Homework No.8

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Simulate the cooling of apple/avocado considering, convection and radiation.

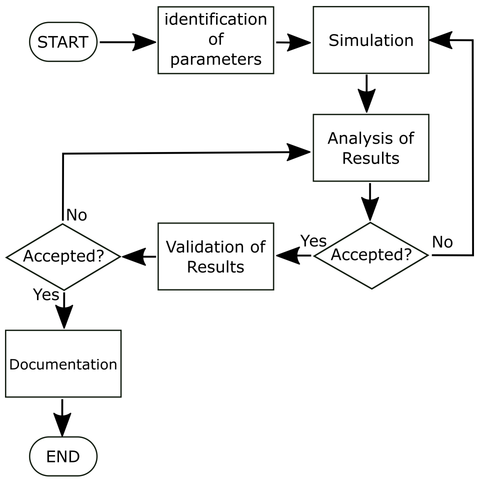

Figure 1: Process Flowchart of CFD simulation

Simulation is done under the following conditions:

- Initial temperature of the fruit 25°C. (Fruit is assumed to be a spherical apple)
- surroundings temperature −10°C
- Air must be stangant or moving at velocity not higher than 2m/s. ($v_{air} = 0$m/s is assumed)
- The methabolic/respiration rate of the fruit must be 40mW/kg

Ansys - Transient Thermal is used to simulate the cooling of an apple through convection and radiation. As shown in Figure 1, the cooling effect is first simulated and then validated through an analytic solution. Results compare the effect of the object's shape as a "spherical-apple" and a "cylindrical-apple" are analyzed.

As the surface of the object is subjected to both convection and radiation, let's do a energy balance on the control volume, assuming the temperature of the sphere is uniform:

$$\begin{pmatrix} \text{Heat in} \\ \text{via} \\ \text{Convection} \end{pmatrix} + \begin{pmatrix} \text{Heat in} \\ \text{via} \\ \text{Radiation} \end{pmatrix} = 0 \tag{1}$$

$$\frac{d}{dt}(\rho V c T) = -(\dot{q}_{conv} + \dot{q}_{rad}) \tag{2}$$

$$\frac{dT}{dt} = -\frac{A}{\rho V c}\left[h(T - T_\infty) + \varepsilon\sigma(T^4 - {T_{surr}}^4)\right] \tag{3}$$

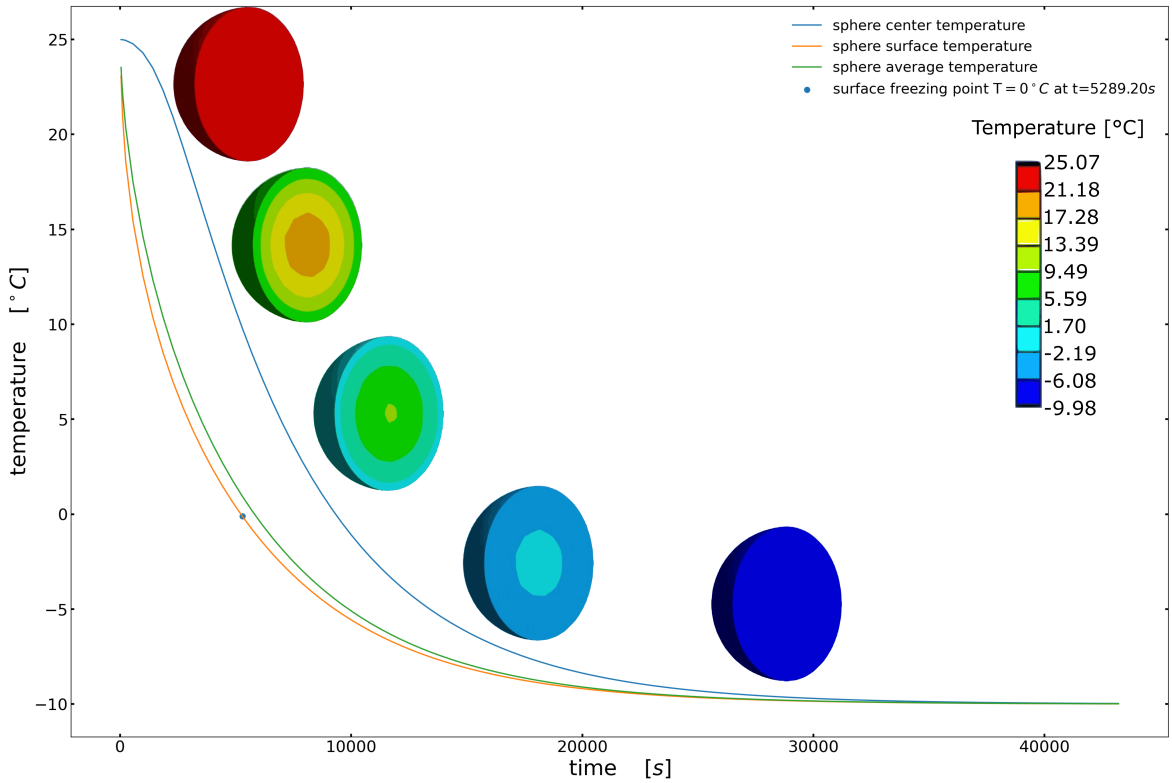

Figure 2: Visualization of a Velocity Field

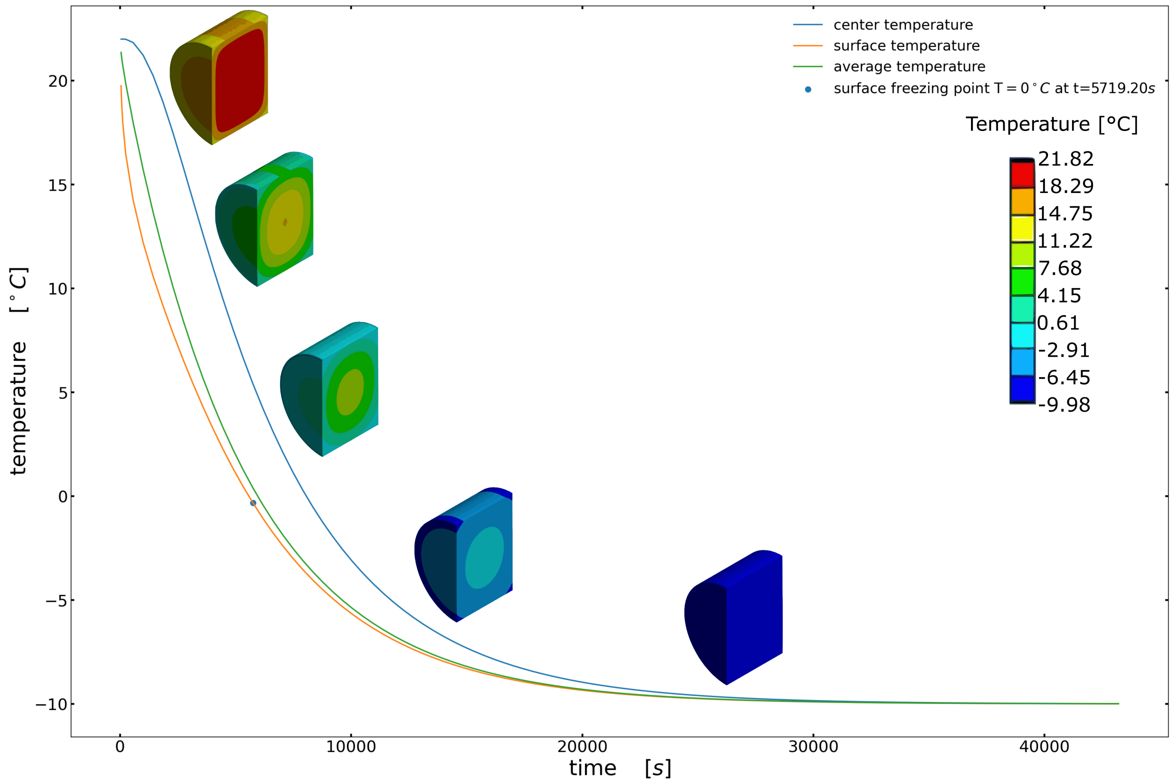

Figure 3: Visualization of a Velocity Field

Given the geometry diameter of 5cm given the following:

$$\rho c_p \frac{\partial T}{\partial t} + \rho c_p v \Lambda T = \nabla \cdot (k\nabla T) + \dot{Q}_v \tag{4}$$

Where: $\rho c_p \dfrac{\partial T}{\partial t}$ is the accumulation of internal energy, $\rho c_p v \nabla T$ is the convection term, $\nabla \cdot (k \nabla T)$ is the conduction term, and $\dot{Q}_v$ is the metabolic heat reate of the fruit.

With the following boundary conditions at the surface:

$$|k\nabla T + h|_{surf} = h(T - T_f) + \varepsilon\sigma(T^4 - {T_w}^4) + \dot{Q}_A \tag{5}$$