Statistical Discovery.™ From SAS.

Building models of models builds awareness—and consensus

In tire testing standards development, a task force of the American Society of Testing and Materials (ASTM) uses JMP for real-time data analysis on roadwheel lab tests. The results have real-world impact.

CHALLENGE

To understand how the laboratory tire-testing environment differs from real road conditions, so that tire manufacturers and regulatory agencies can meet Congressional desires by establishing lab test standards that ensure quality in design and manu–facturing and, therefore, safety on the road.

SOLUTION

The American Society of Testing and Materials (ASTM) Truck/Bus Tire Test Development task group is designing experiments to model tire temperatures and take into account variables like inflation, load, speed and the surface upon which a tire is run.

RESULTS

With JMP, the ASTM task group discovered a big temperature differential from flat-to-curved surfaces; i.e. from real roads to roadwheels in the lab. Now the tire manufacturers and regulatory agency personnel can use models, in real time, to more closely simulate actual truck-tire temperatures at many combinations of surface, load, speed and inflation conditions of interest.

Checked your tires lately? Leighton Spadone has. Spadone is a Goodyear R&D associate, and most recently he's been taking a good, hard look at commercial truck tires as a member of an American Society of Testing and Materials (ASTM) task group charged with developing laboratory high-speed and endurance tests for these tires.

A primary objective toward developing the tests was to measure tire operating temperatures in the real world and compare these temperatures with those of tires tested in a laboratory. That's where JMP statistical discovery software from SAS came in—to model the data, get answers and help communicate them.

The government, through the Department of Transportation (DOT) and the National Highway Traffic Safety Administration (NHTSA), regulates all transportation products. Tire manufacturers must demonstrate that their products pass standardized regulatory tests, at which point they may display the "DOT" symbol on their tire sidewalls, required for highway usage in the United States.

Congress recently tasked NHTSA to review and, if necessary, update tire tests for all vehicles. After studying and upgrading passenger and light-truck tests, the agency requested ASTM assistance for the commercial truck tire phase.

Terry Ruip is a Technology Adviser for Goodyear's Tire Test Engineering Department, and is also Chairman of the ASTM Truck/Bus Tire Test Development task group. He explains the precise nature of the group's mandate: There's a vast difference between tires running on a flat highway as compared with those running against a curved laboratory roadwheel. Because of the effect of the curvature of that roadwheel upon a truck tire, its temperatures are much hotter in the lab than on the road.

"We needed to document what those differences are, so that when we develop new lab-test standards, we will have done so using realistic tire operating temperatures."

In order to do that, the task group established designs of experiment (DOEs) utilizing typical truck tire road operating conditions.

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Leighton Spadone

Creating an ideal design space

The basic objective, Spadone explains, was to build a regression model for this data that would explain the effect of tire operating conditions on internal tire temperatures. “In this particular case, we were most interested in the temperatures on the edges of the belt at the shoulder of the tire and the center-line of the tire. We wanted to build a regression model that, based on our test conditions, predicts the temperature in the tire. And we were successful in doing that,” says Spadone.

“We’re now able to accurately predict belt-edge and center-line temperatures in commercial, over-the-road truck tires, and JMP is the tool that allows us to explore this regression-building process. One of the innovations in this modeling was to realize that tire inflation pressure in PSI [pounds per square inch] and tire load in pounds were not the correct predictors of tire temperature – and that the models needed to be transformed using some relatively complex nonlinear formulas, which we could build easily in JMP in order to get the best model fit and to identify the correct predictors.

“So I think the No. 1 innovation was to move out of the PSI and load space and calculate a design space that models the temperatures much better.”

Exploring exaggerations

With the regression models set and cleaned up and the outliers identified, the next step was to take the prediction equations and build templates, and then explore different conditions on the roadwheel and compare them with conditions on the highway.

“We were looking for equivalent temperatures ‘flat-to-curved,’” Spadone explains. “We wanted to demonstrate that ‘highway equivalent’ operating conditions are required for laboratory testing to avoid tire temperatures significantly hotter than those from ‘the road,’ and we could explain that with these templates.”

Not only did the models make this clear to engineers, but more importantly, says Spadone, to administrators and managers who aren’t engineers or scientists. “We could present these models, in real time, on the screen, to show them what was going on. For example, they might ask, ‘What if we ran a truck tire on the roadwheel at 80-percent inflation, 90-percent load and 75 miles per hour? What would I have to do in the real world, on a flat surface, to equal that center-line temperature?’ And the answer would be that you’d have to run at 90-percent load, 80-percent inflation and 120 miles per hour to approach those same drive tire temperatures.

“They were then able to see that such conditions are extreme. They are exaggerated; nobody expects a truck to go down the road at 120 miles an hour. So once the regression models were made, most of the work was in these templates, showing different what-if scenarios and translating roadwheel conditions into real-world conditions and vice versa.

“With three variables—inflation, load and speed—there are lots of possibilities,” Spadone says. “So you start setting limits—for example, we set limits on the inflation pressure at between 80 and 100. Most of the work was done when we built templates using the prediction equations and looked at variations on the other conditions to see where we get equivalent temperatures ‘flat-to-curved.’ ”

The bottom-line benefit in having these very clear and concise models, is clear communications. “Sometimes there are different viewpoints on the data, and on the nature of the problem,” says Spadone. “So it’s very useful to sit in a room with a computer and your templates and to answer, on the fly, various questions and concerns. Sometimes we can’t answer them, but we can go back and build more templates, and then come back with answers.”

Cutting to the chase

A feature of the JMP software that Spadone finds particularly handy is the prediction profiler, which the task group used considerably in changing conditions and predicting temperatures. “Once you have the model built, you can just sit there and dynamically change conditions and find the answers. This is a really powerful tool for communicating the model. Many times, the answers people got were not the ones they expected. And in some cases, they were taken quite aback,” explains Spadone.

Spadone also lauds the ease of use of the software. "You don't really need to be a trained statistician to use it to good effect. The layout is accessible, and the graphical presentation of the data is very powerful and very convincing," elaborates Spadone.

Ruip can vouch for this ease-of-use assessment. He says, "Several members of the task force had experience working with SAS, and when we started laying out the DOEs, they kept assuring those of us who are non-statisticians that once we collected our data, it would be relatively easy to analyze—because we knew we were going to have tons of data, reams of it. But they said, 'Don't worry about it; the modeling and the derivation of regression models will be fairly easy with JMP.' And they were right."

Spadone adds, "There were members of the task force who were familiar with other vendors' software. A few sessions of interactive JMP model development and asking questions on the fly amazed them. They were really impressed by the power of JMP. We now have a group of converts on the ASTM task force."

Building 'models of models'

Certainly, translating otherwise puzzling data into laymen's terms is something Spadone appreciates. But as one who lives and breathes regression fits he gets really excited about the modeling capabilities in JMP. "Essentially, I use models of models," he summarizes. "In other words, if we set certain parameters as constants—say a load or inflation—and then look at the relationship of speed on the roadwheel to the speed on the highway, I can build another regression fit—that is, a regression fit using predicted regression fits to show the relationship in a picture in the prediction profiler. So we've built a basic model, and then we go in and build models on top of that."

Spadone believes that because they were able to model this data and present it clearly, NHTSA has been appreciative and accepting of the task group's results.

"They have accepted the fact that there is a big temperature differential from flat to curved surfaces," he concludes. "Because of the power of these models and the power of JMP to get answers quickly and display them in such a way that's understandable to everyone, the task group feels it has contributed significantly toward the agency's task of developing new truck tire regulatory tests.

"It's really helped us communicate the stuff that we already knew in our bones," says Spadone, "to take that and present it as scientific fact, and communicate it without argument."

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