Computational Fluid Dynamics: Principles and Applications

Jiri Blazek, http://www.cfd-ca.de

November 12, 2018

The following corrections apply to the 3rd edition of the book published in March 2015 by Elsevier Ltd. (ISBN: 978-0-08-099995-1).

Section 3.1.5: Central and Upwind Schemes

Text on page 42, initial paragraph:

... In this context, it is convenient to differentiate between the discretization of the convective and the viscous fluxes ($\vec{F}_c$ and $\vec{F}_v$ in Eq. (2.19), respectively). ...

Chapter 4: Structured Finite-Volume Schemes

Equation (4.64) on page 96:

$$M_R^- = \begin{cases} 0 & \text{if } M_R \geq +1 \\ -\dfrac{1}{4}(M_R - 1)^2 & \text{if } |M_R| < 1 \\ M_R & \text{if } M_R \leq -1\,. \end{cases}$$

Chapter 5: Unstructured Finite-Volume Schemes

Equation (5.9) on page 128:

$$\vec{r}_c = \frac{\Omega_{123}\,\vec{r}_{c,123} + \Omega_{134}\,\vec{r}_{c,134}}{\Omega_{123} + \Omega_{134}}\,.$$

Equation (5.23) and text following on page 135:

$$\vec{n}_{01}\Delta S_{01} = \vec{n}_L \Delta S_L + \vec{n}_R \Delta S_R\,,$$

and the total face area is given by: $\Delta S_{01} = ||\vec{n}_L \Delta S_L + \vec{n}_R \Delta S_R||_2$.

Equation (5.62) on page 153:

$$\begin{aligned} \alpha_{ij,1} &= \frac{\Delta x_{ij}}{r_{11}^2} \\ \alpha_{ij,2} &= \frac{1}{r_{22}^2}\left(\Delta y_{ij} - \frac{r_{12}}{r_{11}}\Delta x_{ij}\right) \\ \alpha_{ij,3} &= \frac{1}{r_{33}^2}\left(\Delta z_{ij} - \frac{r_{23}}{r_{22}}\Delta y_{ij} + \beta \Delta x_{ij}\right)\,, \end{aligned}$$

Equation (5.74) on page 162:

$$\left(\frac{\partial U}{\partial \ell}\right)_{IJ} \approx \frac{U_J - U_I}{\ell_{IJ}} \,,$$

Chapter 6: Temporal Discretization

Equation (6.85) on page 204:

$$\vec{W}_I^{(k)} = \vec{W}_I^{(0)} - \frac{\alpha_k \Delta t_I^*}{\Omega_I^{n+1}} \left[\bar{I} + \frac{3}{2\,\Delta t}\alpha_k \Delta t_I^* \bar{M}^{n+1}\right]^{-1}$$
$$\cdot \left[\vec{R}_I(\vec{W}^{(k-1)}) + \frac{3}{2\,\Delta t}(\Omega \bar{M})_I^{n+1} \vec{W}_I^{(k-1)} - \vec{Q}_I^*\right] .$$

Equations (6.76), (6.77) and the related text on page 199:

$$\vec{R}_I^{(p+1)} \approx \vec{R}_I^{(p)} + \bar{J}_I\,\Delta \vec{W}^{(p)}$$

with $\Delta \vec{W}^{(p)} = \vec{W}^{(p+1)} - \vec{W}^{(p)}$ and $\bar{J} = \partial \vec{R}/\partial \vec{W}$ being the Jacobian matrix. Inserted into Eq. (6.75) while formulated as an iterative procedure, we obtain for the solution at stage k the expression

$$\left[\frac{(\Omega \bar{M})_I}{\Delta t} + a_{kk}\bar{J}_I\right] \Delta \vec{W}^{(p)} = \frac{(\Omega \bar{M})_I}{\Delta t}\left(\vec{W}_I^n - \vec{W}_I^{(p)}\right) - \sum_{l=1}^{k-1} a_{kl}\,\vec{R}_I^{(l)} - a_{kk}\,\vec{R}_I^{(p)} .$$

This is formally equivalent to Eq. (6.28) and can be solved by any of the implicit methods from the previous subsections. Upon convergence, the solution $\vec{W}^{(p+1)}$ of Eq. (6.77) approximates the intermediate solution at stage k from Eq. (6.75).

Chapter 7: Turbulence Modeling

Equation (7.4) on page 216:

$$\Omega_{ij} = \frac{1}{2}\left(\frac{\partial v_j}{\partial x_i} - \frac{\partial v_i}{\partial x_j}\right) .$$

Equation (7.38) on page 226 and the text below it:

$$\tilde{S} = S + \frac{\tilde{\nu}}{\kappa^2 d^2} f_{v2} \,,$$

$$f_{v1} = \frac{\chi^3}{\chi^3 + C_{v1}^3} \,, \quad f_{v2} = 1 - \frac{\chi}{1 + \chi f_{v1}} ,$$

$$\chi = \frac{\tilde{\nu}}{\nu_L} \,,$$

where S stands for the magnitude of the mean rotation rate, that is,

$$S = \sqrt{2\,\Omega_{ij}\Omega_{ij}} \,,$$

and where Ω_{ij} is given by Eq. (7.4) . In order to avoid numerical difficulties, the term $\tilde{S}$ must never become zero or negative. One possibility is simple limiting like $\tilde{S} = \max(\tilde{S},\ 0.3\,S)$. More elaborate approaches were suggested in Ref. [49].

Equation (7.39) on page 226:

$$f_w = g\left(\frac{1+C_{w3}^6}{g^6+C_{w3}^6}\right)^{1/6},$$

$$g = r + C_{w2}(r^6 - r)\,, \quad r = \min\left[\frac{\tilde{\nu}}{\tilde{S}\,\kappa^2 d^2},\, 10\right].$$

Equation (7.41) on page 227:

$$C_{b1} = 0.1355\,, \quad C_{b2} = 0.622\,,$$
$$C_{v1} = 7.1\,, \quad \sigma = 2/3\,, \quad \kappa = 0.41\,,$$
$$C_{w1} = C_{b1}/\kappa^2 + (1+C_{b2})/\sigma\,, \quad C_{w2} = 0.3\,, \quad C_{w3} = 2\,,$$
$$C_{t1} = 1, \quad C_{t2} = 2, \quad C_{t3} = 1.2, \quad C_{t4} = 0.5\,.$$

Text above Equation (7.42) on page 227:

As pointed out in Ref. [47] , it is convenient to substitute the diffusion term in Eq. (7.36) , that is,

$$\frac{1}{\sigma}\left\{\frac{\partial}{\partial x_j}\left[(\nu_L+\tilde{\nu})\frac{\partial\tilde{\nu}}{\partial x_j}\right] + C_{b2}\frac{\partial\tilde{\nu}}{\partial x_j}\frac{\partial\tilde{\nu}}{\partial x_j}\right\}$$

by the following expression ...

Text to **Initial and boundary conditions** on page 228:

The initial value of $\tilde{\nu}$ is usually taken as $\tilde{\nu} = 0.1\,\nu_L$. The same value is also specified at inflow or far-field boundaries. However, in cases where the transition term f_{t1} (and then mostly also f_{t2}) is omitted, that is, for fully turbulent flows, $\tilde{\nu}$ should be set to 3–5 times the value of ν_L at the inlet or far-field. At outflow boundaries, $\tilde{\nu}$ is simply extrapolated from the interior of the computational domain. At solid walls, it is appropriate to set $\tilde{\nu} = 0$ and hence $\mu_T = 0$.

References on page 246:

[49] Allmaras, S.R.; Johnson, F.T.; Spalart, P.R.: *Modifications and Clarifications for the Implementation of the Spalart-Allmaras Turbulence Model*. ICCFD7-1902, 7th Int. Conf. on Comput. Fluid Dynamics, 2012.

Chapter 8: Boundary Conditions

Equation (8.7) on page 257:

$$(\vec{F}_{c,w}\,\Delta S)_{i,2} = \begin{bmatrix} 0 \\ (n_x)_{i-1,2}\,(p_w)_{i-1/4} \\ (n_y)_{i-1,2}\,(p_w)_{i-1/4} \\ (n_z)_{i-1,2}\,(p_w)_{i-1/4} \\ 0 \end{bmatrix}\frac{\Delta S_{i-1,2}}{2} + \begin{bmatrix} 0 \\ (n_x)_{i,2}\,(p_w)_{i+1/4} \\ (n_y)_{i,2}\,(p_w)_{i+1/4} \\ (n_z)_{i,2}\,(p_w)_{i+1/4} \\ 0 \end{bmatrix}\frac{\Delta S_{i,2}}{2}\,.$$

Equation (8.8) and related text on page 258:

The pressures $(p_w)_{i-1/4}$ and $(p_w)_{i+1/4}$ in Eq. (8.7) can be obtained by linear interpolation, for example,

$$(p_w)_{i+1/4} = \frac{1}{4}(3p_{i,2} + p_{i+1,2}) \, .$$

Chapter 9: Acceleration Techniques

Point 5 of the solution steps described on page 311:

5. Multiply the residual by $\alpha_k \, \Delta t / \Omega$.

Equation (9.59) on page 313 (last term in the first column):

$$\bar{P} = \begin{bmatrix} \rho_p & 0 & 0 & 0 & \rho_T \\ \rho_p \, u & \rho & 0 & 0 & \rho_T \, u \\ \rho_p \, v & 0 & \rho & 0 & \rho_T \, v \\ \rho_p \, w & 0 & 0 & \rho & \rho_T \, w \\ \rho_p H + \rho h_p - 1 & \rho u & \rho v & \rho w & \rho_T H + \rho h_T \end{bmatrix} .$$

Text on page 318:

... the condition number Eq. (9.40) is reduced (the condition number is $C_N \approx 1.62$) and the ...