International Journal of Mechanical and Industrial Engineering

Volume 3 | Issue 2 Article 6

October 2013

NOISE SOURCE LOCATION OF UNDEREXPANDED NONCIRCULAR SLOT JETS

PANENDRA KUMAR SAHU
Indian Institute of Technology Madras, Chennai, Tamilnadu, India, panendra.sahu0404@gmail.com

K SRINIVASAN
Indian Institute of Technology Madras, Chennai, Tamilnadu, India, ksri@iitm.ac.in

NOISE SOURCE LOCATION OF UNDEREXPANDED NON-CIRCULAR SLOT JETS

PANENDRA KUMAR SAHU[1] & K SRINIVASAN[2]

[1,2]Department of Mechanical Engineering, Indian Institute of Technology Madras, Chennai, Tamilnadu, India
E-mail : panendra.sahu0404@gmail.com, ksri@iitm.ac.in

Abstract - It is generally understood that the non-circular jets exhibit better mixing enhancement and noise suppression properties compared to circular jet. The present paper is on the experimental investigation of near acoustic field and noise source location of non-circular underexpanded jets and comparison with circular jet. Square, triangular, rectangular slot jets are considered in this work. The near field overall sound pressure level contours obtained along transverse plane and spanwise plane of non-circular jets and compared with circular jet for nozzle pressure ratio R at 4 and 5 which is analyzed to get noise source location for various jets. The effect of geometry in acoustic field in near field is highlighted in this paper.

***Keywords -** Jet noise; Non-circular Slot jets; Noise source location.*

I. INTRODUCTION

Flow and noise control in jets is a major area of interest for the engineers involved in the design of combustion and propulsion systems. Here, enormous challenge is posed in enhancement of mixing process and suppression of flow induced noise. While the mixing enhancement is necessary for improved combustion efficiency and prevention of thermal instabilities, noise control is essential for factors such as structural integrity and human safety. In the scenario of high speed jet flows, where the flow is mostly turbulent in nature, use of non-circular cross sections is emerging as an efficient passive mechanism for obtaining proper mixing enhancement and noise control. Generally, the dominant part of noise in subsonic jets is produced by the fine scale turbulence and in supersonic jets, noise is emanated by large scale turbulence [1]. The 'source location' of such noise is governed by large scale coherent structures of the jets which also strongly influence the near field pressure fluctuations [2]. The passive control of noise in non-circular geometries is mainly attained due to the alteration of shear layer evolution [3] wherein mixing is also enhanced due to sets of counter rotating streamwise vortices [4]. Mixing is also further enhanced in selected geometries due to the presence of axis-switching phenomena whose influence has been successfully manipulated with the use of vertex generators by Zaman [5]. In case of supersonic jets, the noise emitted from vertex planes is higher than flat edge planes of non-circular slot jets, as can be seen from the work of Jothi and Srinivasan [6]. In addition to its dependence on the shape of the cross section, the noise suppression characteristics show a contrasting sensitivity with respect to the Nozzle Pressure Ratio (NPR). In other words, the far-field Overall Sound Pressure Level (OASPL) measured by them at lower NPR showed an unfavorable performance by non-circular jets as compared to their circular counterpart and the case is vice-versa at higher NPR. Similar characteristics has been revealed for jets emanating from nozzles by Ahuja *et al.* [7] who explored various strategies including the use of non-circular nozzles for reducing supersonic jet noise. It is important to note here that the underlying mechanism of noise emission in supersonic jets.

II. EXPERIMENTAL SETUP AND PROCEDURE

A. *Test Facility*

The free jet facility is supplied with compressed air from two tanks of capacity $10m^3$, pressurized using a 150-hp two stage reciprocating air-compressor. Air is brought to the settling chamber through four inch plumbing. A needle valve is used for controlling stagnation pressure. The settling chamber has a diameter of 380 mm (ID) . The interior of the settling chamber is arranged with flow controlling meshes of progressive fineness, for decreasing intial turbulence level. Further, in order to reduce the structure-borne acoustic disturbances, the inner wall of the settling chamber is lined with acoustic foam. The settling chamber is smoothly converged to 43.5 mm diameter where disk nozzles are mounted using disk holder.

The whole setup is enclosed in an anechoic chamber of dimensions 2.5 m × 2 m ×2 m (wedge tip-to-tip) to create a free field environment. The lower cut-off frequency of the chamber is 630 Hz. To minimize internal reflections due to the traversing system and other elements, acoustic foam is pasted on all reflective surfaces present inside the anechoic chamber. The experimental setup is shown in figure 1(a.) and 1(b.).

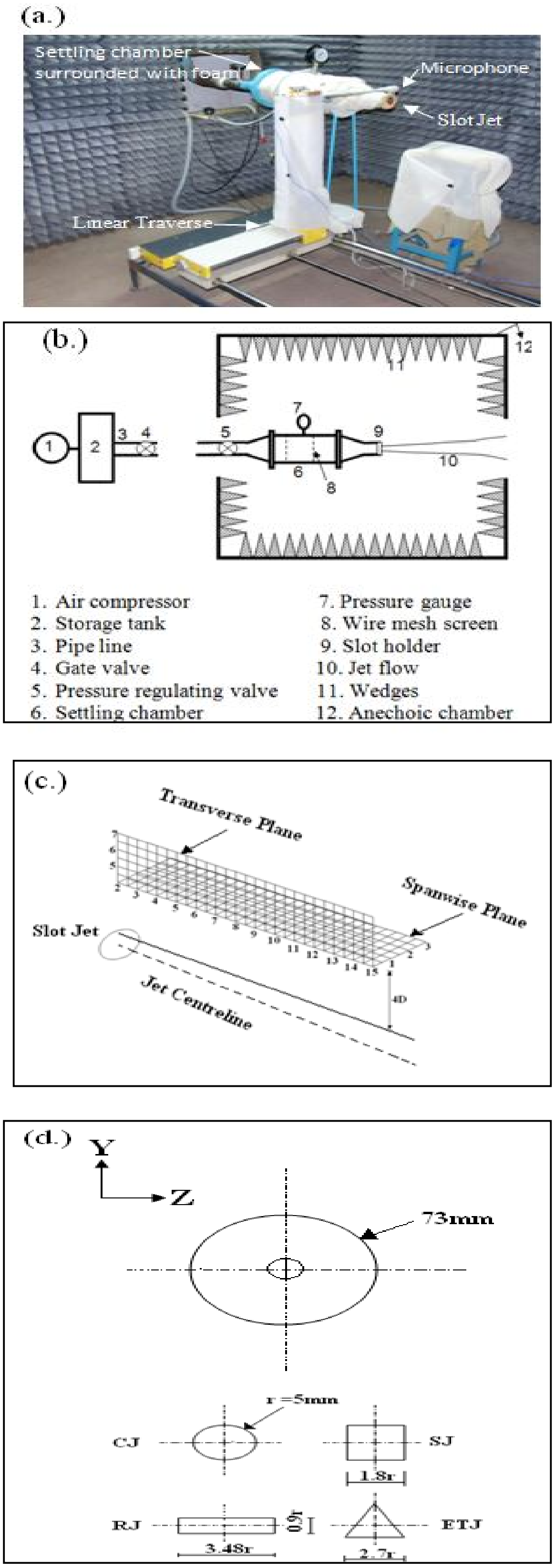


Fig 1: (a) Experimental setup in anechoic chamber, showing the jet facility and linear traversing system. (b)Schematic of the experimental setup. (c.) Schematic of the linear measurement planes. (d.) Geometries considered for the present study. Dimensions are shown in terms of radius of circular jet 'r'.

B. Slot Jets Models

The slots or disk-nozzles are fabricated using mild steel plate of 73 mm diameter and 2 mm thickness. The required circular and non-circular shapes are cut-out at the center of the disk (figure 1(d.)). All non-circular geometries are designed for constant area of 78.5 mm^2 of jet flow, and thus the equivalent diameter of all the slots is 10mm. These slotted disks are mounted on a disk-holder which is in turn connected to the settling chamber.

C. Data Acquisition

A quarter inch condenser microphone (PCB Piezotronics, Model No. 377A01) is used for the entire acoustic measurement. The microphone is attached to the moving arm of the automatic linear traversing system (figure 1(c.)) in which a stepper motor is employed to achieve the required linear movement for the near field measurement. The arrangement of this traverse mechanism and the microphone position are shown in Fig. The synchronization of traversing system with data acquisition system provides the custom designed automated data measurement. The low pass filtered signal at 70 KHz by analog filter (Krohn-Hite Model No. 3364), sampled at the rate of 150 Sa/s is acquired for one second by an eight channel simultaneous sampling card (National Instruments, Model No. NI-PCI-6143). Both data acquisition and traverse motion is automated and controlled by LABVIEW software 7.1.

The measurement planes namely: the transverse plane and spanwise plane along axial flow direction are shown in the figure 1(c.). Equivalent diameter of all slot jets has been kept constant. Jet shear layer was estimated by pitot tube survey for all the cross sections. In case of square and triangular cross sections, the flow and acoustic characterization is carried out along the edge and vertex planes, whereas for the rectangular section the measurement is along its major and minor axis planes. The near field measurements are carried out in such a way that the microphones are always at a distance greater than four equivalent diameters from the jet shear layer.

III. RESULT AND DISCUSSION

The presentation of the results is organized as follows: Firstly, the OASPL contours has been plotted for various non-circular and circular cross sections considered for nozzle pressure ratio R=4 and R=5 in various planes (spanwise and transverse plane). Secondly, the noise source location point of various non-circular jets is compared with circular slot jet.

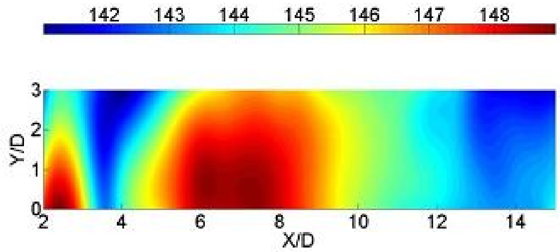
A. OASPL Contours of Non-circular Slot Jets

The Overall Sound Pressure Level contours has been plotted along spanwise and transverse plane for circular jet, square jet, triangular jet and rectangular jet at R =4 and R=5 are shown in below figures 2, 3, 4 & 5 respectively. For underexpanded case, this comparison will be important because in this case different noise components Tonal, BSAN and turbulent mixing noise play a role in the noise source location.

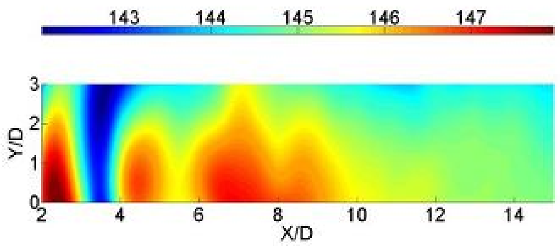
B. Noise Source Location

The location of noise source is identified in these jets by observing the OASPL contours obtained at various planes of interest at R=4 and R=5. The OASPL contours has analyzed along spanwise plane and transverse plane for all non-circular slot jets and compared with circular jets. Table I show the location of noise source identified as the point of maximum OASPL value at various planes correspondingly the inlet geometry.

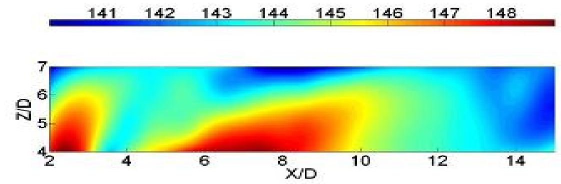
The OASPL contours in transverse plane and spanwise plane shows the distribution of noise source for all geometries. The noise source location comparison of circular and non-circular slot jets explains, source point is nearer to jet exit in case of non-circular jets than circular jet probably due to shorter potential core length since it has investigated that most of the source points will be present at end of potential core length of the jet flow. The potential core length in case of non-circular slot jets is found shorter due to mixing enhancement. The noise source point is little upstream in square jet, rectangular jet and triangular jet than circular jet. In circular jet, due to dominance of tonal, one extra point is present nearer to jet exit (X/D=2) which is not present in the case of non-circular slot jets due to weak shock associated noise content. This comparative study (Table I) shows that due to increase in nozzle sure ratio from 4 to 5, noise source location is moving downwards from the jet exit due to increase in potential core length.



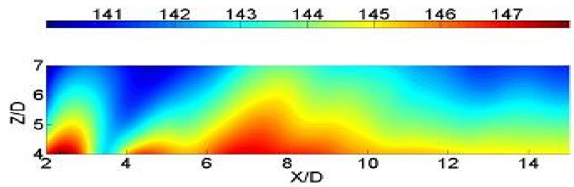
2(a.) at R=4



2(b.) at R=5

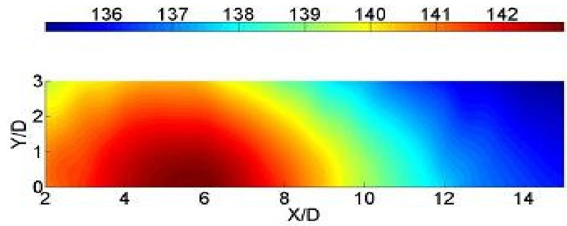


2(c.) at R=4

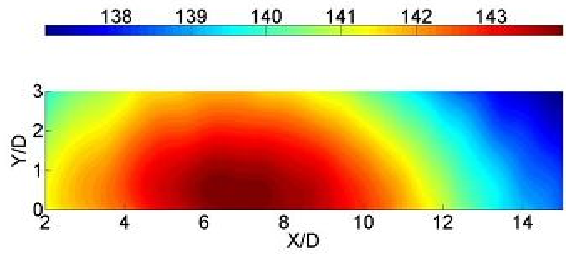


2(d.) at R=5

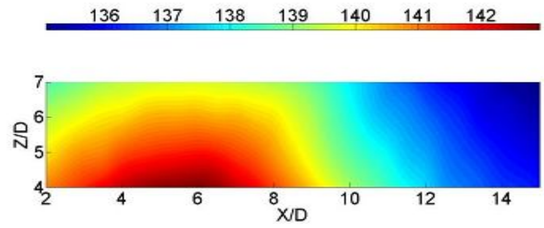
Fig. 2: Circular jet along spanwise plane (a and b) and
Circular jet along transverse plane (c and d).



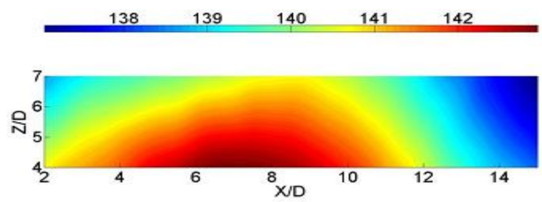
3(a.) at R=4



3(b.) at R=5

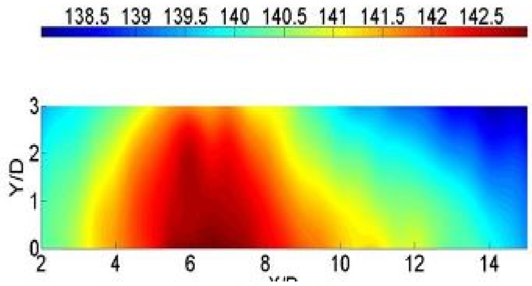


3(c.) at R=4

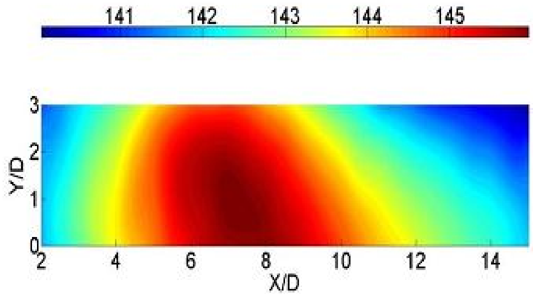


3(d.) at R=5

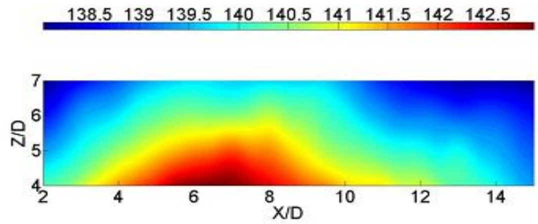
Fig. 3 : Square jet along spanwise plane (a and b) and
Square jet along transverse plane (c and d).



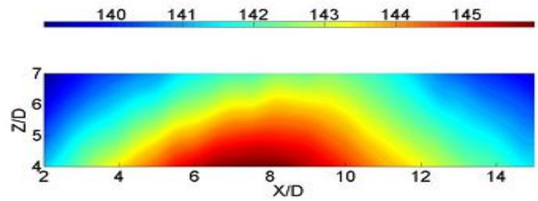
4(a.) at R=4



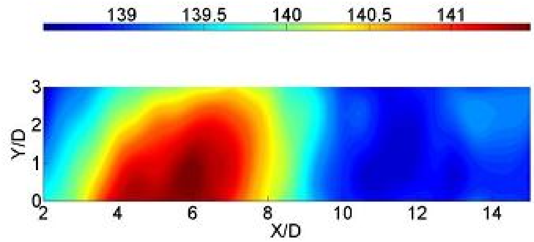
4(b) at R=5



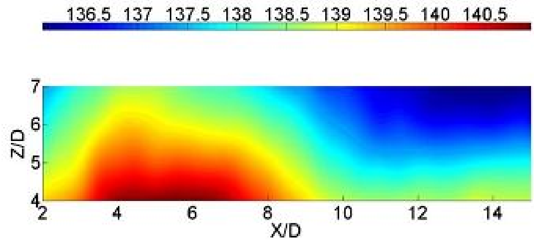
4(c.) at R=4



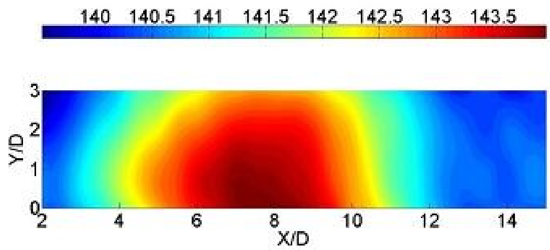
4(d.) at R=5



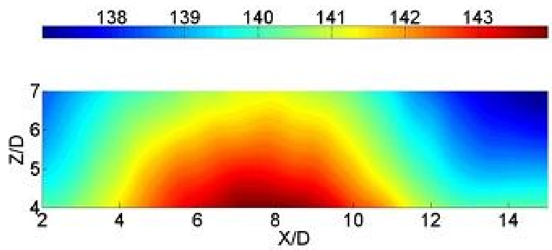
5(a.) at R=4



5(c.) at R=4



5(b.) at R=5



5(d.) at R=5

Fig 5: Rectangular jet along spanwise plane (a and b) and Rectangular jet along transverse plane (c and d)

Geometry	R=4			R=5		
	Spanwise plane (fig)	Transverse plane (fig)	Noise source location(X/D)	Spanwise plane (fig)	Transverse plane (fig)	Noise source location(X/D)
Circular jet	2(a.)	2(c.)	7	2(b.)	2(d.)	8
Square jet	3(a.)	3(c.)	5.5	3(b.)	3(d.)	7
Triangular jet	4(a.)	4(c.)	6.5	4(b.)	4(d.)	7.5
Rectangular jet	5(a.)	5(c.)	5.8	5(b.)	5(d.)	7.5

IV. CONCLUSION

A detailed experimental study of near acoustic characteristics of rectangular jet (aspect ratio 4:1), equilateral triangular jet and square jet has been performed. These jets have been compared with a circular jet with respect to OASPL contours and noise source location. Principal conclusions from these studies are summarized below.

Noise source location point is obtained for all non-circular and circular geometry which concludes due to change in nozzle pressure ratio source point travels outwards to jet exit probably due to increase in potential core length. Further, in non-circular jets source point is nearer to jet exit than circular jet which explains mixing enhancement in non-circular jet and shorten in potential core region due to presence of vertices. In noise source distribution, it is clear that shock associated noise component Tonal and BSAN are very weak in the case of non-circular slot jet whereas for circular jet, it is showing own presence.

REFERENCES

[1] Christopher K. W. Tam: Supersonic Jet Noise. Annual Review of Fluid Mechanics 27 (1995) 17-43.

[2] K. B. M. Q. Zaman: Flow field and near and far sound field of a subsonic jet. Journal of sound and vibration 106 (1986) 1-16.

[3] E. J. Gutmark, F. F. Grinstein: Flow control with non-circular jets. Annual Review of Fluid Mechanics 31(1999) 239-272

[4] W. R. Quinn: Streamwise evolution of a square jet crosssection. AIAA Journal 30 (1992) 2852-2857.

[5] K. B. m. Q. Zaman: Axis switching and spreading of an asymmetric jet: the role of coherent structures dynamics. Journal of Fluid Mechanics 316 (1996) 1-27.

[6] Jothi and Srinivasan: Acoustic Characterstics of Non-circular Slot Jets. Acta Acustica United with Acustica 94 (2008) 229-242.

[7] K. K. Ahuja, J. P. Manes,K. C. Massey, A. B. Calloway: An evaluation of various concepts of reducing supersonic jet noise. AIAA Paper No. 1990-3982, 1990.