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By Karen Donovan

Lately it’s hard not to notice that automobiles have morphed into circuit boards on wheels. Electronics now control every important system in the average passenger vehicle, from entertainment and navigation to chassis and steering, brakes, security, and powertrain. A dazzling menagerie of electronic components populates automotive printed circuit board assemblies.

“In terms of cost, there is more electronic content in vehicles today than even steel,” says Dr. Mahesh Chengalva, Staff Research Engineer at Delphi. “The performance requirements are challenging, and these systems are expected to last ten years or more. It’s a severe vibration and thermal environment, especially for underhood electronics.”

Chengalva is part of the Hardware Analysis and Simulation group at Delphi Electronics & Safety, a division of Delphi Corporation that is headquartered in Kokomo, Indiana. His group provides analysis services to squadrons of Delphi design engineers at work all over the world on the next generation of automotive electronics. As one of the largest automotive systems suppliers in the United States, Delphi runs 170 manufacturing facilities in more than 30 countries. On a typical day, the Kokomo facility alone produces over a million IC packages.

In electronics design and manufacture, package reliability is sacrosanct. The reliability of electronics systems in automotive applications hinges on the reliability of every solder joint on every circuit board. A major factor in solder joint reliability is thermal cycling. “The single largest driver of failure in electronics systems in the field is the repeated temperature cycling that the product generation of automotive electronics. As one of the largest automotive systems suppliers in the United States, Delphi runs 170 manufacturing facilities in more than 30 countries. On a typical day, the Kokomo facility alone produces over a million IC packages.

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of laboratory creep test data on the material Delphi has amassed a substantial amount of characterization of material properties. Thermal cycling reliability starts with creating a valid FEA model for predicting solder reliability gives cycle test would take four months), so the cycling tests are time consuming (a 3,000-cycle test takes about one hour at the most). In the case of this ball grid array, flip chip assemblies, and a variety of surface-mount leaded ICs. To validate the FEA models for each electronic package, the team simulates a set of thermal cycling tests and compares the results of simulations with the results of these tests. “All our FEA models have been carefully correlated with test data,” he says, “so our design engineers can be confident that simulations give accurate predictions of package reliability.”

The D-Cube Doorway
In fact, getting accurate simulation results for thermal reliability has never been easier for Delphi design engineers. They have Abaqus FEA power at their fingertips any time of the day or night, anywhere in the world, thanks to the D-Cube web-based expert system. Up and running on the Web since May 2000, the company-wide site offers a collection of over 200 design optimization tools, materials resources, self-taught tutorials, and notes on engineering lessons learned.

The brainchild of Chengalva and Scott Baxter, a former Delphi colleague, D-Cube is fundamental to the company’s strategy of incorporating simulation upfront in design. To illustrate, Chengalva describes a scenario where a Delphi design engineer in Singapore needs to select a suitable ball grid array package from a number of suppliers. “The designer knows what he wants for package reliability,” he says, “but he needs a way to evaluate each supplier’s product and pick the best one. All he has to do is open the thermal tools section in D-Cube, click on the ball grid array icon, fill out an online form with input parameters, and hit submit.”

Input parameters vary with the type of package. Detailed dimensions of the package assembly, and material properties such as the coefficient of thermal expansion for each part in the assembly, are commonly required input. Once the designer submits the data, the input parameters go to Chengalva’s group for scheduling. The next step, FEA modeling, has been automated to cut preprocessing time from several days for complicated assemblies to about an hour at the most. In the case of this ball grid array, a prebuilt parametric modeler would automatically create a model for the package the designer has specified. Regions of interest in the package geometry are automatically identified for greater mesh refinement.

Finally, the input file goes to the Abaqus solver. Complex three-dimensional simulations might take three or four days of continuous run time. “Once the simulation is complete,” says Chengalva, “the design engineer receives a reliability value. Perhaps this particular package, from this particular supplier, for this particular thermal-cycling profile will last 3,400 cycles. That number is what the designer needs. We can also compute a value for relative life prediction,” (Story continued on page 12)
which helps the designer compare one package with another. Relative life predictions are particularly useful when input data are incomplete.”

It is interesting to note that D-Cube helps tie together the far-flung global centers of Delphi analysis into a single integrated unit. In the example mentioned above, although the request originated in Singapore, it would be processed in Kokomo (USA), with the actual FEA modeling and execution conducted in either Krakow (Poland) or Bangalore (India).

The FEA process automation that D-Cube offers design engineers is an efficient way to assess electronic packages, especially when numerous competing design configurations are being considered. “In electronics, parts may look identical, but their reliability can vary significantly, based on the mechanical structure or on the materials used,” says Chengalva. “For a leaded IC that is used on a FR4 substrate, if you change the material of the lead from copper to Alloy 42, you could have almost a tenfold decrease in solder joint reliability. If not selected carefully, additions such as conformal coats, which are applied to some circuit board assemblies to prevent moisture damage, can interact mechanically with components to degrade reliability. For design engineers, information about reliability as related to these multiple parameters is powerful because it enables tradeoff decisions very early in the design cycle.”

Simulating thermal-cycling reliability using Abaqus FEA saves Delphi an enormous amount of time and cost and opens doors to design innovation. With D-Cube, design engineers can quickly use Abaqus to explore different configurations for automotive electronics packages and select the optimal solution. You might remember that the next time one of those rolling circuit boards passes you on the highway safely at 80 mph.

Mahesh K. Chengalva is a veteran Abaqus user and owner of 11 patents and trade secrets. He has worked for Delphi for 12 years, and was inducted into the Delphi Hall of Fame in May 2006. He is currently technical manager of their mechanical analysis laboratory in their Electronics and Safety division. At Delphi, Mahesh conducts reliability simulations for electronics systems, manages the company’s web-based engineering expert system, provides consulting services to internal customers, and interfaces with overseas technical centers. In his spare time, he is also a founding member of a robot racing team headed for the semi-finals of the DARPA Grand Challenge this October.

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