Universidad Nacional Autónoma de México
Facultad de Química
Departamento de Ingeniería Metalúrgica
Introducción a la Ingeniería de Procesos Metalúrgicos y de Materiales
Profesor: Luis Enrique Jardón Pérez

Tablas y Ecuaciones de Fenómenos de Transporte

TENSOR DE ESFUERZOS

Componentes del tensor de esfuerzos para fluidos newtonianos en coordenadas cartesianas[1] (x, y, z):

$$\bar{\tau}_{xx} = -\mu \left[2 \frac{\partial v_x}{\partial x} - \frac{2}{3} (\nabla \cdot \bar{v}) \right]$$

$$\bar{\tau}_{yy} = -\mu \left[2 \frac{\partial v_y}{\partial y} - \frac{2}{3} (\nabla \cdot \bar{v}) \right]$$

$$\bar{\tau}_{zz} = -\mu \left[2 \frac{\partial v_z}{\partial z} - \frac{2}{3} (\nabla \cdot \bar{v}) \right]$$

$$\bar{\tau}_{xy} = \bar{\tau}_{yx} = -\mu \left[\frac{\partial v_x}{\partial y} + \frac{\partial v_y}{\partial x} \right]$$

$$\bar{\tau}_{xz} = \bar{\tau}_{zx} = -\mu \left[\frac{\partial v_x}{\partial z} + \frac{\partial v_z}{\partial x} \right]$$

$$\bar{\tau}_{yz} = \bar{\tau}_{zy} = -\mu \left[\frac{\partial v_y}{\partial z} + \frac{\partial v_z}{\partial y} \right]$$

[1] $\nabla \cdot \bar{v} = \frac{\partial v_x}{\partial x} + \frac{\partial v_y}{\partial y} + \frac{\partial v_z}{\partial z}$

Componentes del tensor de esfuerzos para fluidos newtonianos en coordenadas cilíndricas[2] (r, θ, z):

$$\bar{\tau}_{rr} = -\mu\left[2\frac{\partial v_r}{\partial r} - \frac{2}{3}(\nabla\cdot\bar{v})\right]$$

$$\bar{\tau}_{\theta\theta} = -\mu\left[2\left(\frac{1}{r}\frac{\partial v_\theta}{\partial \theta} + \frac{v_r}{r}\right) - \frac{2}{3}(\nabla\cdot\bar{v})\right]$$

$$\bar{\tau}_{zz} = -\mu\left[2\frac{\partial v_z}{\partial z} - \frac{2}{3}(\nabla\cdot\bar{v})\right]$$

$$\bar{\tau}_{r\theta} = \bar{\tau}_{\theta r} = -\mu\left[\frac{1}{r}\frac{\partial v_r}{\partial \theta} + r\frac{\partial}{\partial r}\left(\frac{v_\theta}{r}\right)\right]$$

$$\bar{\tau}_{rz} = \bar{\tau}_{zr} = -\mu\left[\frac{\partial v_r}{\partial z} + \frac{\partial v_z}{\partial r}\right]$$

$$\bar{\tau}_{\theta z} = \bar{\tau}_{z\theta} = -\mu\left[\frac{\partial v_\theta}{\partial z} + \frac{1}{r}\frac{\partial v_z}{\partial \theta}\right]$$

[2] $\nabla\cdot\bar{v} = \frac{1}{r}\frac{\partial}{\partial r}(r v_r) + \frac{1}{r}\frac{\partial v_\theta}{\partial \theta} + \frac{\partial v_z}{\partial z}$

Componentes del tensor de esfuerzos para fluidos newtonianos en coordenadas esféricas[3] (r, θ, φ):

$$\bar{\tau}_{rr} = -\mu\left[2\frac{\partial v_r}{\partial r} - \frac{2}{3}(\nabla\cdot\bar{v})\right]$$

$$\bar{\tau}_{\theta\theta} = -\mu\left[2\left(\frac{1}{r}\frac{\partial v_\theta}{\partial\theta} + \frac{v_r}{r}\right) - \frac{2}{3}(\nabla\cdot\bar{v})\right]$$

$$\bar{\tau}_{\varphi\varphi} = -\mu\left[2\left(\frac{1}{r\sin\theta}\frac{\partial v_\varphi}{\partial\varphi} + \frac{v_r}{r} + \frac{v_\theta\cot\theta}{r}\right) - \frac{2}{3}(\nabla\cdot\bar{v})\right]$$

$$\bar{\tau}_{r\theta} = \bar{\tau}_{\theta r} = -\mu\left[\frac{1}{r}\frac{\partial v_r}{\partial\theta} + r\frac{\partial}{\partial r}\left(\frac{v_\theta}{r}\right)\right]$$

$$\bar{\tau}_{r\varphi} = \bar{\tau}_{\varphi r} = -\mu\left[\frac{1}{r\sin\theta}\frac{\partial v_r}{\partial\varphi} + r\frac{\partial}{\partial r}\left(\frac{v_\varphi}{r}\right)\right]$$

$$\bar{\tau}_{\theta\varphi} = \bar{\tau}_{\varphi\theta} = -\mu\left[\frac{1}{r\sin\theta}\frac{\partial v_\theta}{\partial\varphi} + \frac{\sin\theta}{r}\frac{\partial}{\partial\theta}\left(\frac{v_\varphi}{\sin\theta}\right)\right]$$

[3] $\nabla\cdot\bar{v} = \frac{1}{r^2}\frac{\partial}{\partial r}(r^2 v_r) + \frac{1}{r\sin\theta}\frac{\partial}{\partial\theta}(v_\theta\sin\theta) + \frac{1}{r\sin\theta}\frac{\partial v_\varphi}{\partial\varphi}$

CONSERVACIÓN DE MASA

Ecuación de continuidad (conservación de masa) en coordenadas cartesianas (x, y, z):

$$-\left[\frac{\partial}{\partial x}(\rho v_x) + \frac{\partial}{\partial y}(\rho v_y) + \frac{\partial}{\partial z}(\rho v_z)\right] = \frac{\partial \rho}{\partial t}$$

Ecuación de continuidad (conservación de masa) en coordenadas cilíndricas (r, θ, z):

$$-\left[\frac{1}{r}\frac{\partial}{\partial r}(\rho r v_r) + \frac{1}{r}\frac{\partial}{\partial \theta}(\rho v_\theta) + \frac{\partial}{\partial z}(\rho v_z)\right] = \frac{\partial \rho}{\partial t}$$

Ecuación de continuidad (conservación de masa) en coordenadas esféricas (r, θ, φ):

$$-\left[\frac{1}{r^2}\frac{\partial}{\partial r}(\rho r^2 v_r) + \frac{1}{r \sin\theta}\frac{\partial}{\partial \theta}(\rho v_\theta \sin\theta) + \frac{1}{r \sin\theta}\frac{\partial}{\partial \varphi}(\rho v_\varphi)\right] = \frac{\partial \rho}{\partial t}$$

CONSERVACIÓN DE MOMENTUM

Ecuaciones de Navier – Stokes (conservación de momentum) en coordenadas cartesianas (x, y, z) en términos de $\bar{\bar{\tau}}$.

Componente x:

$$\rho\left(\frac{\partial v_x}{\partial t} + v_x\frac{\partial v_x}{\partial x} + v_y\frac{\partial v_x}{\partial y} + v_z\frac{\partial v_x}{\partial z}\right) = -\frac{\partial P}{\partial x} - \left(\frac{\partial \bar{\tau}_{xx}}{\partial x} + \frac{\partial \bar{\tau}_{yx}}{\partial y} + \frac{\partial \bar{\tau}_{zx}}{\partial z}\right) + \rho g_x$$

Componente y:

$$\rho\left(\frac{\partial v_y}{\partial t} + v_x\frac{\partial v_y}{\partial x} + v_y\frac{\partial v_y}{\partial y} + v_z\frac{\partial v_y}{\partial z}\right) = -\frac{\partial P}{\partial y} - \left(\frac{\partial \bar{\tau}_{xy}}{\partial x} + \frac{\partial \bar{\tau}_{yy}}{\partial y} + \frac{\partial \bar{\tau}_{zy}}{\partial z}\right) + \rho g_y$$

Componente z:

$$\rho\left(\frac{\partial v_z}{\partial t} + v_x\frac{\partial v_z}{\partial x} + v_y\frac{\partial v_z}{\partial y} + v_z\frac{\partial v_z}{\partial z}\right) = -\frac{\partial P}{\partial z} - \left(\frac{\partial \bar{\tau}_{xz}}{\partial x} + \frac{\partial \bar{\tau}_{yz}}{\partial y} + \frac{\partial \bar{\tau}_{zz}}{\partial z}\right) + \rho g_z$$

Ecuaciones de Navier – Stokes (conservación de momentum) en coordenadas cartesianas (x, y, z) para un fluido incompresible (ρ = cte) y newtoniano (μ = cte).

Componente x:

$$\rho\left(\frac{\partial v_x}{\partial t}+v_x\frac{\partial v_x}{\partial x}+v_y\frac{\partial v_x}{\partial y}+v_z\frac{\partial v_x}{\partial z}\right)=-\frac{\partial P}{\partial x}+\mu\left(\frac{\partial^2 v_x}{\partial x^2}+\frac{\partial^2 v_x}{\partial y^2}+\frac{\partial^2 v_x}{\partial z^2}\right)+\rho g_x$$

Componente y:

$$\rho\left(\frac{\partial v_y}{\partial t}+v_x\frac{\partial v_y}{\partial x}+v_y\frac{\partial v_y}{\partial y}+v_z\frac{\partial v_y}{\partial z}\right)=-\frac{\partial P}{\partial y}+\mu\left(\frac{\partial^2 v_y}{\partial x^2}+\frac{\partial^2 v_y}{\partial y^2}+\frac{\partial^2 v_y}{\partial z^2}\right)+\rho g_y$$

Componente z:

$$\rho\left(\frac{\partial v_z}{\partial t}+v_x\frac{\partial v_z}{\partial x}+v_y\frac{\partial v_z}{\partial y}+v_z\frac{\partial v_z}{\partial z}\right)=-\frac{\partial P}{\partial z}+\mu\left(\frac{\partial^2 v_z}{\partial x^2}+\frac{\partial^2 v_z}{\partial y^2}+\frac{\partial^2 v_z}{\partial z^2}\right)+\rho g_z$$

Ecuaciones de Navier – Stokes (conservación de momentum) en coordenadas cilíndricas (r, θ, z) en términos de $\bar{\bar{\tau}}$.

Componente r:

$$\rho\left(\frac{\partial v_r}{\partial t}+v_r\frac{\partial v_r}{\partial r}+\frac{v_\theta}{r}\frac{\partial v_r}{\partial \theta}-\frac{{v_\theta}^2}{r}+v_z\frac{\partial v_r}{\partial z}\right)=-\frac{\partial P}{\partial r}-\left(\frac{1}{r}\frac{\partial}{\partial r}(r\bar{\tau}_{rr})+\frac{1}{r}\frac{\partial \bar{\tau}_{r\theta}}{\partial \theta}-\frac{\bar{\tau}_{\theta\theta}}{r}+\frac{\partial \bar{\tau}_{rz}}{\partial z}\right)+\rho g_r$$

Componente θ:

$$\rho\left(\frac{\partial v_\theta}{\partial t}+v_r\frac{\partial v_\theta}{\partial r}+\frac{v_\theta}{r}\frac{\partial v_\theta}{\partial \theta}+\frac{v_r v_\theta}{r}+v_z\frac{\partial v_\theta}{\partial z}\right)=-\frac{1}{r}\frac{\partial P}{\partial \theta}-\left(\frac{1}{r^2}\frac{\partial}{\partial r}(r^2\bar{\tau}_{r\theta})+\frac{1}{r}\frac{\partial \bar{\tau}_{\theta\theta}}{\partial \theta}+\frac{\partial \bar{\tau}_{z\theta}}{\partial z}\right)+\rho g_\theta$$

Componente z:

$$\rho\left(\frac{\partial v_z}{\partial t}+v_r\frac{\partial v_z}{\partial r}+\frac{v_\theta}{r}\frac{\partial v_z}{\partial \theta}+v_z\frac{\partial v_z}{\partial z}\right)=-\frac{\partial P}{\partial z}-\left(\frac{1}{r}\frac{\partial}{\partial r}(r\bar{\tau}_{rz})+\frac{1}{r}\frac{\partial \bar{\tau}_{\theta z}}{\partial \theta}+\frac{\partial \bar{\tau}_{zz}}{\partial z}\right)+\rho g_z$$

Ecuaciones de Navier – Stokes (conservación de momentum) en coordenadas cilíndricas (r, θ, z) para un fluido incompresible (ρ = cte) y newtoniano (μ = cte).

Componente r:

$$\rho\left(\frac{\partial v_r}{\partial t}+v_r\frac{\partial v_r}{\partial r}+\frac{v_\theta}{r}\frac{\partial v_r}{\partial \theta}-\frac{{v_\theta}^2}{r}+v_z\frac{\partial v_r}{\partial z}\right)=-\frac{\partial P}{\partial r}+\mu\left[\frac{\partial}{\partial r}\left(\frac{1}{r}\frac{\partial}{\partial r}(rv_r)\right)+\frac{1}{r^2}\frac{\partial^2 v_r}{\partial \theta^2}-\frac{2}{r^2}\frac{\partial v_\theta}{\partial \theta}+\frac{\partial^2 v_r}{\partial z^2}\right]+\rho g_r$$

Componente θ:

$$\rho\left(\frac{\partial v_\theta}{\partial t}+v_r\frac{\partial v_\theta}{\partial r}+\frac{v_\theta}{r}\frac{\partial v_\theta}{\partial \theta}+\frac{v_r v_\theta}{r}+v_z\frac{\partial v_\theta}{\partial z}\right)=-\frac{1}{r}\frac{\partial P}{\partial \theta}+\mu\left[\frac{\partial}{\partial r}\left(\frac{1}{r}\frac{\partial}{\partial r}(rv_\theta)\right)+\frac{1}{r^2}\frac{\partial^2 v_\theta}{\partial \theta^2}+\frac{2}{r^2}\frac{\partial v_r}{\partial \theta}+\frac{\partial^2 v_\theta}{\partial z^2}\right]+\rho g_\theta$$

Componente z:

$$\rho\left(\frac{\partial v_z}{\partial t}+v_r\frac{\partial v_z}{\partial r}+\frac{v_\theta}{r}\frac{\partial v_z}{\partial \theta}+v_z\frac{\partial v_z}{\partial z}\right)=-\frac{\partial P}{\partial z}+\mu\left[\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial v_z}{\partial r}\right)+\frac{1}{r^2}\frac{\partial^2 v_z}{\partial \theta^2}+\frac{\partial^2 v_z}{\partial z^2}\right]+\rho g_z$$

Ecuaciones de Navier – Stokes (conservación de momentum) en coordenadas esféricas (r, θ, φ) en términos de $\bar{\bar{\tau}}$.

Componente r:

$$\rho\left(\frac{\partial v_r}{\partial t}+v_r\frac{\partial v_r}{\partial r}+\frac{v_\theta}{r}\frac{\partial v_r}{\partial \theta}+\frac{v_\varphi}{r\sin\theta}\frac{\partial v_r}{\partial \varphi}-\frac{{v_\theta}^2+{v_\varphi}^2}{r}\right)=-\frac{\partial P}{\partial r}-\left(\frac{1}{r^2}\frac{\partial}{\partial r}(r^2\bar{\tau}_{rr})+\frac{1}{r\sin\theta}\frac{\partial}{\partial\theta}(\bar{\tau}_{r\theta}\sin\theta)+\frac{1}{r\sin\theta}\frac{\partial\bar{\tau}_{r\varphi}}{\partial\varphi}-\frac{\bar{\tau}_{\theta\theta}+\bar{\tau}_{\varphi\varphi}}{r}\right)+\rho g_r$$

Componente θ:

$$\rho\left(\frac{\partial v_\theta}{\partial t}+v_r\frac{\partial v_\theta}{\partial r}+\frac{v_\theta}{r}\frac{\partial v_\theta}{\partial \theta}+\frac{v_\varphi}{r\sin\theta}\frac{\partial v_\theta}{\partial \varphi}+\frac{v_r v_\theta}{r}-\frac{{v_\varphi}^2\cot\theta}{r}\right)$$

$$=-\frac{1}{r}\frac{\partial P}{\partial \theta}-\left(\frac{1}{r^2}\frac{\partial}{\partial r}(r^2\bar{\tau}_{r\theta})+\frac{1}{r\sin\theta}\frac{\partial}{\partial\theta}(\bar{\tau}_{\theta\theta}\sin\theta)+\frac{1}{r\sin\theta}\frac{\partial\bar{\tau}_{\theta\varphi}}{\partial\varphi}-\frac{\bar{\tau}_{r\theta}}{r}-\frac{\cot\theta}{r}\bar{\tau}_{\varphi\varphi}\right)+\rho g_\theta$$

Componente φ:

$$\rho\left(\frac{\partial v_\varphi}{\partial t}+v_r\frac{\partial v_\varphi}{\partial r}+\frac{v_\theta}{r}\frac{\partial v_\varphi}{\partial \theta}+\frac{v_\varphi}{r\sin\theta}\frac{\partial v_\varphi}{\partial \varphi}+\frac{v_r v_\varphi}{r}-\frac{v_\theta v_\varphi\cot\theta}{r}\right)=-\frac{1}{r\sin\theta}\frac{\partial P}{\partial \varphi}-\left(\frac{1}{r^2}\frac{\partial}{\partial r}(r^2\bar{\tau}_{r\varphi})+\frac{1}{r}\frac{\partial\bar{\tau}_{\theta\varphi}}{\partial\theta}+\frac{1}{r\sin\theta}\frac{\partial\bar{\tau}_{\varphi\varphi}}{\partial\varphi}-\frac{\bar{\tau}_{r\varphi}}{r}+\frac{2\cot\theta}{r}\bar{\tau}_{\theta\varphi}\right)+\rho g_\varphi$$

Ecuaciones de Navier – Stokes (conservación de momentum) en coordenadas esféricas (r, θ, φ) para un fluido incompresible (ρ = cte) y newtoniano (μ = cte)[4].

Componente r:

$$\rho\left(\frac{\partial v_r}{\partial t}+v_r\frac{\partial v_r}{\partial r}+\frac{v_\theta}{r}\frac{\partial v_r}{\partial \theta}+\frac{v_\varphi}{r\sin\theta}\frac{\partial v_r}{\partial \varphi}-\frac{{v_\theta}^2+{v_\varphi}^2}{r}\right)=-\frac{\partial P}{\partial r}+\mu\left[\nabla^2 v_r-\frac{2}{r^2}v_r-\frac{2}{r^2}\frac{\partial v_\theta}{\partial \theta}-\frac{2}{r^2}v_\theta\cot\theta-\frac{1}{r^2\sin\theta}\frac{\partial v_\varphi}{\partial \varphi}\right]+\rho g_r$$

Componente θ:

$$\rho\left(\frac{\partial v_\theta}{\partial t}+v_r\frac{\partial v_\theta}{\partial r}+\frac{v_\theta}{r}\frac{\partial v_\theta}{\partial \theta}+\frac{v_\varphi}{r\sin\theta}\frac{\partial v_\theta}{\partial \varphi}+\frac{v_r v_\theta}{r}-\frac{{v_\varphi}^2\cot\theta}{r}\right)=-\frac{1}{r}\frac{\partial P}{\partial \theta}+\mu\left[\nabla^2 v_\theta+\frac{2}{r^2}\frac{\partial v_r}{\partial \theta}-\frac{v_\theta}{r^2\,sin^2\,\theta}-\frac{2\cos\theta}{r^2\,sin^2\,\theta}\frac{\partial v_\varphi}{\partial \varphi}\right]+\rho g_\theta$$

Componente φ:

$$\rho\left(\frac{\partial v_\varphi}{\partial t}+v_r\frac{\partial v_\varphi}{\partial r}+\frac{v_\theta}{r}\frac{\partial v_\varphi}{\partial \theta}+\frac{v_\varphi}{r\sin\theta}\frac{\partial v_\varphi}{\partial \varphi}+\frac{v_r v_\varphi}{r}-\frac{v_\theta v_\varphi\cot\theta}{r}\right)$$

$$=-\frac{1}{r\sin\theta}\frac{\partial P}{\partial \varphi}+\mu\left[\nabla^2 v_\varphi-\frac{v_\varphi}{r^2\,sin^2\,\theta}+\frac{2}{r^2\sin\theta}\frac{\partial v_r}{\partial \varphi}+\frac{2\cos\theta}{r^2\,sin^2\,\theta}\frac{\partial v_\theta}{\partial \varphi}\right]+\rho g_\varphi$$

[4] $\nabla^2=\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial}{\partial r}\right)+\frac{1}{r^2\sin\theta}\frac{\partial}{\partial \theta}\left(\sin\theta\frac{\partial}{\partial \theta}\right)+\frac{1}{r^2\,sin^2\,\theta}\left(\frac{\partial^2}{\partial \varphi^2}\right)$

CONSERVACIÓN DE ENERGÍA TÉRMICA

Ecuación de conservación de energía térmica en coordenadas cartesianas (x, y, z):

$$\left[\frac{\partial}{\partial x}\left(k\frac{\partial T}{\partial x}\right)+\frac{\partial}{\partial y}\left(k\frac{\partial T}{\partial y}\right)+\frac{\partial}{\partial z}\left(k\frac{\partial T}{\partial z}\right)\right]+\dot{q}+2\mu\left[\left(\frac{\partial v_x}{\partial x}\right)^2+\left(\frac{\partial v_y}{\partial y}\right)^2+\left(\frac{\partial v_z}{\partial z}\right)^2\right]$$
$$+\mu\left[\left(\frac{\partial v_x}{\partial y}+\frac{\partial v_y}{\partial x}\right)^2+\left(\frac{\partial v_y}{\partial z}+\frac{\partial v_z}{\partial y}\right)^2+\left(\frac{\partial v_z}{\partial x}+\frac{\partial v_x}{\partial z}\right)^2\right]=\rho C_p\frac{\partial T}{\partial t}$$

Ecuación de conservación de energía térmica en coordenadas cartesianas (x, y, z) considerando solo conducción y propiedades constantes:

$$\alpha\left(\frac{\partial^2 T}{\partial x^2}+\frac{\partial^2 T}{\partial y^2}+\frac{\partial^2 T}{\partial z^2}\right)=\frac{\partial T}{\partial t}$$

Ecuación de conservación de energía térmica en coordenadas cilíndricas (r, θ, z) considerando solo conducción y propiedades constantes:

$$\alpha\left[\frac{\partial^2 T}{\partial r^2}+\frac{1}{r}\frac{\partial T}{\partial r}+\frac{1}{r^2}\frac{\partial^2 T}{\partial \theta^2}+\frac{\partial^2 T}{\partial z^2}\right]=\frac{\partial T}{\partial t}$$

Ecuación de conservación de energía térmica en coordenadas esféricas (r, θ, φ) considerando solo conducción y propiedades constantes:

$$\alpha\left[\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial T}{\partial r}\right)+\frac{1}{r^2\sin\theta}\frac{\partial}{\partial \theta}\left(\sin\theta\frac{\partial T}{\partial \theta}\right)+\frac{1}{r^2\, sin^2\,\theta}\left(\frac{\partial^2 T}{\partial \varphi^2}\right)\right]=\frac{\partial T}{\partial t}$$

CONSERVACIÓN DE ESPECIES QUÍMICAS

Ecuación de continuidad (conservación de masa) en coordenadas cartesianas (x, y, z) para una especie química A:

$$-\left[\frac{\partial}{\partial x}\left(n_{A,x}\right)+\frac{\partial}{\partial y}\left(n_{A,y}\right)+\frac{\partial}{\partial z}\left(n_{A,z}\right)\right]+r_A=\frac{\partial \rho_A}{\partial t}$$

Ecuación de continuidad (conservación de masa) en coordenadas cartesianas (x, y, z) para una especie química B:

$$-\left[\frac{\partial}{\partial x}\left(n_{B,x}\right)+\frac{\partial}{\partial y}\left(n_{B,y}\right)+\frac{\partial}{\partial z}\left(n_{B,z}\right)\right]+r_B=\frac{\partial \rho_B}{\partial t}$$

Para una mezcla binaria (A y B):

$$n_A+n_B=\rho_A v_A+\rho_B v_B=\rho v$$

$$\rho_A+\rho_B=\rho$$

$$r_A=-r_B$$

Ecuación de continuidad (conservación de masa) en coordenadas cartesianas (x, y, z) para una especie química A:

$$-\left[\frac{\partial}{\partial x}\left(N_{A,x}\right)+\frac{\partial}{\partial y}\left(N_{A,y}\right)+\frac{\partial}{\partial z}\left(N_{A,z}\right)\right]+R_A=\frac{\partial c_A}{\partial t}$$

Ecuación de continuidad (conservación de masa) en coordenadas cartesianas (x, y, z) para una especie química B:

$$-\left[\frac{\partial}{\partial x}\left(N_{B,x}\right)+\frac{\partial}{\partial y}\left(N_{B,y}\right)+\frac{\partial}{\partial z}\left(N_{B,z}\right)\right]+R_B=\frac{\partial c_B}{\partial t}$$

Para una mezcla binaria (A y B):

$$N_A+N_B=c_A v_A+c_B v_B=cv$$

$$c_A+c_B=c$$

$$Pero\ en\ este\ caso\ R_A\ no\ es\ necesariamente-R_B, depende\ de\ la\ estequiometría$$

Ecuación de conservación de la especie química A, en una mezcla binaria (A y B) en coordenadas cartesianas (x, y, z) considerando solo conducción y propiedades constantes:

$$D_{AB}\left(\frac{\partial^2 c_A}{\partial x^2}+\frac{\partial^2 c_A}{\partial y^2}+\frac{\partial^2 c_A}{\partial z^2}\right)+R_A=\frac{\partial c_A}{\partial t}$$

Ecuación de conservación de la especie química A, en una mezcla binaria (A y B) en coordenadas cilíndricas (r, θ, z) considerando solo conducción y propiedades constantes:

$$D_{AB}\left[\frac{\partial^2 c_A}{\partial r^2}+\frac{1}{r}\frac{\partial c_A}{\partial r}+\frac{1}{r^2}\frac{\partial^2 c_A}{\partial \theta^2}+\frac{\partial^2 c_A}{\partial z^2}\right]+R_A=\frac{\partial c_A}{\partial t}$$

Ecuación de conservación de la especie química A, en una mezcla binaria (A y B) en coordenadas esféricas (r, θ, φ) considerando solo conducción y propiedades constantes:

$$D_{AB}\left[\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial c_A}{\partial r}\right)+\frac{1}{r^2\sin\theta}\frac{\partial}{\partial \theta}\left(\sin\theta\frac{\partial c_A}{\partial \theta}\right)+\frac{1}{r^2\, sin^2\,\theta}\left(\frac{\partial^2 c_A}{\partial \varphi^2}\right)\right]+R_A=\frac{\partial c_A}{\partial t}$$