## 3.5 Friction losses in pipes and fittings

### 3.5.1 Pipes

When water flows through a pipe the friction between the wall of the pipe and the water slows the water down and uses up some of its energy, such that a loss of head $\Delta H$ (normally denoted $H_f$) along the pipe results which relates to the pipe diameter $d$ and length $l$ and the free stream velocity $v$ by the *Darcy-Weisbach* equation:

$$H_f = \lambda \frac{l}{d} \frac{v^2}{2g} \tag{3.9}$$

where $\lambda$ is the *Darcy-Weisbach friction factor*, and depends on the surface roughness, $\kappa$, and the Reynolds number. It also usual practice to define the head loss per unit length of pipe ($\Delta H/l$) as the *hydaulic gradient*, $s$, so that the above equation becomes:

$$s = \frac{\lambda}{d} \frac{v^2}{2g} \tag{3.10}$$

where $\lambda$ can be obtained most accurately from *Moody diagrams*, derived from the *Colebrook-White* equation. The Colebrook-White equation is not readily employed directly, but several simplifications exist - including the *Swamee–Jain* approximation:

$$\lambda = \frac{0.25}{\left[\log\left(\frac{\kappa}{3.7d} + \frac{5.74}{\mathrm{Re}^{0.9}}\right)\right]^2} \tag{3.11}$$

where pipe roughness ($\kappa$) takes units of length and typical values are given in Table 7. Under highly turbulent conditions, i.e. when $5.74/Re^{0.9} << \kappa/3.7D$, the second term in the denominator of Equation 3.11 disappears and the expression simplifies to:

$$\lambda = \frac{0.25}{\left[\log\left(\frac{\kappa}{3.7d}\right)\right]^2} \tag{3.12}$$

*Table 7:* Pipe roughness values in mm

| *Pipe characteristics* | *κ (mm)* |
|---|---|
| New plastic and non-ferrous | 0.03 |
| Spun bitumen or cement lined ductile iron | 0.05 |
| Steel (uncoated) | 0.05 |
| Good ductile or cast iron | 0.05 |
| Galvanised steel | 0.15 |
| Precast concrete | 0.15 |
| Tuberculated water mains up to 20 years old | 1.5 – 15 |
| Tuberculated water mains up to 50 years old | 0.3 – 30 |