Degree of reaction

Again the desirability of large α_2 is indicated and the same limitations are encountered, so that typical values of α_2 are near 70^o. For the special case of axial outlet velocity and constant V_f, α_3 and β_2 are zero and the velocity diagram becomes a rectangle. The stage work output is then

$$\psi = 1$$

Thus, for the same blade speed and for axial outlet velocities, the impulse stage work is twice that of the 50% reaction stage. However, we can expect the impulse stage to have somewhat greater loss, since the average fluid velocity in the stage is higher and the boundary layer on the suction side of the rotor blades may be significantly thicker and closer to separation, depending on the turning angle and blade spacing. The 50% reaction stage is not uniquely desirable, of course. One can use any degree of reaction (greater then zero) to design a turbine of acceptable performance.

The gas flow angles at inlet and exit of blades can be expressed in terms of Ψ, ϕ and R.

For the rotor blade, the relative total enthalpy remains constant and we have,

$$h_2 + \frac{V_{r_2}^2}{2} = h_3 + \frac{V_{r_3}^2}{2}$$

or,

$$h_2 - h_3 = \frac{V_{r_3}^2}{2} - \frac{V_{r_2}^2}{2}$$

If the axial velocity is the same upstream and downstream of the rotor, then

$$h_2 - h_3 = \frac{(V_{r_{w_3}} - V_{r_{w_2}})(V_{r_{w_3}} + V_{r_{w_2}})}{2}$$

The Eq.(14.1) becomes,

$$R = \frac{(V_{r_{w3}} - V_{r_{w_2}})(V_{r_{w_3}} + V_{r_{w2}})}{(V_{w_2} - V_{w_3})}$$

Again from the velocity triangle (Fig 13.2),

$$V_{w_2} - V_{w_3} = V_{r_{w2}} - V_{r_{w3}}$$

Thus,

$$R = -\left(\frac{V_{r_{w3}} + V_{r_{w2}}}{2U}\right) \qquad (14.4)$$

$$= -\frac{1}{2}\frac{V_f}{U}(\tan\beta_2 + \tan\beta_3)$$

$$R = -\frac{1}{2}\phi\,(\tan\beta_2 + \tan\beta_3) \qquad (14.5)$$

Solving Eq.13.5 and Eq.14.5, we have

$$\tan\beta_2 = (\psi - 2R)/2\phi \qquad (14.6)$$

$$\tan\beta_3 = (\psi + 2R)/2\phi \qquad (14.7)$$

and from geometric relation

$$\tan\alpha_2 = \tan\beta_2 + \frac{1}{\phi} \qquad (14.8)$$

$$\tan\alpha_3 = \tan\beta_3 + \frac{1}{\phi} \qquad (14.9)$$

Hence, from given values of Ψ, ϕ and R we can estimate gas flow angles and the blade layout.