Design of machine elements: a very general procedure

- Fully define: **objectives, constraints, functional specifications**
- Analysis:
  - Application of equilibrium conditions: static and dynamic
  - Identify critical sections: stress and strain analyses
  - Identify and consider: effects of stress concentrations, residual stresses, material characteristics, etc...
  - Apply design criteria: safety factors, failure theories, fatigue life, vibrations, deformations, etc...
- Select component geometry/dimensions/materials that satisfy objectives and constraints: **design iterations**
- Design review and presentation
Design Project

Report 02 is due on Thursday, Sept 19 @ lecture time

Tasks to accomplish:

- From Report 01:
  - Update report. See these notes + Notes in your Report 01
  - State “objectives” of the project
  - Update background research/data on: typical dimensions of the machine of interest. Specifically of the two components under consideration
  - Specify characteristics of the specific components of interest: dimensions, geometries, design configurations, materials used, etc. You need these for future analyses
  - Determination of applied loads
  - FBDs: overall and for each component of interest; include parametric calculations for \( q(x) \), \( V(x) \), \( M(x) \), \( \theta(x) \), and \( \delta(x) \)
  - Identification of “Critical Sections and Points” - w/stress cubes
  - Stress analysis - principal normal stress/Mohr’s circles

With quantitative & numerical info. and data

There’s no limit on the length of your report, but... be brief and to the point...

MEMO format, please
Design project for this course: objectives

Do note: this is an unstructured, engineering, project! (e.g., design teams must fully define design parameters, constraints, etc.)

- Detailed design of the main shaft and selection of corresponding bearings and fixtures of a Vestas' V52-850 kW wind turbine
- Detailed design of the tower of a Vestas' V52-850 kW wind turbine
Design project for this course

Cutaway of a typical wind turbine with blade pitch control

Vestas’ turbine: V52-850 kW

<table>
<thead>
<tr>
<th>Weight (IEC IA/IEC IIA)</th>
<th>60 m</th>
<th>67 m</th>
<th>78 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hub height:</td>
<td>60 m</td>
<td>67 m</td>
<td>78 m</td>
</tr>
<tr>
<td>Tower:</td>
<td>140 t/124 t</td>
<td>158 t/142 t</td>
<td>203 t/199 t</td>
</tr>
<tr>
<td>Nacelle:</td>
<td>61 t</td>
<td>61 t</td>
<td>61 t</td>
</tr>
<tr>
<td>Rotor:</td>
<td>37 t</td>
<td>37 t</td>
<td>37 t</td>
</tr>
<tr>
<td>Total:</td>
<td>238 t/222 t</td>
<td>256 t/240 t</td>
<td>301 t/297 t</td>
</tr>
</tbody>
</table>
Design Project: FBD and general considerations

- $M_y$ (yaw)
- $M_x$ (pitch)
- $M_z$ (roll)

- x-axis
- y-axis
- z-axis
You need to define (and analyze) overall FBD first.

Definition of FBD's for individual components depends on mechanical configuration chosen.

Some initial dimensions are "fixed". Others are to be determined.
Design Project: overall FBD and some general considerations

What is the “tip-speed” ratio for this machine? What is “tip-speed” ratio? Do we need this ratio?

Consider:
- V wind: [5, 25] m/s ⇒ Need: tip-speed ratio (to determine angular speed of rotation.)
- Loading: wind pressure ⇒ Bending ⇒ Torque: T
  - Include: weight of
    - Blades,
    - Hub,
    - Nacelle
    - Tower, &
    - wind pressure on tower (linear/parabolic/other distribution)?
  - Tower: variable cross-section to minimize weight
- Recall:
  (a) Power = (output torque) • (angular speed)
  (b) Conservation of energy:
    \[
    \frac{1}{2}mV^2 + P = \text{constant}
    \]
  (c) Consider Betz's criterion to include efficiency of machine.
  (d) Power = (Torque) • (Angular speed)
  (e) Tip-speed ratio

This is only a suggested diagram