Deviation Angle

While the simple, empirical approach of the last section has practical and educational value, it is also valuable to consider the structure of the flow in more detail, and to examine how higher level solutions to the flow might be used to predict the performance of a cascade of a particular geometry. In doing so, it is important to distinguish between performance characteristics that are the result of idealized inviscid flow and those that are caused by viscous effects. Consider, first, the inviscid flow effects. König (1922) was the first to solve the potential flow through a linear cascade, in particular for a simple cascade of infinitely thin, straight blades. The solution leads to values of the deviation, δ, that, in turn, allow evaluation of the shut-off head coefficient, ψ_0, through equation (Mbcb17). This is shown as a function of solidity in figure 1. Note that for solidities greater than about unity, the idealized, potential flow exits the blade passages parallel to the blades, and hence $\psi_0 \rightarrow 1$.

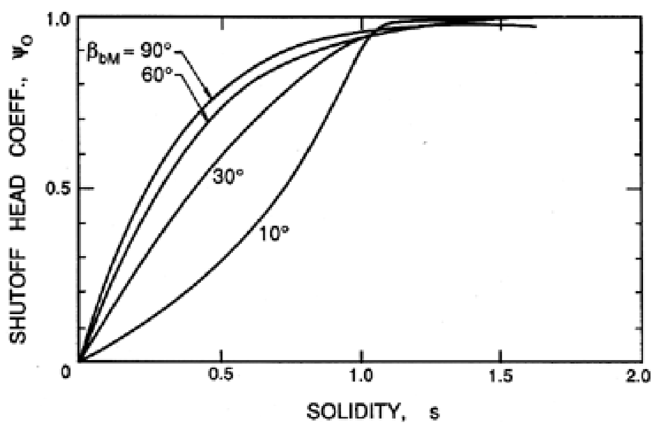

Figure 1: The performance parameter, ψ_0, as a function of solidity, s, for flat plate cascades with different blade angles, β_b. Adapted by Wislicensus (1947) (see also Sabersky, Acosta and Hauptmann 1989) from the potential flow theory of König (1922).

Another approach to the same issue of relating the flow angle, β_2, to the blade angles, is to employ an empirical rule for the deviation angle, $\delta = \beta_{b2} - \beta_2$ (equation (Mbba2)), in terms of other geometric properties of the cascade. One early empirical relation suggested by Constant (1939) (see Horlock 1973) relates the deviation to the camber angle, θ_c, and the solidity, s, through

$$\delta_N = C\ \theta_c / s^{\frac{1}{2}} \tag{Mbcc1}$$

where the subscript N refers to nominal conditions, somewhat arbitrarily defined as the operating condition at which the deflection $(\beta_2 - \beta_1)$ has a value that is 80% of that at which stall would occur. Constant suggested a value of 0.26 for the constant, C. Note that β_2 can then be evaluated and the head rise obtained from the characteristic (Mbcb12). Later investigators explored the variations in the deviation angle with other flow parameters (see, for example, Howell 1942), and devised more complex correlations for use in the design of axial flow rotors (Horlock 1973). However, the basic studies of Leiblein on the boundary layers in linear cascades, and the role which these viscous effects play in determining the deviation and the losses, superceded much of this empirical work.