Chapter 10
Integrated Numerical Modeling of SOFCs
Mechanical Properties and Stress Analyses

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Nomenclature

\( d \)  distance between diffraction plane
\( h \)  \( \equiv h_t + \sum m_m H_m \)
\( h_t \)  thermal enthalpy
\( m_m \)  mass fraction of mixture constituent \( m \)
\( n \)  unit vector normal to the boundary
\( p \)  piezometric pressure
\( q \)  heat loss term
\( r \)  reaction rate
\( s_i \)  momentum source components
\( s_h \)  energy source
\( t \)  time
\( x_i \)  Cartesian coordinate \( (i = 1, 2, 3) \)
\( u_i \)  absolute fluid velocity component in direction \( x_i \)
\( \tilde{u}_j \)  relative velocity between fluid and local coordinate frame that moves with velocity \( u_{cj} \)
\( \sqrt{g} \)  determinant of metric tensor
\( D \)  diffusion constant
\( E \)  Young’s modulus
\( E_0 \)  cell operating voltage
\( E_i \)  Nernst potential at the \( i \)th cell
\( F_{h,j} \)  diffusional energy flux in direction \( x_j \)
\( G \)  Gibbs energy
\( H_A \)  total enthalpy of air in the channel
\( H_F \)  total enthalpy of fuel in the channel
\( H_m \)  heat of formation of constituent \( m \)
\( H_S \)  enthalpy in the electrolyte
\( J \)  current density

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Solid oxide fuel cells (SOFCs) are composed of ceramic components and the mechanical reliability of these components is a significant issue in the development of SOFCs. In particular, the durability of the components against stresses during operation is a serious problem. To evaluate the mechanical reliability of SOFCs, the magnitude of the stresses in cell components and the strength of the components against the stresses must be considered precisely. Stresses in SOFCs are categorized into four types.

1. A thermally induced residual stress. The origin of the residual stresses is a mismatch of thermal expansion behaviors among the components. Rigid connection of each component with different thermal expansion coefficients causes residual stresses. For example, the electrolyte and electrodes are fabricated and connected at a high temperature. If the thermal expansion behaviors are not identical among the components, residual stresses will occur in the cell at room temperature. For stacks, similar residual stresses will occur by a mismatch of thermal expansion behavior among cells and other stack components.

2. A thermally induced stress.