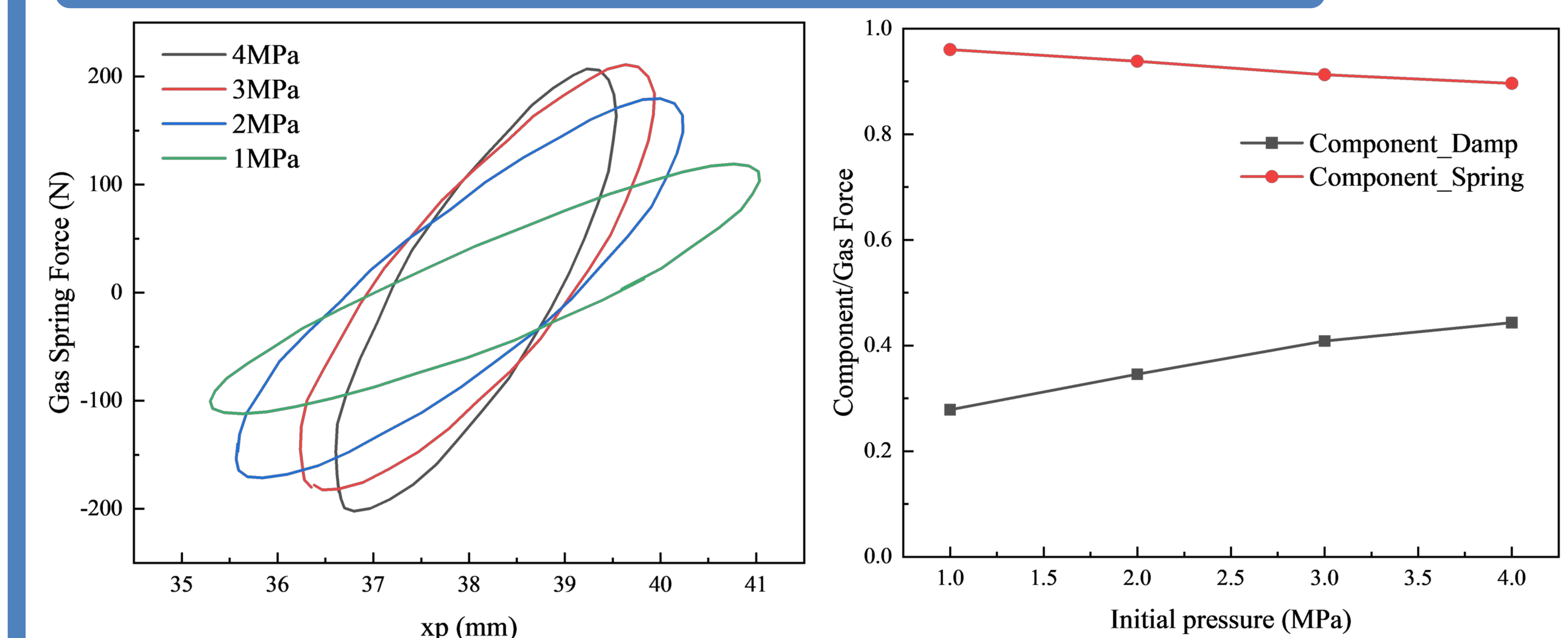

Figure 5 (a). Gas spring force changes with initial pressure; **(b).** Gas Force Proportion Variation via initial pressure

- The values of gas spring force are different at the same position.
- Initial pressure ∝ Stiffness of the gas spring
- Component_spring is higher than Component_damp at the same initial pressure.
- Initial pressure ∝ Damping component of the gas force

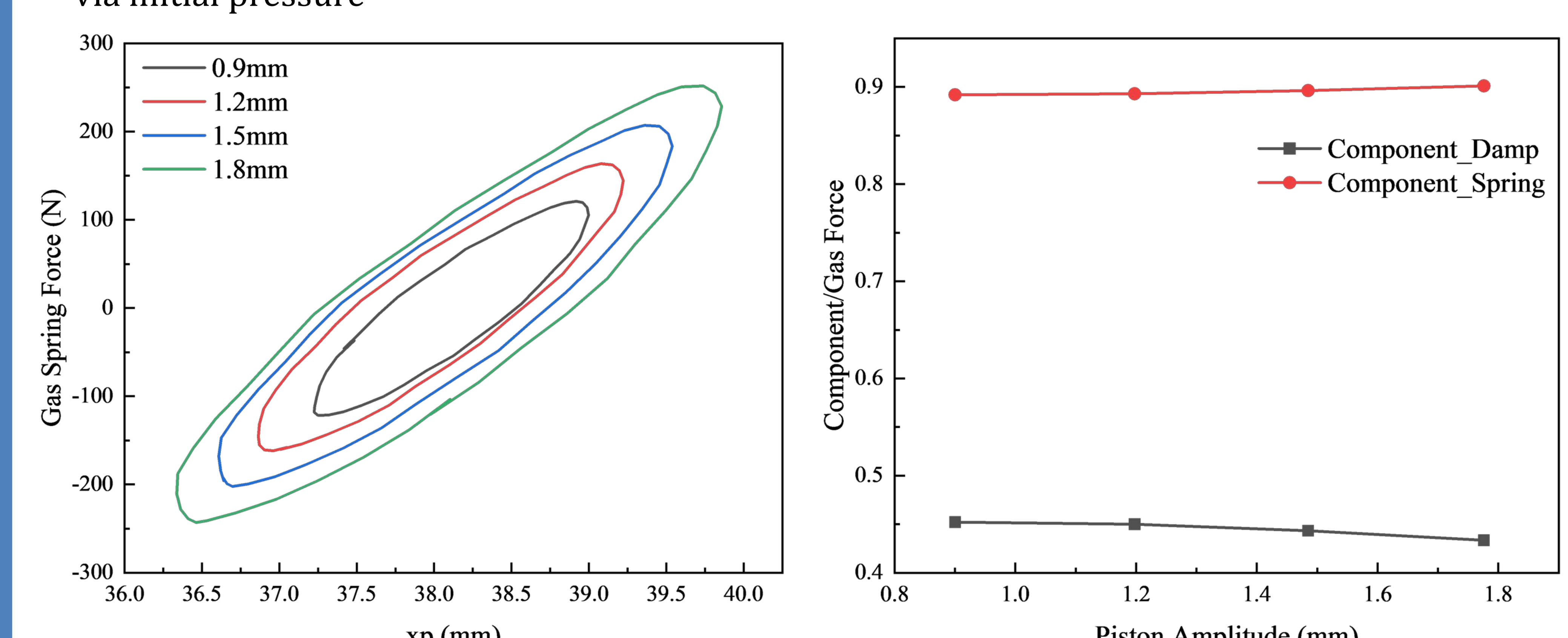

Figure 6(a). Gas spring force changes with piston displacement; **(b).** Gas force Proportion Variation via piston amplitude

- The AC power source provides different excitation voltages that change the amplitude of the piston.
- The change of piston amplitude has little influence on the stiffness characteristics of the gas spring and the proportion of the spring component and the damping component.

Conclusion

(1) The rotation vector decomposition method and system resonance method are used to test the gas spring stiffness and experimentally compare. The results show that the gas spring stiffness measured by the two methods is basically the same, with a maximum difference of less than 10%.
(2) The initial pressure of the gas spring chamber is proportional to the damping component of the gas spring stiffness and gas force.
(3) The piston amplitude has little effect on the stiffness of the gas spring and the proportion of each component.