DYNAMICS OF FORCED SYNCHRONIZATION IN THERMOACOUSTIC SYSTEM

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Introduction

When an oscillator with a natural frequency f_0 is put under the influence of a periodic force with frequency $f \sim f_0$, a variety of phenomena can be observed. When the influence is unidirectional, 1:1 forced synchronization takes place in a triangular region called Arnold tongue on a plane of detuning $\Delta f = f - f_0$ vs. forcing strength. In the lower part of the synchronization region with relatively weak forcing, the oscillator goes from phase drift to phase locking regions through a saddle-node bifurcation. In the upper part with a strong forcing, it enters suppression region through torus-death bifurcation, where the amplitude of natural oscillations are damped by external force. The boundary between phase drift and suppression or phase locking region has been observed [1], [2]. However, boundary of saddle-node and torus-death bifurcation in synchronous state has not been observed experimentally. In this study, we experimentally observe the dynamics of oscillator in synchronous state in forced synchronization in thermoacoustic system.

Experimental setup

Experiments are performed on thermoacoustic oscillator shown in figure 1. The oscillator with a straight resonant tube is filled with atmospheric air at room temperature. The regenerator is sandwiched by hot and cold heat exchangers. External force is supplied by the acoustic driver composed of the speaker and the bellows. The oscillations of the external forced oscillator system are examined by measuring the acoustic pressure with a pressure transducer mounted on the closed end of resonant tube.

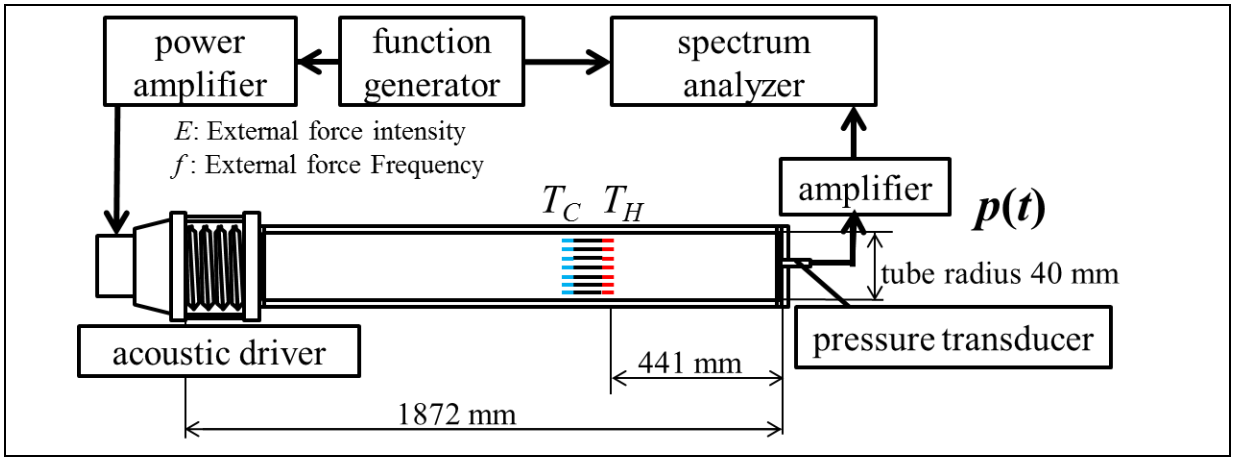

Figure 1: *The experimental setup*

The time-series data of the pressure is projected onto the real part on a complex plane and imaginary part of the signal was obtained by Hilbert transformation. And the complex plane itself is rotated with frequency of external force. When the system is in an asynchronous state, the trajectory of pressure on the complex plane rotates with angular velocity resulting from the frequency difference between external force and oscillator. When the system is synchronized, the trajectory comes to rest. To observe the dynamics of oscillator in synchronous state, we added perturbation to break the synchronous state once and observed trajectory to be synchronous again.

Results

The Arnold tongue and dynamics in synchronous state are shown in figure 2. In the synchronous process with a weak forcing (D−>A), rotation of trajectory became slow and stopped (saddle-node bifurcation). In the synchronous process with a strong forcing (D−>B), trajectory radius became small and stopped (torus-death bifurcation).The trajectory rotated without including the origin in region C (phase modulation). The dynamics of oscillation in synchronous region was different between week forcing and strong forcing region. In the case of weak forcing, trajectory moves along a circular orbit which is traces of natural oscillation (phase locking). However, trajectory does not move along in the case of strong forcing (suppression).

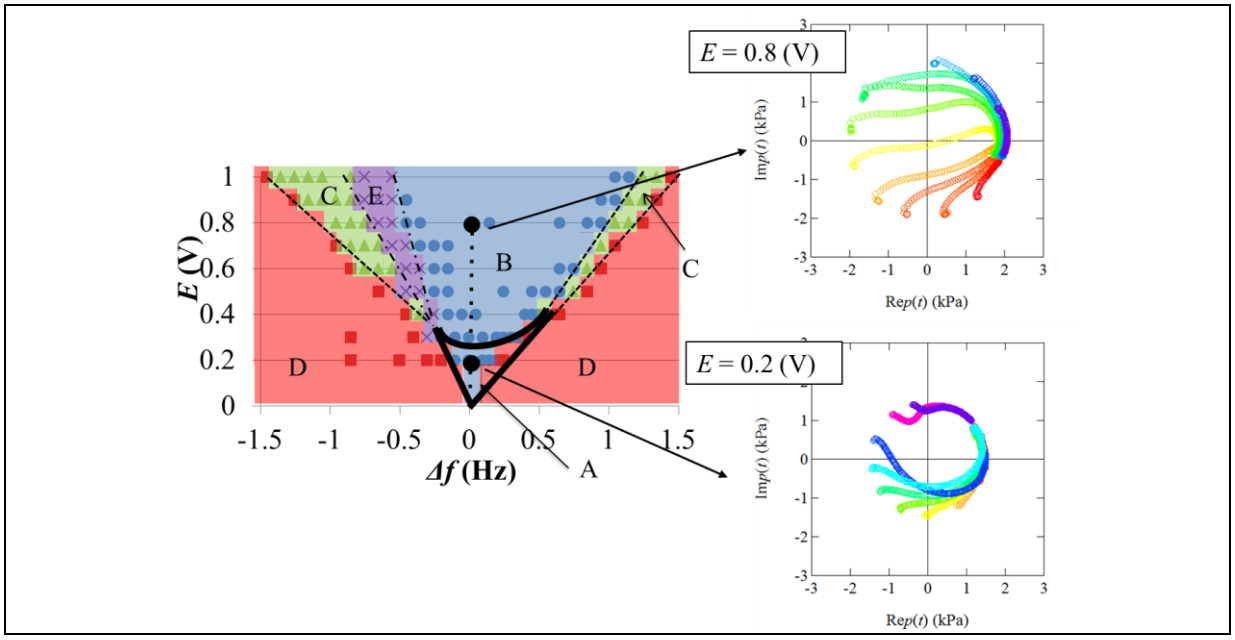

Figure 2: *The synchronous region and synchronous state.*

Summary

The dynamics of oscillator in synchronous state are experimentally observed in forced synchronization in thermoacoustic system by observing the trajectory of oscillation in complex plane. The dynamics of oscillation in synchronous region was different according to the strength of external force.

References

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