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Experimental Study of Symmetrical and Asymmetrical Twinjet for Low Mach Numbers

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ABSTRACT

This experimental work deals with the study of mixing characteristics in twinjets (circle-circle and circle-ellipse) for low mach numbers. In both cases, the flow is free jet. The flow was emanated into the ambient and quiescent surrounding. The distance between the two nozzle axes was kept constant as 20 mm (S/D = 2). The results were plotted for measurements taken in the axial direction for Mach numbers 0.2, 0.3 and 0.4. For circle-circle nozzle, radial profiles were also plotted for M = 0.2 and 0.3. This study mainly concentrates on mixing enhancement and centerline Mach number decay. The merge point and combined point were easily identified and compared for these two configurations. This work provides an insight about the effect of nozzle geometry in twinjet.

KEYWORDS

mixing enhancement, merge point, combined point

INTRODUCTION

There is an intensive increase in research of twinjets for the past three decades. Twinjet is a passive mixing control technique which plays an important role in engineering as well as other applications. The mixing in twinjet can be applied for various fields such as aerospace, automobiles, chemical, agricultural, etc., Twinjet normally refers to the jets issuing from two nozzles discharging into free or confined surroundings. When the jets are exhausted from the exit of the nozzles, there is a mutual entrainment between the jets and also with the surrounding atmosphere. The jets after its exit get deflected and are attracted towards each other. This finally leads to the merging at the centerline between the two nozzles. The point at which the jets merge is called merge point and the region upstream of this merge point is called as converging region as the jets try to converge in this region. In the converging region, counter-rotating vortices exists and hence it is called recirculation zone as identified by Fujisawa et al. [3]. The pressure inside the converging region is of negative value as presented by kumar et al. [5] and it can be called sub-atmospheric region. At the merge point, the subatmospheric pressure reaches the atmospheric pressure approximately. Downstream of the merge point, there is a huge energy and momentum transfer between the jets. This leads to a steep increase in velocity of the flow and the jets mix rapidly. The flow velocity attains maximum at a certain point called combined point and the maximum velocity is shifted from nozzle axis to the symmetrical plane between the jets as experimentally investigated by okamoto et al. [11]. The region between the merge point and combined point is the merging region. Downstream of the combined point is the combined region where the jets coalesce to form a single jet and decay is also the same as the single jet. In the combined region, the flow becomes self-preserving and self-similar. After the merging region, the flow resembles a single jet as experimentally investigated by Disimile et al [2]. The three regions in the twinjet was experimentally and numerically investigated by Moustafa et al. [9] and kumar et al [5].

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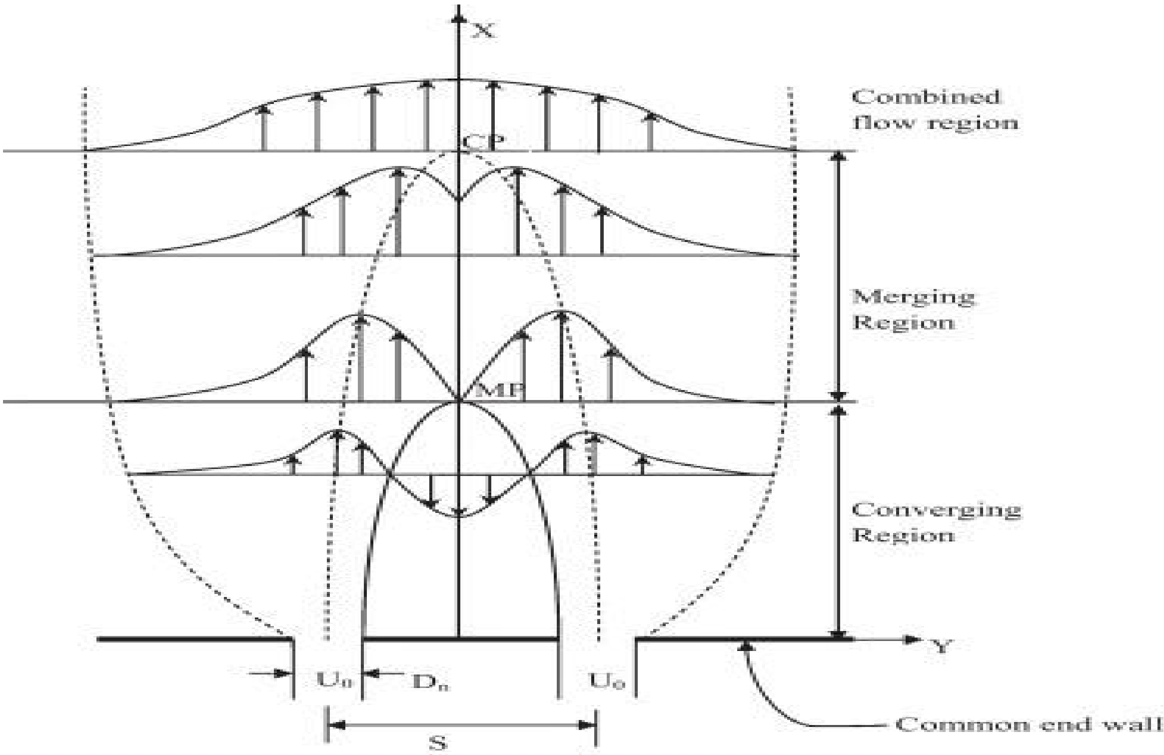

Fig. 1: Flow regions of twinjet

EXPERIMENTAL SETUP

The experiment was done in high speed jet test facility in Madras Institute of Technology. The experimental setup consists of two compressors, two storage tanks, moisture separator, pressure regulator, settling chamber and traverse mechanism. The capacity of each storage tank is 10 bar. Moisture separator removes moisture of the air discharged from the storage tanks. Pressure regulator is used to regulate the flow from the storage tank to the settling chamber. The settling chamber expels the air to the nozzle to be tested. The traverse mechanism has a Pitot tube attached to it which moves in all the three X, Y and Z directions. The tube from the Pitot tube probe is connected to the pressure transducer (NETSCANNER^{TM} Model 9116) which measures the total pressure at the desired location. The exit flow area of the circular and elliptical nozzle was kept constant as done by Quinn et al. [13] as 78.5 mm^2 so that mass flow at the exit is same for both the twinjets. Measurements were taken in the centerline of the twinjet along axial direction. The data were collected for every single rotation of the spindle in the traverse mechanism which moves the Pitot tube by 2 mm.

RESULTS AND DISCUSSION

In general, asymmetric nozzle exhibits greater mixing than axisymmetric nozzle. Hence, implementing asymmetric nozzle in twinjet leads to better mixing enhancement. Mi et al. [8] in his experimental work proved that the decay and hence, the mixing is faster in non-circular nozzle relative to circular nozzles. Seyed et al. [14], Gutmark et al. [4] and Piyush et al. [12] highlighted that the initial conditions such as nozzle geometry had a profound effect on mixing performance and interaction between the jets. The centerline Mach number decay profiles are similar to the mean streamwise velocity profiles along the symmetrical plane as identified by Anderson et al. [1].

CENTERLINE MACH NUMBER DECAY IN AXIAL DIRECTION

Fig. 2: centerline Mach number decay of the two twinjets for M = 0.2

From fig. 2, for M = 0.2, it is evident that the recirculation zone for circle-circle twinjet is greater than for circle-ellipse which shows that the jets from circle-ellipse nozzle merge earlier. As the recirculation zone is larger in circle-circle, the jets converge slower compared to circle-ellipse. The merge point where the circle-ellipse and circle-circle reaches a zero velocity is at X/D = 3 and 3.9 approximately. The combined point of circle-ellipse and circle-circle was attained at an X/D ratio of 6.5 and 8.5 respectively. This shows that the circle-ellipse nozzle mix faster than circle-circle as the combined point is achieved at a shorter distance with respect to merge point.

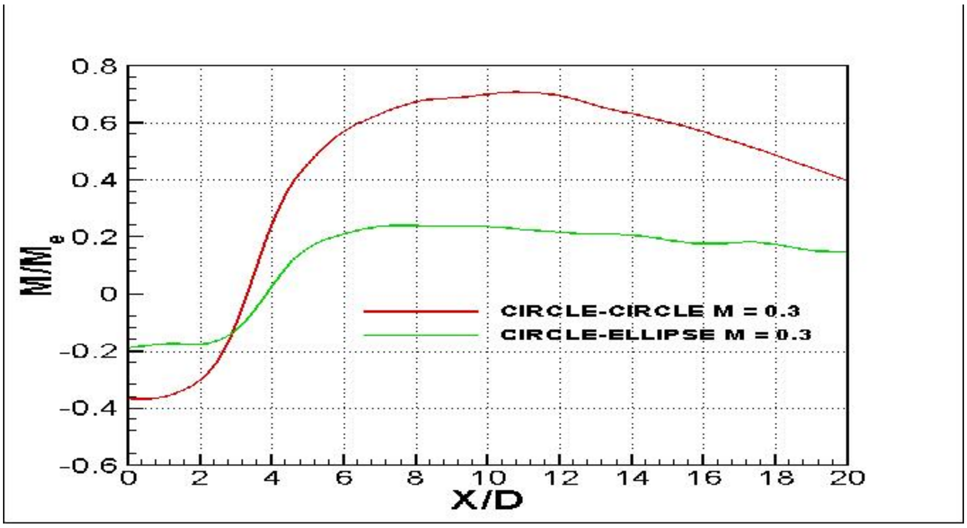

Fig. 3: centerline Mach number decay of the two twinjets for M = 0.3

From Fig. 3, it is clearly understood that eventhough circle-circle twinjet reaches the merge point earlier (at X/D = 3.5) than circle-ellipse (at X/D = 4), the later mixes rapidly. Though the converging of jets is faster in case of circle-circle, there is a greater energy transfer in circle-ellipse after the merge point, which causes the mixing to occur rapidly, compared to circle-circle nozzle. This is shown by the combined point of circle-ellipse which is at an X/D ratio of 7 whereas it is approximately 10 for circle-ellipse. But in case of circle-circle, it is around 10 - 12 which shows that the jets mix slower compared to circle-ellipse. Also, it is clear from the plot that the mixing occurs rapidly in circle-ellipse although the jets merge later than circle-circle. The decay is also faster in circle-ellipse which also indicates that there is a better mixing enhancement.

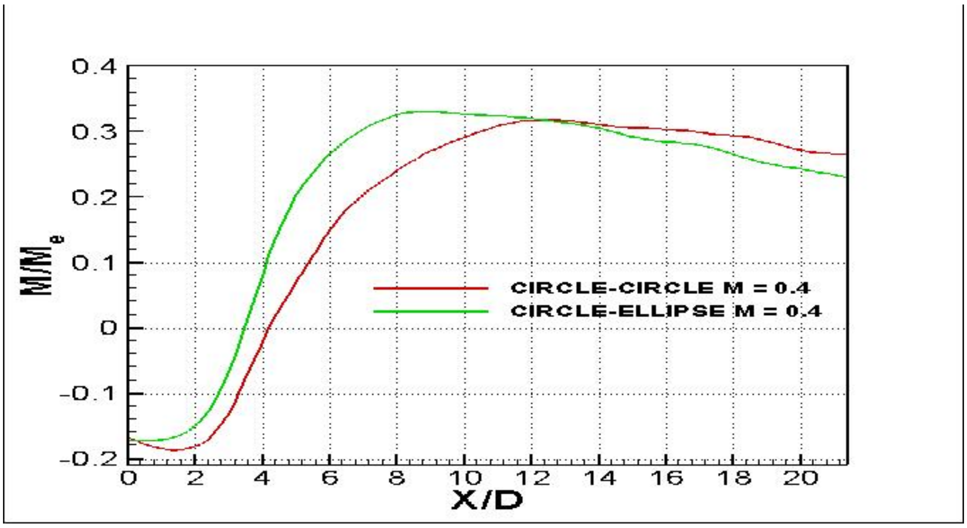

Fig. 4: centerline Mach number decay of the two twinjets for M = 0.4

Fig. 4 also exhibits that circle-ellipse nozzle mixes faster. In circle-ellipse, the merge point was attained at an X/D ratio of 3.5 and combined point around 8, whereas for circle-circle merge point and combined point was achieved at an X/D ratio of 4 and 12 respectively. The decay is also faster in circle-ellipse which ensures a faster mixing.

MACH NUMBER DECAY IN RADIAL DIRECTION

Fig. 5 and 6 shows the Mach number decay of circle-circle twinjet in radial direction for numerous axial locations (X/D = 0, 2, 3, 4, 5, 6, 8, 10, 12, 16 and 20). The profiles are similar to that of one obtained by Moustafa [9]. The plot exhibits symmetrical profile of the jets from the two circular nozzles with respect to Y-axis. Near the nozzle exit, the velocity fluctuates due to the existence of converging region upto an X/D ratio of 4 and then the flow resembles a single jet in each nozzle with maximum velocity at one peak. The converging region is shown by the negative values.

From Fig. 5, it is observed that the merge point of circle-circle nozzle for M = 0.2 and 0.3 is achieved approximately at X/D = 3 and 4 as shown in Fig. 2.

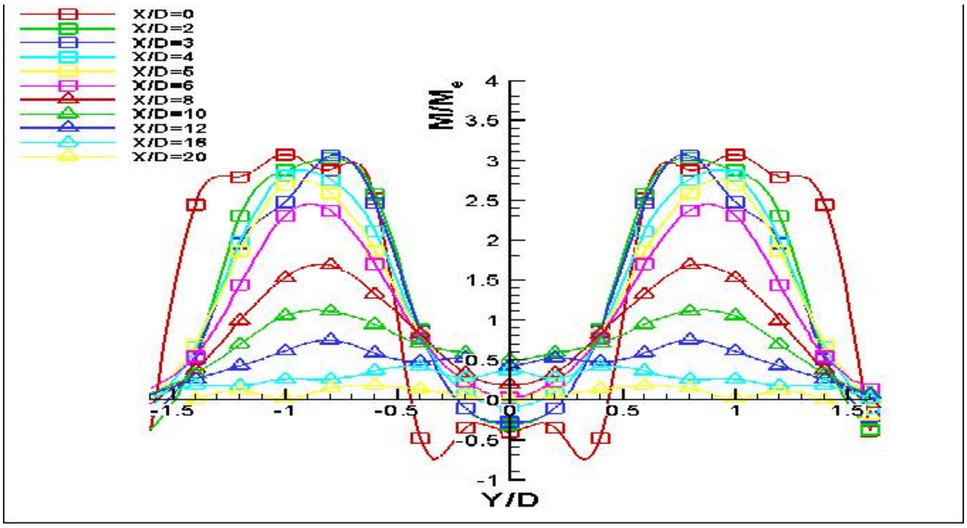

Fig. 5: radial Mach number decay of the circle-circle twinjet nozzle for M = 0.2

For M = 0.3, the velocity magnitude at the nozzle axis is higher than that achieved for M = 0.2. It is clearly understood from the plots that the twinjet tends to resemble single jet after X/D = 12 i.e., far downstream of the nozzle exit as shown in the Fig. 1.

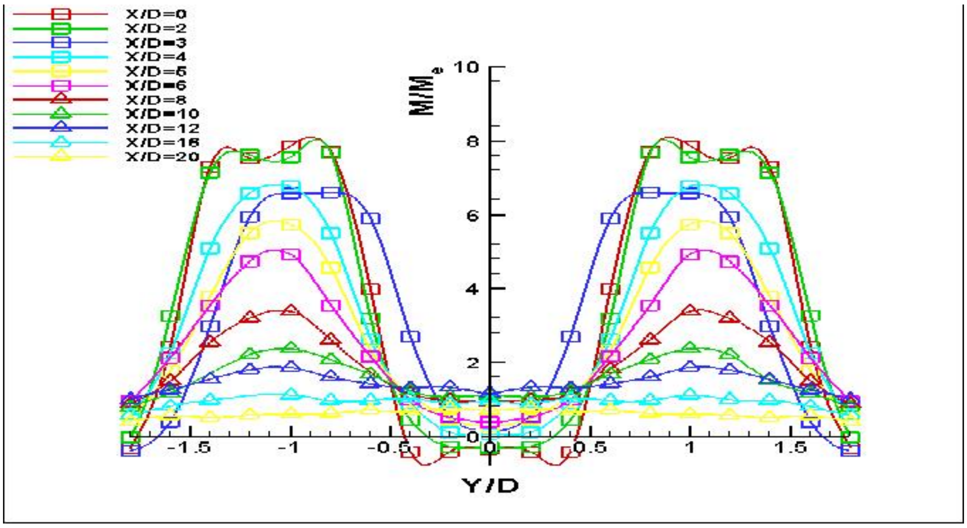

Fig. 6: radial Mach number decay of the circle-circle twinjet nozzle for M = 0.3

CONCLUSION

The merge point, combined point and Mach number decay shows that there is a rapid mixing in the merging region of circle-ellipse compared to circle-circle nozzle. Hence, circle-ellipse exhibit better mixing enhancement compared to circle-circle twinjet nozzle. This proves that nozzle geometry has a greater impact in the flowfield. From the radial profile it is also clear that the flow tends to resemble a single jet far downstream of the nozzle exit.

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