Friction moments of ball joint supports used in structural test rigs subjected to cyclic loading

**Malo Rosemeier, Thomas Gebauer, Catherine Lester and Moritz Bätge
Presented by David Melcher**

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Motivation

- 1) Understand the structural response of a ball joint supported specimen subjected to bending and torsion
- 2) Determine friction coefficients and thus friction moment of the joints
- 3) Validate finite element models

Method

Ball joint

Methods

Detailed ball joint model - Finite element discretization

- Implemented in Mechanical ANSYS Parametric Design Language (MAPDL)
- Ball modelled as sphere type of TARGET170
- Housing meshed SOLID185 elements
- Contact between ball and housing with CONTA174 using penalty stiffness method
- Bolts modeled and pretensioned

Methods

Analytical ball joint model

Friction moment for ball pressed into half-shell (Tzou 1991):

$$M = FR \frac{\mu}{\sqrt{1 + \mu^2}}$$

Friction moment for pretensioned BJ:

$$M = k2F_p R \frac{\mu}{\sqrt{1 + \mu^2}}$$

$k = 1.5$ (derived from detailed solid FE)

$F = 2F_p$ (two half-shells pretension)

Methods

Simplified ball joint model - Finite element discretization

- Should behave like analytical model
- Implemented in Mechanical ANSYS Parametric Design Language (MAPDL)
- Housing meshed with SHELL281
- Ball modelled as sphere type of TARGE170
- Contact between ball and housing with CONTA174 using penalty stiffness method
- Tuned CNOF factor to match the analytical solution

Methods

Beam experiment

Methods

Beam experiment - Measurement equipment

- 8 markers with speckle pattern were tracked with a stereo camera system
- A digital image correlation system (DIC) determined displacements of markers
- Twist along z-axis calculated from top and bottom marker pairs

Methods

Beam model - Finite element discretization

- 2 ball joint models
- BEAM189 type used with C-shaped section
- Rigid MPC184 connected joints with beam

Results and Discussion

Displacements

- Friction coefficient in ball joint was varied between $\mu = 1.5\text{E-}4 \dots 5.0\text{E-}4$
- Good fit

Results and Discussion

Twist along span

- Model's twist response is sensitive w.r.t. μ
- Model has a good match with $\mu = 3.3\text{E-}4$ for $\Delta\vartheta_z = 0.055^\circ$ between beam ends
- Only measurement value at $z = 0.35$ does not fit well

Conclusions

- Simplified BJ FE model of ball joint successfully implemented in MAPDL and verified with detailed solid FE model and analytical solution
- Simplified BJ and beam modeled experiment and revealed a friction coefficient of $\mu = 3.3\text{E-}4$
- Friction coefficient of $\mu = 3.3\text{E-}4$ leads to a friction moment given by BJ manufacturers data sheet
- This study validated the boundary conditions of a ball joint supported specimen, i.e., a wind turbine rotor blade component

Thank you for your attention!

Questions?

Contact:

Malo.rosemeier@iwes.fraunhofer.de

David.melcher@iwes.fraunhofer.de