[0158] Without Capillary Forces:

$$v_z = \frac{\rho g \delta^2 \cos\beta}{2\mu}\left[1 - \left(\frac{x}{\delta}\right)^2\right] \tag{3}$$

[0159] With Capillary Forces within the Channel Included (Note not Surface Capillary Features):

$$v_z = \delta^2\left[\frac{1}{2}\left(\frac{\rho g}{\mu}\right)\cos\beta - \frac{2}{LD_H}\left(\frac{\sigma}{\mu}\right)\cos\theta\right]\left[1 - \left(\frac{x}{\delta}\right)^2\right] \tag{3}$$

[0160] where

[0161] μ=liquid viscosity

[0162] σ=liquid surface tension

[0163] θ=wall adhesion contact angle

[0164] D_H=channel hydraulic diameter

[0165] L=channel total length

[0166] θ=local acceleration of gravity.

[0167] Calculating the Cross-Sectional Average $<v_z>$:

$$<v_z> = \frac{1}{\delta}\int_0^\delta v_z dx = \begin{cases} \frac{1}{3}\left(\frac{\rho g}{\mu}\right)\delta^2\cos\beta \text{ without capillary forces} \\ \frac{1}{3}\delta^2\left[\left(\frac{\rho g}{\mu}\right)\cos\beta - \frac{4}{LD_H}\left(\frac{\sigma}{\mu}\right)\cos\theta\right] \text{ with capillary forces} \end{cases} \tag{4}$$

[0168] Substitution of the expression for $<v_z>$ in Eqn (4) into Eqn (2) yields the following partial differential equation for $\delta(z,t)$:

[0169] Without Capillary Forces:

$$\frac{\partial\delta}{\partial t} + \frac{2}{3}\left(\frac{\rho g}{\mu}\right)\delta^2\cos\beta\frac{\partial\delta}{\partial z} = 0 \tag{5a}$$

[0170] With Capillary Forces:

$$\frac{\partial\delta}{\partial t} + \frac{2}{3}\delta^2\left[\left(\frac{\rho g}{\mu}\right)\cos\beta - \frac{4}{LD_H}\left(\frac{\sigma}{\mu}\right)\cos\theta\right]\frac{\partial\delta}{\partial z} = 0 \tag{5b}$$

[0171] The solution to this equation yields the washcoat thickness as a function of axial location and elapsed time:

$$\delta(z,t) = \begin{cases} \sqrt{\frac{3}{2}\left(\frac{\mu}{g\rho\cos\beta}\right)\left(\frac{z}{t+t_o}\right)} \text{ without capillary forces} \\ \sqrt{\frac{3}{2}\left(\frac{\mu}{g\rho\cos\beta - \frac{4}{LD_H}\sigma\cos\theta}\right)\left(\frac{z}{t+t_o}\right)} \text{ with capillary forces} \end{cases} \tag{6}$$

[0172] The variable t_o is a normalization constant such that the average film thickness over the entire length of the channel, L, is equal to δ_o, the initial film thickness, at time t=0. Specifically, we require

$$\frac{1}{L}\int_0^L \delta(z, t=0)dz = \delta_o$$

[0173] which gives the following value for the normalization constant:

$$t_o = \frac{2}{3}\left(\frac{\mu}{\rho g\cos\beta}\right)\frac{L}{\delta_o^2}$$

[0174] Special Modeling Requirements or Assumptions

[0175] Assumptions

[0176] The model only considers 1-dimensional drainage of washcoat under gravitational, viscous loss, and capillary forces. If desired, an alternative value can be specified for the drainage rate u_o to obtain the initial film thickness during, for example, pump assisted evacuation of the channel.

[0177] The model is most applicable to single or parallel flat plates. Specifically, there are no wicking effects accounted for in the corners of a rectangular channel. In practice, substantially thicker (more than 2× the flat region) coatings are observed in the corners of the microchannel reactor when a fill and drain method of coating is used.

[0178] No provisions have been made for liquid film blow-off during the purge cycle. However, it should be recognized that current washcoat protocol calls for drainage (either gravity or pump-assisted) prior to purge cycle. Therefore, up to the time that purge cycle commences, this model should be reasonably accurate for predicting liquid film thickness distribution.

[0179] The model assumes the fluidic properties remain constant point values for all time. In particular, drying of the film is not accounted for in this model.

[0180] Restrictions

[0181] The following restrictions on use of this model should be followed:

[0182] The expression in Eqn (6) should only be applied to estimate the attrition in the wet washcoat film layer during drainage after the majority of the fluid has been removed from the channel. There may be some subjectivity associated when to set t=0 in the model. From the standpoint of validation, t should be set equal to zero when the gas can pass through the entire length of the channel, i.e. at no place is the entire cross-sectional area occluded with liquid.

[0183] The model is most applicable when the liquid film thickness is dominated by gravitational forces. Wall adhe-