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Vindkraft i kallt klimat

Tekniskt kunnande – en resurs för Norrland

Milan Veljkovic,

VinterVind, Piteå, 2010.02.03.

LULEÅ UNIVERSITY OF TECHNOLOGY

Agenda

- Resurser på LTU (forskning and utbildning)
- Stålbyggnad- en forskningsgrupp inom LTU
  - Ett nytt koncept för vindtorn
  - Nya rekommendationer för dimensionering, montering och underhåll
  - Vad är det nästa steget i vindtorn utvecklig
- Hur går vi vidare med kommersialiseringen av forskningen?

LTU resources

- Fluid Mechanics: Aerodynamics of Wind Power
  - Staffan Lundström
- Machine Elements: Lubrication at low temperatures
  - Erik Höglund, Elisbet Kassfeldt
- Computer Aided Design: Functional Product Development
  - Lennart Karlsson

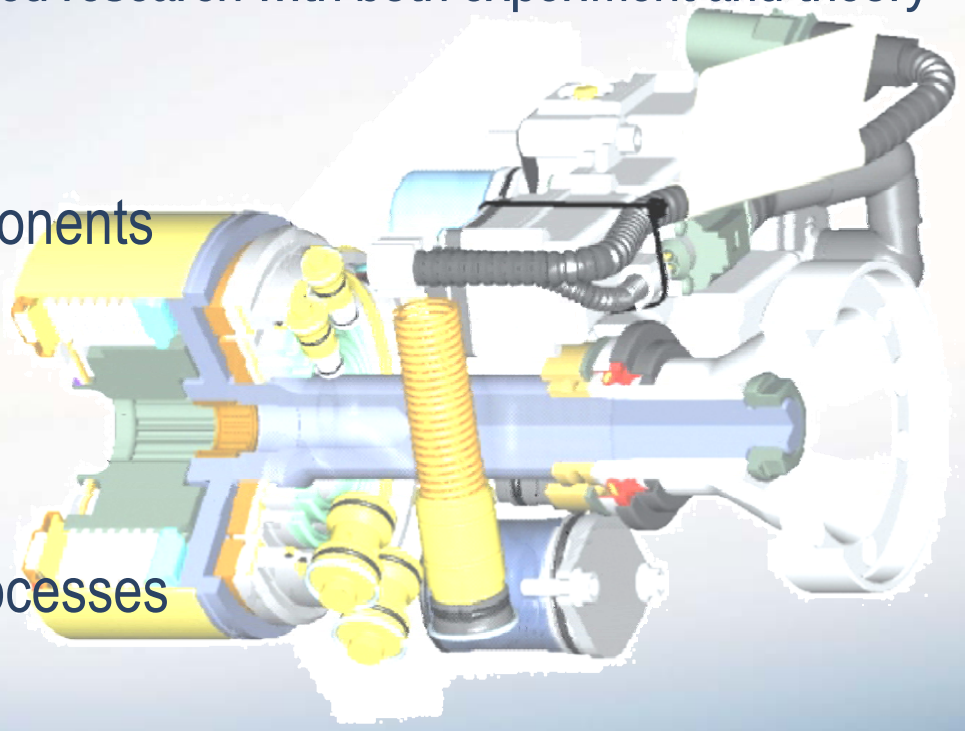
- Structural Engineering: Concrete Foundation
  - Mats Emborg
- Structural Engineering: Ice research
  - Lennart Fransson

LTU resources

Division of Machine Elements

From fundamental to applied research with both experiment and theory

- Tribology of machine components
- Lubrication and lubricants
- Wear of materials
- Tribotesting
- Modelling of tribological processes



LTU resources
Div. of Structural Engineering

- Environmental friendly concrete
  - Low CO2 emission
  - Optimization of the locally produced components
  - Lower cement contents
  - Self compacting concrete
- Prefabrication of the tower

Undergraduate Courses

- SNOW AND ICE

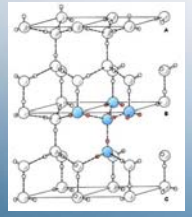
Origin, physical properties, applications

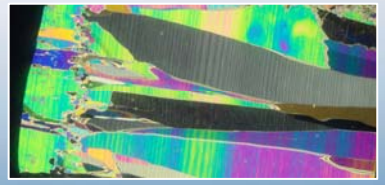
- ARCTIC ENGINEERING

Construction in cold regions

- ICE KNOWLEDGE

Safety aspects, bearing capacity of ice.





LTU resources

- Centrum for High-Performance Steel
  - Mats Oldenburg
    - Milan Veljkovic

50% delfinansiering av industrirelevanta projekt i Norrbotten och Västerbotten

Steel Structure

One of the main areas of research

Application of Higher Strength Steel in Construction

Steel wind tower, connections

LTU PhD students


Jörgen Eriksen


Christine Heistermann


Tim Heistermann

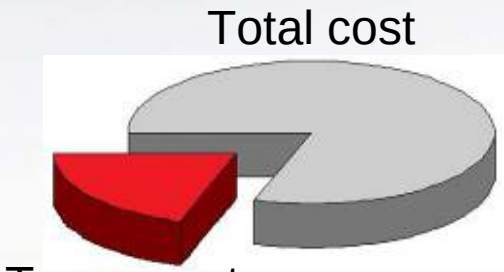

Olga Garzon


Marouene Limam


Joakim Sandström

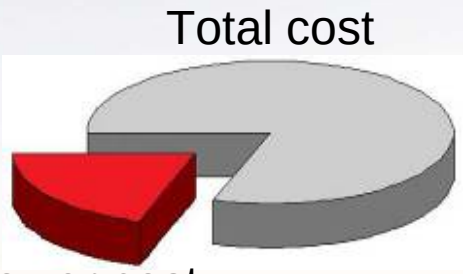
Why improvements of wind towers are needed?

1. For economical reasons
   - 15 to 20 % of installation costs
   - About 350 k€/MW



Why improvements of wind towers are needed?

1. For economical reasons
   - 15 to 20 % of installation costs
   - About 350 k€/MW
- Worlds market 2008
- 27 GW of new turbines
  - 36,5 billion € (total value of new generation eq.)
  - 1,35 mil. €/MW
    - Tower costs 280 k€/MW 7,5 billion €
      - » Europe 2,4 billion €
- Sweden (2009) 1,56 GW (1,68 mil.€/MW)
    - Total market 2,6 billon €
    - Tower market 0,5 billion €

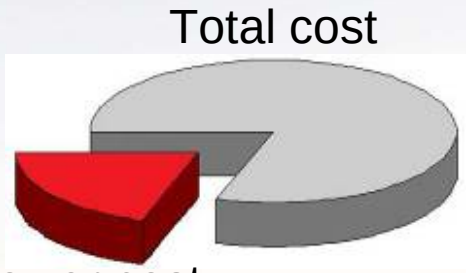


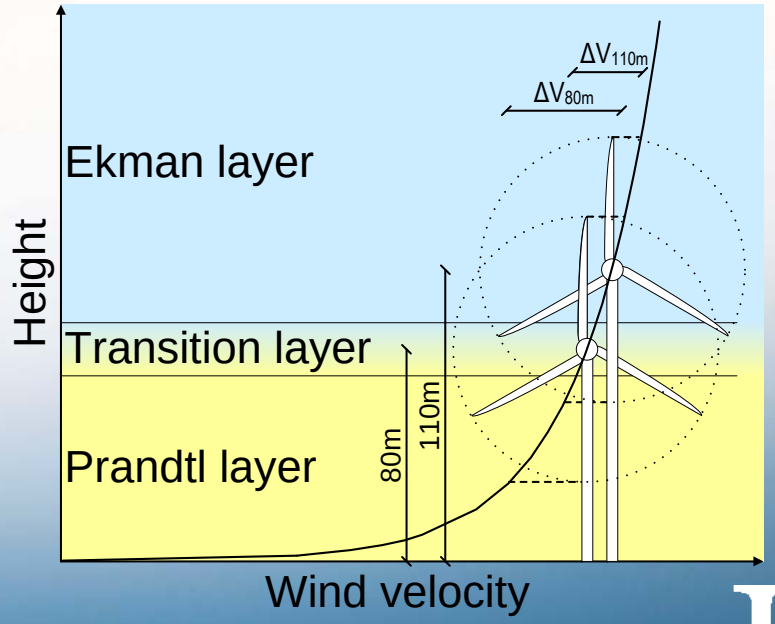
Why improvements of wind towers are needed?

1. For economical reasons
   - 15 to 20 % of installation costs
   - About 350 k€/MW
2. For building higher
   - Larger rotors
   - Higher wind speed
   - Steadier wind

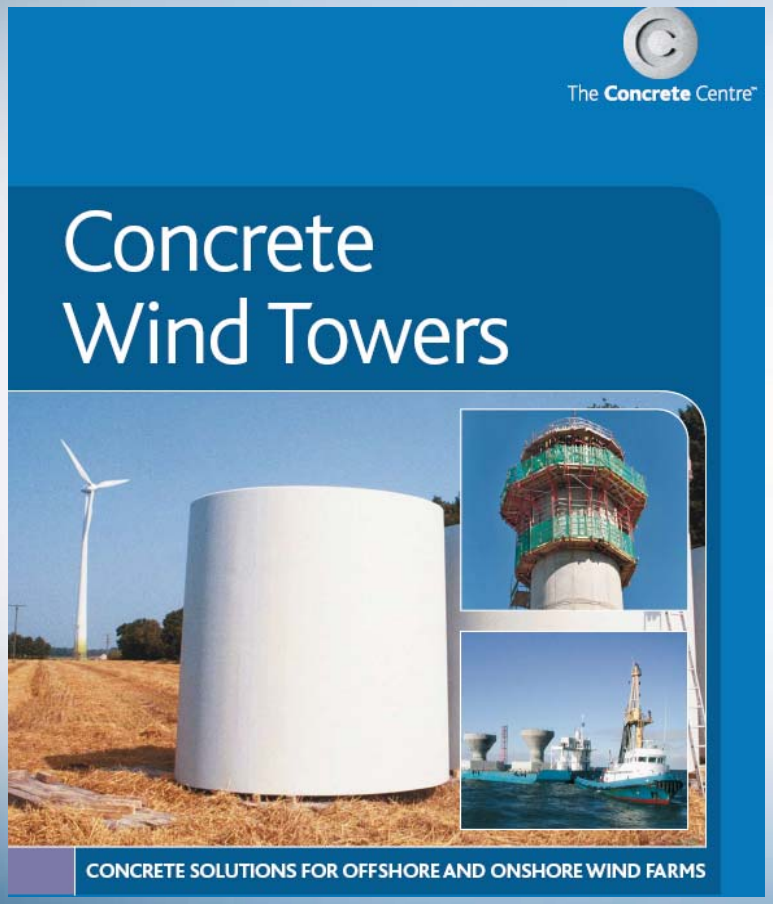
⇨ Need for optimized design

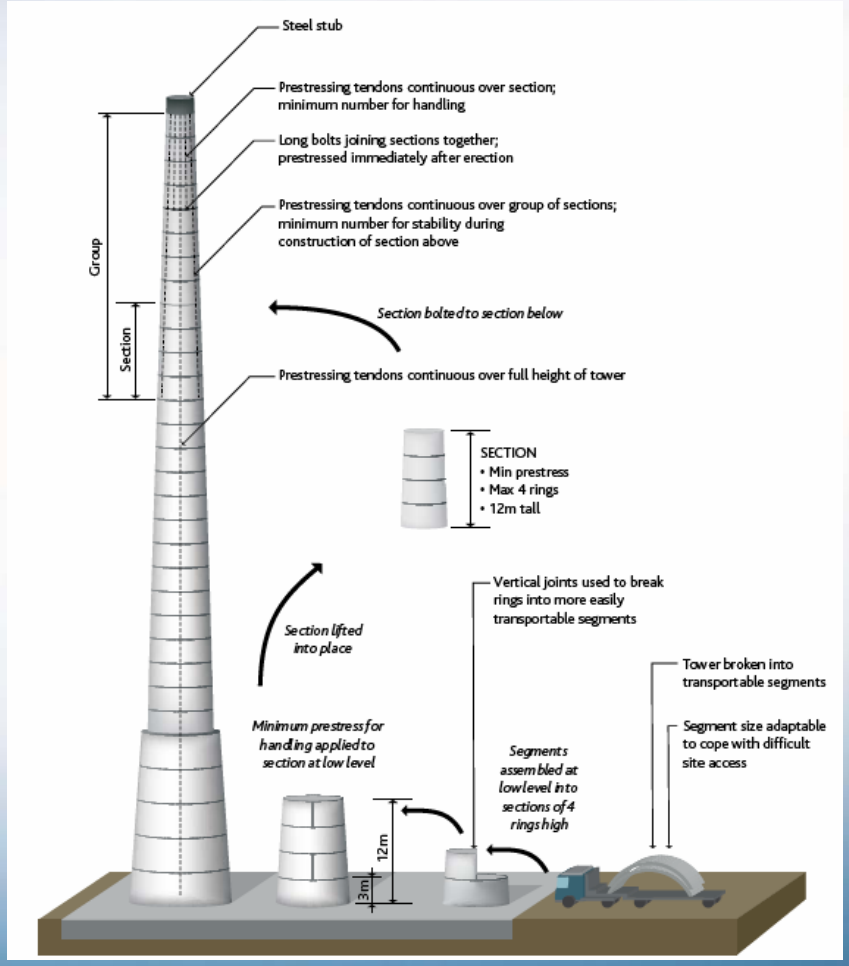
⇨ best resistance/cost ratio within given constraints





Tower Alternatives
Concrete Tower





Tower Alternatives
Hybrid Tower

May 2009 Grevenbroich 2,3 MW,

133m hub height, total 233m

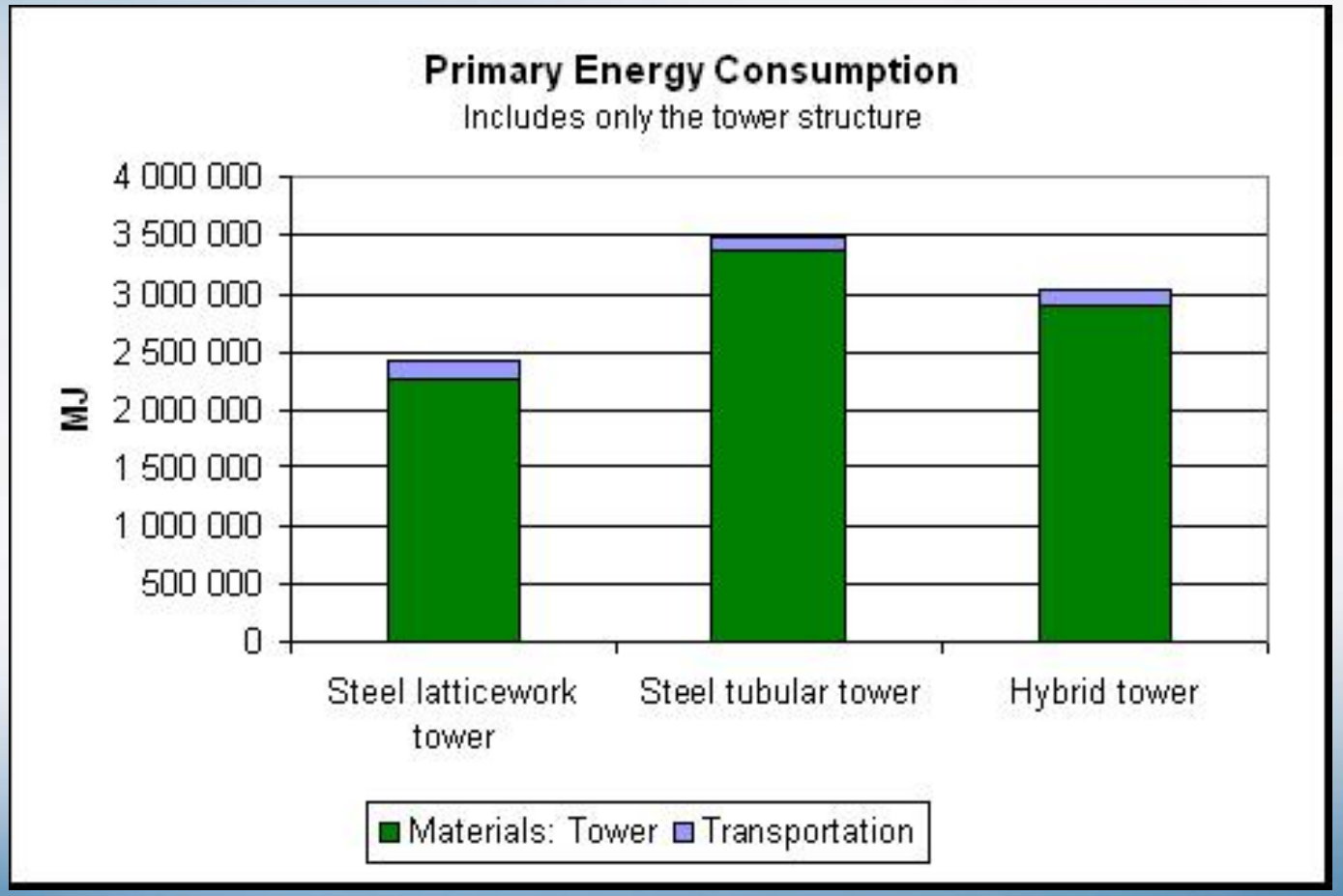
Tower Alternatives
Lattice Tower

near Antwerp, 111m 1,5 Mw, 2006

SeeBA 160-m-Gittermast Laasow Lausitz Brandenburg
Foto: Jan Oelker, 2006 jan.oelker@gmx.de

LCA

One segment



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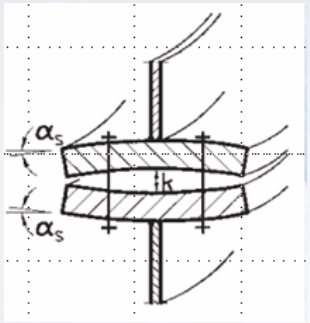
Research Fund for Coal & Steel

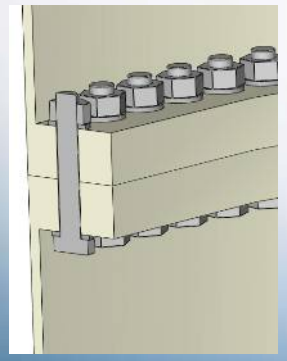
HISTWIN
High-Strength Steel Tower for Wind Turbine
Contract: RFSR-CT-2006-00031

Energimyndigheten
Vindforsk Dnr 2008-000225 Projektnr 31132-1

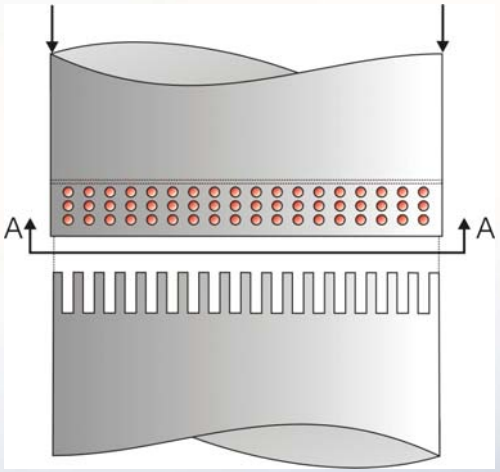
High-strength steel tower for wind turbines

HISTWIN-Research project
Programme of the Research Fund for Coal and Steel, 2006-2009
Vindforsk, Energimyndigheten, 2008

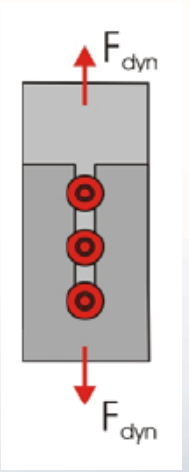




REPOWER 5M assembled in 2004, Germany



New



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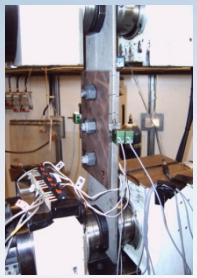
Applied Research Approach

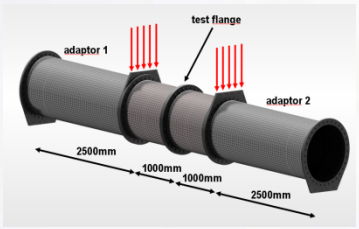
Testing

•Segment test on a new friction connection, 2007-2008



•Static
•Long time measurements
•In-situ, TCB bolts

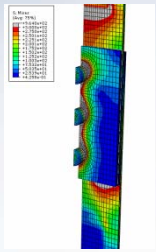
•Model test, flange and friction connection, 2008



•In-situ measurements on a tower executed in 2007, measurements 2008

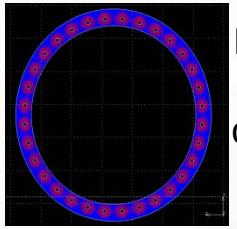
• Fatigue tests on a new friction connection

Evaluation

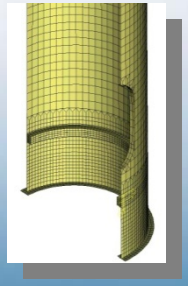


Simple connection 2007-2008

OK



Flange and friction connection, 2008



Fatigue tests 2008,

FEA 2008-2009

FEA

Objective

Design model 2008

Design model 2008

Design guideline 2009

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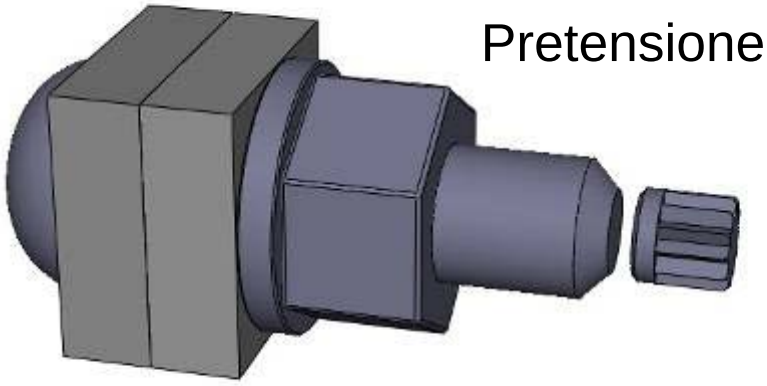
Special fasteners: Tension Control Bolts

- Quick and easy installation
- Properties equivalent to HS Bolts 10.9
- No torsion in the shank
- Corrosion protection

TCB S10T M20-55mm



Pretensioned !

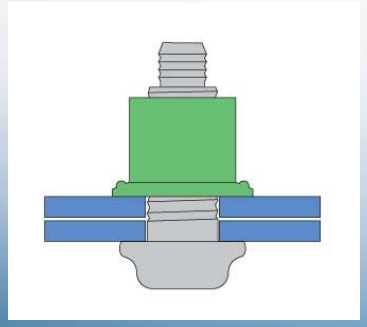
Electric shear wrench

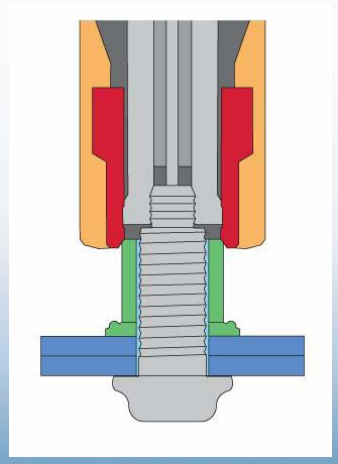
Various bolts

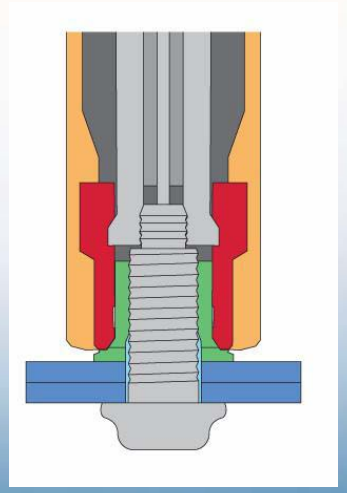
- HUCK-bolts

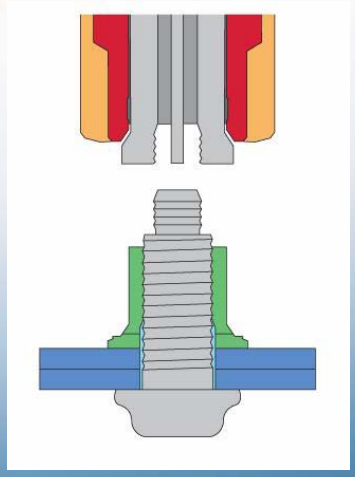
Advantages

- High, consistent clamp load
- Vibration proof
- High fatigue endurance, high shear and tensile loadings
- Quick, easy and quiet installation



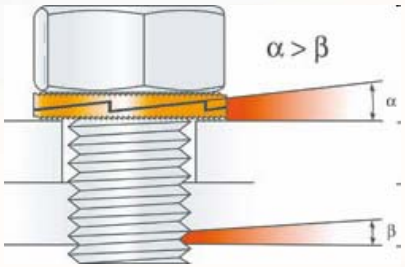






Various bolts

- Normal Bolts plus Nord-Lock washers



Advantages

- Tension makes the bolt self-locking
- Fastener safe to extreme vibration and dynamic loads

What we have learned?

- Behaviour of assembling joints
- Static resistance
- Fatigue resistance

- Bolt forces (achieved pretension and variations over lifetime)
- Faying surfaces (friction and endurance)

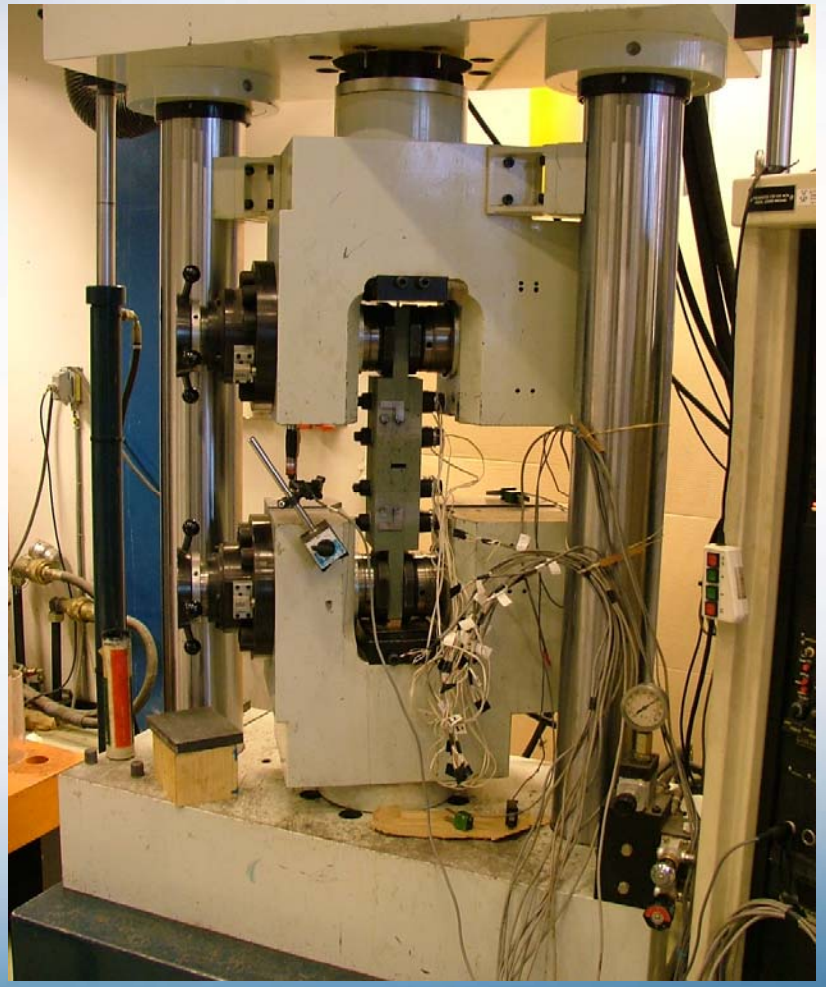
- Comparison of different bolt types for optimal design for life time

Standard friction tests (10)

- S355
- Ethyl silicate zinc rich paint

- Load cells for bolt forces
- Slip measurements

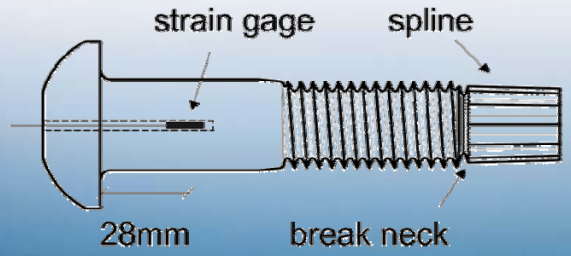
⇨ Friction coefficient

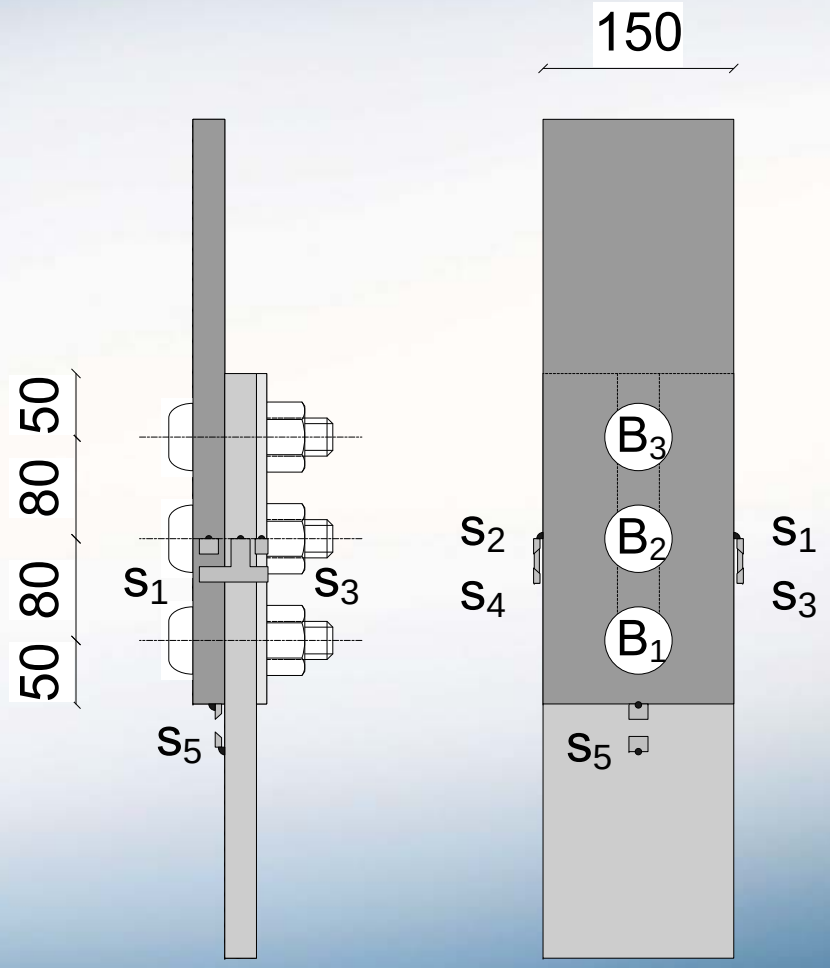


Static segment tests (28)

- Segment tests = flat section of the cylindrical connection

- 25 mm and 8 mm plates (S355)
- M30 and M20 TCBs S10T (~10.9)
- Cover plates (hardened steel) instead of round washers





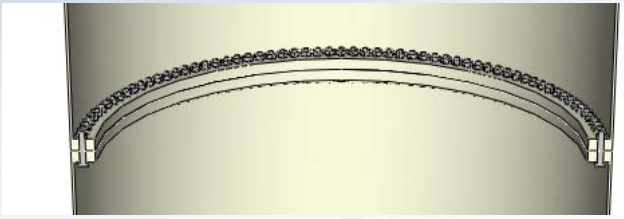
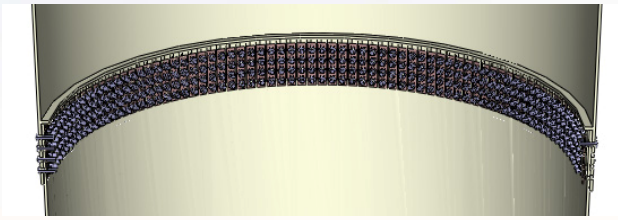
Long term tests

- "Standard" configuration
- Load levels: 60 % and 80 % of static resistance
- Duration: 15 weeks

⇨ Creep
⇨ Relaxation
⇨ Remaining resistance

Long term test rigs

Material costs-savings

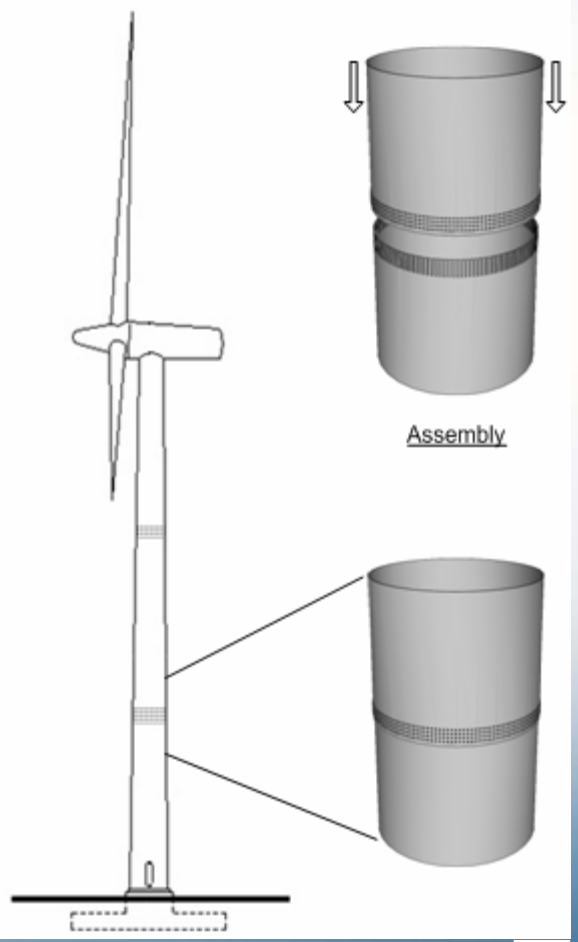
	Flange connection			Friction connection		
						
	Unit price [€]	Qty.	Total cost [€]	Unit price [€]	Qty.	Total cost [€]
Bolts	20.32	124	2520	5.45	588	3205
Flanges	6762	2	13524	-	-	-
			16044			3205

(Data from REpower, 2007) (Quote from TCB Ltd., 2007)

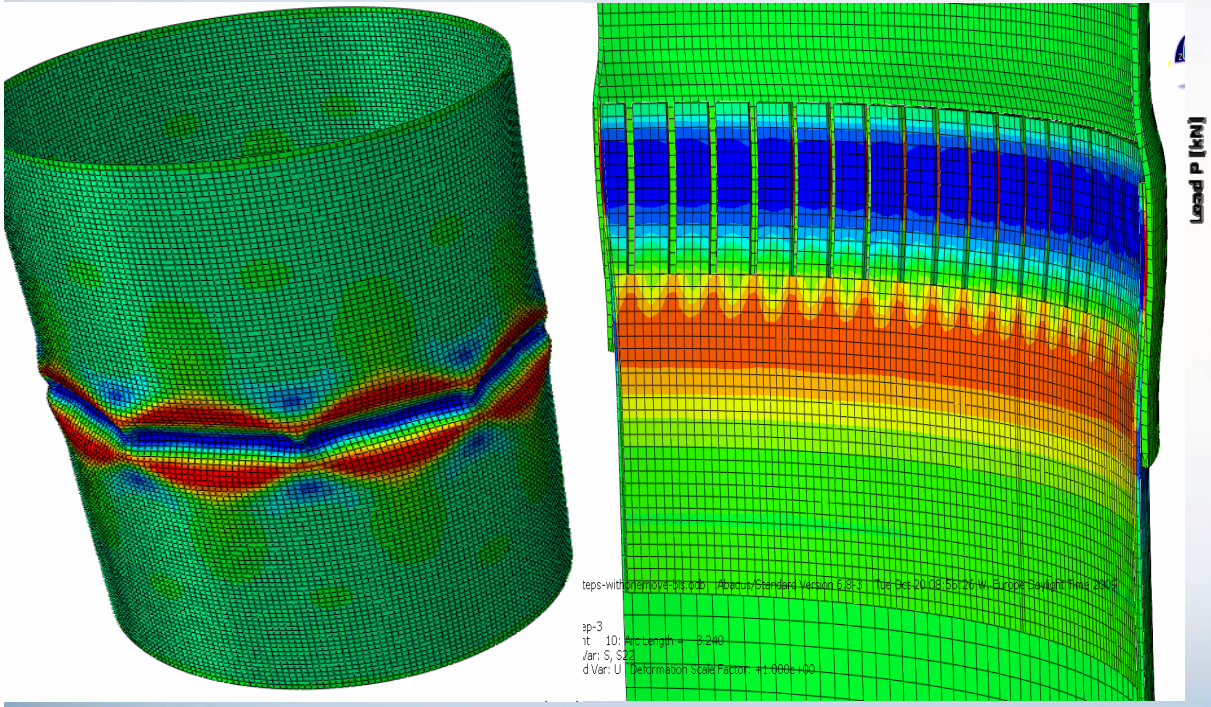
- Material costs for the connection cut down by about 80 %

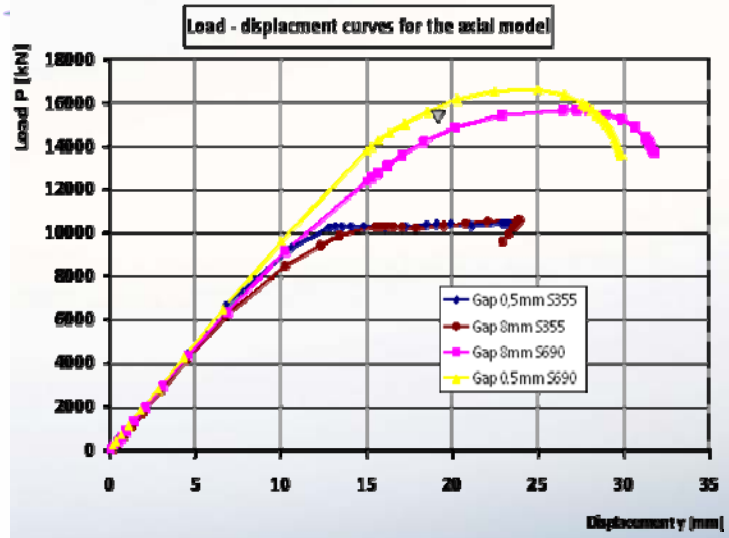
Inluence of the connection on the tower resistance

- Length: 6000 mm
- Material : Steel S355
- Thickness : 20mm
- Boundary condition: a fixed restrain at the bottom and pinned on the top part

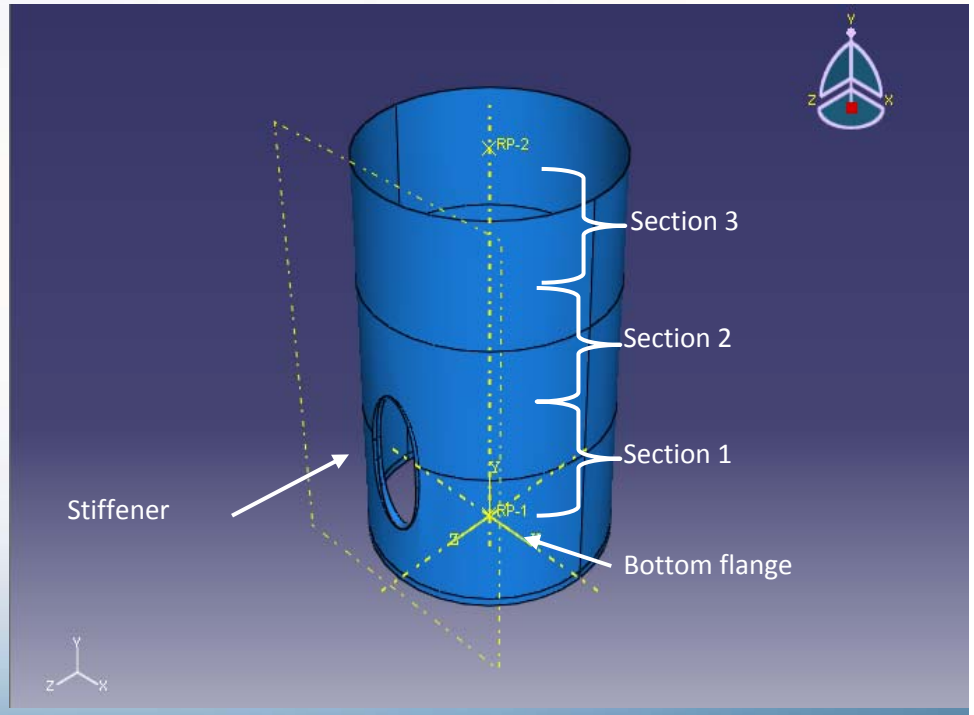


Finite Element Analysis





Stress distribution around the door opening of a steel tower for wind turbines



Main properties of the FE model

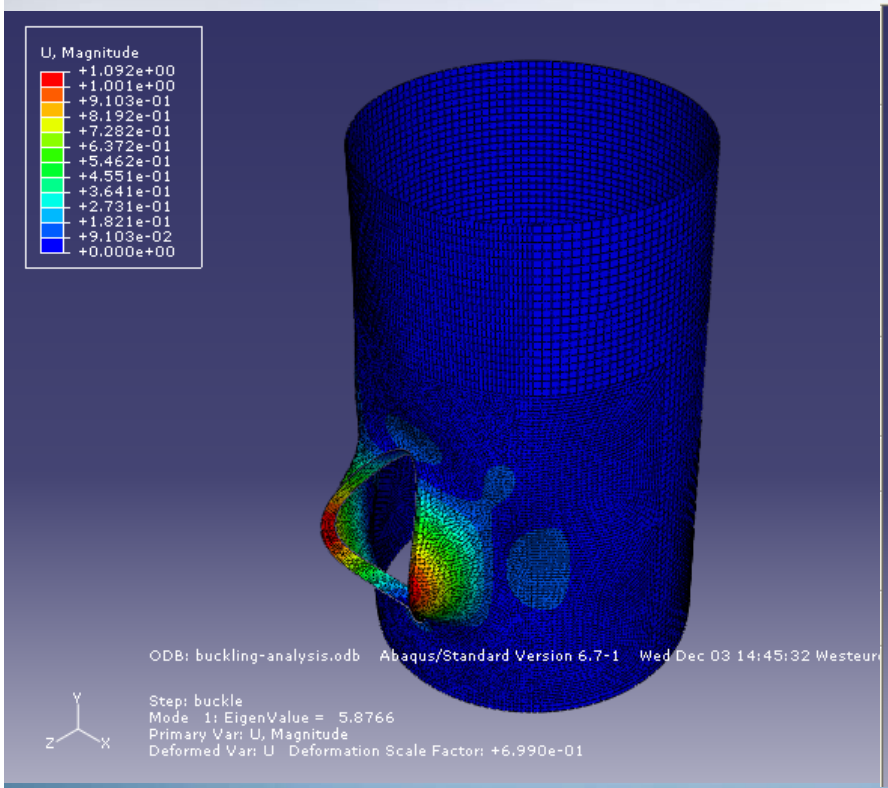
- Geometry: Tower MM92 with 80m hub height
- Loading: Load which created maximum stress level at the door opening

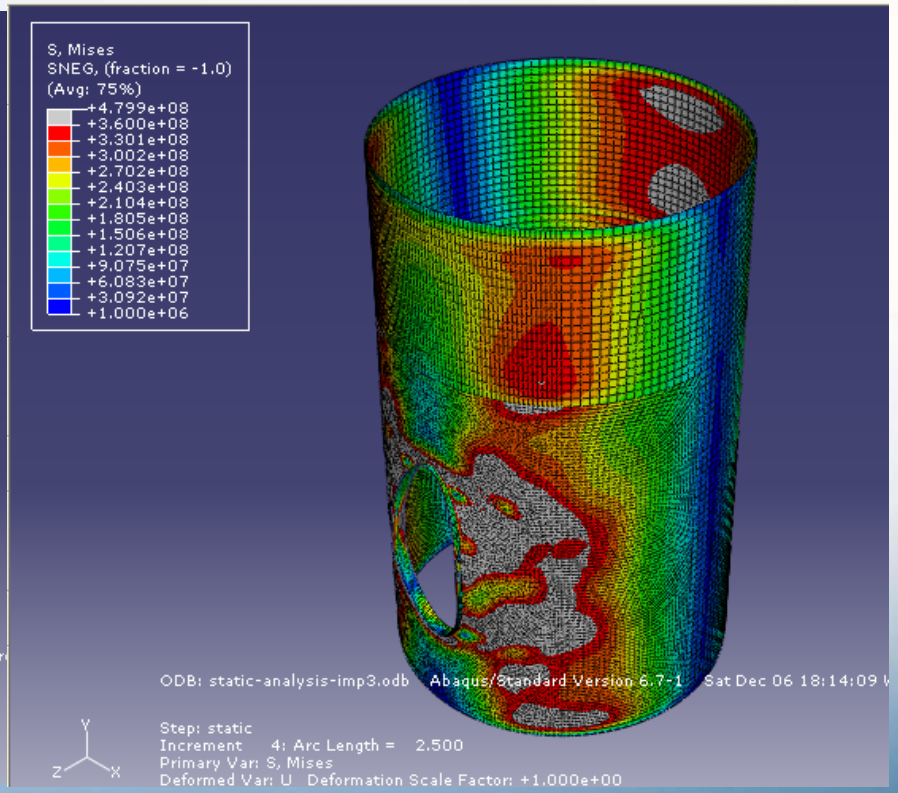
  → geometry and load values provided by REpower
- Boundary condition: Fixed at the bottom of the tower
- Material: Steel S355 used in the executed tower and

  Steel S690 as an alternative

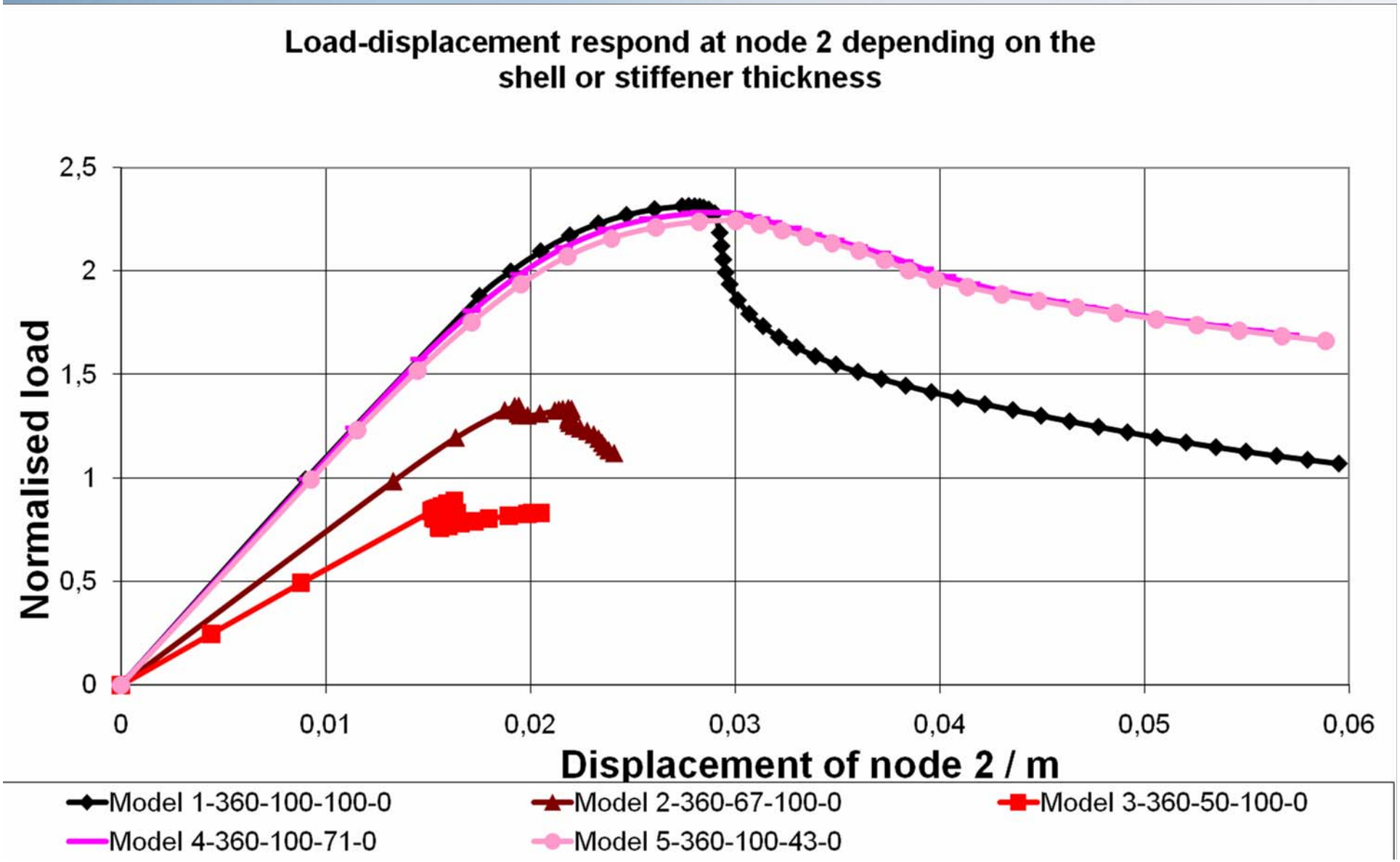
Investigation of non linear effects

- Imperfection was introduced in the model
- The first eigenmode of the structure was used

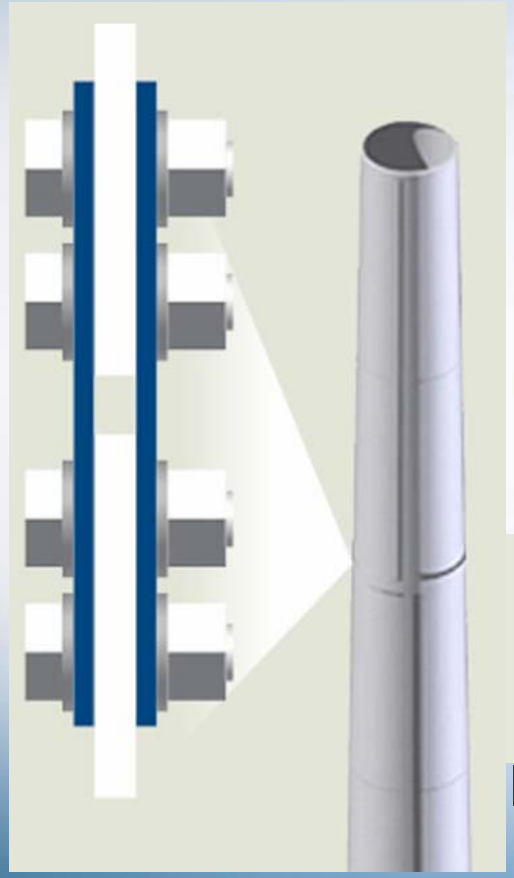


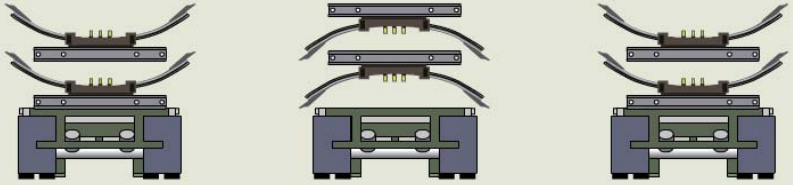


Influence of varied shell or stiffener thickness

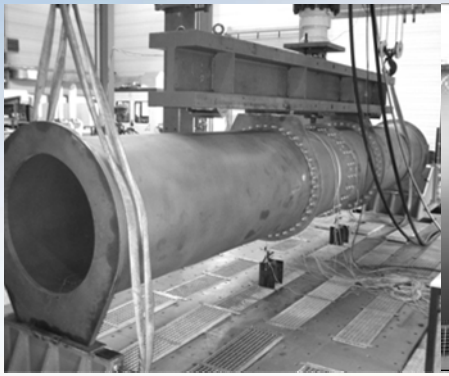


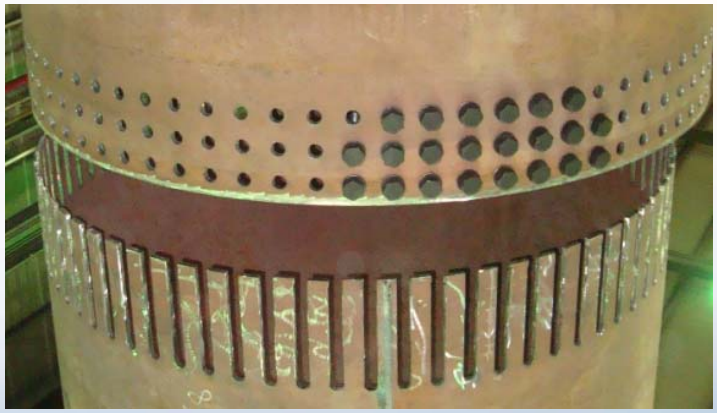
Alternatives
Modular steel tubular tower

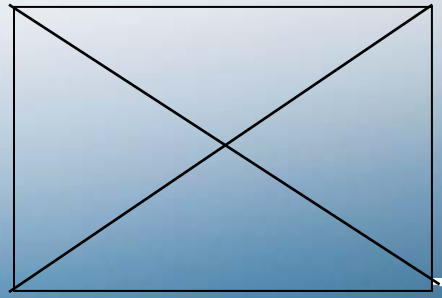




Evolution of Tubular Steel Towers



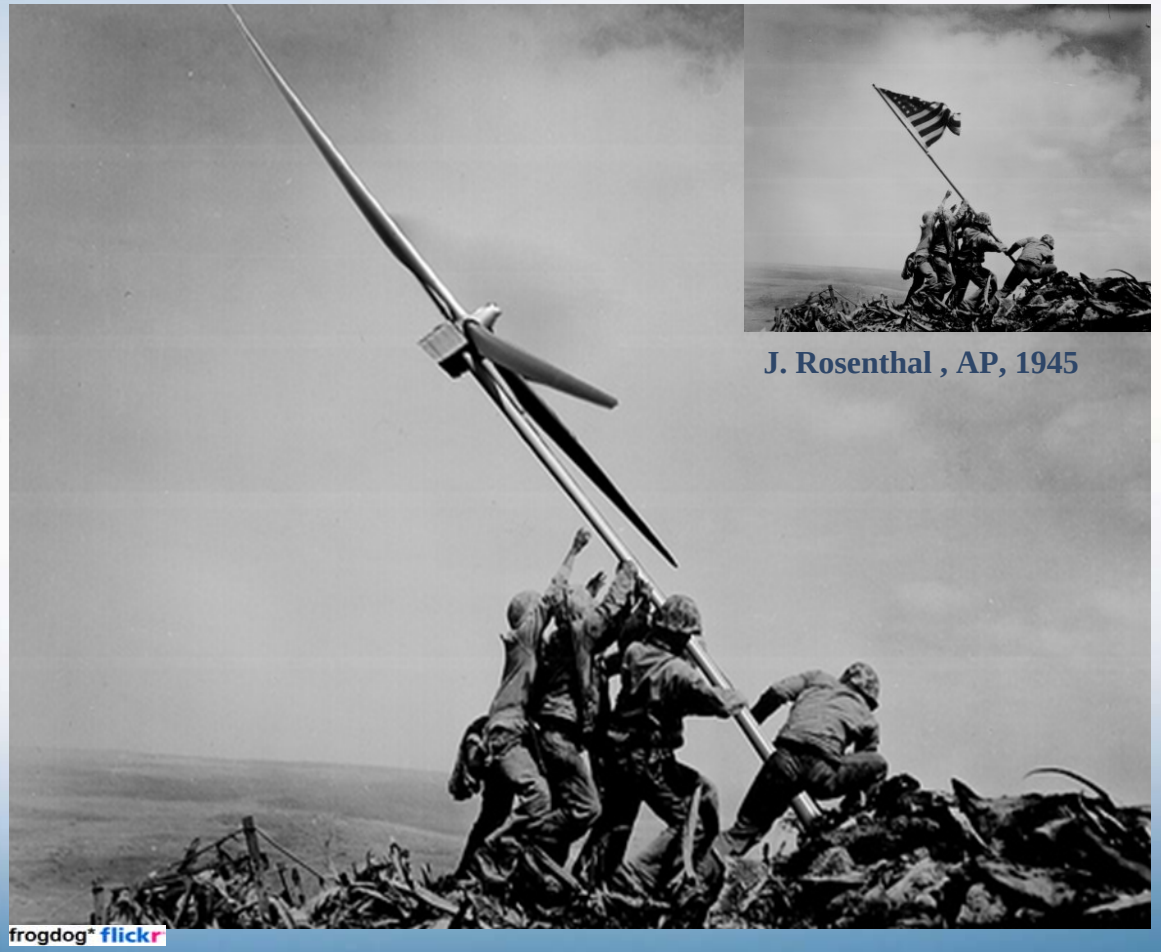




Hur (snabbt) går vi vidare?

- Har vi områden att bygga vindfarmer på ett hållbart sätt?
- Har vi potential att skapa nya lösningar och optimera den befintliga?
- Bidrar vindkraftsindustrin till ökad tillväxt?
- Kan ni vi göra något för att få ”grönare” verkstadsindustri (i Norrbotten)?

”Steel Wind Tower Marines”



J. Rosenthal , AP, 1945

”Steel Wind Tower Marines”
……..even in the cold climate

J. Rosenthal , AP, 1945


Luleå tekniska univeristet, LTU
Great ideas grow
better below zero!
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