Development of an improved screw model at faurecia

Dipl.-Ing. M. Meyer / Faurecia Autositze, Stadthagen / Germany

1 Short introduce in the problem / motivation

Some years ago Faurecia used a very simple screw model. In this model the screw holes are filled by a rigid body and the screw shaft is modeld by a simple spring beam with an unrealistic stiffness. But this model doesn't represent the behavior of screws in real test. With this simple model it was not possible to get the peeling effect of the holes. And the deformation of the part and the screw was unrealistic. Also the forces inside the screw were too high.

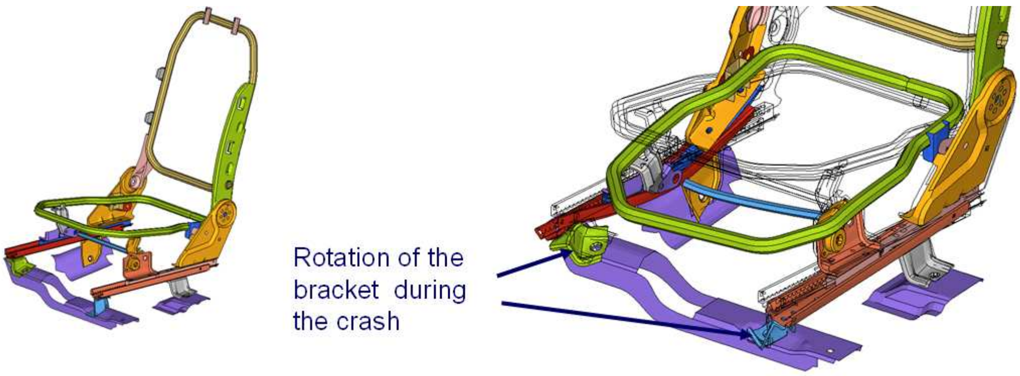


Fig. 1: Deformation of screw connections on seat structures

Due to the goal to reduce the time to market and the number of prototypes to develop a new product it was necessary to develop a better screw model. At the end of 2008 a new keyword was available in LS-Dyna with which it was easy to implement a defined preforce on a beam element. This was the point to start with an improved screw model.

The target for this screw model is:

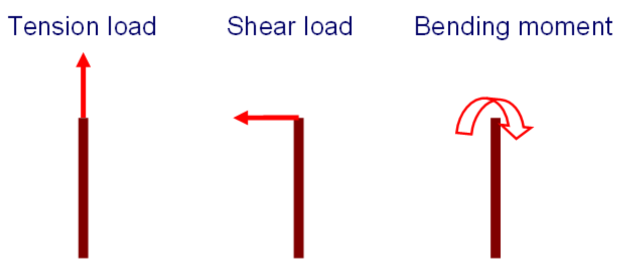
- Respect the time step of crash model
- Peeling effect on holes
- Realistic forces / moments
- Detection of failure

2 Validation of beam elements with solid mesh

The target for a crash model is to have as short as possible calculation time by the best possible quality of results. To reach this for the screw model only a beam model is possible to be used. So the first step was to analyze the quality of result compared to a fine solid mesh. For that a simple rod model with different loads was used.

- Tension load
- Shear load
- Bending moment

These loads represent the conditions during crash on the screws. For the rod model different numbers of beams are used and for comparison the rod was modeld with a fine solid mesh.



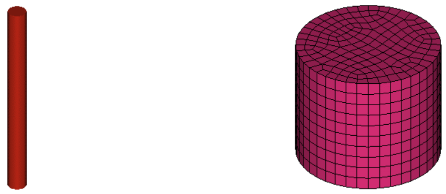


Fig. 2: Rod as beam and solid model, loading direction

2.1 Tension

In the fist step the behavior of the beam was tested by a tension load. The results are shown in Fig. 3.

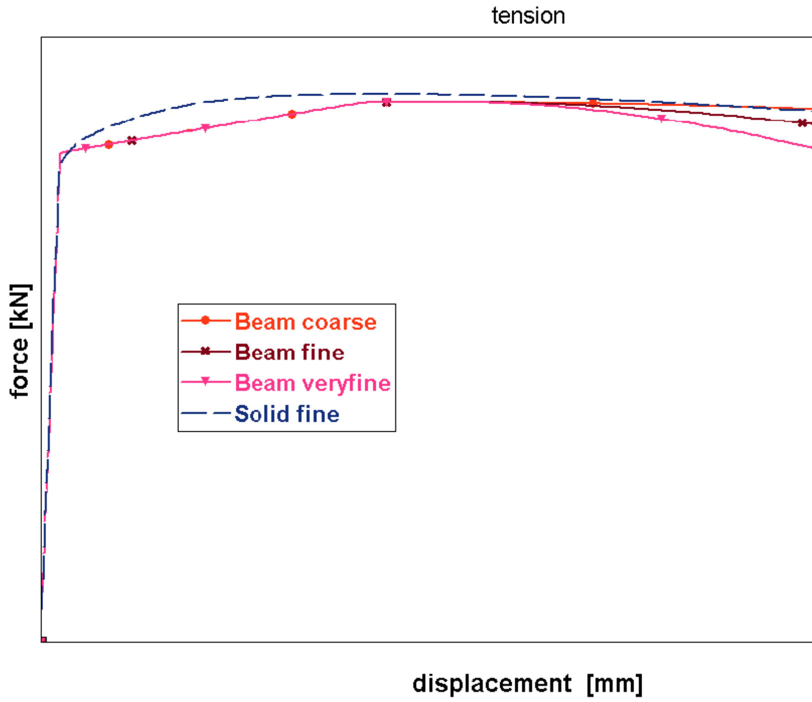


Fig. 3:Force vs. displacement under tension load

The reason for the difference between solid and beam at the beginning is because for spotweld beams only a simple bilinear material model (*MAT_SPOTWELD) is available. For solid a lot of different material models are available. Here we used a *MAT_PIECEWISE_LINEAR_PLASTICITY with a Swift approximation. After uniform elongation we see an influence of the number of beams. With a higher number of elements the degreasing is higher as with less. So if we define a material we must validate the material for the min. and max. element size in our model.

2.2 Shear

The next step is a shear load on the rod. The results are shown in Fig. 4.

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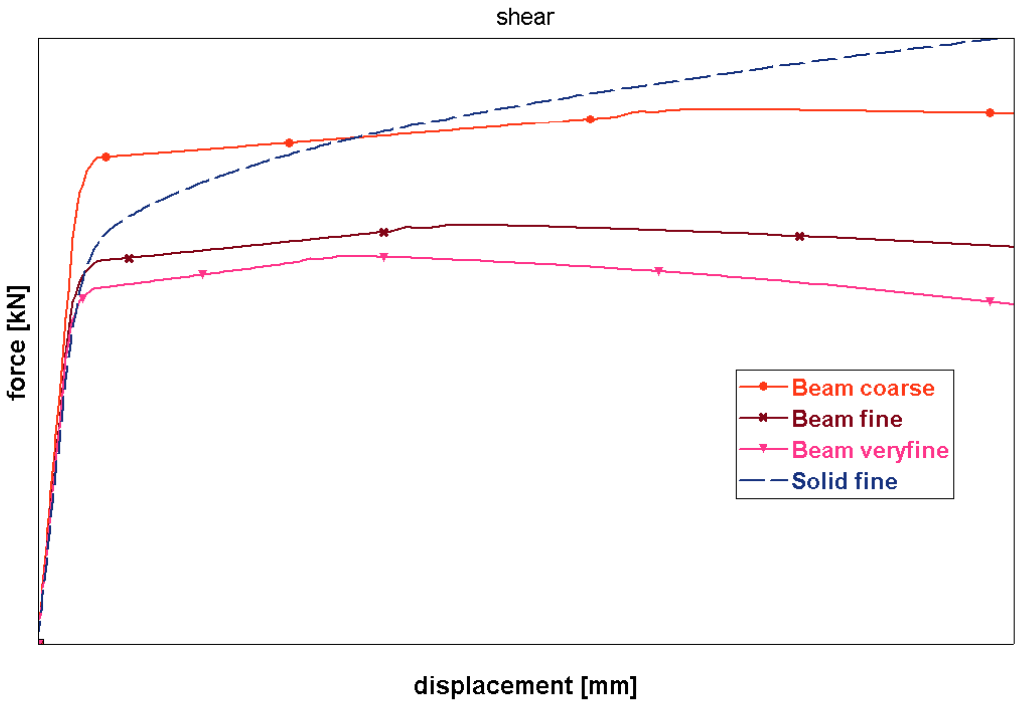

Fig. 4: Force vs. displacement under shear load

Here the influence of the mesh size is higher as for tension. With the coarse mesh the point of plastification is later as with solid. But the max force is closer to the solid result as for the finer meshed models. On a screw connection shearing occurs between two parts. So the effected area of the screw model will be every time one element. In conclusion the precision of the results on shearing is in case of screws ok.

2.3 Bending moment

The last step is to implement a bending moment on the rod. In Fig. 5 the results are displayed.

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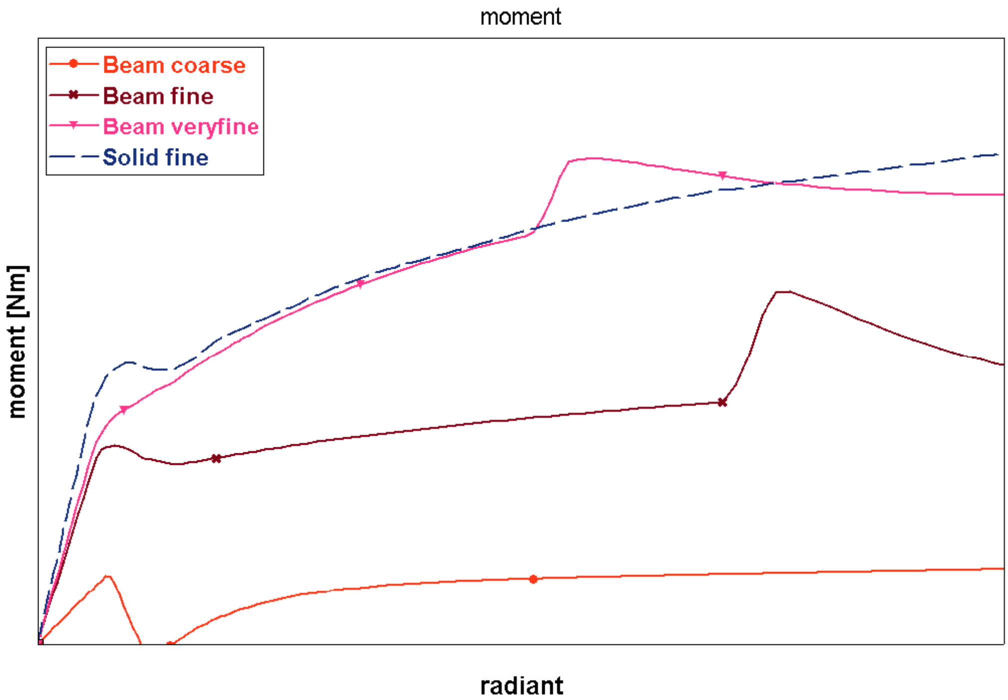

Fig. 5: Moment vs. angle under bending moment

With a coarse mesh the result of the solid mesh is not reached. Only with the fine beam mesh the results are the same as with solid. Only at the beginning of plastification and at the middle the beam results deviate from the solid result. In conclusion the screw model should have a very fine mesh.

2.4 Conclusion

As result of this first study we see that the beam model is useable for a screw model and the precision of results are close to a fine meshed solid model. So in the next step the screw model was developed based on this knowledge.

3 Development of the first screw model

The model is on the basics compare able to the model show by Daimler on the German User Conference in Bamberg [1]. The goal of the first model was to be able to get in simulation the peeling effect on the hole, the rotation of the connection and to increase the quality of the output.

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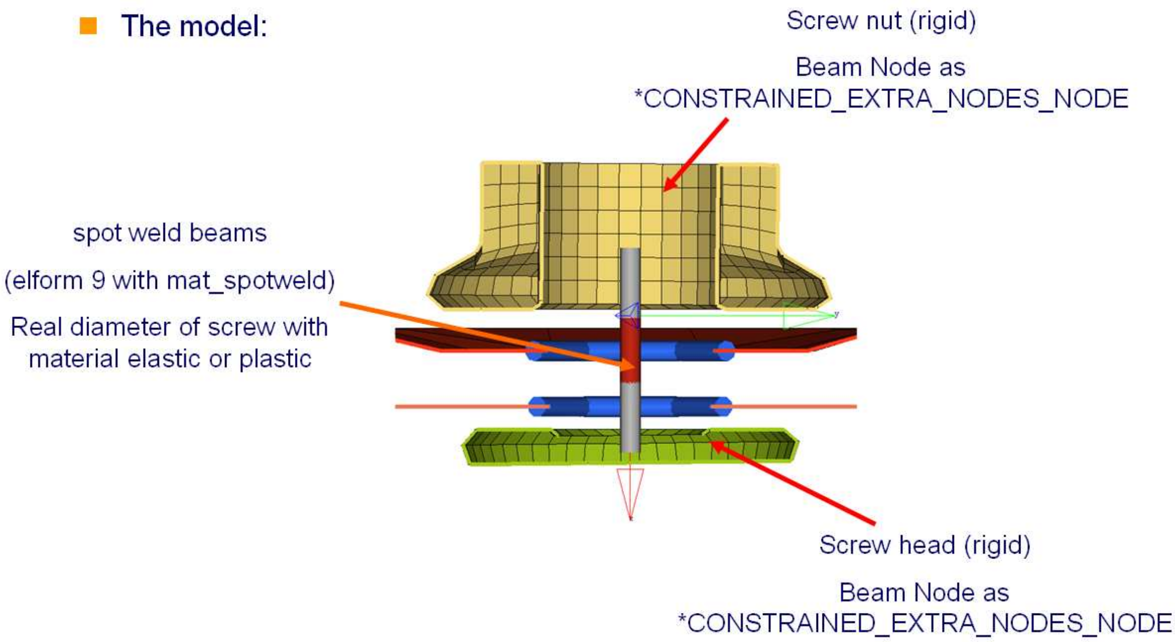

Fig. 6: Improved screw model

The basics of the screw model are (Fig. 6)

- Screw beam shaft as spotweld beam. Preforce of screw realized by keyword*INITIAL_AXIAL_FORCE_BEAM. Material model *MAT_SPOTWELD (as other elastic plastic material models not available)
- Screw head and nut as rigid part. Meshed with shell elements on the outer surface. Connected to the shaft beams with *CONSTRAINED_EXTRA_NODES_NODE
- Contact between shell parts by *CONTACT_AUTOMATIC_SURFACE_TO_SURFACE
- Contact between screw shaft to screw hole by *CONTACT_AUTOMATIC_GENERAL

3.1 Problems of the first screw model

With this first screw model we were able to detect the peeling effect. But the failure of screw is not possible to detect (Fig. 7). As standard the resultant screw forces were used to calculate a v. misses stress value to conclude on failure of the screw. But this calculation is not working fine. The reason is the assumption of the first model that the screw shaft deforms only elastic. But in reality the shaft deforms elastic plastic. So in the next step an elastic plastic material damage model was determined for the screw model.

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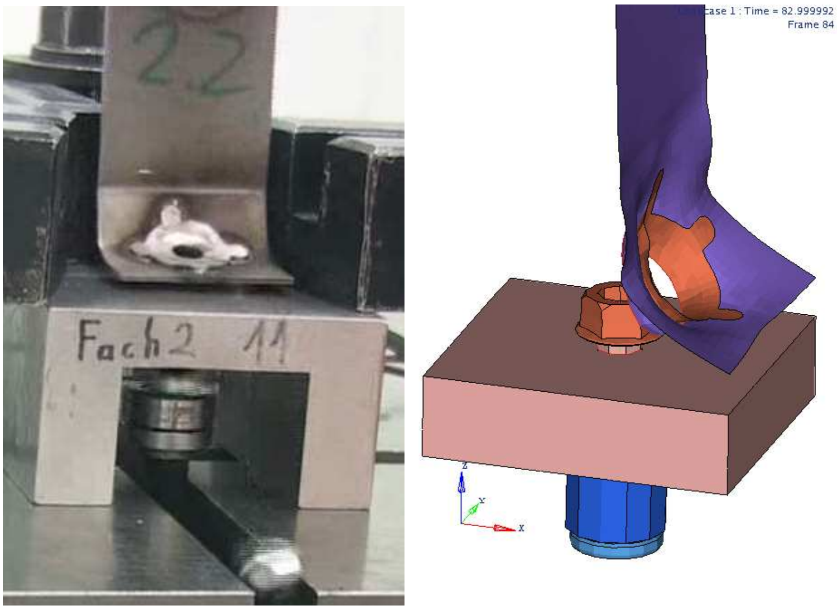

Fig. 7: Left picture: failure of screw in test. Right picture: peeling in FEA

4 Material detection and validation test tests

To characterize the material law for the different class of screw materials, a simple screw tension test was used. For that a screw is fixed between two stiff parts. The force and the displacement were measured and a material flow curve was extracted. The test was done for different screw classes like 8.8, 10.9 and 12.9 and for different screw length and screw dimensions.

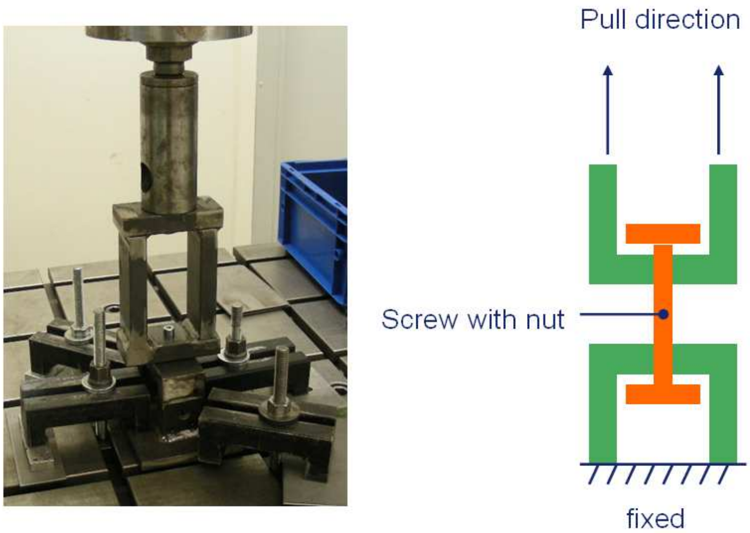

Fig. 8: Test configuration for material detection test.

As for spotweld beams only a simple bilinear material law is available this detected flow curve was simplified and validated. To be able to simulate the failure of the screw the *MAT_SPOTWELD_DAMAGE-FAILURE is used. In the next step the found material law was validated by simulation of the material test.

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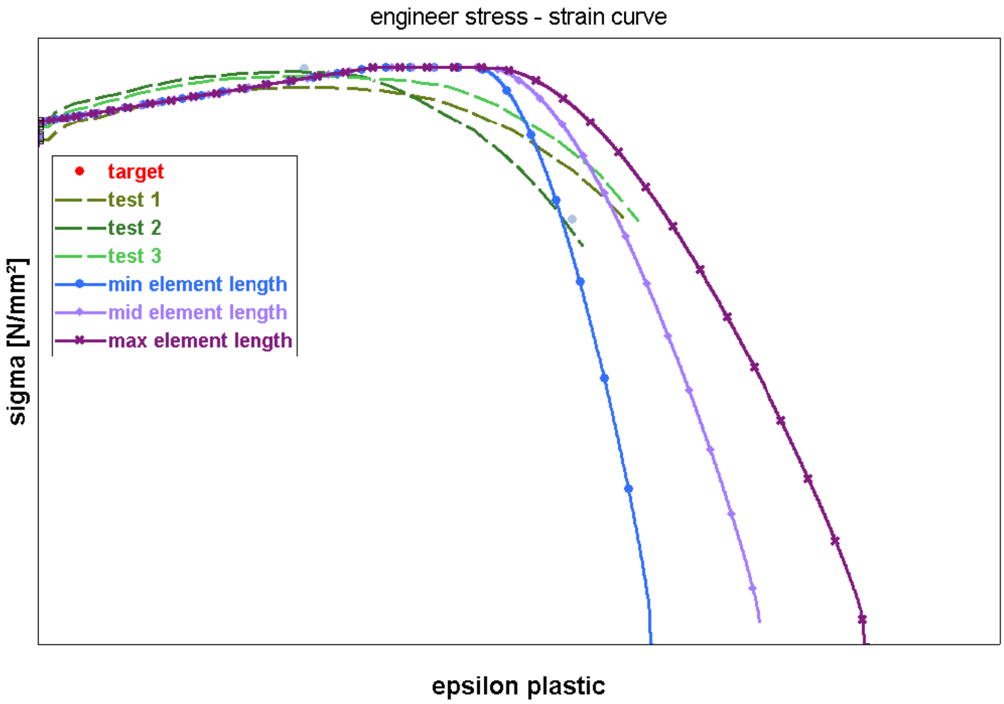

Fig. 9: Validation of material card - σ vs. ε_{plast}

The results between the real test and the simulation are - known the issue of the only available bilinear material law – close together (Fig. 9). Until uniform elongation the deviation is low. Here the simulation model is a little bit pessimistic compared to real test. The plateau of max stress is later in simulation and longer as in test. After uniform elongation the simulation is too optimistic. Negative is of course the dependency of number of elements in simulation. But we see the same range of scattering in real tests as we have with the mesh size variation in FEA.

5 Screw validation test

The next step was to validate the improved screw on real conditions. For this an L-shape was used to get a loading condition with bending, tension and shear on the screw. This L-shape represents a typical connection of belts to the track profiles. In the real test the axial force of the screw, the displacement and the force of the pull device was measured.

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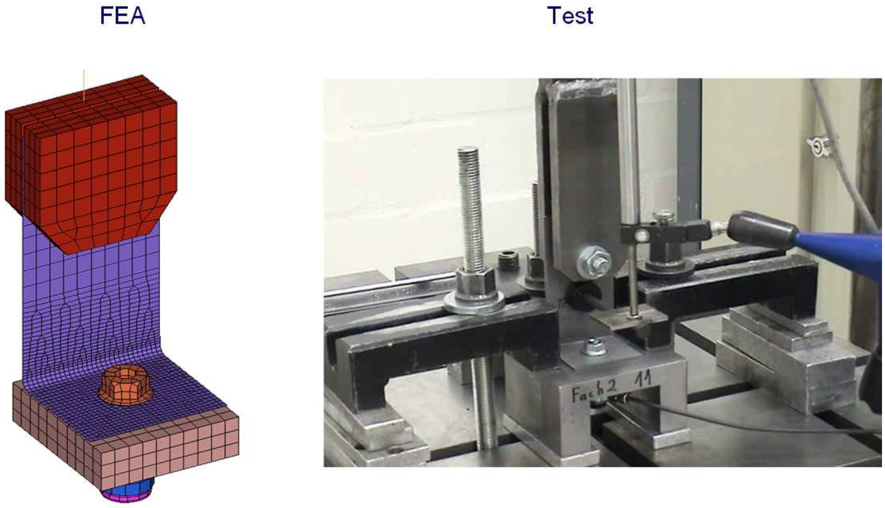

Fig. 10: Test configuration for screw validation test

In the test a preforce was implemented and measured by a force measurement ring. The ring was placed between the fixation and the screw head on the bottom.

Fig. 11: Comparison of simulation with test after failure.

Looking to the peeling the results between simulation and real test are the same. By using a material damage failure model (We used the MatFEM damage failure model) for the L-part, the elements are eliminated at the same area as the material fails in real test.

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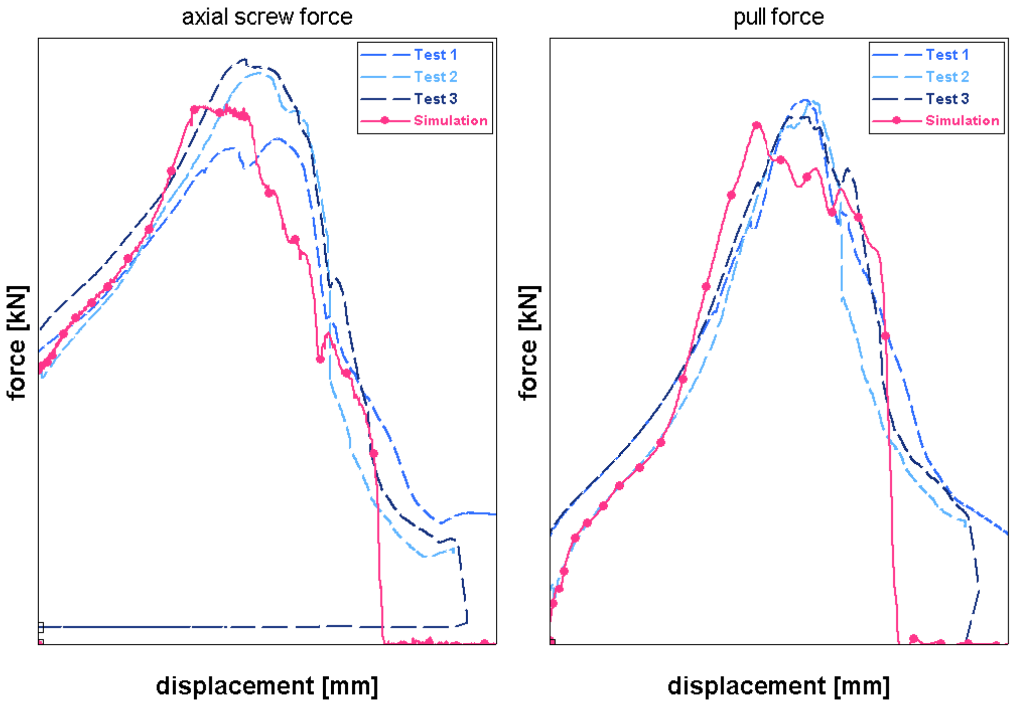

Fig. 12: Comparison simulation with test results – force vs. displacement

The comparison of the axial screw force and the pull force the deviation is less (Fig. 12). We see that in the simulation the slope of the axial screw force and pull force is higher as in test. The max axial screw force is between the test results, for pull force we reach the same value in simulation and test.

What is the reason for the deviation on the slope between test and FEA ? By analyzing the parts after testing we see a high deformation on the nut (Fig. 13). At the side of pull the flange is deformed. As we are using a rigid nut in simulation, we shorted the nut as it is deformed after test to see the influence of this deformation on the results.

Fig. 13: Deformation of nut after test and reduced nut in FEA

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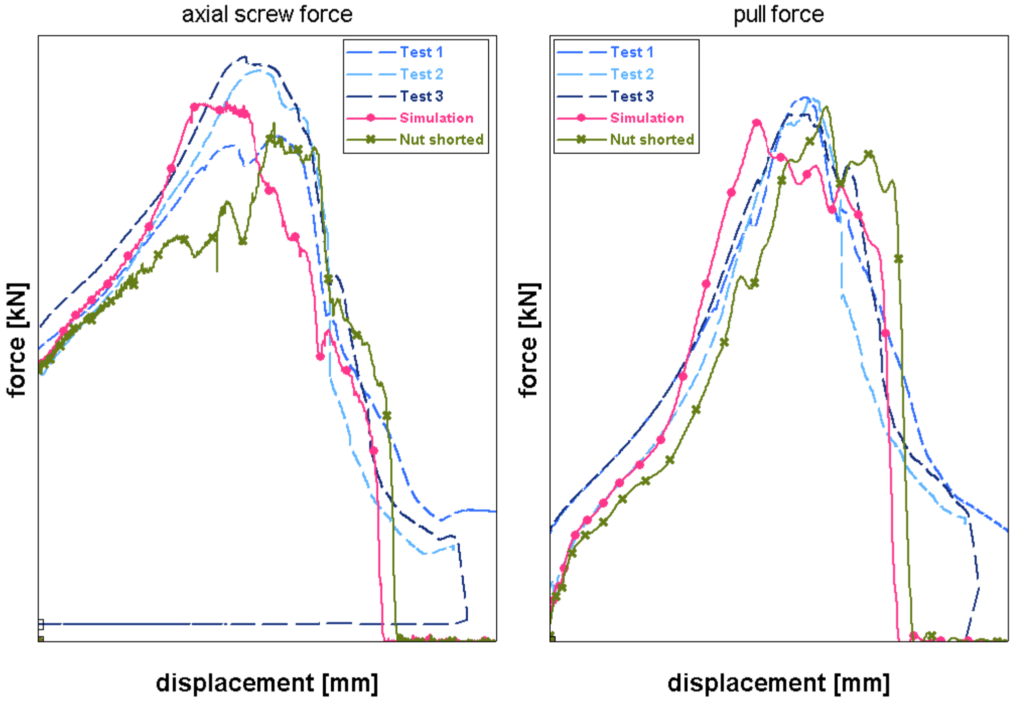

Fig. 14: Comparison test with simulation with shorted nut – force vs. displacement

After shorting the nut the slope of the force in simulation is now less then the slope from test results (Fig. 14). Also the max force is reached in FEA now later as in real test. So this deformation on the nut has a high influence on the slope.

6 Conclusion

In conclusion we were able to build up a simple screw model which full fill our time step request and with a high quality of out put. Now we are able to analyze the forces and the failure behavior of screw connections in simulation.

Now we get the same results as in reality. This is shown in the simple test where we have in one case a peeling effect and in the other case a failure of the screw (Fig. 15 and 16).

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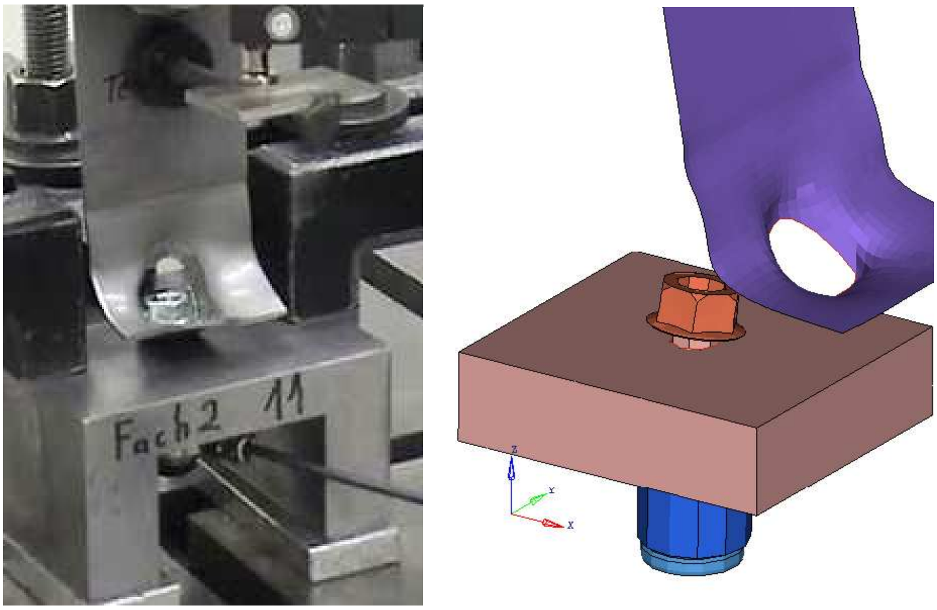

Fig. 15: Peeling in test and simulation

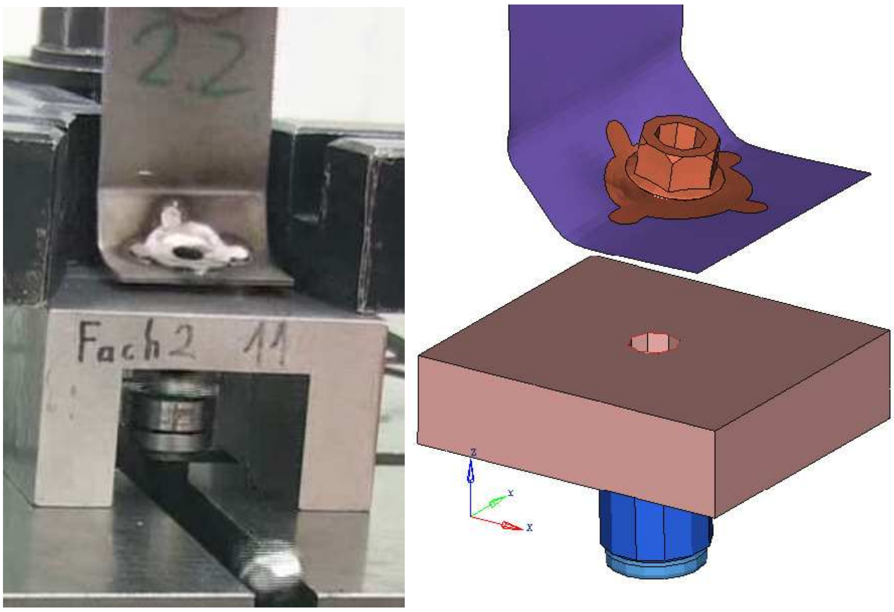

Fig. 16: Failure of screw in test and simulation

7 Literature

[1] Sonnenschein, U: Modelling of bolts under dynamic loads, LS-Dyna Anwenderforum, Bamberg 2008

[2] N.N. LS-Dyna Keyword user's manual, version 971, volume 1, May 2007

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