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Frequency analysis of noise around supersonic jet

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Three kinds of noises, turbulent mixing noise, screech noise and broadband shock-associated noise are known to be generated around an under-expanded supersonic free jet [Tam, 1995]. Since screech tone has a sharp peak at a specific frequency and causes problems such as noise pollution and destructive structural fatigue, the generating mechanism and the noise characteristics such as the amplitude and the frequencies have been investigated by many researchers ever since Pawell [1953] first reported its existence. The screech tone is usually generated when the nozzle pressure ratio is in the range of 2 to 6, and most studies of the noise is performed for that pressure ratio range by using microphones. This study is performed in the higher pressure ratio range. Experiments of the sound pressure measurements are carried out by using a microphone. In addition, the density field around the free jet is also visualized by using an optical technique. The flow visualization technique is found to be useful in studying the acoustic noises.

Under-expanded free jet is generated by releasing high pressure air into the atmosphere through a circular hole of 5mm diameter. The air pressure is controlled by a regulator and is measured by a pressure transducer located upstream of the nozzle hole. Jet noises are measured at downstream of the nozzle hole by a condenser microphone (RION UC-54) and the data are stored in PC through the amplifier (RION UN-14). Three different nozzle geometries, straight-type, diverging-type and converging-type are used in the experiment. The optical flow visualization technique of Schrielen method with double optical passage scheme is used. This method has four times more sensitivity compared with the conventional Schrielen technique

From the flow visualization images obtained for the nozzle pressure ratios from 2 to 6, concentric fringes centered at a point downstream from the nozzle exit in the jet are clearly seen. The frequencies estimated from the fringe intervals and the sound speed agree well with those measured with a microphone. This proves the usefulness of the flow visualization in studying acoustic field.

As the nozzle pressure ratio increases, it is observed that the screech frequency and the sound level also decrease. When the ratio is increased beyond 6, no clear peak frequencies are detected. Instead, in this region, it is observed in the flow visualization images that sound waves are generated at around the nozzle exit and propagates in the direction of the jet. The estimated frequencies of the sound waves from the images are beyond the upper frequency limit of our microphone. It is also found from the flow images that the sound wave frequencies extend broad range without clear dependency on the nozzle pressure ratio. These characteristics of the sound wave correspond to those of turbulent mixing noise.

The acoustic pressure measurements with a microphone and the flow visualization technique of double-light-passage Schrielen method are used in this study to investigate the acoustic field around supersonic free jets. Experimental data of the screech tone obtained with the two different methods agreed well and demonstrated that the flow visualization is an useful method of investigating acoustic problems. The flow visualization technique was applied for investigating the noise generated with the high nozzle pressure ratio. It is found that the noises generated in the pressure ratio region are the turbulent mixing noises.

Keywords: Supersonic free jet, Jet noise, Frequency analysis