

# EXPERIMENTAL DATA REQUIREMENTS FOR VALIDATION

## Background

Credible experimental data are needed to show how well a computer model reproduces the reality that it is trying to simulate. The set of data needed for validation of computer models comes from system tests, subsystem tests and one or more of what may be referred to as precision tests.

## Experiment Requirements

Precision Tests. A precision test may be thought of as a physical realization of an initial-boundary value problem. To qualify as a precision test, the specimen geometry, initial conditions, boundary conditions and material constitutive behavior must be prescribed accurately. Generally, data from the archive literature do not meet the requirement of precision testing, so it is usually necessary to perform experiments dedicated to model validation.

The response of the test specimen to the loading must be measured with known high accuracy. Some of the data collected during the test may include the load and the boundary conditions, which might change throughout the test. This will leave no, or only a few assumptions needed by the modeler, and will provide as many constraints as possible on the model inputs.

The test-specimen material needs to be well-characterized with little scatter. Additionally, a constitutive model that is sophisticated enough to provide an accurate mathematical description of the material behavior needs to be calibrated using reliable, high-quality constitutive data.

A quality control program is necessary to assure that dimensional tolerances and material specifications are known and meet the test requirements.

Model validation is more than matching results of a single test, even if that test is comprehensive and well done. Several tests should be performed, starting with a simple test and adding complexity in stages. Simplicity can be attained in the geometry, materials, boundary conditions and loads.

Tests should be performed to determine sensitivities to parameters so that the details of the differences between measured and computed behavior can be studied. For example, the computed result could be systematically different from the measured because of uncertainty in material strength.

System and Subsystem Tests. System and subsystem tests are not necessarily non-precision tests. However, because of the complexity and size of these tests, it is usually not possible to prescribe all the test conditions so that a unique deterministic initial-boundary value problem can be formulated. As the size and complexity of a test grows, the uncertainty in the prescription of the loads, boundary conditions, geometry and response increases. It may be that the best way to deal with this imprecision is to perform probabilistic or possibilistic (bounding) simulations that cover the credible ranges of test parameters and variables. The computer model would be validated if the test result were a probable outcome of the simulations.

The data to be collected in these tests must include the data that determine the performance and acceptability of the system. If acceleration is the performance measure, then acceleration must be measured and simulated. True, the displacement history would probably be easier to simulate and (maybe) to measure, but if high-frequency acceleration is the "make-or-break" issue, then that is what must be predicted accurately by the model.

## **Measurement Requirements**

Measurements must be credible, and their credibility must be established through calibration of the transducers and documentation of inaccuracies related to nonlinearity, repeatability and hysteresis. Uncertainty in measurement accuracy is rarely quoted.

Many sources can affect a gauge output. Transducers should be calibrated in an environment similar to that of the test, e.g., at elevated temperature. If a transducer is sensitive to the environment, and the environment changes significantly during the test, the transducer sensitivity to environment must be established so that the resulting data can be corrected to account for the sensitivity to environment. The compliance of any test fixtures must be determined if it contributes to the measurement of displacement. Additional tests dedicated to demonstrating the accuracy of the measurements have been shown to be very helpful.

Redundant measurements are needed to establish the precision (scatter) in the test results. This can be accomplished by repeating tests, or by placing similar transducers at symmetrical locations if the test has adequate symmetry. Independent or corroborative measurements, e.g. stress and velocity, help to establish the consistency of the data.

Precision tests need to produce a variety of data so that many aspects of the model can be validated. This is important because although some quantities may be of secondary importance, accurate predictions of these responses show that the model accurately predicts the primary response for the right reason. This is essential for confidence that the models can make accurate predictions for problem specifications that are different from those included in model development and validation.

Measurements of point quantities should be made in families so that fields can be estimated.

## **Coordination with Modelers**

Modelers should have input to the design of the precision tests. What is simple to an experimenter may not be simple to a modeler, and vice versa. There needs to be a shared understanding of what responses are hard to measure or hard to predict. The need for collaboration should not be overlooked.

Finally, it is essential that the modelers not know the test results before the model prediction is complete. Exceptions, of course, are the measured load and boundary conditions, if applicable. Because many problems show significant sensitivity to physical and numerical parameters, it is often easy to adjust the prediction of highly sophisticated computer models to match measurements.