used to mixed-flow impeller.

2. Slip factor correlations for mixed-flow impeller

Staniz (1952) analyzed slip phenomenon in a mixed-flow impeller as Figure 1 and he defined the slip factor

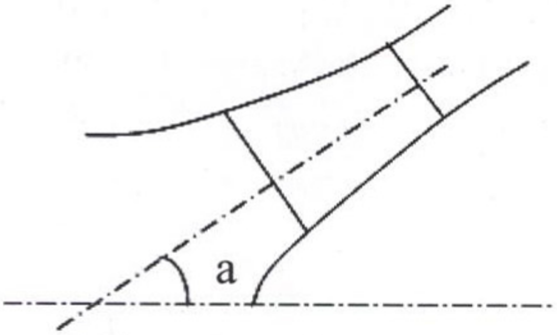

Fig 1. Representaion of staniz mixed-flow impeller.

correlation as:

$$\delta = 1 - \frac{1.98}{Z} \sin\alpha \tag{1}$$

Wiesner's correlation is as follows:

$$\delta = 1 - \frac{\sqrt{\cos\beta_{2b}}}{Z^{0.7}} \tag{2}$$

Staniz point out that the equations (2) should be correlated by impeller exit inclination angle before used for mixed-flow impeller.

Lewis's (1996) analysis has established that for a mixed-flow impeller slip factor should be given by an equivalent radial impeller with M blades.

$$M = \frac{Z}{\sin\alpha} \tag{3}$$

It's interesting to see that the staniz correlation (equation 2) can be transform to

$$\delta = 1 - \frac{1.98}{Z/\sin\alpha} = 1 - \frac{1.98}{M} \tag{4}$$

Based on the method of M blades, slip factor correlations of centrifugal impeller can be used to mixed-flow impeller while no proper mixed-flow slip factor models exist. Such as the stodola correlation:

$$\delta = 1 - \frac{\pi\cos\beta_{2b}}{M} = 1 - \frac{\pi\cos\beta_{2b}}{Z}\sin\alpha \tag{5}$$

Visser (1994) obtained an exact expression for the slip factor by a new conformal mapping technique. Since the exact solution is very complex to be used in practical design and performance analysis. Paeng (2001) formulate a new simple correlation of the slip factor that is in good agreement with the experiments and Visser's theory. Paeng's correlation is as following equation:

$$\delta = 1 - f\frac{\sin(\frac{\pi}{Z}\cos\beta_{2b})}{1+\sin(\frac{\pi}{Z}\cos\beta_{2b})} \tag{6}$$

Backstrom (2006) formulate a unified slip factor for centrifugal impeller based on Singular Relative Eddy (SRE) method. His correlation is:

$$\delta = 1 - \frac{1}{1 + F_0(c/s_e)(\cos\beta_{2b})^{0.5}} \tag{7}$$

Where:

$$c/s_e = \frac{(1-RR)Z}{2\pi\cos\beta_{2b}}$$

Backstrom regard solidity c/se as main variable for the slip factor.

Qiu (2007) suggests that the flow coefficient at the impeller exit is also an important variable for the slip factor when there is blade turning at the impeller discharge. His correlation is :

$$\sigma = 1 - \frac{F\pi\cos\beta_{2b}\sin\alpha}{Z} - \frac{Fs_2\phi_2}{4\cos\beta_{2b}}\left(\frac{d\beta}{dm}\right)_2 + \frac{F\phi_2 s_2\sin\beta_{2b}}{4\rho_2 b_2}\left(\frac{d\rho b}{dm}\right)_2 \tag{8}$$

Based on the slip factor correlations above, there are two ways for calculating mixed-flow impeller slip factor: (1) Following the way of Staniz and Lewis, that is using Impeller exit inclination angle correction or M blades to transform the slip factor for centrifugal impeller to mixed-flow machine. (2) Following the way of Qiu, setting up correlation that can be used to mixed-flow machine