# Investigation on the influence of the clearance of linear alternator on thermoacoustic electricity generator without resonator

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## Background

The clearance of linear alternator plays an important role in the performance of thermoacoustic electricity generator without resonator. It not only effects the leakage through it, which has a direct influence on the differential pressure, but also the damping of the linear alternator. So a suitable clearance has significance for thermoacoustic electricity generator.

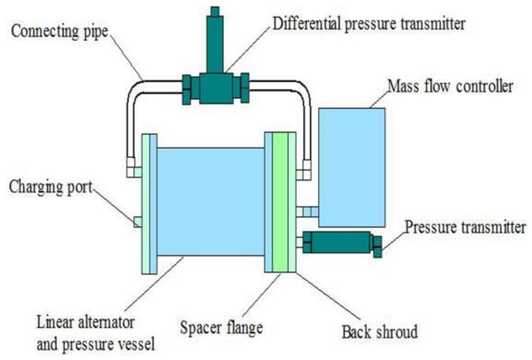
## Objectives

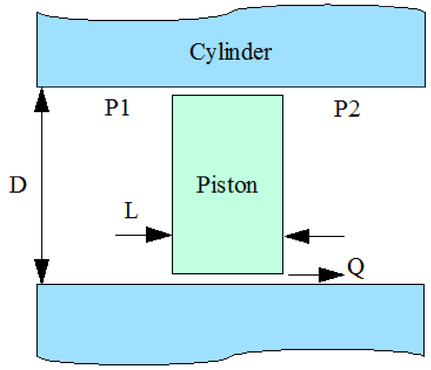
- Finding an exact formulae of clearance, and this would be useful for us to get an appropriate clearance.
- Analyze the influence of clearance and damping through simulation and experiment

## Conclusion

- Data processing result shows that the formulae based on mass leakage is closer to the actual situation than volume leakage.
- The smaller clearance and damping the higher electric power, but the smaller clearance the larger damping.
- In practical application, an equilibrium point of clearance and damping for a higher electric power should be got with the consideration of machining accuracy and assembly technique.

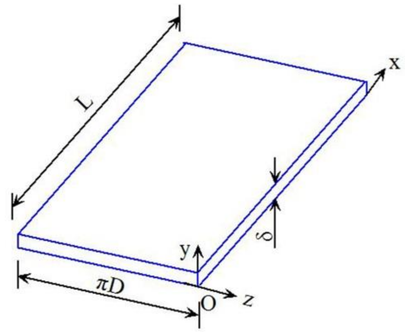
## Measurement equipment and mechanism



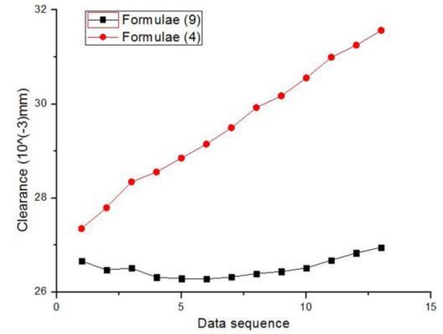

During the nitrogen charged into the pressure vessel, the gas will flow through the clearance slowly. The pressure transmitter measures the pressure before piston, $p_2$. The differential pressure transmitter measures the differential pressure, $\Delta p$, between the front and rear of the piston. Then, we can get the pressure after piston,$p_1 = p_2 + \Delta p$. The leakage, $Q$, can be measured by mass flow controller. In the measuring experiment, thirteen sets of data have been recorded at every equilibrium condition.

## Data processing



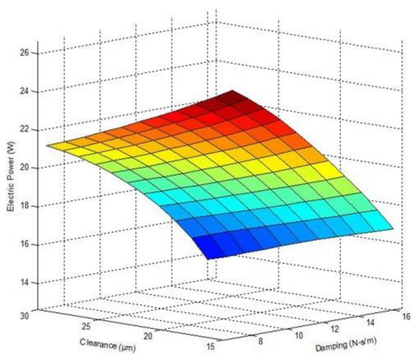

Formula (4) based on volume leakage $\delta = \left(\frac{12\mu LQ}{(p_1-p_2)\pi D}\right)^{\frac{1}{3}}$

Formula (9) based on mass leakage $\delta = \left(\frac{24p_2\mu LQ}{({p_1}^2-{p_2}^2)\pi D}\right)^{\frac{1}{3}}$




The result of formula (9) is between 26.2~26.96μm that is closer to the actual clearance. While the result of formula (4) is between 27.3~31.6μm, the span is larger and this is the deviation from actual.

## Simulation result




$$Q = \frac{({p_1}^2 - {p_2}^2)\pi D\delta^3}{24\mu\rho RTL} \qquad Z_m = \frac{R_m}{A^2} + \frac{i\left(\omega M - \frac{K}{M}\right)}{A^2} = \frac{\Delta p}{Q}$$

The bigger the clearance the bigger the leakage, and the equivalent impedance of the clearance branch becomes smaller, so the engine performance gets worse.

The bigger the damping the smaller the leakage, and the piston peak stroke becomes smaller and this will cause a smaller induced electromotive force. As a result, the engine performance gets worse.

The decrease of clearance and damping can improve the electric power. While in table1, it is very clear that the damping decreases when clearance increases. This becomes difficult for seeking smaller clearance or damping only to get a high electric power. The trick is considering clearance and damping at the same time and finding an equilibrium point of them.

## Experiment result

The electric power results from experiment is consistent with simulation, and the relative error is just lower than 6%. The difference is when the clearance is 30μm, the engine didn't oscillation in experiment. This is because with the increase in clearance, the leakage through the clearance increases, and the differential pressure before and after the piston decreases, and then the gas force decreases. When the phase difference between pressure and displacement remains the same, the component force of the gas force in phase with the speed, which is also named useful gas force, decreases. When the clearance is too large, the useful gas is too weak to push the piston, so the engine cannot oscillation.

Table1 Results of simulation and experiment

| Clearance (μm) | Damping(N-s/m) | (Simulation) Electric power(W) | (Experiment)Electric power(W) |
|---|---|---|---|
| 15 | 16 | 25.9 | 24.72 |
| 25 | 10 | 19.26 | 18.16 |
| 30 | 7 | 16.89 | No oscillation |