Wind Turbine Gearbox Design Project

Background

Wind turbines are becoming increasingly popular devices for converting wind energy into electricity. The concept is to mount airfoil shapes onto a rotor such that as the wind blows over the airfoils, the shaft is urged to turn. The shaft speed is usually much slower than is needed for efficient electricity generation, so a gear box is used to increase the speed between the turbine blades and the generator. In addition to these basic components, most wind turbine generators also include a means for feathering the airfoils in high winds to keep them from spinning too fast, and means for pointing the airfoils in the most advantageous direction (usually into the wind). Figure 1 shows a typical conceptual layout of one design for a wind turbine which consists of the following parts: a tower for support and lift, turbine blades to catch the wind, a gearbox for transmission, a generator to convert mechanical energy to electricity.

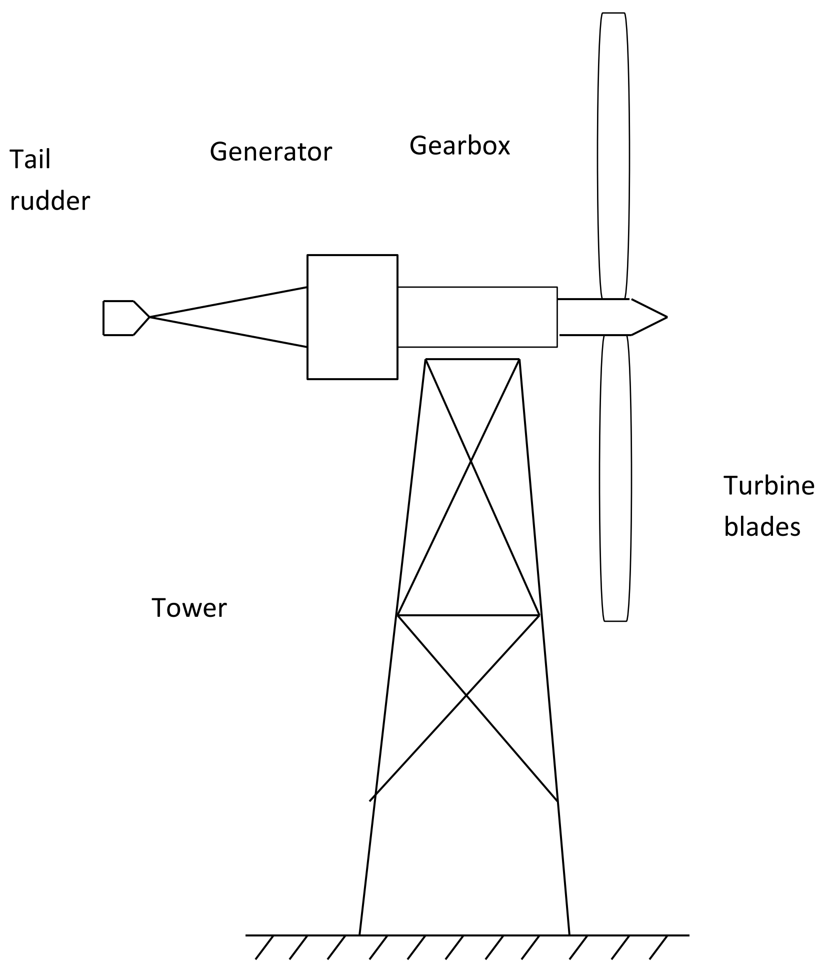

Figure 1. Wind turbine parts

Project Description

You are to work in a team to design the gearbox for the wind turbine, which is supported by a 60 foot tall tower. Use a compound reverted gear train to increase the rotational speed from the input to the output. The diameter of the blades is 17 feet. The gearbox consists of spur gears, rolling element bearings, shafts, keys, and retaining rings.

Specifications

The following are design specifications for the gearbox:

Weight and size	Minimize
Material	You should select the materials for your design
Gear train value	Nominally 18:1; minimum ratio: 17:1; maximum ratio: 21:1
Shaft arrangement (Figure 2)	• The input and output shafts should be in line • Use a compound reverted gear train • Input shaft: protruding 4 inches out of front of gearbox • Output shaft: protruding 2 inches out of rear of gearbox • Provide adequate key slots on the input and output shafts • Show how various shaft attachments are connected to the shafts
Weak link	Design the keys as the weak link of the gearbox, i.e., if anything would fail, it would be the keys in order to protect other parts
Load	• <u>Typical load</u>: 20mph wind and 200rpm blade rotational speed, this gives the following loading on the input shaft of the gearbox: — Torque from the three blades: 38.6 ft-lbs — Lateral load (weight of blades and hub, which are mounted directly on the input shaft of the gearbox): 260lbs — Axial load (thrust from the three blades): 50.25lbs • <u>Large load</u>: large wind can produce loads up to 3 times the typical loads. The turbine speed is, however constant at 200rpm since it is regulated by adjustable pitch blades.
Life	10 years continuous operation
Reliability	99% for all parts
Factors of safety	Keys and shafts: $n_f = 2, n_y = 2$ Bearings: fatigue: *n*=1 Bearings for static large load conditions: n=1 Gears: fatigue safety of factors are n=1.2 for surface and n=1.5 for bending Other parts: yield and fatigue factors of safety of at least 2.

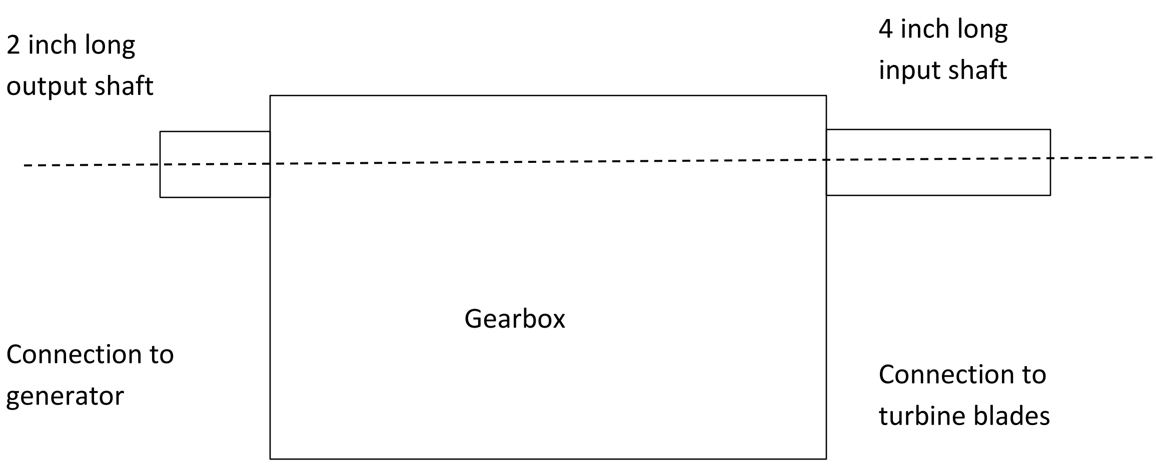

Figure 2. gearbox

Design Checklist

Overall

Design specification
Layout/assembly drawing
Function description
Overall size

For each gear

Equivalent design loads
Rotational speed
Diametral pitch
Number of teeth
Tooth Quality (Q_v)
Face width
Rim effects (if any) to remove weight
Material
Attachment to shaft
Final design analysis
Realized factors of safety (bending and pitting)

For each bearing

Design loads (equivalent loads)
Bearing selection (Type of bearing; Bore; OD; width; etc.)
Rating life in hours, and reliability

For each shaft

Part drawings as needed (size, fillets, shoulders, key slots, retaining ring grooves, etc.)
Material
Final design analysis (loads; FBDs, shear and moment diagrams; critical planes and points; stresses; deflections and rotations (within the recommended limits for bearings and gears); etc.)
Realized factors of safety (static and fatigue)
Show how bearings and gears are attached to the shafts

For each key

Part drawings as needed
Type of key
Size (length; width; height; etc.)
Keyway type and dimensions
Factors of safety
Show how the keys are used as the weak links

For each retaining ring

Size (thickness; groove diameter; etc.)
Allowable axial thrust

Optimization

Minimize the weight and size of the design