Mechanical Engineering: Year One Capstone Assesment

2019/2020

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3.3 The gears will be enclosed in a housing to help hold the mechanism together and prevent the ingress of contaminants. Suggest suitable materials for this housing, ensuring you provide justification for your suggestions (taking into account a range of factors including properties, and economic issues). Given your suggestions above, qualify these by providing consideration for how such an enclosure could be manufactured. What manufacturing processes might principally be required? 5

4 Tower **5**

4.1 The tower in the picture is a single tube which is also normally made of steel. Explain why this is likely to be manufactured from a different grade of steel to that used in the gearbox. What properties are needed in this particular context? 5

5 Energy generation **5**

5.1 Designers are considering the maximum power that could be generated by this turbine in two theoretical case studies. In case A, the incoming wind speed is 25 m/s and the air speed after passing through the blades is 15 m/s. In case B, the incoming wind speed is 20 m/s and the final speed is 12 m/s. Describe the concepts needed to estimate the maximum theoretical output of a wind turbine, and calculate the maximum theoretical power output for both these cases when the blade length is 37 m. Take the value of 1.2 kg/m3 for air density. 5

5.2 Consider the various terms in the energy equation as they relate to a wind turbine. Describe briefly which terms are important for the wind turbine, and connect terms in the equation to the major sources of energy loss. Comment on the implications for wind turbine efficiency. 5

5.3 The world's most powerful commercial wind turbine today has a blade length of 82m and is rated at 9.5 MW. Comment briefly on the reasons why the numbers calculated using your theoretical approach above are far larger than this actual capacity. 5

6 Energy storage **5**

1 Blades

1.1 For the blades of the wind turbine, composite materials are usually employed. Why is this the case?

A composite material may be employed for their favourable properties. The material of a wind turbine is likely to be a fibreglass reinforced epoxy or polyester (Iberdrola 2020). Creating such a composite yields better strength, elasticity and corrosion resistance than an alternative e.g. aluminium. The orientation of the fibres in the matrix can be specifically arranged to combat the force of the wind on the blade, reducing the probability of failure (cracking, deformation) in the material.

1.2 For the blades of the wind turbine, composite materials are usually employed. Why is this the case?

1.3 What significant issues can you see with using composites in this engineering application? [For example, you could consider economic or environmental challenges]

1.4 The power (W in J/s) produced by a wind turbine depends on blade length (B), the incoming wind speed (V), and air density (ρ). Derive one dimensionless number relevant to the problem using W as the dependent parameter. Use this dimensionless number to comment on the implications of doubling the blade length.

Using Buckingham Pi:

$$[W] = ML^2T^{-3} \tag{1}$$
$$[B] = L \tag{2}$$
$$[V] = LT^{-1} \tag{3}$$
$$[\rho] = ML^{-3} \tag{4}$$
$$W = B^a V^b \rho^c \tag{5}$$
$$ML^2T^{-3} = L^a L^b T^{-b} M^c L^{-3c} \tag{6}$$
$$c = 1, b = 3, a = 2 \tag{7}$$
$$W = B^2 V^3 \rho \tag{8}$$
$$k = \frac{W_1}{B^2V^3\rho} \text{ and } k = \frac{W_2}{4B^2V^3\rho} \tag{9}$$
$$W_1 = \frac{W_2}{4} \tag{10}$$
$$4W_1 = W_2 \tag{11}$$

From this we can see that doubling the blade length (B), quadruples the power output of the wind turbine.

1.5 Considering the answer above, discuss the trade-offs associated with choosing longer blades for a turbine of a fixed height.

Naturally, choosing larger blades for a turbine of a fixed height creates a limit to how large the blades can be before the turbine's tower would not be able to structurally support the weight of the blades. Hence, using larger blades requires the use of stronger materials in order to support their weight. Using stronger materials is more expensive to procure and manufacture, driving up initial costs. If the turbine cannot produce enough power to become econimically viable over its lifetime, this would cause problems for the manufacturer.

2 Gearbox (dynamics)

2.1 Derive a simple relationship for the gear ratio expressed as a function of number of teeth in the sun and ring gears of an epicyclic (or planetary) gear train.

2.2 Perform a conceptual design of an epicyclic gear system for a 1.5 MW wind turbine if the three blades spin at a design speed of 12 rpm and the high-speed shaft in the generator needs to spin at 1680 rpm. Provide information on the configuration of your proposed planetary gear set (note: the 5 laws of planetary gearing – see the provided videos) and the input/output torque ratio that can be achieved by your system. Neglect friction and assume that the angular acceleration of the gears (which are rigid and non-deformable) is zero. You must indicate the number of teeth in each gear and provide a schematic drawing.

2.3 Wind gusts and turbulence lead to misalignment of the drive train and premature failure of the gear components. How could this be mitigated?

2.4 Comment on the advantages/disadvantages of an epicyclic gear system in the context of a wind turbine gear box.

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URL: *https://www.iberdrola.com/press-room/top-stories/wind-turbines-blades*