Use of steel for towers of wind turbines and support structures

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Overview

- Background
- State of the Art
- Problems and possibilities
- Outlook
Wind Energy and other energy sources

2014 LCOE – Global ranges and baselines

- Conventional global
- Renewables global
- Wind global
- 2014 Baseline
- ‘Grid parity’

Source: MAKE Consulting

Note: Unsubsidized LCOE
Offshore Wind levelized Cost of Energy

Bubble Area represents capacity of wind farm

Source: DNV-GL
How about inshore, instead of offshore?

$v_{av., \, 50 \, m}$ Hamburg: 5 m/s
$v_{av., \, 50 \, m}$ near the coast: 6 m/s
$v_{av., \, 50 \, m}$ Munich: 4 m/s

$E_{wind} \sim v^3$

so $E_{Coast} = 2E_{Hamburg} = 4E_{München}$
Too little wind inshore?

Source: Fraunhofer IWES
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Costs of tower and support structures Onshore: 15%

Source: NREL
Costs of tower and support structures Offshore: 25%

- Balance of Station: 52%
- Turbine: 32%
- Soft Costs: 16%
- Assembly, Transport, & Install: 20%
- Electrical Infrastructure: 10%
- Port & Staging: 1%
- Support Structure: 18%
- Development: 2%
- Project Management: 1%
- Surety Bond: 8%
- Insurance: 3%
- Contingency: 3%
- Construction Finance: 3%

Source: NREL
State-of-the-art: towers of wind turbines

- Wind turbines: amongst the largest and highest loaded structures
- Due to growth of the industry and growth of installed capacity – repetition important
- Also: the industry is more driven by innovation than the construction industry
- Right now: S235, S355 are the main steel grades in use – as for the construction industry
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Arguments in favour of use of higher steel grades

- Static strength: increases linearly with $f_y$

- Buckling
  - Slenderness: $\lambda \approx l/D$ for thin-walled towers
  - For low slenderness, $\lambda \leq 50$ (e.g. 150 m high, 3 m ø), buckling strength increases almost linearly with the $f_y$
Arguments against use of higher steel grades

- Weldability: more care needed
- Toughness (earthquake resistance)
- Fatigue
  - With high SCF, no weld measures: virtually no influence of $f_y$
  - Lower SCF, post-weld treatment to introduce compressive stresses: almost linear increase with $f_y$ achievable
- Price
- Lack of standards
Price

- Towers: dead weight no major cost post
- Transport and installation costs is a factor
- S235: 100%
- S355: 103%, practically a no-brainer
- S460: 110%, doable
- S690: 170%, hardly economical over S460, unless weight is a severe problem
Fatigue

Welding:

- Influence of the mean stress: typically unknown, a tensile mean stress equal to the yield stress has to be (conservatively) assumed, fatigue strength similar to lower grade steels, no benefit

- Unless this mean stress can be lessened or even be converted to a compressive stress, e.g. UIT (ultrasonic impact treatment)

- Other connection methods, such as grouting or pre-stressed bolts can also help to utilize the higher potential strength, e.g. Siemens tower.
Standards

- EC 3: focus on mild steels, with no “bonus” for higher steel grades
- No bonus for fatigue improvement of post weld treatments
- Based on a rather rigid and simplistic classification of structural details
- The class $\sigma_c$ is the stress range at 2 million cycles, S-N lines have a slope of 1:3 until 5 million cycles (at 0.73 $\sigma_c$) and a fatigue limit at 0.40 $\sigma_c$
- Can be used as a first, conservative approach

- GL: sceptical about use of steels exceeding S460:
  “high strength steels having nominal yield strengths (or 0.2% proof stresses) exceeding 460 N/mm$^2$ may be employed in exceptional cases only, with the corresponding technical justification and with GL consent

- Thus other standards need to be used (or developed!) in order to allow economical use of high strength steels for the fatigue loaded structures needed here
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The road ahead
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Call for abstracts coming soon!

Fraunhofer IWES
THANK YOU FOR YOUR ATTENTION

Any questions?
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