HYDRAULIC TURBOMACHINES
Exercises 5 - Axial Turbines

Hydropower plant equipped with Kaplan turbines

The Gezhouba power plant is located in the Hubei province, China (the frequency of the electrical grid is equal to $f_{grid} = 50$ Hz). It is equipped with 2 Kaplan turbines of 176 MW and 5 Kaplan turbines of 129 MW. In this problem, we will investigate the 176 MW units. A cut-view of the Kaplan unit is given in Figure 1.

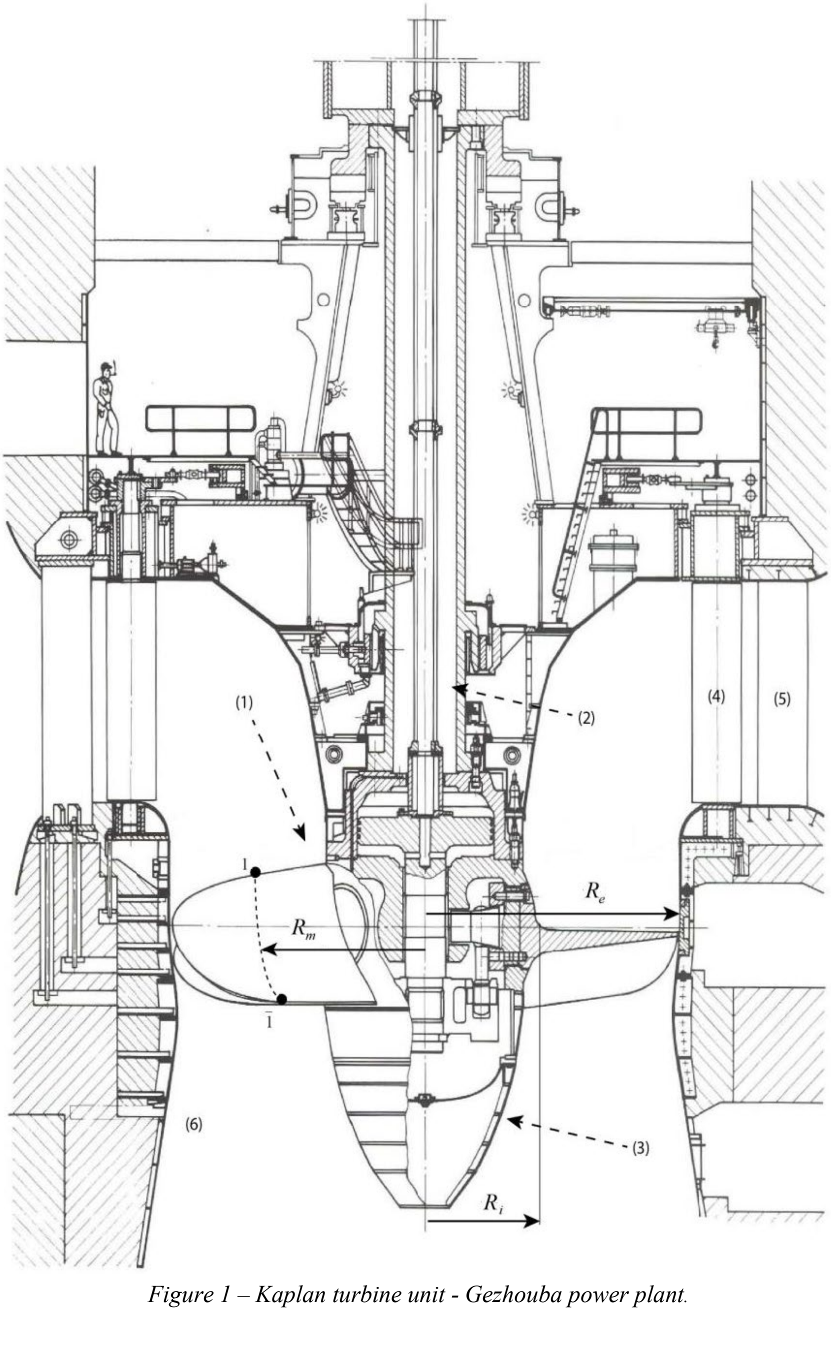

Figure 1 – Kaplan turbine unit - Gezhouba power plant.

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1. Name the components in Figure 1:

Number	Name
(1)	
(2)	
(3)	
(4)	
(5)	
(6)	

2. Compute the specific potential energy of the installation for an upstream reservoir level of $Z_B = 45$ m and a downstream reservoir level of $Z_{\bar{B}} = 25$ m. The value of the gravitational constant is $g = 9.794$ m s^{-2}.

3. For a nominal discharge of $Q = 1130$ m^{3}s^{-1}, the head losses of the installation have been measured and are equal to $\sum gH_r = 13.48$ J kg^{-1}. Compute the available specific energy of the turbine. Deduce the net head H of the turbine.

4. For this turbine, the pole number of the generator is equal to $Z_0 = 110$. Compute the runner frequency n and the specific speed ν of the runner.

5. Compute P_h, the hydraulic power. The value of water density ρ is 998 kg m^{-3}.

6. We assume an energy efficiency for this turbine of $\eta_e = 92$ %. Compute the transformed (or supplied) specific energy E_t.

7. Compute the torque experienced by the runner shaft T_t.

8. Compute the mechanical efficiency (defined by $\eta_{me} = \eta_{rm} \cdot \eta_m$), and global machine efficiency. Neglect the generator losses.

9. The streamline $1-\bar{1}$ is assumed to be on a cylinder with a mean radius R_m. The internal and external diameters are equal to $D_i = 4.520$ m and $D_e = 11.3$ m. Compute the peripheral runner speed U_1 and $U_{\bar{1}}$.

10. By considering that the flow at the runner outlet is purely axial, compute Cu_1 the peripheral component of the absolute velocity at the runner inlet.

11. Compute the meridional components of the absolute velocity Cm_1 and $Cm_{\bar{1}}$.

12. From the previous results, compute the angles α_1 and β_1 at the runner inlet, and $\alpha_{\bar{1}}$ and $\beta_{\bar{1}}$ at the runner outlet.

13. Finally, sketch the corresponding velocity triangles at the runner inlet and outlet.