ME 637 - Particle -II

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Turbulence Deposition

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Turbulence Deposition

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Outline

- Turbulence Diffusivity
- Semi-Empirical Models
- Deposition on Smooth Walls
- Deposition on Rough Walls
- Gaseous Deposition

Turbulence Deposition

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Turbulent Flux

$$J = (D + \nu^T)\frac{dC}{dy}$$

Eddy Diffusivity

$$\frac{\nu^T}{\nu} = \begin{cases} (\frac{y^+}{14.5})^3 & 0 \le y^+ \le 5 \\ \frac{y^+}{5} - 0.959 & 5 \le y^+ \le 30 \end{cases}$$

Wall Units $y^+ = \frac{yu^*}{\nu}$

Shear Velocity $u^* = \sqrt{\frac{\tau_0}{\rho^f}}$

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For a Constant Flux

$$\frac{dC}{dy} = \frac{J}{D + \nu^T}$$

Friedlander and Johnstone (1959)

Wood (1981)

$$\tau^+ = \frac{u^{*2}\tau}{\nu} = \frac{\rho^p d^2 u^{*2}}{18\rho^f \nu^2} = \frac{1}{18}(\frac{\rho^p}{\rho^f}) \mathrm{Re}_d^{*2}$$

$$\mathrm{Re}_d^* = \frac{u^* d}{\nu}$$

Deposition Velocity

$$u_D^+ = \frac{u_D}{u^*} = \frac{J}{c_0 u^*} = \frac{D + \nu^T}{\nu}\frac{dc^+}{dy^+}$$

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Wood (1981)

$\tau^+ \le 1$ → $u_D^+ \approx \frac{3\sqrt{3}}{29\pi} s_c^{-2/3} = 0.057 s_c^{-2/3}$

$1 < \tau^+ < 10$ → $u_D^+ = 0.057 s_c^{-2/3} + 4.5\times10^{-4}\tau^{+2}$

$\tau^+ \ge 265$ → $u_D^+ = 0.13$

$17 \le \tau^+ \le 200$ → $u_D^+ \approx \frac{2.6}{\sqrt{\tau^+}}(1 - \frac{50}{\tau^+})$

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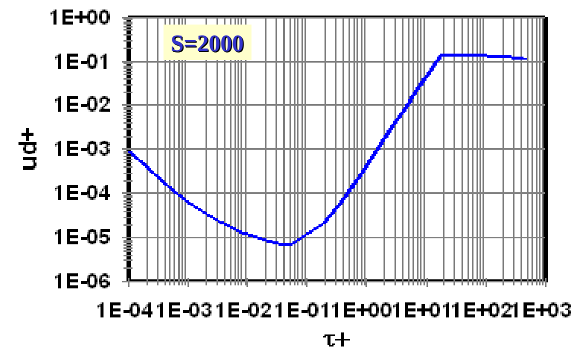

Deposition on Rough Walls

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Deposition Velocity → $u_D^+ = \frac{1}{I_B + I_s}$

$0.45k^+ < 5$

$I_B = 24.2$

$$I_s = 14.5 S_c^{2/3}\left[\frac{1}{6}\ln\frac{(1+\phi)^2}{1-\phi+\phi^2} + \frac{1}{\sqrt{3}}\tan^{-1}\frac{2\phi-1}{\sqrt{3}} - \frac{1}{6}\ln\frac{(1+\phi_k)^2}{1-\phi_k+\phi_k^2} - \frac{1}{\sqrt{3}}\tan^{-1}\frac{2\phi_k-1}{\sqrt{3}}\right]$$

$k^+ = \frac{ku^*}{\nu}$ $\phi = \frac{1}{2.9} s_c^{1/3}$ $\phi_k = \frac{k^+}{32.2} s_c^{1/3}$ $s_c = \frac{\nu}{D}$

Deposition Velocity for Rough Walls

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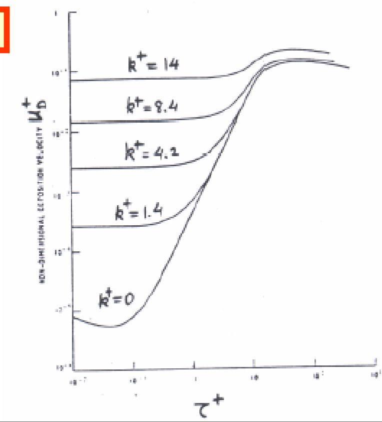
Wood (1981)



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Fan and Ahmadi

Sublayer Model

$$
u_d^+ = \begin{cases} \left\{ 0.084Sc^{-2/3} + \frac{1}{2}\left[\frac{\left(0.64k^+ + \frac{d^+}{2}\right)^2 + \frac{\tau_p^{+2} g^+ L_1^+}{0.01085(1+\tau_p^{+2} L_1^+)}}{3.42 + \frac{\tau_p^{+2} g^+ L_1^+}{0.01085(1+\tau_p^{+2} L_1^+)}} \right]^{1/\left(1+\tau_p^{+2} L_1^+\right)} \times \left[1 + 8e^{-(\tau_p^+ - 10)^2/32}\right] \frac{0.037}{1 - \tau_p^{+2} L_1^+ \left(1 + \frac{g^+}{0.037}\right)} \right\} & \text{if } u_d^+ < 0.14 \\ 0.14 & \text{otherwise} \end{cases}
$$

Deposition Velocity for Rough Walls

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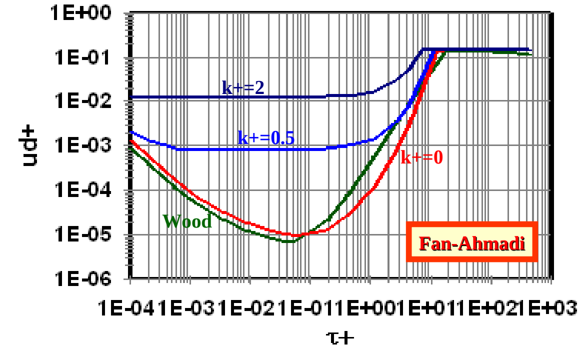

Gravitational Deposition

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Gravitational Sedimentation Velocity

$$u_D \approx u^t = \tau g$$

$$u_D^+ = \tau^+ g^+$$

$$g^+ = \frac{\nu g}{u^{*3}}$$

Gravitational Sedimentation Velocity

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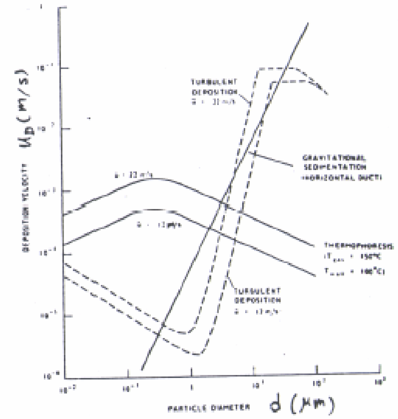
Wood (1981)



Deposition Velocity for Smooth and Rough Walls

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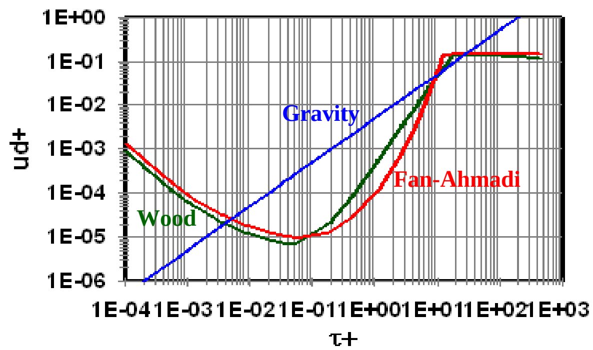

Gaseous Mass Transfer in Turbulent Flows

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Deposition Velocity

$$u_D^+ = \frac{0.2}{s_c + \ln\left(\frac{s_c^{-1} + 5.04}{s_c^{-1} + 0.04}\right)}$$

$s_c >> 25$

$$u_D^+ = \frac{0.2}{s_c + \ln(1 + 5.04 s_c)}$$

Gaseous Mass Transfer in Turbulent Flows

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Deposition Velocity for Rough Walls

$0.45k^+ < 5$

$$u_D^+ = \frac{0.2}{(1 - 0.09k^t)s_c + \ln(1 + 5.04 s_c)}$$

$5 < 0.45k^+ << 30$

$$u_D^+ = \frac{0.2}{\ln[(11.1 s_c^{-1} + 56)/k^t]}$$

Wall Flux Non-absorbing

$$J = U_D(C_0 - C_w) = U_D C_0 \left(1 - \frac{C_w}{C_0}\right)$$

Concluding Remarks

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- **Turbulence Diffusivity**
- **Semi-Empirical Models**
- **Deposition on Smooth Walls**
- **Deposition on Rough Walls**
- **Gaseous Deposition**