Abstract

The mixing characteristics of circular and non-circular twin jets are investigated using both experiment and RANS-based shear stress transport (SST) $k-\omega$ turbulence model. The numerical simulations are performed for a jet exit Mach number of 0.8 and a Reynolds number of 4.1 $\times 10^5$ based on an equivalent exit diameter. The spacing effect was studied for symmetrical (circle-circle, ellipse-ellipse, square-square, and triangle-triangle) twin jets at S/D_e ratios of 1.25, 1.50, 1.75, and 2.0, respectively. The asymmetrical twin jets are also simulated at an S/D_e ratio of 2 to comprehend the mixing characteristics and compare them with symmetrical twin jets. The simulated twin jets are compared with circular twin jets and respective single jets. Subsequently, the plane sonic twin jets are simulated at equal and unequal nozzle pressure ratios to investigate the effect of expansion on the twin jet's flow field.

From the simulated circular and non-circular single jets, the triangular jet's potential core length was found to be shortened by 26% compared to the circular jet, indicating that mixing was superior for the triangular jet. The results also showed that the triangular jet mixes better with atmospheric fluid, followed by the elliptical jet, verified by shorter L_{pc}, K_s, and higher K_u. The axis-switching phenomenon was seen in the elliptical and triangular jets, while the square underwent a 45^0 rotation in the downstream direction. Low levels of turbulent intensity were seen in the core region for all the configurations.

The results related to S/D_e effects on twin jets indicated that near the exit, the twin jets are secluded from each other and resemble a free jet, forming potential core length. Out of the chosen twin jets, the triangular twin jets promote mixing efficiency in both streamwise and transverse directions, which is verified by a shorter core length and converging region. The decay rate was greater for the Twin Triangular jet, while the spread rate was higher for the Twin Major jet. For each twin jet, the contour and profile plots of the streamwise turbulent

intensity showed low levels of turbulence intensity in the core region near the jet exit. The merging and combined point locations change linearly from the exit with an increasing S/D_e ratio. Among the tested asymmetrical twin jets, the Circular-Major configuration experienced shorter core length and greater decay. Compared to symmetrical twin jets, the turbulent intensity peak values were reduced by 8% due to the differential turbulence levels in the top and bottom jets of an asymmetrical twin jet. At the far downstream locations ($X/D_e = 17$), the asymmetrical twin jet velocity profiles become closer to the self-similar profile, while the symmetrical twin jets still maintain the bell shape, indicating that momentum exchange between asymmetrical twin jets was rapid and the jet spreads faster. A higher expansion in twin jets results in a longer supersonic core for equal NPR. Earlier merging was observed for unequal NPR twin jets while combined point locations are elongated compared to equal expansion in twin jets.

The experimental study examined the mixing characteristics of non-circular (elliptic and square) single jets across subsonic, sonic, and underexpanded conditions. Subsequently the symmetrical and asymmetrical twin jets are also investigated experimentally at subsonic, sonic and underexpanded conditions to determine the effect of asymmetry and Mach number on twin jets flow field. The experimental results qualitatively match the numerical results. The shadowgraph images of underexpanded twin jets show that the strength of shocks intensifies with an increase in NPR, and the Mach disk was seen only at higher NPR values.