Presented at the COMSOL Conference 2009 Milan

Multibody Contact Analysis of an Rzeppa CV-Joint

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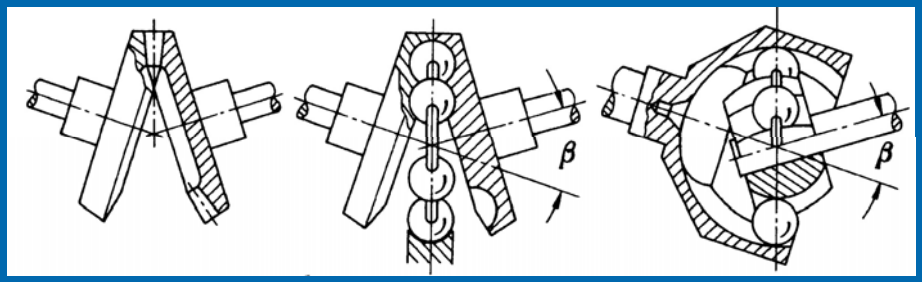
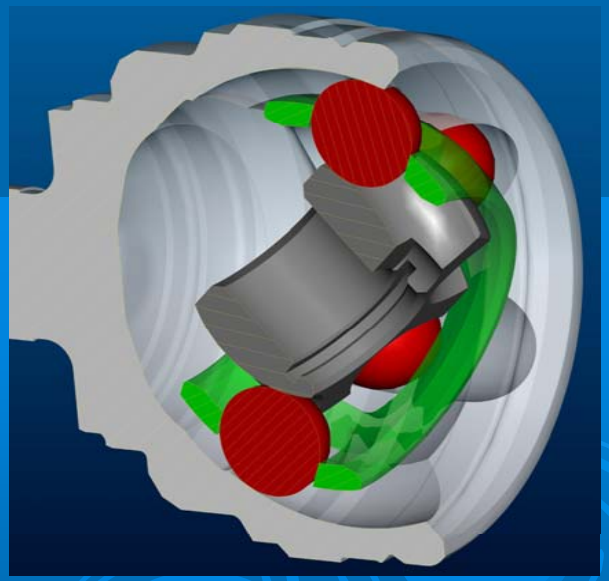
Comsol Conference 2009

Milano, 16 ottobre 2009

CV-Joint, an introduction

- Constant velocity joints have a long story behind
- Considering a modified bevel gears couple introducing spheres instead of teeth is an early eighteen's century's idea
- Along the '30s Alfred H. Rzeppa (a FORD engineer) made significant improvements in such component design
- Nowadays they are widely used in many applications especially in the automotive industry



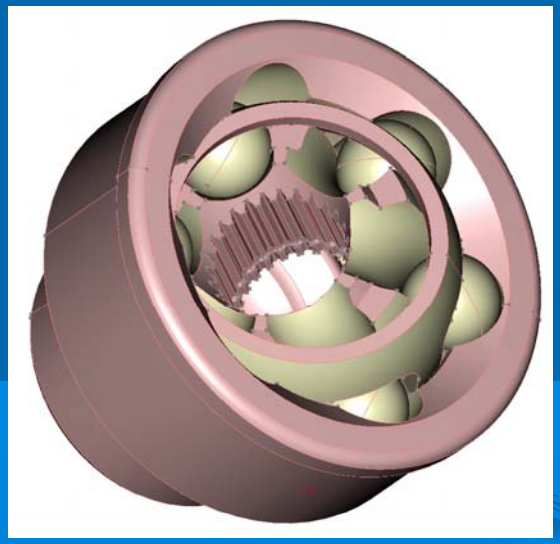


The main components in a common CV-Joint are:

- Outer race (light grey)
- Inner race (dark grey)
- Balls (red)
- Cage (green)

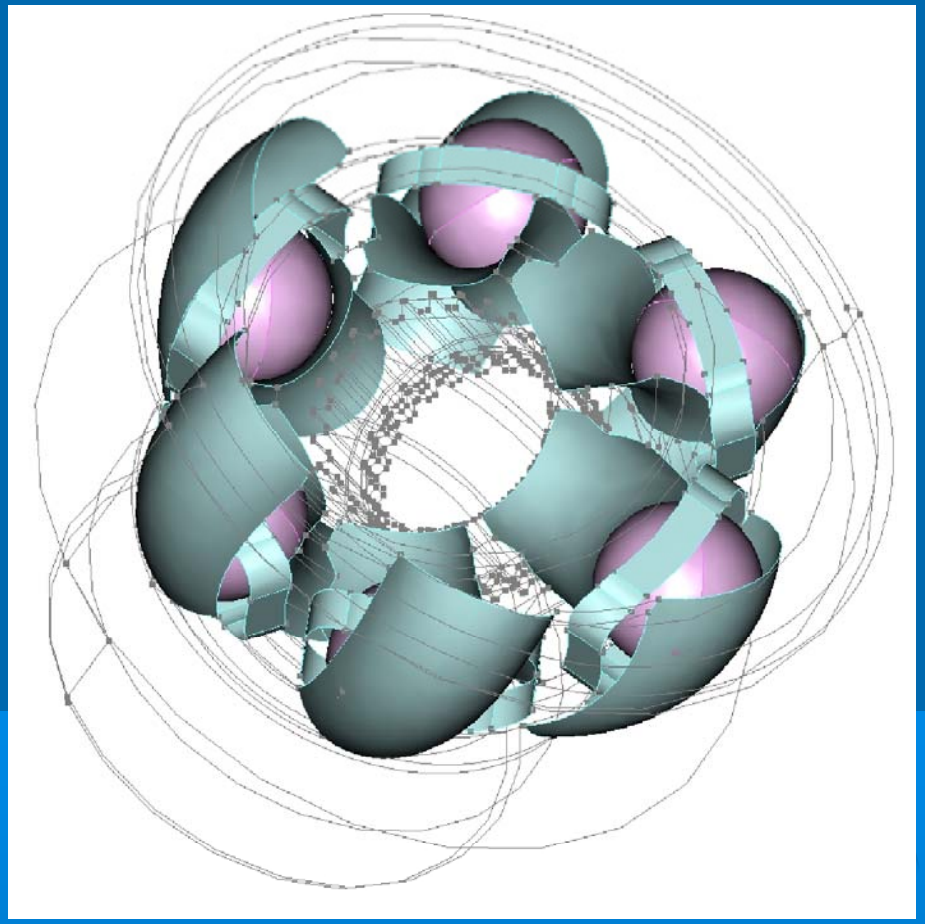
Model characteristics

- Simplified outside geometry
- Unique isotropic material used for all components
- No pre-stress in materials (real materials are heat-treated)
- No friction among components taken into account
- Simplified constraints
- Resisting torque positioned in an “easy” place
- Rough mesh to minimize processing time



Contact pairs

- In a real CVJoint all the components are in contact among them
- Balls are in contact with all the components
- Inner and outer race are in contact with balls and cage
- The cage is in contact with all the components

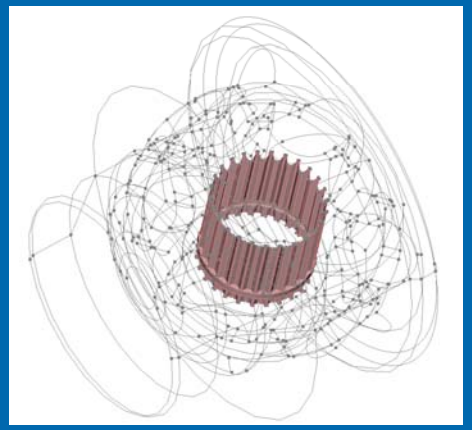


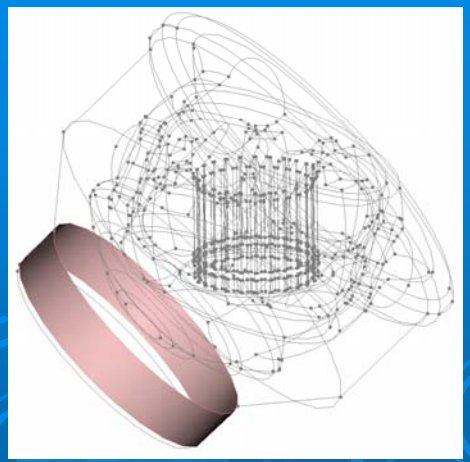
In Comsol model only three contact pairs are enough for a complete definition (master vs. slave):

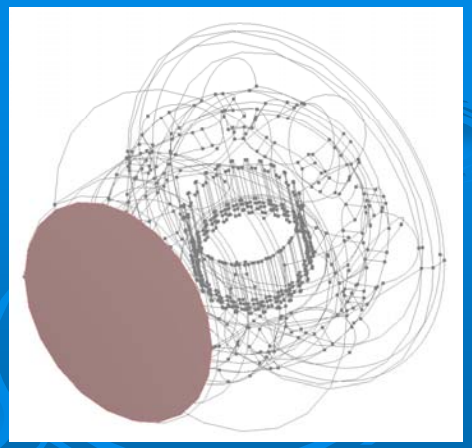
- Cage vs. Inner race
- Cage vs. Outer race
- Cage, inner and outer race Vs. Balls

Constraints & Loads

- A fixed angle between outer and inner race has been considered for the analysis
- The rotation has been imposed at the spline in the inner race (prescribed displacement)
- Outer race is kept at a fixed angle imposing a roller at the bottom surface
- Resisting torque has been applied in an “easy” position of simplified outer race geometry



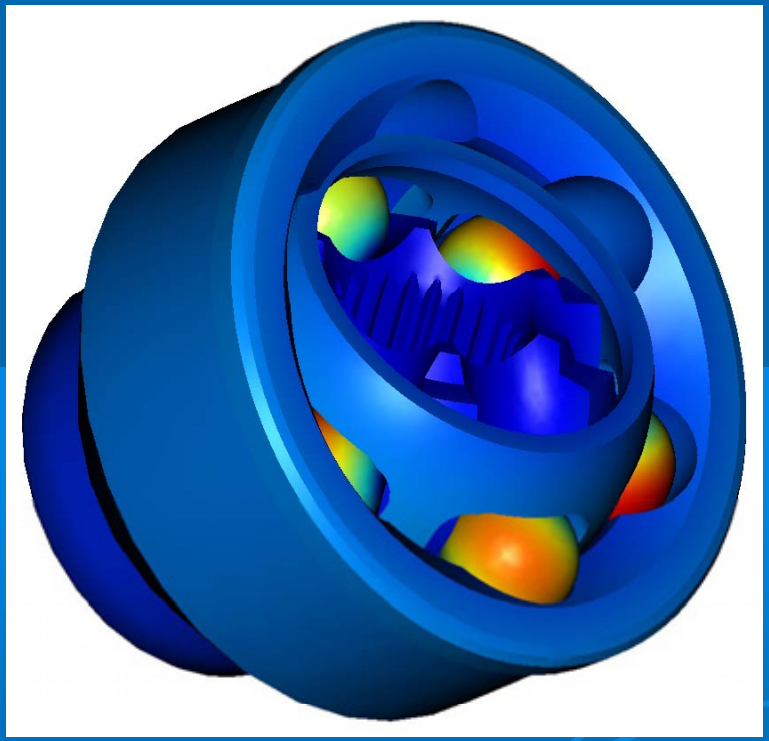


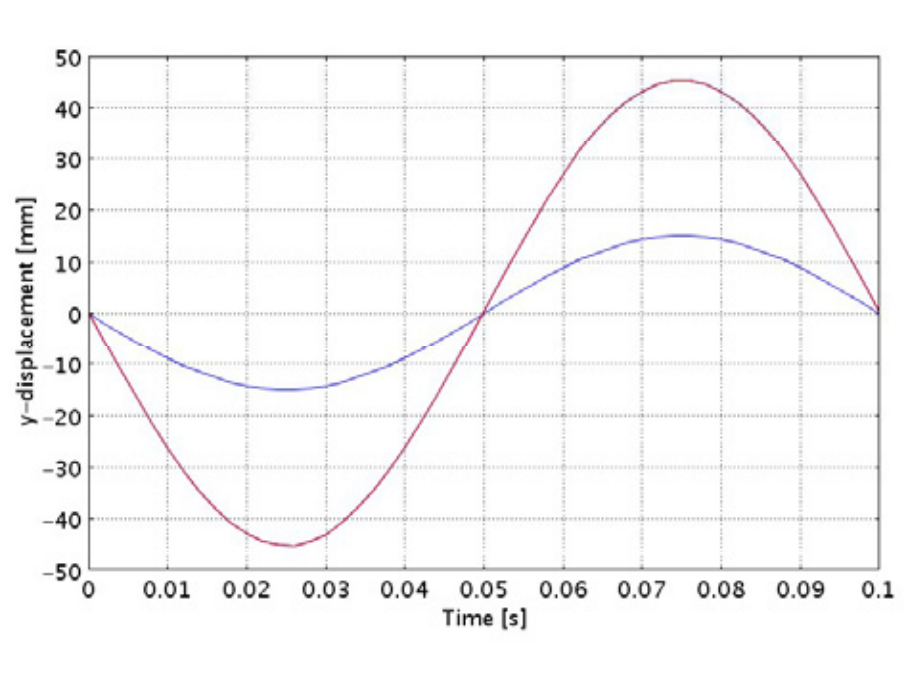


Model Summary

- About 106.000 Degrees of Freedom
- Time-dependent Analysis
- Linear System Solver PARDISO
- 2 Dual-Core (Xeon 2.33 GHz) 64 bits Linux Workstation, 8GB RAM
- Processing Time: about 100 hours

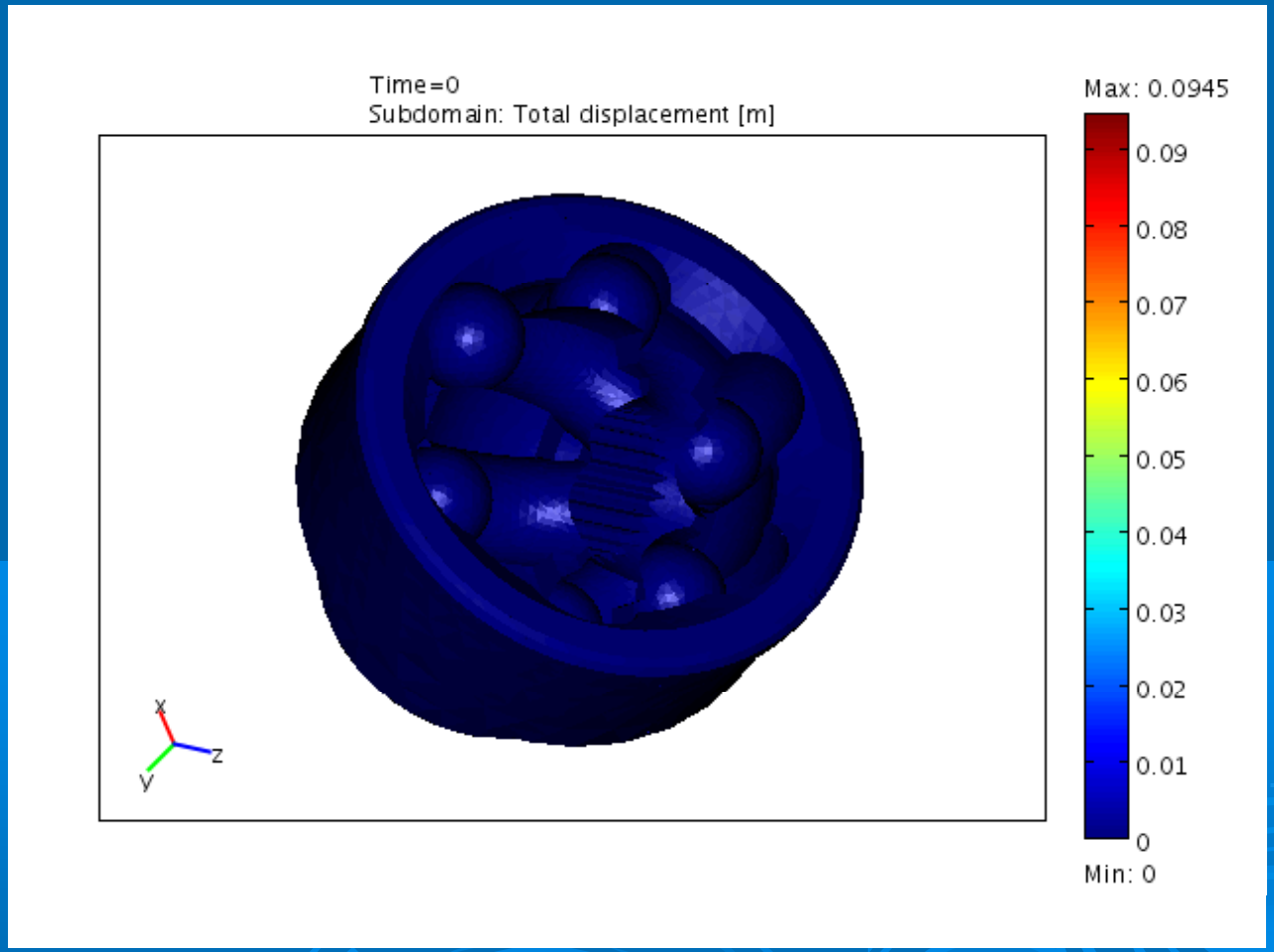
Results: Kinematic



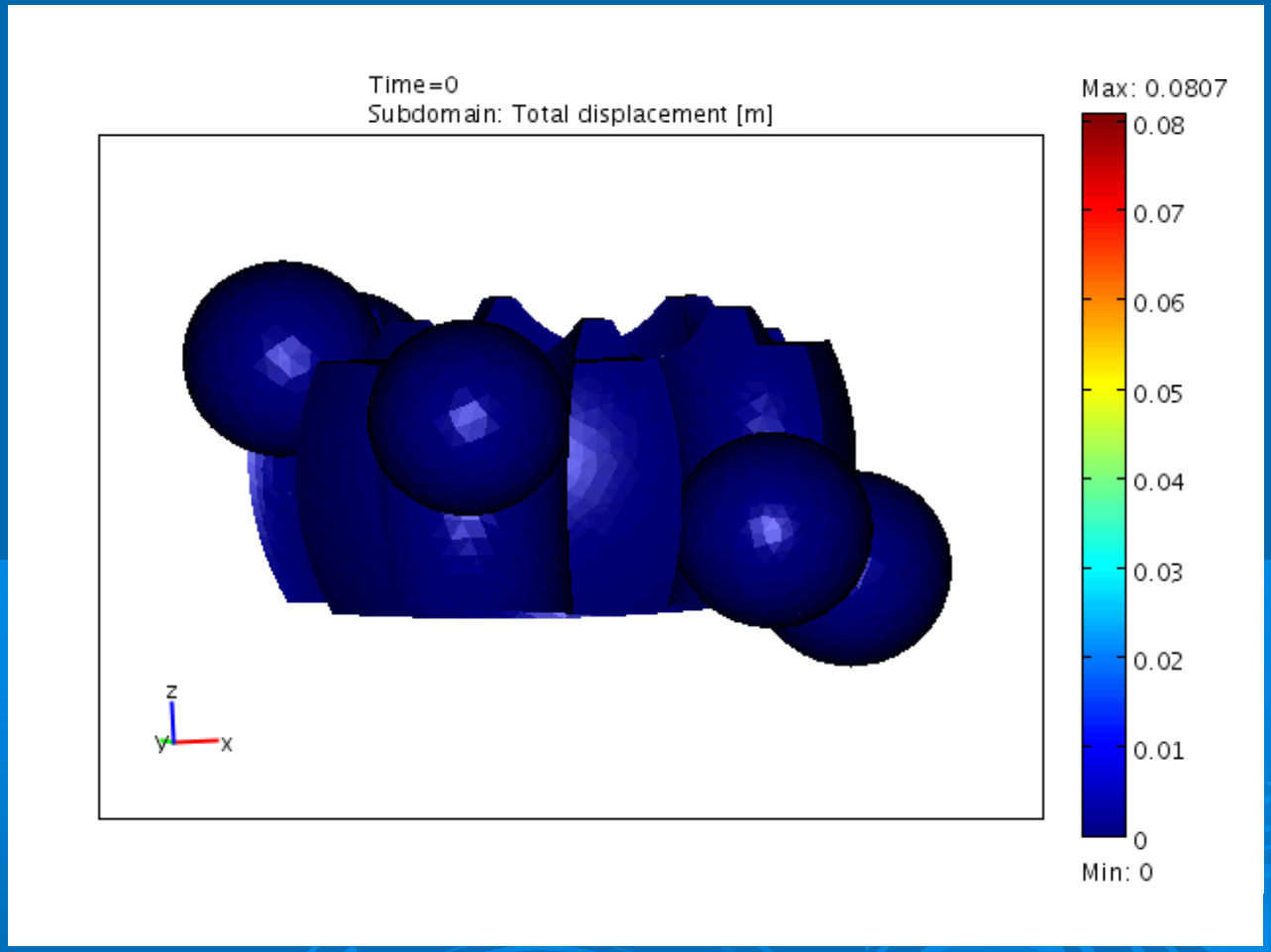


Kinematic analysis shows excellent relation between inner and outer race displacement value (the only difference between the two points is due to different radial position)

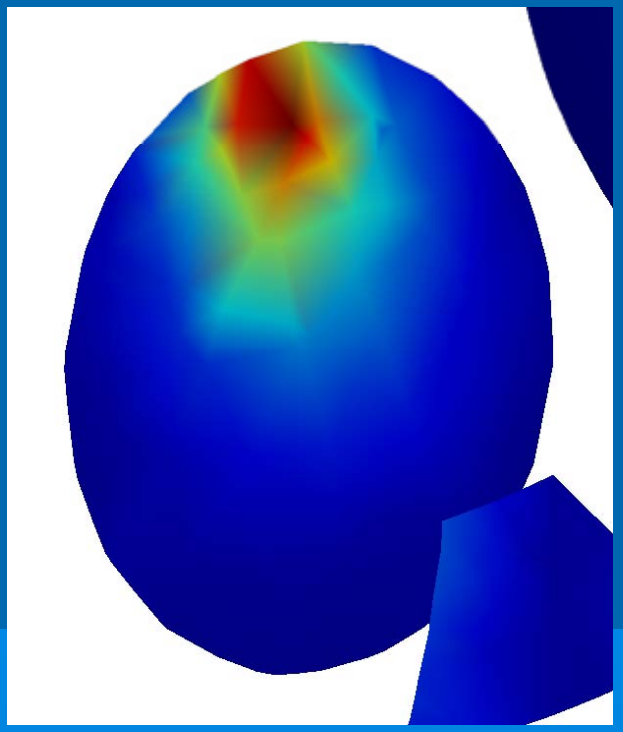
Results: Kinematic



Results: Kinematic

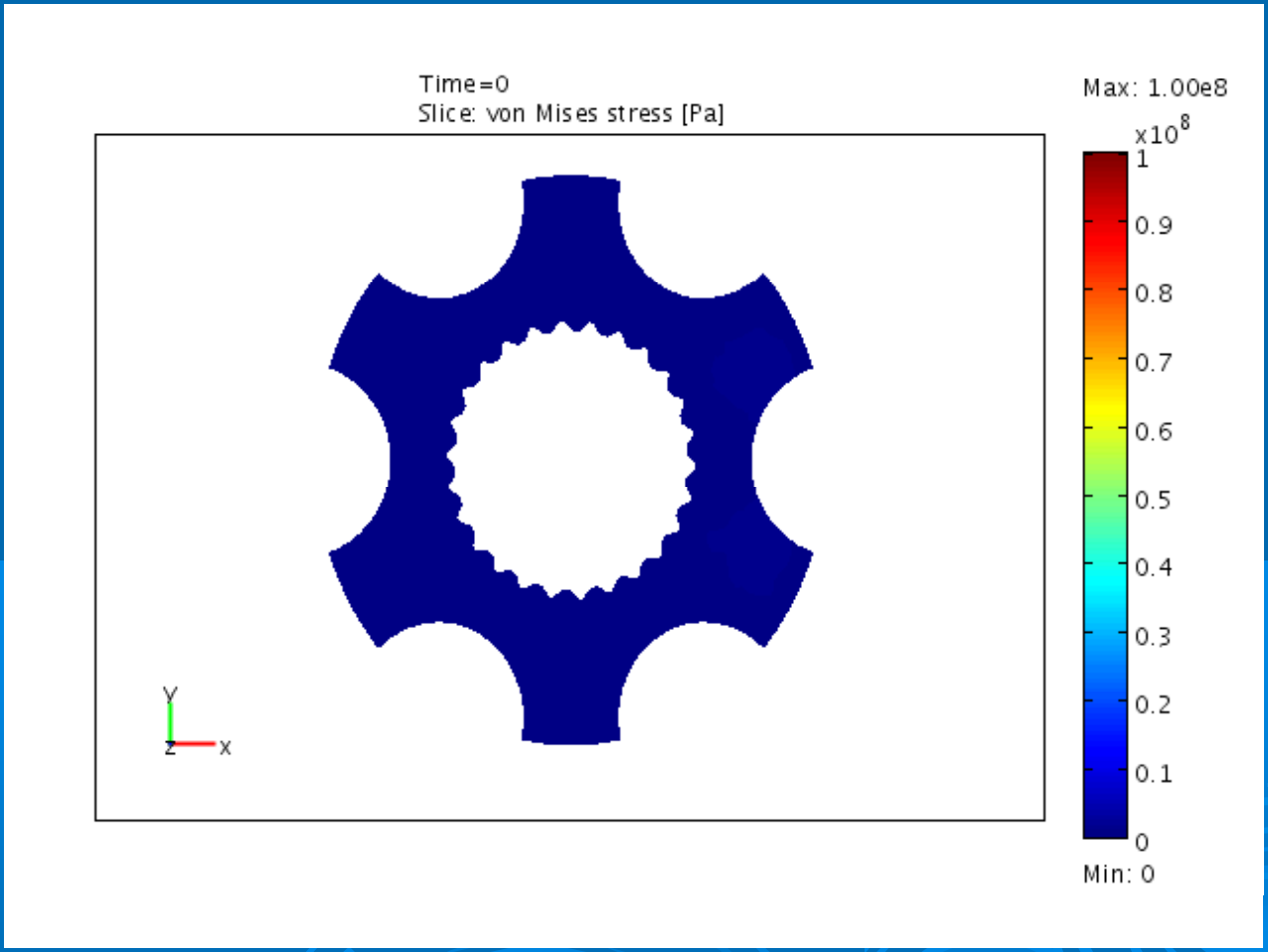


Results: Stress

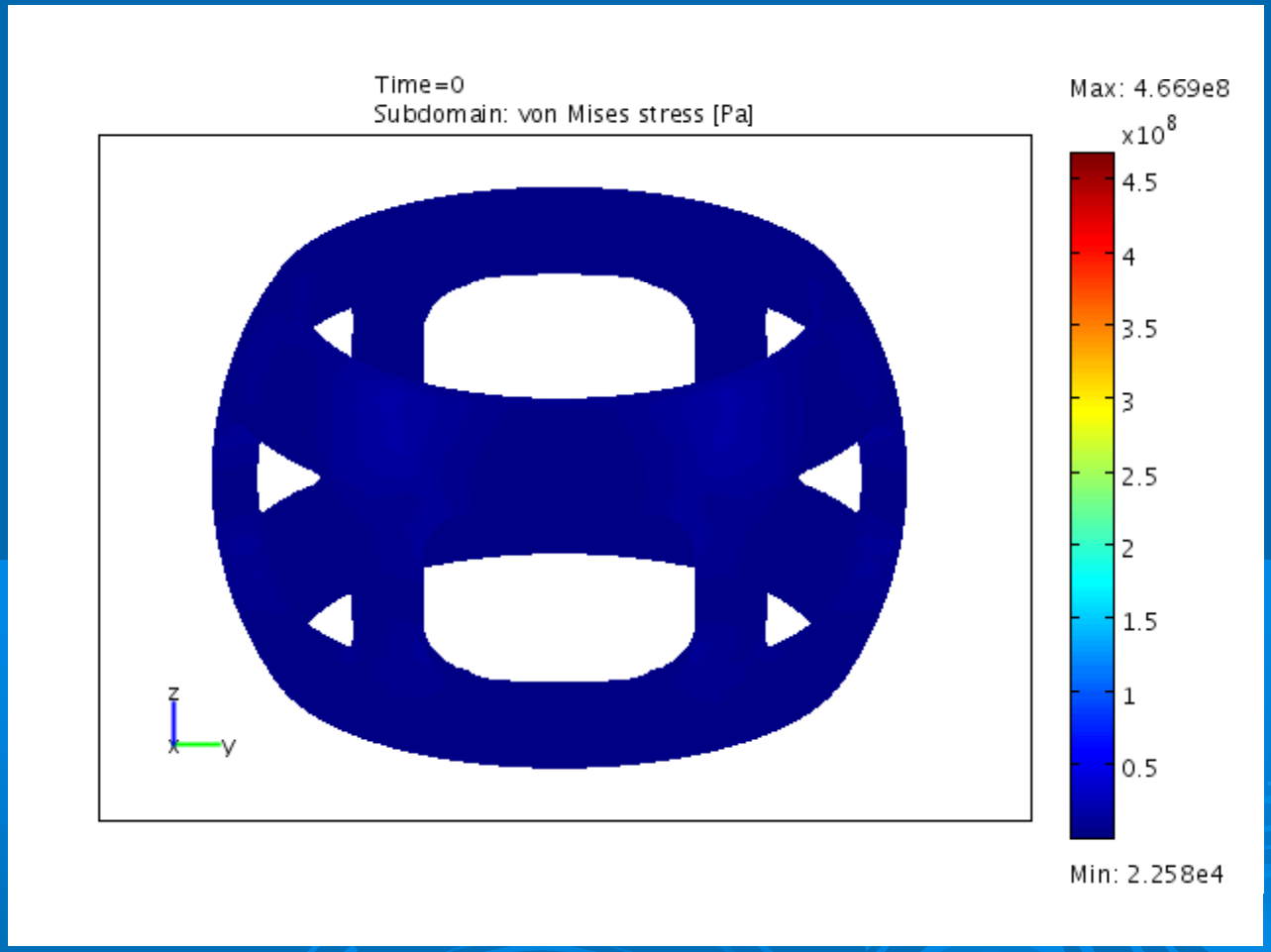


Stress distribution shows a typical pattern derived from rigid bodies contact stress (Hertzian contact) in which the maximum mean value is located under the body's surface.

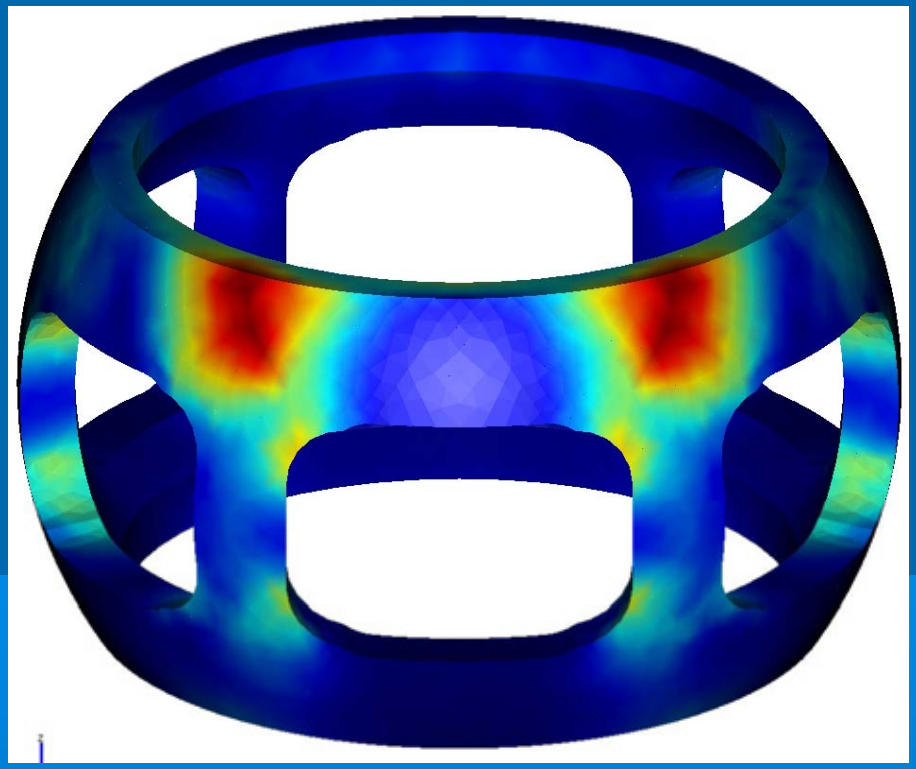
Results: Stress

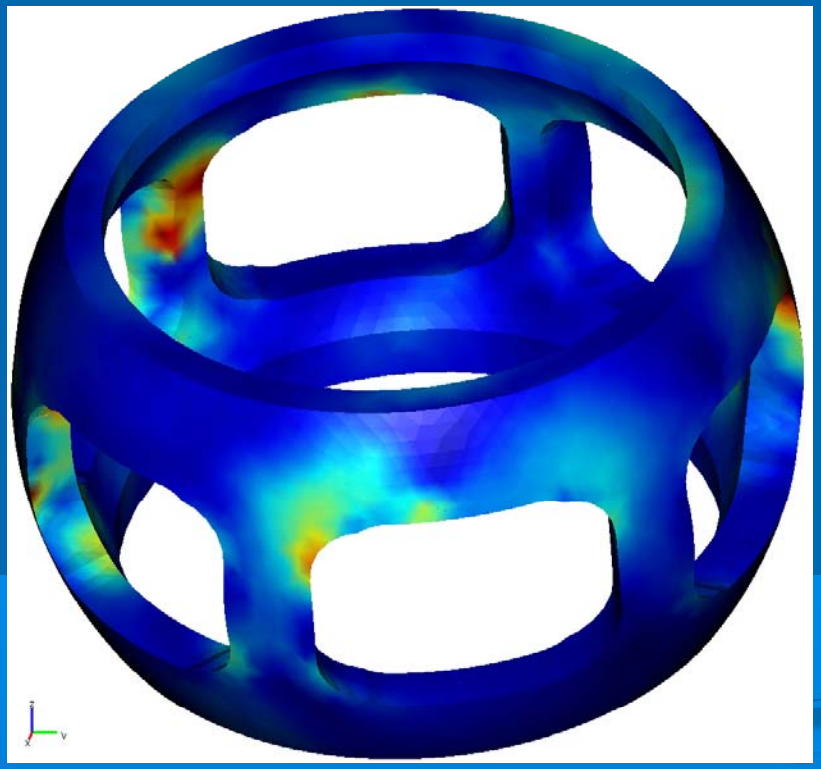


Results: Stress



Stress: the cage





Stress distribution in the cage is very peculiar and reflects this component’s typical failure mode

Analysis of results

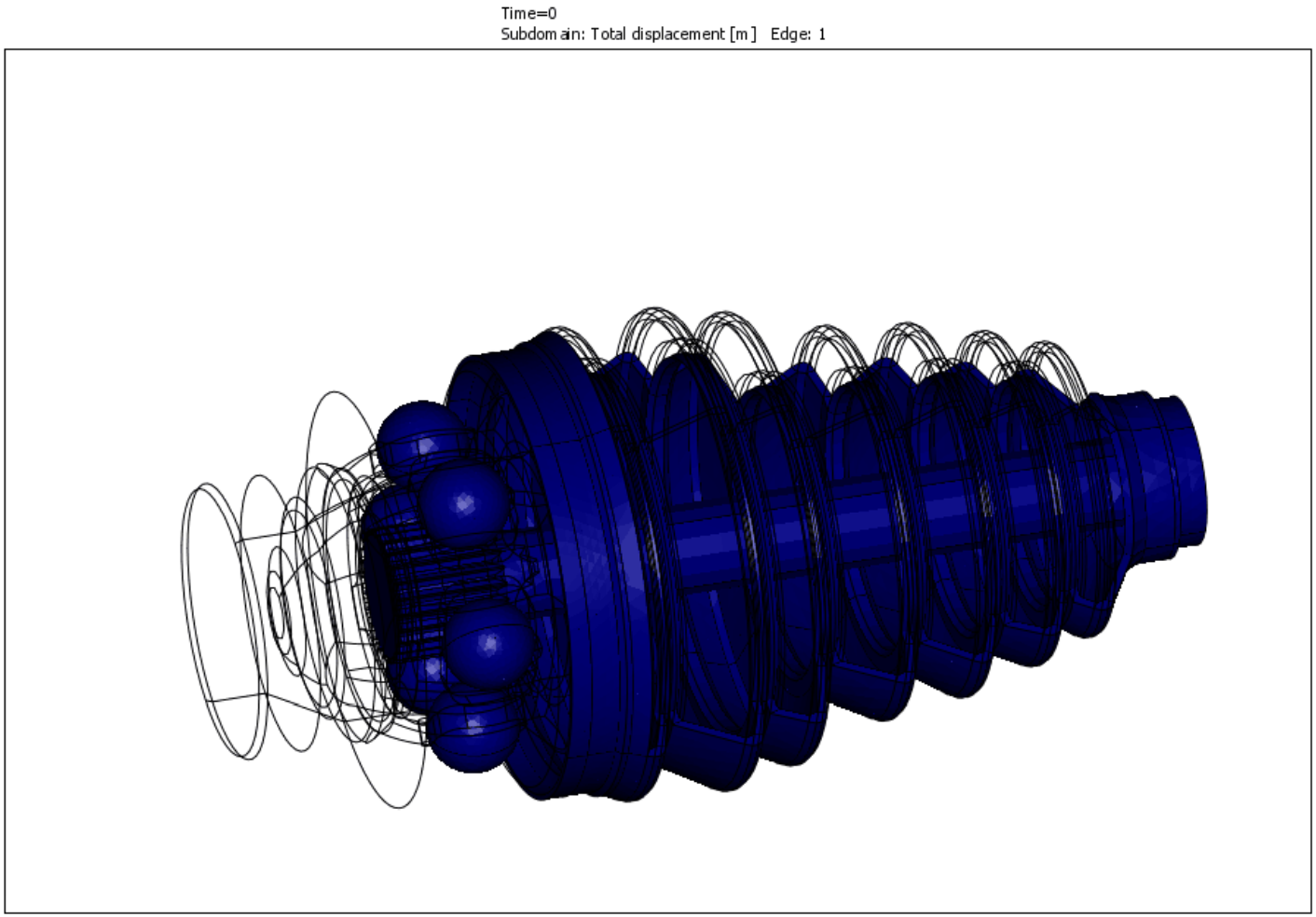
Looking at the results it can be pointed out that:

- **The Kinematics is correct** (but some calculated values can be “noisy” due to a coarse time step and mesh)
- **The stress** present in all the components **is reasonable**, with limitation near the Constraints and Loads (due to approximation introduced in the analysis)
- **Local stress values** near the contact areas are lower than the closed-loop calculated ones (again due to the coarse mesh used); this effect was expected
- The absolute values of stress aren’t reliable for a real component comparison due to the absence of pre-stresses in the materials

Next steps

- Full CV-Joint Model (complete geometry)
- Real Materials (including pre-stress)
- Friction among components
- Include grease effects
- Real Constraints & Loads
- Finer Mesh (especially around contact areas) to improve accuracy
- Investigate fatigue phenomena
- Segregated Solver

Next steps: first results



Acknowledgements

Thanks to Gian Luigi Zanotelli