Supplementary Materials

(Detailed description of the numerical analysis model)

The mathematical governing equations (continuity equation, momentum equation and energy equation) used in our CFD model to predict the flow of solar updraft tower (SUT) are as follows. These equations are written in a two-dimensional (2D) cylindrical coordinate system for the 2D axisymmetric SUT geometry [1].

1. Continuity equations

$$\frac{\partial}{\partial t}(\rho) + \frac{1}{\mathrm{r}}\frac{\partial}{\partial \mathrm{r}}(r\rho u) + \frac{\partial}{\partial z}(\rho w) = 0$$

2. Momentum equations

$$\frac{\partial}{\partial t}(\rho u) + \frac{1}{\mathrm{r}}\frac{\partial}{\partial \mathrm{r}}(r\rho uu) + \frac{\partial}{\partial z}(\rho uw) = -\frac{dp}{dr} + \frac{1}{\mathrm{r}}\frac{\partial}{\partial \mathrm{r}}(\mu\, \mathrm{r}\frac{\partial}{\partial \mathrm{r}}(\mathrm{u})) + \frac{\partial}{\partial z}(\mu\, \frac{\partial}{\partial z}(\mathrm{u})) - 2\mu\frac{\mathrm{u}}{\mathrm{r}^2}$$

$$\frac{\partial}{\partial t}(\rho w) + \frac{1}{\mathrm{r}}\frac{\partial}{\partial \mathrm{r}}(r\rho uw) + \frac{\partial}{\partial z}(\rho Vw) = -\frac{dp}{dz} + \frac{1}{\mathrm{r}}\frac{\partial}{\partial \mathrm{r}}(\mu\, \mathrm{r}\frac{\partial}{\partial \mathrm{r}}(\mathrm{w})) + \frac{\partial}{\partial z}(\mu\, \frac{\partial}{\partial z}(\mathrm{w})) - (\rho_0 - \rho)\mathrm{g}$$

3. Energy equation

$$\frac{\partial}{\partial t}(\rho T) + \frac{1}{\mathrm{r}}\frac{\partial}{\partial \mathrm{r}}(r\rho uT) + \frac{\partial}{\partial z}(\rho VT) = \frac{1}{\mathrm{r}}\frac{\partial}{\partial \mathrm{r}}(r\frac{\lambda}{C_p}\frac{\partial}{\partial \mathrm{r}}(T)) + \frac{\partial}{\partial z}(\frac{\lambda}{C_p}\frac{\partial}{\partial z}(T))$$

4. Standard k-ε model

In standard k-ε model, the turbulent kinetic energy k and its dissipation rate ε are calculated using the following transport equation.

$$\frac{\partial}{\partial t}(\rho \mathrm{k}) + \frac{\partial}{\partial x_i}(\rho \mathrm{k}u_i) = \frac{\partial}{\partial x_j}[(\mu + \frac{\mu_t}{\sigma_\mathrm{k}})\frac{\partial \mathrm{k}}{\partial x_j}] + G_\mathrm{k} + G_b - \rho\varepsilon - \mathrm{Y}_M + \mathrm{S}_\mathrm{k}$$

$$\frac{\partial}{\partial t}(\rho \varepsilon) + \frac{\partial}{\partial x_i}(\rho \varepsilon u_i) = \frac{\partial}{\partial x_j}[(\mu + \frac{\mu_t}{\sigma_\varepsilon}) + \frac{\partial \varepsilon}{\partial x_j}] + C_{1\varepsilon}\frac{\varepsilon}{\mathrm{k}}(G_\mathrm{k} + C_{3\varepsilon}G_b) - C_{2\varepsilon}\rho\frac{\varepsilon^2}{\mathrm{k}} + \mathrm{S}_\varepsilon$$

G_k : the generation of the turbulence kinetic energy due to the average velocity gradients.

G_b : the generation of the turbulence kinetic energy due to buoyancy.

Y_M : the influence of the fluctuating expansion in compressible turbulence to the overall dissipation rate.

The k and ε are used to calculate the turbulent viscosity μ_t using the following equation:

$$\mu_t = \rho C_\mu \frac{\mathrm{k}^2}{\varepsilon}$$

In this paper, $C_{1\varepsilon}$, $C_{2\varepsilon}$, C_μ, σ_k, σ_ε are given as follows:

Constant	$C_{1\varepsilon}$	$C_{2\varepsilon}$	C_μ	σ_k	σ_ε
Value	1.44	1.92	0.09	1	1.3

Reference

1. ANSYS Fluent. 12.0 Theory Guide.