ENE 401 – Energy Design Project I

WEEK 10: PROBLEM SOLUTION

- **Problem Solution**

➢ Tip-speed ratio

- 2 different blade geometry are examined to study the effects of blade geometry on the power coefficient (C_p) of HAWT (3 blades) with changing tip speed ratios (λ).

- There are 2 blade models which are used in the present flow problem with different pitch angles of their airfoils.

- 20 m/s wind speed is applied at the inflow boundary. Turbines have 3 different angular velocity *Ω* (rad/s), 600 rpm, 1800 rpm and 3000 rpm. Therefore the tip speed ratios are:

$$\lambda_1 = \frac{20\pi(0.35m)}{20m/s} = 1.1$$

$$\lambda_2 = \frac{60\pi(0.35m)}{20m/s} = 3.3$$

$$\lambda_3 = \frac{100\pi(0.35m)}{20m/s} = 5.5$$

- According to each tip speed ratios, torque values of turbines (τ)(N.m) are identified from the Function Viewer of the XFlow.

- For the Model 1, the mean torque values are shown as;

- When rotational speed is 600 rpm, $\lambda_1 = 1.1$, $\tau_1 = 1.42\ Nm$

- When rotational speed is 1800 rpm, $\lambda_2 = 3.3$, $\tau_2 = 2.84\ Nm$
- When rotational speed is 3000 rpm, $\lambda_3 = 5.5$, $\tau_3 = 2.51\ Nm$

- To calculate power coefficient C_p, the formula is used;

$$. C_p = \frac{P}{\frac{1}{2}\rho U_\infty A}$$

- The extracted power (P) is $\Omega \times \tau$. So that;

$$U_\infty = 20\ m/s$$

$$\rho = 1.225\ kg/m^3$$

$$A = \pi(0.35\ m^2)$$

$$C_{p_1} = 0.05$$

$$C_{p_2} = 0.28$$

$$C_{p_3} = 0.42$$

For the Model 2, the mean torque values are shown as;

- When rotational speed is 600 rpm, $\lambda_1 = 1.1$, $\tau_1 = 0.49\ Nm$
- When rotational speed is 1800 rpm, $\lambda_2 = 3.3$, $\tau_2 = 1.41\ Nm$
- When rotational speed is 3000 rpm, $\lambda_3 = 5.5$, $\tau_3 = 1.78\ Nm$

- To calculate power coefficient C_p, the formula is used;

$$. C_p = \frac{P}{\frac{1}{2}\rho U_\infty A}$$

- The extracted power (P) is $\Omega \times \tau$. So that;

$$U_\infty = 20\ m/s$$

$$\rho = 1.225\ kg/m^3$$

$$A = \pi(0.35\ m^2)$$

$$C_{p_1} = 0.02$$

$$C_{p_2} = 0.14$$

$$C_{p_3} = 0.30$$

- For Model 2, the torque value is smaller than the Model 1 and likewise, the power coefficient are found to be smaller.

- In Table 5 shown the data for power coefficient, torque and tip speed ratio of Model 1 and Table 6 for Model2 to summarize the quantitative data.

Rotational Speed (Ω)	**Tip Speed Ratio (λ)**	**Torque (τ)**	**Power Coefficient (C_p)**
rpm	**---**	**N.m**	**---**
600	1.1	1.42	0.05
1800	3.3	2.84	0.28
3000	5.5	2.51	0.42

Table 5. Calculated coefficients for Model 1

Rotational Speed (Ω)	**Tip Speed Ratio (λ)**	**Torque (τ)**	**Power Coefficient (C_p)**
rpm	**---**	**N.m**	**---**
600	1.1	0.49	0.02
1800	3.3	1.41	0.14
3000	5.5	1.78	0.30

Table 6. Calculated coefficients for Model 2