The Need for "Simulation-Quality" Material Data

Material testing for simulation is about understanding how to best describe a material's behaviour as input for the CAE code. Such testing requires expertise and experience beyond testing performed in a typical test laboratory: while the test instruments may be the same, the knowledge of CAE and experience with diverse materials is increasingly important.
FEA software such as ANSYS are being increasingly used for non-linear simulations such as those listed below. We discuss how DatapointLabs' uncommon material expertise helps you avoid problems when the data is being generated for

- Rubber hyperelastic modeling
- Foam / hyperfoam and crushable foam modeling
- Plastics: elastic-plastic modeling, visco-elasticity and stress-relaxation
- Metals: kinematic and isotropic hardening, cyclic plasticity
- Crash and drop testing: rate dependent stress-strain models
- Metal forming: forming limit diagram (FLD) and spring-back material modeling
- Process Simulation including injection-molding, blow-molding and thermoforming CAE

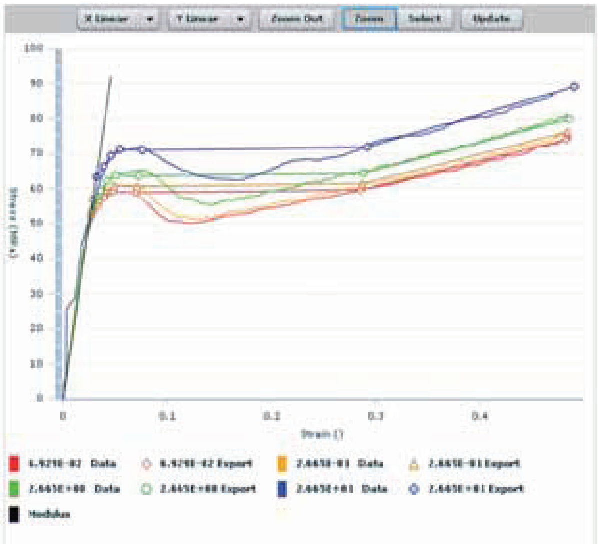

Figure 1: LS-DYNA MAT24 Crash Material Model Calibration

More than one method to get the data

Obtaining material data for non-linear FEA is not easy because the testing can be highly complicated. Hyperelastic material modeling requires testing in different modes such as uniaxial, biaxial or shear. For use in FEA, DatapointLabs performs these tests with a calibrated load cell to measure the stress, and an extensometer to measure the local strain in the gauge region of the test specimen.
Some test labs measure strain using instrument displacement instead of extensometry but this brings error from the test into the FEA. Now, when tests are performed at high speeds for the calibration of crash material models, careful instrument design is needed to avoid noise and oscillation in the stress-strain data, as presented in our paper at the NAFEMS World Congress, 2009 [1]. If noise exists, the quality of the simulation is degraded. The error here is not due to wrong methodology of testing, but the wrong choice of instrumentation.

Understanding the region of interest for your FEA

Rubber materials suffer damage by chain breakage during the first deformation (Mullins effect), which results in a considerably different stress-strain behavior seen between the first pull and the subsequent cyclic loadings [2]. DatapointLabs develops data and model calibration depending on whether the initial deformation is being simulated as compared to cyclic loading.

Understand the impact of the environmental conditions of your product. DatapointLabs maintains extensive facilities to test materials at elevated or cryogenic temperature, in saline (for in-vivo biomedical simulation), or other fluids-soaked environments.

Understanding how well the model accommodates the real-life simulation

Visco-elastic and stress relaxation data acquisition requires understanding of the complex visco-elastic theory: it can be applied only for small strain simulation, but FEA of rubber and plastics is often performed at large strains. DatapointLabs has deep expertise in applying visco-elasticity to real-life simulation. In the modeling of foams, DatapointLabs assists clients with the selection of the material model that is most suitable for the type of foam: crushable, elastic, visco-elastic or hyperfoam. [3]. This service is included with the testing ordered.

Experience with diverse materials

Products of today utilize an astonishing variety of materials ranging from metals, rubber, plastic, foam to films, fiber, composites, ceramics and glass. Being able to test each of these widely differing materials with the same high level of accuracy demands familiarity with such materials. DatapointLabs has tested over 18,000 materials over the past 15 years for physical properties such as tensile, compressive, shear, high strain rate, hyperelastic, visco-elastic, creep, stress relaxation, fatigue, thermal expansion and conductivity, viscosity, PVT.

Understanding material modeling and CAE

As we see in the above outlined cases, the material data requirements of the various material models used in CAE are often complex and unclear. It is not common for test laboratories to be familiar with CAE. With over a decade-long focus on CAE, DatapointLabs has the unique credentials required to meet the exacting demands of new product development. DatapointLabs works in direct partnership with over 15 of the world's most prominent CAE software vendors to make TestPaks® which are packages that include the material testing, material model selection, model calibration and validation processes. The CAE user simply requests a TestPak®, sends the material sample and then receives, 5 days later, the material data plus a digital input file ready for the specified CAE. DatapointLabs online catalog offers over 150 TestPaks®.

Conclusion

It is clear that considerable thought and effort must therefore be paid to correct material modeling and that this part of CAE cannot be taken lightly. Certainly, universities and research institutes possess the scientific understanding to perform material testing. However, their instruments and test technicians are not dedicated to this kind of testing. Their laboratories are usually not ISO 17025 quality certified. The few cases above just serve to illustrate the nature of the problem which is quite wide-spread ranging from rate dependency [1] to process simulation [4]. The data must be clean and free from instrument artifact. It must be correct and appropriate for the simulation. Finally, the process of calibrating these material models is often error prone because, for a variety of reasons, the models cannot accommodate the observed material behavior. This lack of fidelity then results in a limitation in the ability of the model to describe the real life situation in FEA.
Ordering TestPaks® from DatapointLabs reduces these risks!

About the Author

Mr. Hubert Lobo is a recognized leader in the understanding of non-linear material behavior, and how it impacts virtual product design. With >20 years of experience in this area, he brings valuable insights to the product development community in its efforts to design with modern day materials like plastics, rubber, foams and composites.
Mr. Lobo has a Masters degree in Engineering from Cornell University. He has authored numerous articles and the Handbook of Plastics Analysis. In 2002, the Society of Plastics Engineers honored Mr. Lobo, recognizing his pioneering work in quantification of material behavior for CAE. He is the founder and President of two successful companies: DatapointLabs, an expert materials testing company that generates representative properties for CAE, and Matereality, providing material database solutions for virtual product development. DatapointLabs and Matereality are based in Ithaca, New York State, USA, hometown of the famous Cornell University.

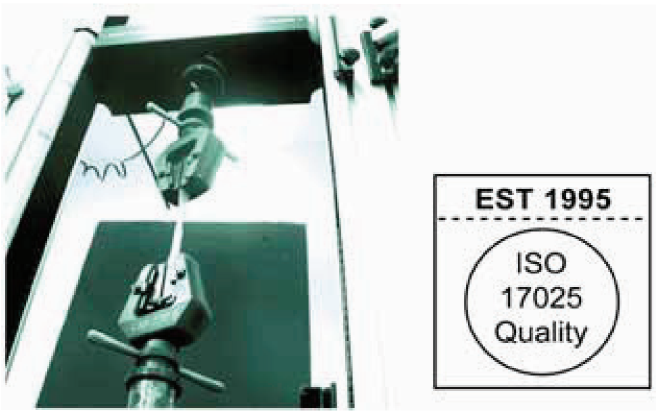

Figure 2: Sophisticated instrumentation and expert technical staff are needed

About DatapointLabs and EnginSoft:

DatapointLabs offers expertise for precise "Simulation-Quality" Material Data to EnginSoft and its customers in Italy as part of our Resellers Agreement with EnginSoft SpA.

Stefano Odorizzi, General Manager of EnginSoft:

Precise material data and correct material modeling are important for our customers' sophisticated simulation work, design and product development.
We are delighted to collaborate with DatapointLabs and to offer their expertise to our customers in Italy who can now benefit

Why clients treat DatapointLabs as the expert partner for product development!

Our clients have come to realize that material data used for CAE applications cannot be ordered from a material test laboratory that is not familiar with simulation. The cost for removing this important source of CAE inaccuracy is trivial compared to the risk of product failure. Time wasted by a highly qualified CAE analyst attempting to get a good simulation result with bad test data can also be much more expensive.

DatapointLabs makes it easy for CAE users to get good material model calibrations for CAE in a timely and cost-effective way.

- Cost savings: only the required tests are performed
- Highly pertinent: properties of the actual material being simulated
- Save effort: the CAE user does not waste time selecting and calibrating material models
- Fast Results: data in 5 business days; a 48 hour RUSH service is available.
- High Quality: DatapointLabs has been ISO 17025 certified since 2000, ensuring that the tests are performed on calibrated, traceable instruments by technicians trained to do this job correctly.
- Best and cutting edge Technology Center: Online Order Placement Service at www.datapointlabs.com
- DHL Sample Pickup Service from countries in Europe, 2 day express delivery to DatapointLabs!
- Digital Test Data download available at www.matereality.com via Matereality Data Delivery Service. Each client gets a Personal Material Database to store their material properties on this digital platform.

from the company's speedy material testing services and knowledge.
DatapointLabs is a partner of ANSYS, Inc., Livermore Software Technology Corp. and the TechNet Alliance.

For more information about the services in Italy, please contact:
Name, email of contact person at EnginSoft.
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Model of a Multimass Hyperelastic System and its Parametric Identification

In the description of systems with non-rigid connections, models with lumped parameters are widely used. In these cases, the number of masses usually does not exceed four and connections are represented by different rheological models. The most frequently used models are two-element models of Kelvin-Voigt and Maxwell and three-element models of Bingham, Shvedova. However, they are not applicable for the description of dynamics of the systems that contain links from hyperelastic materials, experiencing relevant reversible deformations.
Thus, the development of a simple and at the same time highly accurate model of a hyperelastic element is a very relevant task. In the present research, the hyperelastic element is represented by two consequently connected viscoelastic bodies of Kelvin-Voigt with different elasticity modules and viscosity coefficients. A non-linear damper, which possesses memory, is included in one of the bodies and is parallel to the elements of Hooke and Newton. The damper is based on the generalized Bouc-Wen model of dynamic hysteresis, which is described by an ordinary differential equation of the first order.
It is difficult to adjust the mathematical model of the proposed hyperelastic element. It contains 13 coefficients, most of which specify the shape of the hysteresis loop and therefore can not be measured directly during experiments. However, the model allows us to take into consideration the elastic aftereffect, the Bauschinger effect, that enhances the accuracy of the description of nonrigid systems' dynamics.
The unknown coefficients of the model are determined by parametric identification based on prior available information about their admitted region (should not contradict the physical meaning) and on the experimental data, obtained from the studied nonrigid system.
The Identification process consists of solving a multiobjective optimization problem, having as constraints the inequalities with the values of models coefficients.
The optimization objectives are:

- minimize the root-mean-square deviation of responses of the real system and its model at harmonic input action;
- minimax Wald's criterion of deviation of responses of real systems and its model at step input excitation;
- minimize the weighted sum of values of two previous objective functions at the mixed input action.

The efficiency of the proposed model of the hyperelastic element and the method of identification of its parameters was estimated using a system consisting of a DC motor, a two-stage parallel-shaft reducer and a rotating mass. For their connection, hollow aluminum shafts with hyperelastic inserts in the form of rubber tubing were used. The model of this system was developed in the MatLab / Simulink package and contained 27 unknown coefficients, including the reduction ratio. Antitorque moment was accepted equal to zero; loss due to frictional forces was neglected. The optimization process was carried out in the program modeFRONTIER with the use of the MOGA-II algorithm (multiobjective genetic algorithm with elitism). The values of velocities and angles of the DC-motor, and rotating mass were considered as responses of the system. As a result of calculations a set of Pareto-optimal solutions was defined, from which a vector of desired parameters of model was selected. When the resulting model worked out mixed input action, the error was of 4-7 % from experimental data, while the errors of a model with elements of Hooke and Kelvin-Voigt were of 16-19% and 11-14% respectively. Therefore, the proposed model of hyperelastic element and the method of identification of its parameters are highly effective and can be used to describe the dynamics of nonrigid systems with high accuracy.

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