Bridgestone Costa Rica: Getting a Grip with Design of Experiments

Bridgestone Corporation, the world's largest tire and rubber company, manufactures tires in locations around the world for use in a wide variety of applications. Its products are sold in over 150 nations and territories. Among the company's facilities is its Costa Rica plant, which produces 12,000 tires every day for 23 markets in Central America and the Caribbean, and employs more than 1,000 people. But the plant faced two challenges: certifying a new tire by meeting U.S. Department of Transportation regulations, and overcoming a bottleneck that limited the overall production of light truck tires at the plant. Six Sigma black belt Kenneth Quirós Acuña embarked on a project that, if successful, would address both challenges. He and his project team used Minitab Statistical Software to identify critical factors affecting both production levels and the certification tests, design an experiment to find optimal settings for those factors, and develop a model the company could use to produce and certify more tires with more speed.

BRIDGESTONE

ORGANIZATION

Bridgestone Costa Rica

OVERVIEW

- World's largest rubber and tire manufacturer
- Distributes products in more than 150 countries
- Costa Rica facility produces 12,000 tires per day

QUALITY CHALLENGE

Increase plant capacity and certify new tires more quickly.

PRODUCTS USED

Minitab® Statistical Software

RESULTS

- Initial project savings of $74,200
- Optimized tire tread process
- Saved $2.5 million in opportunity costs

The Challenge

When engineers at the plant looked at how capacity might be increased, they found that the chief bottleneck in production was a lack of tread. The plant had two types of tread-making machines: an extruder that makes tread in a single piece, and a ribbon-tread machine that makes tread by extruding many small ribbons.

The ribbon-tread machine was being underused. But efforts to get more use out of the machine faltered when tires created with it failed to meet the standards needed for certification.

Plant managers believed it was too difficult to make qualified light truck tires using the ribbon-tread machine, which involved multiple steps and complicated variables such as feed rate and increments width. Programming the machine had proved extremely difficult. "It is not easy to reproduce a tread shape using ribbons because you have to find the correct combination of factors," Quirós says. "The feed rate, drum velocity, extrusion velocity, and other factors all need to be in balance to produce a good tread."

Quirós and his team realized that with so many steps in the tire-making process, and so many potential factors, he first needed to narrow his focus to create a manageable project. "When we looked at different combinations of factors to better understand why we had issues with the ribbon-tread machine, we realized that about 80 percent of the problems involved a specific tire certification test."Tires are built and cured according to exacting technical specifications. If a tire passes preliminary building and curing tests, it proceeds to other tests required by the U.S. Department of Transportation. Factors assessed include drum width; sidewall location and width; ribbon tread profile; body plies bias; linear velocity; drum transversal velocity; and more.

A project team at Bridgestone's Costa Rica plant used Minitab Statistical Software to increase capacity and certify new tires more efficiently.

Tires that meet these specifications go on to the plunger test, in which a rounded plunger is forced into the center of the tread of an inflated tire. Testers measure the energy required to either penetrate the tire, or contact the surface of the tire rim. The Costa Rica plant's ribbon-tread tires weren't meeting the guidelines.

"Some tests have a bit of flexibility," Quirós explains, "but a tire that can't pass the plunger test can't be certified, so that's where we focused our efforts. We set out to create a model that yielded specifications for tires that passed the plunger test without hampering their performance on other tests."

How Minitab Helped

First, the team members ranked variables in the tire-making process according to their importance for certification. After an initial analysis, the team prioritized four factors for further investigation. However, they needed to ensure that changing the factor settings in order to pass the plunger test did not adversely affect a tire's performance on other certification tests.

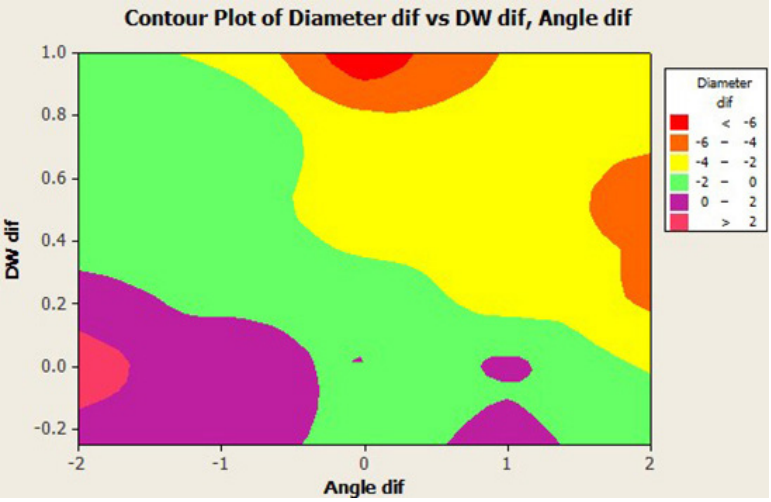
"One of the most important tests is the diameter, so we needed first to understand whether those four factors affected diameter," Quirós explains. "If so, our model needed to account for that." By performing multiple regression analysis on these four factors and tire diameter data, the team discovered the most important factors were angle and weight. "So in our model, those input values had a constraint, and we were able to generate an equation to set those input values appropriately."

Now Quirós used Minitab's Design of Experiment tools to quickly and efficiently gather the data he needed to develop his model. "Because testing tires is a destructive process, it's very expensive to set up experimental runs," he notes. "But Design of Experiments lets us study multiple variables simultaneously using the least number of runs, so we get enough data for reliable results without wasting time and resources gathering more data than we need." He selected a 2-level factorial design that would let him assess high and low settings for each of the four key process input variables with only 16 runs.

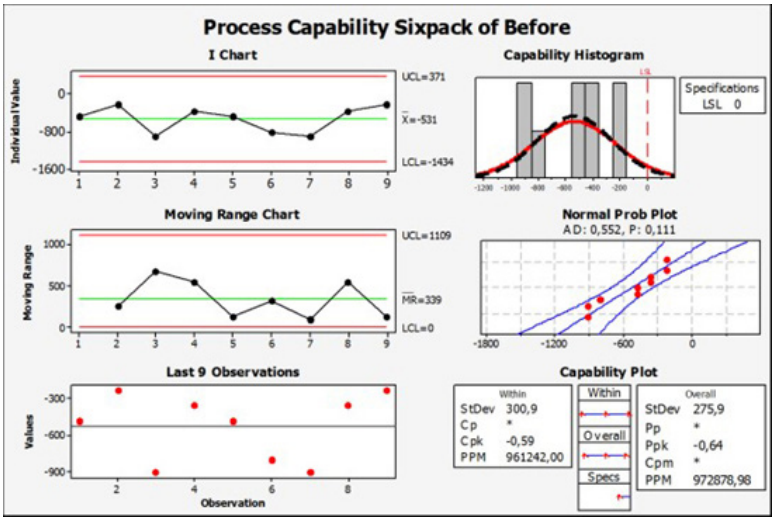
Before collecting their data, the team performed a measurement systems analysis with Minitab to ensure they were collecting good data. They also assessed the baseline capability of the ribbon-tread process using Minitab's Process Capability Sixpack™. The results revealed that while the process was stable, the capability of the process to meet certification standards was poor. Now they were ready to produce their 16 experimental tires, and put them through the certification tests, including the diameter and plunger tests.

When Quirós and his team analyzed the experimental data in Minitab, the results showed that all four factors, and the interactions between them, had a significant effect on plunger test results. This was great information, but using it to derive a precise model would be difficult without a tool that could take the experimental results and let the team forecast how different variable settings would affect the tire's performance.

Fortunately, Minitab's Response Optimizer tool does just that, making it easy for Quirós to fine-tune the process settings to produce the best possible results. "Using the optimizer helped us attain and surpass our goal for the plunger test," he says. "We used it to create our predictive model and define our optimal input settings. Then we gathered more data at these settings and used Minitab to perform multiple regression analysis and validate the factor values."



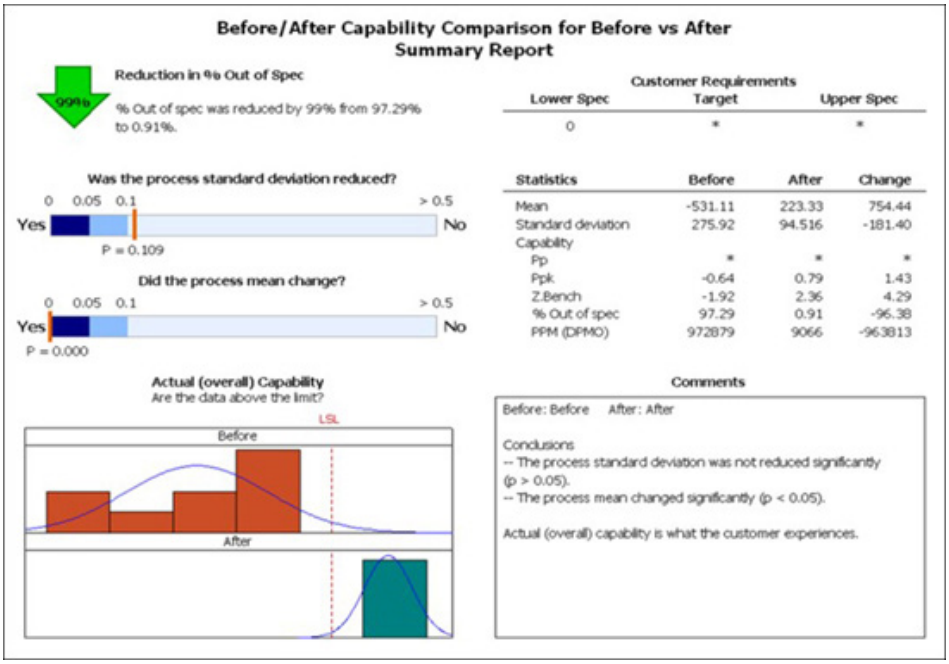
Minitab's contour plot made it easy for Quirós and his team to explore the relationship between their ribbon-tread variables and the diameter of the finished tires.



When the team looked at the plant's ribbon-tread machine data using Minitab's Process Capability Sixpack™, they found that while the process was stable, its ability to meet certification standards was poor, as shown by the extremely low Ppk and Cpk values.

Results

Based on the results of those analyses, the team redesigned how they used ribbon-tread to make light truck tires. Before new tires were made, the plant managers would review the last specifications. Previous and proposed values for angle and drum width would be evaluated in a spreadsheet programmed with equations from DOE. If they were acceptable, data about the other two factors in the process would be added.



To validate their results, the project team used the Minitab Assistant's Capability Analysis tool. The Assistant's output makes it easy to communicate the results of an analysis to all stakeholders, even those with little statistical experience. The project's success has helped people throughout the facility appreciate how data analysis can help solve even longstanding quality challenges.

The new model was tried on a tire size that had proven particularly challenging in the past. The team used the model to determine effective factor settings, then made some tires with the new process settings. To validate the results, they used the Minitab Assistant's Capability Analysis tool. They also created a before-and-after control chart, which revealed how dramatically the new model improved the tire's performance in the plunger test.

"We achieved our results," Quirós says. "Whenever we changed the level of a parameter, and ran the tests again, the average was very close to what the model predicted. The result was perfect. We're now exceeding the target for the plunger test."

Use of the new model soon was expanded to other tire sizes, too. The model was next applied to a different size of light-truck tire, one that had not passed certification with ribbon tread before. This time, the process was qualified after the first trial. Since then, Quirós and his team have also successfully applied the model to tires used in agriculture.

The success of the project has increased production at the Costa Rica facility, saving hundreds of thousands of dollars and resulting in more than $2 million in opportunity costs. "Now we can use the ribbon-tread process to make more tread, so we can make more tires," Quirós says. But the benefits of this project go beyond the bottom line, he points out. "The Six Sigma methodology can transform an organization, and even projects with small savings can have a large impact on a company. It changes the culture of the people working with you. They see how practical data analysis is, and that it's very useful to use tools like Minitab to look at your data every day. Now, when issues come up, people around the plant ask, 'How can we use statistics to solve these problems?'"