FNI Solver Governing Equations

Navier-Stokes equation system averaged by Reynolds (steady Cartesian coordinate system):

$$\frac{\partial}{\partial t}\iiint_{Vol}\overline{\Lambda}dV = -\oiint_S(\overline{F}_C\vec{i}+\overline{G}_C\vec{j}+\overline{D}_C\vec{k},d\vec{S}) + \oiint_S(\overline{F}_D\vec{i}+\overline{G}_D\vec{j}+\overline{D}_D\vec{k},d\vec{S}) \quad ;$$

$$\overline{\Lambda} = \begin{bmatrix}\rho\\ \rho u\\ \rho v\\ \rho w\\ \rho[e+\frac{q^2}{2}]\end{bmatrix}; \qquad \overline{F}_C = \begin{bmatrix}RU\\ RU^2+P\\ RUV\\ RUW\\ RUH\end{bmatrix}; \qquad \overline{G}_C = \begin{bmatrix}RV\\ RUV\\ RV^2+P\\ RVW\\ RVH\end{bmatrix}; \qquad \overline{D}_C = \begin{bmatrix}RW\\ RUW\\ RVW\\ RW^2+P\\ RWH\end{bmatrix};$$

$$\overline{F}_D = \begin{bmatrix}0\\ (\mu+\mu_t)\tau_{xx}\\ (\mu+\mu_t)\tau_{xy}\\ (\mu+\mu_t)\tau_{xz}\\ (\mu+\mu_t)(\mathrm{u}\tau_{xx}+\mathrm{v}\tau_{xy}+\mathrm{w}\tau_{xz})+\gamma(\frac{\mu}{\Pr}+\frac{\mu_t}{\Pr_t})\frac{\partial e}{\partial x}\end{bmatrix}; \quad \overline{G}_D = \begin{bmatrix}0\\ (\mu+\mu_t)\tau_{yx}\\ (\mu+\mu_t)\tau_{yy}\\ (\mu+\mu_t)\tau_{yz}\\ (\mu+\mu_t)(\mathrm{u}\tau_{yx}+\mathrm{v}\tau_{yy}+\mathrm{w}\tau_{yz})+\gamma(\frac{\mu}{\Pr}+\frac{\mu_t}{\Pr_t})\frac{\partial e}{\partial y}\end{bmatrix};$$

$$\overline{D}_D = \begin{bmatrix}0\\ (\mu+\mu_t)\tau_{zx}\\ (\mu+\mu_t)\tau_{zy}\\ (\mu+\mu_t)\tau_{zz}\\ (\mu+\mu_t)(\mathrm{u}\tau_{zx}+\mathrm{v}\tau_{zy}+\mathrm{w}\tau_{zz})+\gamma(\frac{\mu}{\Pr}+\frac{\mu_t}{\Pr_t})\frac{\partial e}{\partial z}\end{bmatrix};$$

$$\tau_{xx} = 2\frac{\partial u}{\partial x}-\frac{2}{3}\operatorname{div}\vec{V}; \qquad \tau_{xy}=\tau_{yx}=\frac{\partial v}{\partial x}+\frac{\partial u}{\partial y};$$

$$\tau_{yy} = 2\frac{\partial v}{\partial y}-\frac{2}{3}\operatorname{div}\vec{V}; \qquad \tau_{yz}=\tau_{zy}=\frac{\partial w}{\partial y}+\frac{\partial v}{\partial z};$$

$$\tau_{zz} = 2\frac{\partial w}{\partial z}-\frac{2}{3}\operatorname{div}\vec{V}; \qquad \tau_{zx}=\tau_{xz}=\frac{\partial u}{\partial z}+\frac{\partial w}{\partial x}; \qquad \operatorname{div}\vec{V}=\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z};$$

$$p=R\rho T; \quad q^2=u^2+v^2+w^2; \quad e=\frac{1}{(\gamma\text{-}1)}\frac{p}{\rho}=c_vT; \quad H=e+\frac{q^2}{2}+p/\rho; \quad \gamma=\frac{c_v+R}{c_v}; \quad Pr=\frac{\mu c_p}{\lambda}; \quad Pr_t=0.89;$$

$$\frac{\mu}{\mu_c}=\left(\frac{T}{T_c}\right)^{3/2}\frac{T_c-T_s}{T+T_s}; \qquad T_c=288^oK; \qquad T_s=122^oK;$$

A.N.Sekundov' one-equation turbulence model “ν_{t90}” is recommended for closing of governing equations for wide series of external and internal fluid problems.

$$\frac{\partial\mu_t}{\partial t}=-(\frac{\partial u\mu_t}{\partial x}+\frac{\partial v\mu_t}{\partial y}+\frac{\partial w\mu_t}{\partial z})+\frac{\partial}{\partial x}\left[(c_1\mu_t+\mu)\frac{\partial\mu_t/\rho}{\partial x}\right]+\frac{\partial}{\partial y}\left[(c_1\mu_t+\mu)\frac{\partial\mu_t/\rho}{\partial y}\right]+\frac{\partial}{\partial z}\left[(c_1\mu_t+\mu)\frac{\partial\mu_t/\rho}{\partial z}\right]+\mu_tJ;$$

$$J=c_2\Gamma\times\frac{(\mu_t/\mu+5.6)^2-18.56}{(\mu_t/\mu-5.6)^2+32.64}+\frac{c_3}{\rho}(u\frac{\partial\rho}{\partial x}+v\frac{\partial\rho}{\partial y}+w\frac{\partial\rho}{\partial z})-c_4\frac{\mu_t}{\gamma p}\Gamma^2-\frac{1}{\rho}\frac{c_5\mu_t+c_6\mu}{S^2};$$

$$\Gamma^2=2(u_x^2+v_y^2+w_z^2)+(u_y+v_x)^2+(u_z+w_x)^2+(v_z+w_y)^2=\frac{\partial U_i}{\partial x_j}(\frac{\partial U_i}{\partial x_j}+\frac{\partial U_j}{\partial x_i});$$

$$c_1=2; \quad c_2=0.2; \quad c_3=0.7; \quad c_4=5; \quad c_5=3; \quad c_6=50;$$