A Study on Transonic Tone Generation in Convergent-Divergent Nozzles

申, 昇永

https://doi.org/10.15017/1398550

出版情報：九州大学, 2013, 博士（工学）, 課程博士
バージョン：

氏　　名：申 昇 永

論文題名：A Study on Transonic Tone Generation in Convergent-Divergent Nozzles
(先細末広ノズル内のトランソニックトーン発生に関する研究)

区　　分：甲

論 文 内 容 の 要 旨

Supersonic jet noise problems have long been a very important issue in many diverse engineering applications such as supersonic aircraft, jet propulsion thrust vectoring, fuel injection for supersonic combustion, soot blower devices, thermal spray devices, etc. In general, it is known that the supersonic jet noise consists of three major components: the turbulent mixing noise, the broadband shock-associated noise, and the screech tones. However, according to recent report, the transonic tone can occur independently of the general noise components at low nozzle pressure ratios when a shock wave occurs within the divergent section of convergent-divergent nozzle without any abrupt area change. About the transonic tone, a great deal of experimental and numerical research of the diffusion of the transonic tone has been carried out. Especially, Zaman et al. investigated the characteristics of the transonic tone in various nozzle conditions, and provided correlation equations to predict the frequency from a collection of data for single round nozzles. Moreover, they showed that transonic tone takes place similarly to the (no-flow) longitudinal acoustic resonance of a conical section with one end closed and the other end open. However, it remains unclear under what process the transonic tone can occur in actual flow complicated by shock oscillation and shock wave/boundary layer interaction phenomenon. The primary objectives of this thesis are to investigate the characteristics and generation mechanism of transonic tone at low nozzle pressure ratios when shock wave occurs within the supersonic nozzle.

These objectives are accomplished by experimental works. Three major objectives of the present work are listed as follows: The objectives are

(1) To understand the acoustic characteristics of transonic tone and its variation according to nozzle pressure ratio and to examine which region has the transonic tone source by comparing the nozzle-lip thickness effects on the transonic tone frequency and amplitude with screech tone’s one
(2) To investigate the relationship between the transonic tone and the first shock wave oscillation or wall static pressure fluctuation when the transonic tone occurs.
(3) To examine the effect of nozzle-lip length on transonic tone as a supplement the validity of feedback mechanism of transonic tone.

In Chapter 1, the background and research progress of general supersonic jet noise and transonic tone have been briefly explained. The motivation and major objectives of the present thesis are also described in this chapter.

In Chapter 2, the fundamental acoustic characteristics of transonic tone and its control techniques are explained as a literature review.

Chapter 3 gives a full description of the facility and experimental apparatus used for the present work.

In Chapter 4, the acoustic characteristics of transonic tone and the effects of nozzle-lip thickness on the transonic tone in axisymmetric convergent-divergent nozzle are discussed with comparing the acoustic characteristics of screech tone according to the nozzle-lip thickness variation.

Chapter 5 describes an experimental work to investigate characteristics and generation mechanism of the transonic tone in 2-dimensional supersonic nozzle. In particular, the frequency of the first shock wave oscillation and wall static pressure fluctuation are analyzed and tried to correlate to the transonic tone and a feedback mechanism for generation of transonic tone is proposed.

Chapter 6 describes an experimental work to investigate the effect of nozzle-lip length on transonic tone in 2-demensional supersonic nozzle.

Chapter 7 summarizes the important findings obtained from Chapter 4, 5 and 6. And some recommended directions for future research are also suggested.

The results obtained obviously show that the acoustic characteristics of transonic tone are different from the screech tone. And distinctly from the screech tone, it is found that the transonic tone has internal noise source.

When the transonic tone occurs, the frequencies of the shock wave and wall static pressure fluctuations correspond to the transonic tone and it is expect that there is a feedback loop between the shock wave and the nozzle exit but it is not clear yet.

And the transonic tone reduced at stage 1 about 5~10 dB when the nozzle-lip attached at the side of large separation zone in the nozzle and the extended nozzle-lip also affected the shock wave oscillations, wall static pressure fluctuations and cross-correlations between the shock wave and the wall static pressure fluctuations.