Experimental Investigation on Noise Suppression in Supersonic Jets from Convergent-Divergent Nozzles with Baffles

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The acoustic properties of supersonic jet noise from a convergent-divergent nozzle with a baffle have been studied experimentally over the range of nozzle pressure ratios from 2.0 to 8.0. Acoustic measurements were conducted in a carefully designed anechoic room providing a free-field environment. A new approach for screech noise suppression by a cross-wire is proposed. Schlieren photographs were taken to visualize the shock wave patterns in the supersonic jet with and without the cross-wire. The effects of the baffle and the cross-wire on acoustic properties are discussed. It is shown that the baffle has little effect on the screech frequency for the underexpanded supersonic jet without the cross-wire. Also, the cross-wire introduced in supersonic jets is found to lead to a significant reduction in overall sound pressure level.

Keywords: convergent-divergent nozzle, noise suppression, screech tone, supersonic jet.

Introduction

It has been widely recognized that surfaces in the near field such as a thick nozzle lip or a plenum flange significantly alter the characteristics of a jet noise. Supersonic jets from nozzles with such surfaces are pertinent to valves of various shapes operating at a high pressure ratio, sootblower nozzles for boiler cleaning, and nozzles for other engineering applications. Under certain operating conditions, jets from nozzles produce a discrete tone referred as screech. Although many investigations have been carried out on the jet noise from nozzles with such surfaces, almost all of the past studies were on the jet noise from convergent nozzles with baffles. Therefore, the details of the jet noise from convergent-divergent nozzles with baffles largely remain unknown.

Various approaches such as mixer-ejector nozzles and small tabs on a nozzle exit have been used or proposed to overcome the noise issue. However, these approaches result in the extra equipment and the mass consumption of gas, and a drastic decrease in total pressure along the jet centerline, respectively. Also, although reflector surfaces have been used to suppress screech noise by some researchers, the details of the jet flowfield affected by the surfaces are far from clear.

The present investigation concerns supersonic jets from axisymmetric convergent-divergent nozzles with baffles which are the most basic flow element in many technological applications and intends to understanding of such noise fields. Also, we propose a new method for the screech noise suppression and examine the effects on the acoustic properties of the method experimentally.

Experimental Facility and Procedure

The experiment was conducted in an anechoic room of the Gasdynamic Laboratory at Kyushu University in
Kasuga, Fukuoka, Japan. A plan view of the room and the small supersonic jet facility is shown schematically in Fig.1. The overall dimensions of the room are approximately 4.9X4.6X4.6 meters. The room is lined with about 300 mm thick acoustic absorption material to dampen the reverberant sound field. The room is anechoic at all frequencies above approximately 120 Hz. The jet facility consisted of a cylindrical plenum chamber, 164 mm in length and 97.1 mm in diameter. The nozzle with a design Mach number of 1.5 was attached to a brass plenum flange of 240 mm in diameter and 47 mm in thickness. The plane of the plenum flange, i.e., the baffle surface was perpendicular to the nozzle axis and positioned at just nozzle exit plane. A wide range of nozzle pressure ratios was selected to cover the conditions for strong embedded shocks in both the overexpanded and underexpanded ranges of converging-diverging nozzles. In terms of the parameter $\beta = (M_j^2 - 1)^{1/2}$, the pressure ratio range varied as $0.3 < \beta < 1.8$, where $M_j$ is the fully expanded Mach number. $M_j$ is related to the nozzle pressure ratio $p_0/p_b$ as

$$M_j = \sqrt{\frac{2}{\gamma - 1} \left( \frac{p_0}{p_b} \right)^{(\gamma-1)/\gamma} - 1}$$

where $p_0$ is the stagnation pressure in the plenum chamber, $p_b$ the back pressure, and $\gamma$ the ratio of the specific heat of the gases.

Fig.2 shows the arrangement of the convergent-divergent nozzle with a baffle and the wires used for noise suppression. As shown in Fig.2, the two piano wires of 0.5 mm in diameter and 20 mm in length soldered crosswise on the centerline of each wire were strung across the flow and placed with support wires of 25 mm long and 0.5 mm diameter from the nozzle plane. We call the wires including the support wires a cross-wire in the present paper.

Acoustic measurements were made with a 1/4 in. diameter Ono Sokki MI-6420 condenser microphone and an associated CF-0610 microphone amplifier and power supply. As shown in Fig.1, the microphone was positioned 160 mm from the jet centerline and the radial position was 200 mm from the center of the nozzle exit plane. Spectral analyses of the noise signals were made with an Ono-Sokki Model DS0221 FFT analysis software, with a bandwidth of 50 Hz. A conventional schlieren system with a spark source of a 20 ns pulse duration was used to visualize the noise field including shock waves.

**Results and Discussion**

**Schlieren visualization**

The visualizations were carried out for a fixed value of a nozzle pressure ratio defined by $p_d/p_b$, where $p_0$ is the stagnation pressure in a plenum chamber and $p_b$ the back pressure which is the same as an atmospheric pressure. The nozzle pressure ratio was adjusted by altering the plenum pressure manually. Fig.3 is typical schlieren pictures showing underexpanded supersonic jets from a convergent-divergent nozzle with and without the cross-wire. The $p_d/p_b$ for the flow was 5.0 and the flow was from left to right. A knife edge was

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**Fig.1 Experimental facility**

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**Fig.2 Arrangement of wires for noise suppression**

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**Fig.3 Typical schlieren photographs of supersonic jets with and without cross-wire**

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