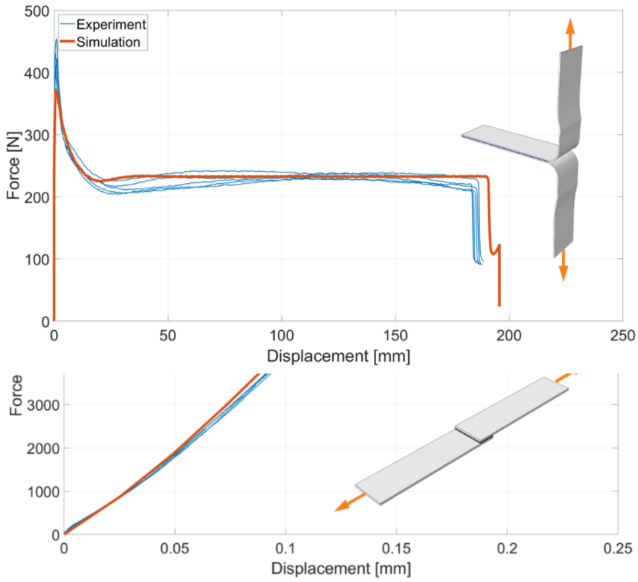
Finite Element Analysis for the Assessment of Adhesive Bonds for Railway Vehicles

Challenging problems in today's methods of engineering are most often not solvable with analytics while tests on real components are commonly time- and cost-intensive or simply too difficult to perform. This is especially true for the structural integrity assessment of entire railcars, wagons, or large subcomponents of these. However, with increasing computer performance, numerical simulation techniques, such as the finite element method (FEM), can conveniently be applied for the approximate solution of technical problems. The FEM is the most widely used numerical method for solving partial differential equations related to engineering problems that otherwise wouldn't be possible to solve. The FEM subdivides a large system into smaller, simpler parts that are called finite elements. Studying or analyzing a phenomenon with FEM is often referred to as finite element analysis (FEA).

Today FEA is a well-established and essential analysis tool for technical computations in many disciplines in- and outside of 3M. Using FEA together with appropriate simplifications and assumptions, even extremely complex structures such as entire rail vehicles can be assessed for their structural performance, integrity and crashworthiness as demanded by the industry standards DIN EN 12633 (Structural Requirements of Railway Vehicle Bodies) and DIN EN 15227 (Crashworthiness Requirements for Railway Vehicle Bodies). Another important industry standard that is especially dedicated to the adhesive bonding of railway vehicles and parts is the DIN 6701, see [1], which consists of four parts. The third part, DIN 6701-3, deals specifically with guidelines for construction, design and assessment of adhesive bonds on railway vehicles. A strength assessment for the adhesive is required, which can be done by means of FEA. In a more general sense, this is also part of the new standard DIN 2304-1, see [2], which is not restricted to rail industry. All this is key to further establish adhesive bonding technologies in the rail industry and help to enable multi-material constructions and lightweight design as investigated in the project ULWAK, which 3M was a part of, see [3].

From a computational efficiency point of view, it is possible to perform the adhesive strength assessment for thick (i.e. larger than 1.5mm) rubber-like elastic bonds. However, it is almost impossible to simultaneously perform the adhesive strength assessment for thin (i.e. smaller than 1.0mm) bonds with an acceptable element resolution over the bond thickness because of the enormous differences in dimensions of the railcar components and the bond thicknesses. One of the challenges is the transfer of the loads and boundary conditions from the entire system to a smaller sub-system.

Another challenge is the definition of an appropriate material model for the adhesive. In order to obtain reliable results by means of FEA it is crucial to have accurate models available for all materials involved in the problem. Such material models, sometimes also referred to as material data cards, describe the mechanical behavior of the real material and ideally capture the major physical effects identified by suitable testing and characterization of the materials. Every finite element model requires a calibrated material model for each material to be simulated. Different techniques can be used to determine the necessary material parameters. All these techniques require experimental test data and the selection of an appropriate material model. This is followed by a



procedure for determining the parameters for the model from the experimental data, i.e. the calibration, verification and validation of the model with respect to experimental data. The validation can be done based on a T-peel test or a single lap shear test (see graphic). Upon completion one can be sure that the model performs well under the assumptions taken.

3M's global technical support team is ready to support you with answers to your questions around adhesive characterization, modeling and simulation. We have developed state-of-the-art test and simulation capabilities for structural and pressure-sensitive adhesives that allow us to model and predict performance, damage, failure, influence on vibration damping (NVH) for wheel noise reduction, see [4], and many other applications.

For more information contact your local 3M representative or go to 3m.com/rail and click on the "ASK A 3M EXPERT" link.

References

[1] [DIN 6701 - Adhesive bonding of railway vehicles and parts.
[2] Fraunhofer Institute IFAM, Online Webinar on Adhesive Strength Assessment according to DIN 2304-1, 26.06.2018.
[3] Project ULWAK, accessible online via www.tib.eu or https://doi.org/10.2314/GBV:841407525
[4] https://www.pressreleasefinder.com/3M/3MPR027/en/