Hydropower Plants: Generating and Pumping Units
Solved Problems: Series 6

1 NON-DIMENSIONAL NUMBERS FOR A TURBINE MODEL TEST

When performing model testing, an accurate calculation of the non-dimensional numbers is of key importance for the operation of hydraulic turbines and the transposition of the efficiency from the model scale to the prototype scale. Three non-dimensional parameters are particularly important: the IEC speed factor n_{ED}, the IEC discharge factor Q_{ED}, and the Thoma number σ.

1) When performing the model test of a turbine, which important quantities need to be monitored for comparing the efficiency and the operating condition of the prototype scale with that of the reduced scale turbine?
   Also, which component/parameter must be exactly the same in the prototype and model scales?

   It is important to monitor the available head H, the discharge Q, the turbine rotational frequency n, and the torque T, as they are essential for knowing the efficiency of the machine and compare the characteristics to the prototype.

   For comparison purposes, the geometry of the turbine must be exactly the same as the prototype.

2) Express the non-dimensional parameters n_{ED} and Q_{ED} as functions of the reference diameter D_{ref}, the discharge Q, the turbine specific energy E, and the rotational frequency n [s^{-1}].

$$n_{ED} = \frac{nD_{ref}}{\sqrt{E}}$$

$$Q_{ED} = \frac{Q}{D_{ref}^2 \sqrt{E}}$$

3) Express the specific speed ν and IEC specific speed n_{QE} as functions of Q_{ED} and n_{ED}.

$$\nu = 2^{\frac{1}{4}} \sqrt{\pi Q_{ED}}\, n_{ED}$$

$$n_{QE} = \sqrt{Q_{ED}}\, n_{ED}$$

For questions 4) to 6), use the information about the installation of the turbine and the setting level h_s which are depicted in Figure 1.

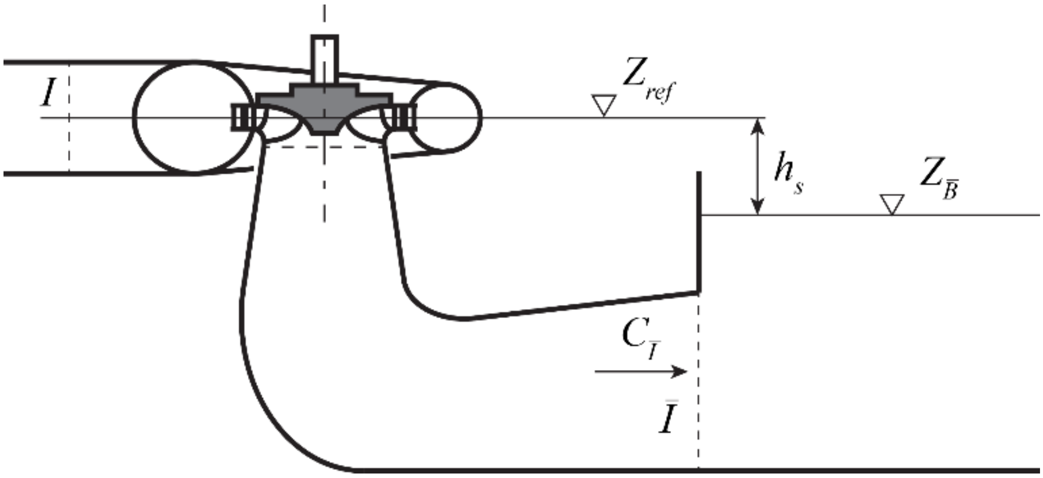

Figure 1: Machine setting level

4) Express the Net Positive Suction Specific Energy (*NPSE*) as a function of $gH_{\bar{I}}$, Z_{ref}, and the saturated pressure p_v.

$$NPSE = gH_{\bar{I}} - \frac{p_v}{\rho} - gZ_{ref}$$

5) Express the Thoma number σ defined by $\frac{NPSE}{E}$, using the setting level $h_s = Z_{ref} - Z_{\bar{B}}$, the flow velocity $C_{\bar{I}}$, the saturated pressure p_v and the atmosphere pressure p_a. Take the singular losses term $gH_{r\bar{I}\div\bar{B}}$ into account, knowing that the draft tube outlet can be considered as a water outflow with $K_v = 1$.

$$\sigma = \frac{NPSE}{E} = \frac{gH_{\bar{I}} - \frac{p_v}{\rho} - gZ_{ref}}{E} = \frac{\frac{p_a}{\rho} + gZ_{\bar{B}} + \frac{1}{2}C_{\bar{I}}^2 - \frac{p_v}{\rho} - gZ_{ref}}{E} = \frac{\frac{p_a - p_v}{\rho} - gh_s + \frac{1}{2}C_{\bar{I}}^2}{E}$$

6) Describe what is the risk of operating the plant at a low Thoma number.

At low Thoma number, a turbine is subject to cavitation which occasionally gets unstable, and often causes serious problems for hydraulic systems such as erosion, fatigue, efficiency loss, resonance and power swings.