Figure 9 illustrates the H_2O mole fraction contours. The formation of H_2O shows the presence of a flame. The contour clearly shows the penetration of fuel jet, diffusion, and mixing of fuel and air mixture due to the influence of the oblique shock. The total temperature at the exit is maximum for the Case 3 (with coordinates x_1 200.0, y_1 0.0; x_2 42.2; y_2 30.0) as the interaction of the reflections is much more compared with that of other cases. The shear layer of the strut gets strongly influenced by these oblique shocks. The change of $\boldsymbol{y_2}$ coordinate from 30 mm to 45 mm has little influence on combustion efficiency. From the numerical study, the combustion efficiency is maximum for Case 3 (with coordinates x_1 200.0, y_1 0.0; x_2 42.2; y_2 30.0). The efficiency of this strut configuration is 64.5%. The combustor efficiency for Case 4 (with coordinates x_1 357.5, y_1 0.0; x_2 357.5; y_2 30.0) is 42.31%. The strut configurations with two sets of fore and aft struts show higher efficiency compared to those of other cases. The mole fraction goes as high as 0.30 for these cases as the flow reaches the exit of the combustor.

EFFECT OF MACH NUMBER

This section discusses the effect of variation of inlet Mach number on the mixing and flame stabilization. The inlet Mach number is increased by 0.5 from Mach 2.0 to Mach 3.0. The contours of Mach number, H_2 mole fraction, H_2O mole fraction, and static temperature are illustrated in Figures 10–13.

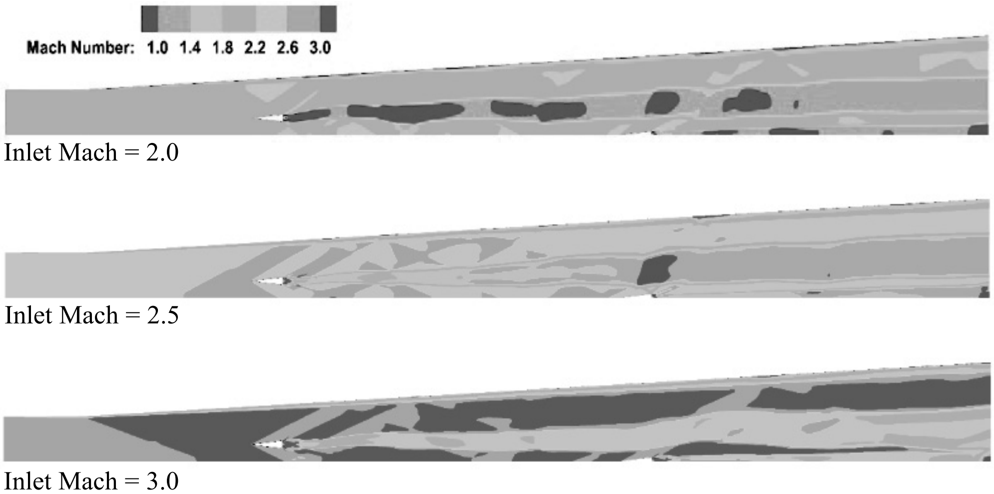

Figure 10. Contours of Mach number for the configuration of Case 6 (with coordinates x_1 545.0, y_1 0.0; x_2 170.0; y_2 15.0).

The distance of the oblique shock incidence at the top wall of the combustor increases with an increase in the Mach number. This is because of the shock wave angle, and β decreases with increase in the Mach number when the strut angle is kept constant. The contours illustrated in Figure 10 show the reflections of the oblique shock from the top and bottom wall of the combustor. The multiple reflections from combustor walls have a great impact on mixing and enhancing the combustion phenomenon of the combustor as explained in the earlier section. Static pressure at the inlet decreases with an increase in the inlet Mach number. An instantaneous increase in static pressure is observed across the oblique shock as expected. All the strut configurations show a similar flow phenomenon.

The contours of hydrogen (fuel) mole fraction shown in Figure 11 represent the penetration of the fuel into the supersonic flow stream for a range of inlet Mach numbers 2-3. The diffusion of the hydrogen is rapid for the inlet Mach 2.0. As the Mach number is increased to 2.5 and 3.0, the diffusion of the hydrogen to the mainstream happens in a much slower rate. The inlet flow velocity magnitude for inlet Mach 3.0 is in the order 1550 m/s. The base of the strut with recirculation zone acts as a flame holder. The oblique shocks reflected have no much influence for high Mach flows.

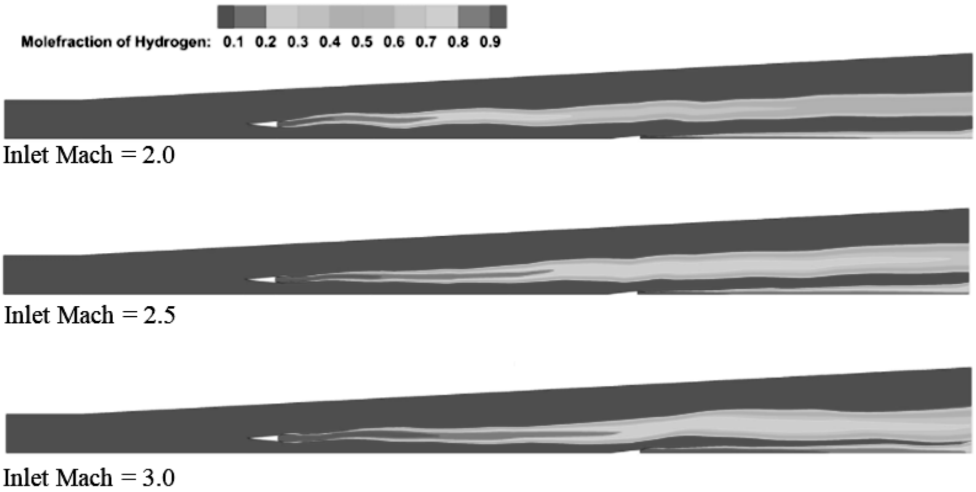

Figure 11. Contours of hydrogen (fuel) for the configuration of Case 6 (with coordinates x_1 545.0, y_1 0.0; x_2 170.0; y_2 15.0).

The diffusion of the hydrogen is rapid for inlet Mach 2.0. As the Mach number at the inlet increases to 3.0, the mixing of the hydrogen into the mainstream happens at a much slower rate. The velocity magnitude for inlet Mach 3.0 is in the order 1550 m/s. The oblique shocks reflected no influence for high Mach flows.

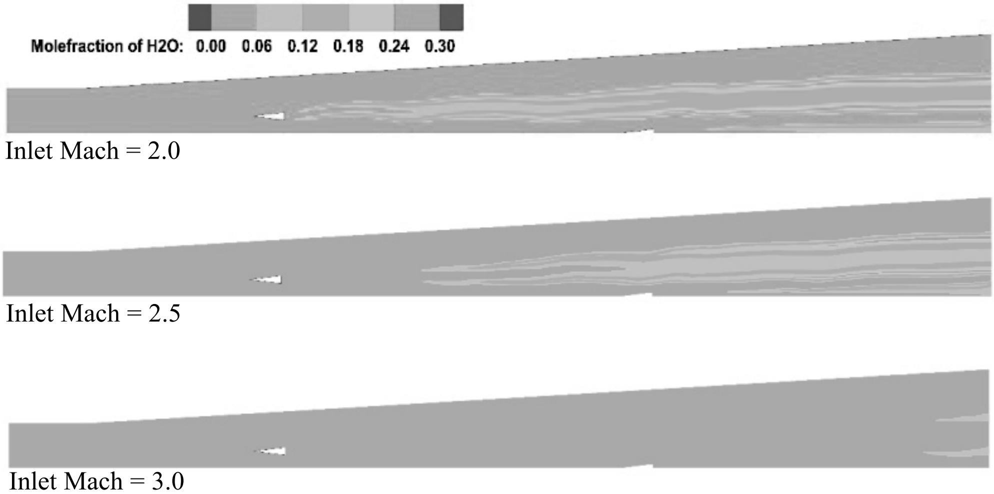

Figure 12. Contours of H_2O for the configuration of Case 6 (with coordinates x_1 545.0, y_1 0.0; x_2 170.0; y_2 15.0).

For Mach 2.0, as in Figure 10, subsonic regions are formed when the reflections from the bottom wall of the combustor meet the flow from the base of the strut. These subsonic regions help in improving the static temperature to rise and enhance the combustion phenomenon. Since there is no heat addition in shock phenomenon, the total enthalpy and total temperature remain constant across the shocks. However, both static and total temperature rise due to combustion heat release. The static temperature on the upper wall of the combustor is much higher due to multiple reflections and thickening of the boundary layer. The combustion commences much earlier for inlet Mach 2.0 compared to other higher Mach number cases. This could be due to mixing delay. The static temperature rise is noted only when the flow reaches the exit. The static temperature rise is seen only from X=940 mm from the leading edge of the combustor inlet as can be seen from Figure 13. The maximum static temperatures attained for the strut configuration of Case 6 (with coordinates x_1 545.0, y_1 0.0; x_2 170.0; y_2 15.0) for inlet Mach 2.0, 2.5, and 3.0 are 2730 K, 2728 K, and 1631 K, respectively. Thus, combustion is delayed, and efficiency is adversely affected by higher inlet Mach numbers. A similar effect is noted for all the strut configurations studied.

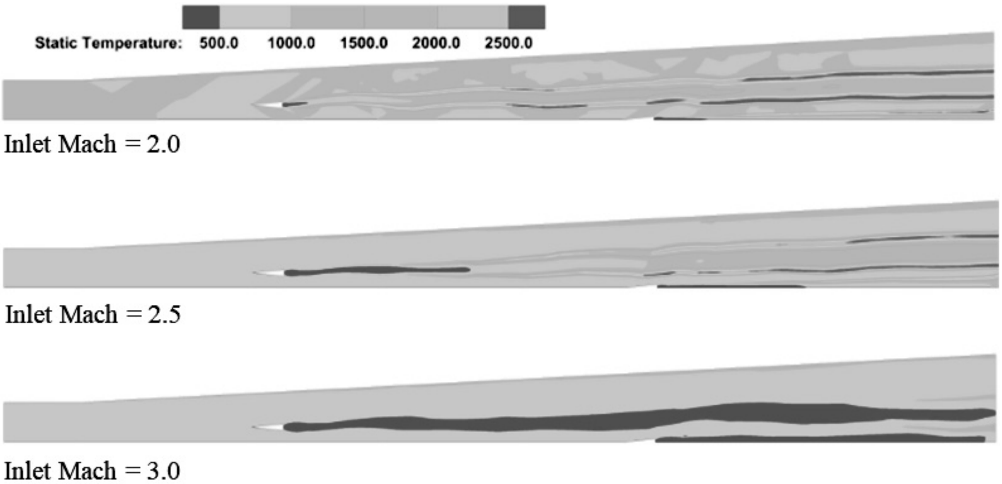

Figure 13. Contours of static temperature for the configuration of Case 6 (with coordinates x_1 545.0, y_1 0.0; x_2 170.0; y_2 15.0).

CONCLUSION

In a strut-based supersonic combustor, the strut configurations and the operating conditions have a profound influence on the mixing and combustion characteristics. The strut base acts as a flame holder and improves combustion efficiency in the wake region. The fuel residence time is significantly increased with proposed strut configurations. The recirculation region at a subsonic regime shows effective combustion characteristics. The most efficient combustion is noted for the strut configuration of Case 3 (with coordinates x_1 200.0, y_1 0.0; x_2 42.2; y_2 30.0). In Case 3, the secondary struts were placed near the starting of wall divergence, which is upstream of the central strut. The study shows that the efficiency depends heavily on the oblique shock interactions with the main supersonic flow. The proper placement of the struts inside the combustor is important to improve mixing and combustion. The configurations in which the struts are located one above the other and located towards the exit of the combustor have lower combustion efficiency. It is concluded that the combustion efficiency is maximum when two struts are located at the front and one at the back. The interaction of the oblique shock with the main flow is degraded to a larger extent at higher Mach numbers.

ACKNOWLEDGMENT

All computations were performed on Aziz Supercomputer at King Abdulaziz University's High-Performance Computing Center (http://hpc.kau.edu.sa/). The author would like to acknowledge the computer time and technical support provided by the center.

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