Degree of reaction

From the velocity diagram, we can see that

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

i.e. $$V_{w_2} - V_{w_3} = 2V_{r_{w2}}$$

$$= 2(V_{w_2} - U)$$

$$= 2U\left(\frac{V_f}{U}\tan\alpha_2 - 1\right)$$

Then, $$\psi = \frac{V_{w_2} - V_{w_3}}{U}$$

$$= 2(\phi\tan\alpha_2 - 1) \qquad (14.2)$$

The Eq (14.2) illustrates the effect of the nozzle outlet angle on the impulse turbine work output.

It is evident, then, that for large power output the nozzle angle should be as large as possible. Two difficulties are associated with very large α_2. For reasonable axial velocities (i.e., reasonable flow per unit frontal area), it is evident that large α_2 creates very large absolute and relative velocities throughout the stage. High losses are associated with such velocities, especially if the relative velocity V_{r_2} is supersonic. In practice, losses seem to be minimized for values of α_2 around 70^o. In addition, one can see that for large α_2 $[\tan\alpha_2 > (2U/V_f)]$, the absolute exhaust velocity will have a swirl in the direction opposite to U. While we have not introduced the definition of turbine efficiency as yet, it is clear that, in a turbojet engine where large axial exhaust velocity is desired, the kinetic energy associated with the tangential motion of the exhaust gases is essentially a loss. Furthermore, application of the angular momentum equation over the entire engine indicates that exhaust swirl is associate with an (undesirable) net torque acting on the aircraft. Thus the desire is for axial or near-axial absolute exhaust velocity (at least for the last stage if a multistage turbine is used). For the special case of constant V_f and axial exhaust velocity $V_{w_3} = 0$ and $V_{w_2} = 2U$, the Eq.14.2 becomes,

$$\psi = 2 \qquad \left[\because \tan\alpha_2 = \frac{V_w}{V_f} = \frac{2U}{V_f} = 2/\phi\right]$$

For a given power and rotor speed, and for a given peak temperature, Eq. (14.2) is sufficient to determine approximately the mean blade speed (and hence radius) of a single-stage impulse turbine having axial outlet velocity. If , as is usually the case, the blade speed is too high (for stress limitations), or if the mean diameter is too large relative to the other engine components, it is necessary to employ a multistage turbine in which each stage does part of the work.