Simulation of 3D Supersonic Hydrogen-Air Jet

Mixing by TVD scheme

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The developing of TVD scheme to modeling a three-dimensional parabolized Reynolds equations

\[
\frac{\partial E}{\partial x} + \frac{\partial (F - F_v)}{\partial y} + \frac{\partial (G - G_v)}{\partial z} = 0
\]  

(1)

is given. Turbulence is simulated using Baldwin–Lomax model. The solution technique of the equations (1) is similar to [1]. Jacobi matrixes \( A = \frac{\partial E}{\partial U}, B = \frac{\partial F}{\partial U}, C = \frac{\partial G}{\partial U} \) have the same form as in [2].

Eigenvalues of matrix \( B \) are

\[
\lambda_1 = -a_2 + \frac{\sqrt{a_2^2 - 4a_1a_3}}{2a_1}, \quad \lambda_{2,3,4} = \frac{\nu}{u}, \quad \lambda_5 = -a_2 - \frac{\sqrt{a_2^2 - 4a_1a_3}}{2a_1},
\]

where \( a_1 = -\omega a^2 - \omega(\gamma - 1)u^2 + \gamma u^2, \quad a_2 = \omega(\gamma - 1)u\nu - (\gamma + 1)u\nu, \quad a_3 = \nu^2 - a^2, \)

\( U = (\rho, \rho u, \rho v, \rho w, E_i)' \), \( E_i = \rho h - p + 0.5 \rho \nu^2 \).

Eigenvalues of matrix \( C \) can be received by replacing \( \nu \) on \( w \).

A numerical simulation are implemented at the following values of characteristic parameters: \( \gamma = 1.4, 1 \leq M_a \leq 3, \quad 0.05 \leq M_\infty \leq 5, \quad 1 \leq n \leq 10, \quad M_a \) is Mach number of a hydrogen jet, \( M_\infty \) is Mach number of an air stream. Comparison of the axial velocity with experimental data at \( M_a = 3; \quad M_\infty = 0.05, \quad n = 1 \) are shown in Figure 1.

Inflow of a supersonic hydrogen jet from elliptic nozzle into supersonic air flow was investigated too. In Figure 2 a structure of axial velocity component in various sections of a jet are shown. From numerical experiments it follows that character of distribution of a velocity field at some regime parameters is not similar to an axisymmetric case.

References


Figure 2

\[ M_a = 2, \quad M_x = 3, \quad n = 2, \quad T_0 = 1, \quad T_x = 0.3 \]

1. \( x/R = 8.5 \); 2. \( x/R = 9.68 \); 3. \( x/R = 14.5 \); 4. \( x/R = 27.8 \)