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Studies on the Flowfield of Multijet with Square Configuration

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Abstract

MEASUREMENTS of mean velocity, spread rate, and merging point location were made to investigate the flowfield generated by four identical jets of air in a square configuration, issuing from axisymmetric nozzles in a common end wall and mixing with the ambient air. The effect of stagnation pressure ratios as well as the nozzle spacings on the flowfield behavior were investigated. The effect of nozzle configurations was also studied. The results show that the nature of the mean velocity profile as well as the mean velocity decay are unaffected by the pressure ratio. The nozzle spacing effect on the mean velocity decay is only marginal. The four jets interact with axis switching at the midpoint between them, which implies better mixing.

Contents

It is well known that the multijet has many advantages over a single jet. The advantages include better mixing and noise reduction.[1] Recently, many investigators have used a non circular nozzle[2] (triangular, elliptic, etc.) to improve the jet mixing process. The elliptic jets were shown to be capable of entraining large amounts of surrounding fluid relative to that entrained by a circular jet.[3] The main advantage for using these geometries is the axis-switching phenomenon. However, the fabrication of such geometrical shapes is somewhat difficult. The circular nozzle fabrication is easier, and an attempt was made to identify the advantage of the multijet (good mixing) and the noncircular jet (axis switching) by keeping the four nozzles in a square configuration, with the arrangement as shown in Fig. 1. The nozzle exit diameter d_e was 4.2 mm, and the nozzle spacings S were chosen as $S = 12$, 16, 18, and 22 mm. The nozzles' axes were aligned parallel to the X axis of the three-dimensional traversing system. The stagnation pressure was varied from 1.25 to 2.5 atm. The total pressure in the jet was measured by a three-hole pressure probe of 0.3 mm i.d. All measurements were made in the X-Y plane at two positions in the Z direction. The total pressure reading was taken from the axis of the top jet or the symmetric axis between the two base jets to the distance at which the mean velocity became zero in the Y direction. This step was repeated at several positions downstream (up to $50d_e$) from the nozzle exit plane.

The mean velocity profiles in the X-Y plane of the top jet at $x/d_e = 18.5$ is shown in Fig. 2. Earlier measurements[4] of single and triple jets also appear on the plot for comparison.

The centerline mean velocity u_n decay of the top jet as a function of the stagnation pressure ratio p_∞/p_0 is presented in Fig. 1. As shown, the jet velocity decay as well as the potential core length have a fairly weak dependence on the stagnation pressure ratio. It is important to note that the velocity profiles for the higher values of stagnation pressure ratios ($p_\infty/p_0 < 0.528$) were plotted after the flow becomes subsonic. This result agrees well with that obtained from a plane jet.[5]

The decay of the centerline mean velocity of the top jet with nozzle spacing and the comparison with the decay rates of the single jet and of the top jet in the triple jet configuration are shown in Fig. 3. The top jet shows the same behavior as that of a single jet. The decay rate is more than that of a single jet. Far downstream the jet velocity approaches the single jet velocity, which indicates that, at far downstream, the jets combine to form a single jet. Significant decay occurs between $x/d_e \simeq 5$ and 25 for a single jet. The corresponding values for the top jet with $S = 22$ mm are 2.5 and 15. The potential core length decreases with increasing nozzle spacing, and its value for a single jet is approximately $5d_e$. For the top jet with $S = 22$ mm, it is equal to $2.5d_e$.

The growth of the top jet y/d_e variation with nozzle spacing as a parameter is shown in Fig. 4. This is the distance between the nozzle axis and the point at which the velocity becomes half of the maximum velocity. For $x/d_e \geq 15$, the top jet grows linearly with x/d_e for all nozzle spacings as a single jet; however, the slope angles are slightly different, and these angles depend upon S. This shows that the surrounding entrainment for a single jet is not so strong as that for the multijet.

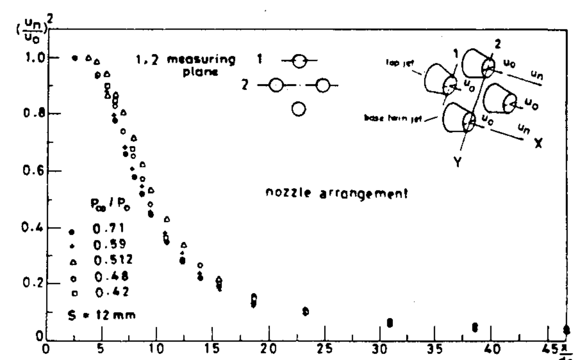

Fig. 1 Mean velocity profiles of the top jet.

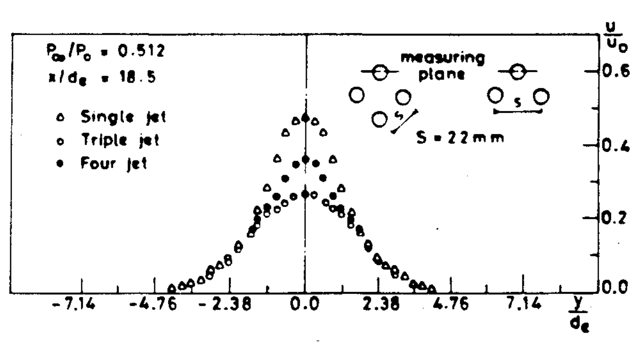

Fig. 2 Normalized nozzle centerline mean velocity decay of the top jet with varying pressure ratio.

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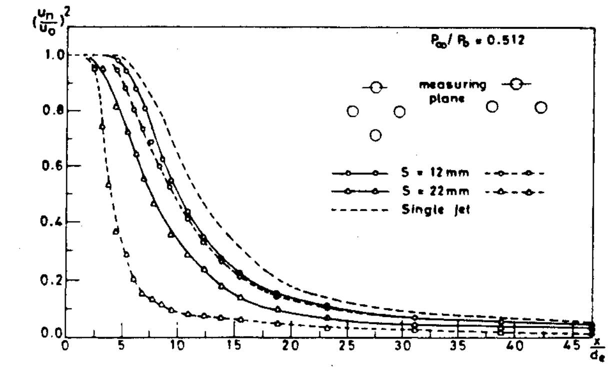

Fig. 3 Nozzle centerline mean velocity decay of the top jet and comparison with triple and single jets.

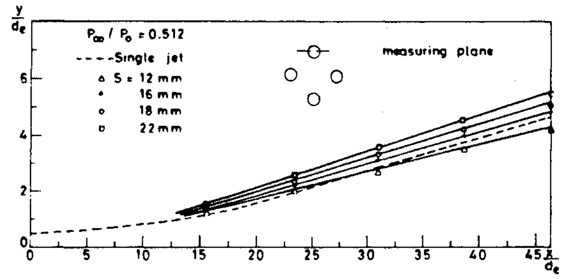

Fig. 4 Spreading ratio of the top jet.

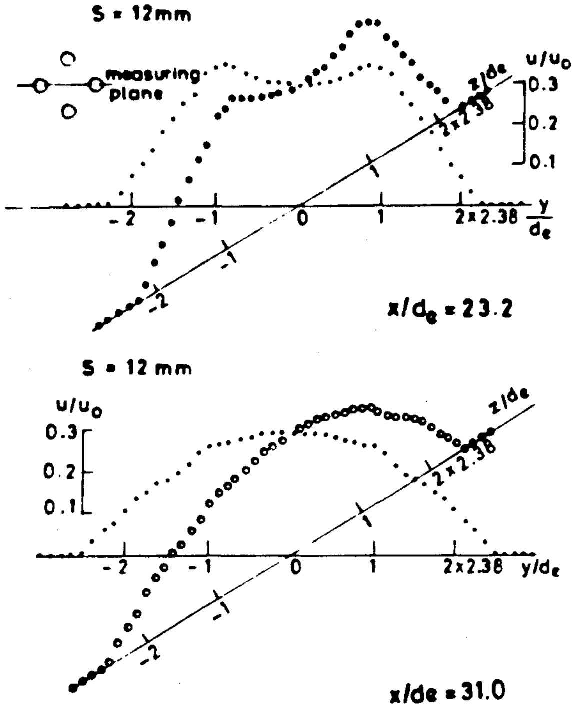

Fig. 5 Mean velocity profiles of the four jets ($p_\infty/p_0 = 0.512$).

The velocity distributions of the base jet in the X-Y and X-Z planes are shown in Fig. 5. For $S = 12$ mm, the jets merge at $5 \leq x/d_e \leq 25$ and combine at $x/d_e \geq 25$, and these values increase with increasing S. The interaction between the jets leads to an axis switching. The axis-switching point is located on the symmetric axis at the midpoint between the jets. Therefore, the crossover area becomes wider compared to other nozzle geometry (elliptic jet). This may be considered as a distinct advantage of the present configuration.

The effect of nozzle spacing on the maximum velocity u_m and jet velocity u_j decay is shown in Fig. 6. The nozzle spacing

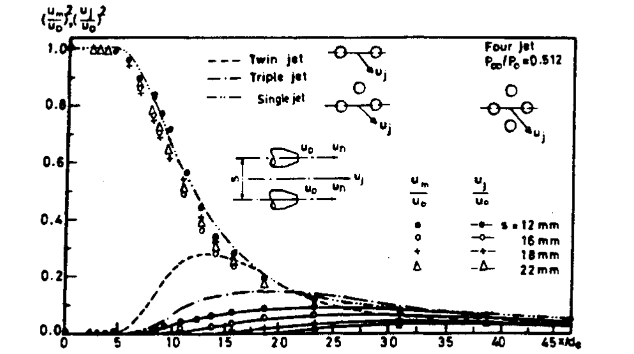

Fig. 6 Maximum and jet mean velocity profiles of the base jet.

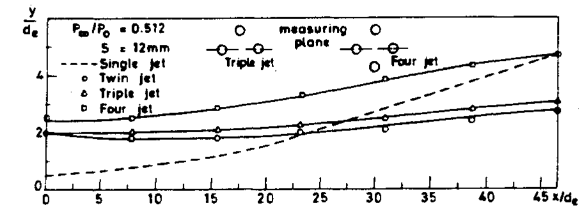

Fig. 7 Comparison of spreading ratio for different nozzle configurations.

shows a slight influence on the maximum velocity decay. However, it strongly influences the jet velocity profiles. The jet velocity increases with x/d_e up to the location at which the jets combine and behave like a single jet. The peak value of u_j seems to be considerably influenced by S. It decreases and shifts far from the nozzle exit with increasing S. This is because at lower values of nozzle spacing the maximum velocity shifts more rapidly to the midpoint between the jets than at the higher values of nozzle spacing. Also, the peak velocity value for the present configuration is less than that of the twin and triple jets which in fact implies better mixing.

The jet widths of the base twin jet with that of the single, the twin, and the same twin jet in the triple jet configuration are shown in Fig. 7 for comparison. The jet widths with $S = 12$ mm for all multijets in the inner region are larger than those of a single jet. However, far downstream the jet widths become smaller than the single jet width. The intersecting point (between the single jet and the multijet widths) changes with nozzle configuration. In the four-jet configuration up to $x/d_e = 50$, the jet width is larger than the single jet width. It is also wider than the width of the twin and triple jet configurations. This also indicates that the surrounding entrainment is influenced by the nozzle jet configuration.

From the present investigation, it is found that the nozzle configuration plays a vital role in the mixing process. It shows a distinct influence on the velocity decay as well as the jet growth. The axis-switching phenomenon is observed with the present configuration, and the crossover area becomes wider.

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