Tire Test Data: Using MI for Product/Process Improvement

Advances in acquiring, storing, and reporting measurements from equipment in the final finish department have created the ability for tire manufacturers to actively monitor their end product for statistically relevant trends that can point to upstream product, machine, and process issues. Today's high-end testing equipment can collect increasing amounts of more accurate data in even faster cycle times than before. This is changing the requirements that manufacturers have for their data information systems.

Historically, to evaluate a tire uniformity machine waveform metric like radial force variation it was sufficient to calculate and store basic measurements (like peak-to-peak and the magnitudes from the first few harmonics). Not only do these harmonics make the largest contributions to problems with the ride of the tire, but they are also traceable to established upstream causes in curing and tire assembly. Now, manufacturers are interested in much higher harmonics of a waveform, looking for additional improvements in curing and tire assembly and even potential improvements in component preparation.

But while these advances have continued to provide a greater data volume for evaluation of product and process, analysis efforts have been concentrated on increasing available data and reporting production trends through the use of traditional tools like tabular / SPC (Statistical Process Control) graphic reports and spreadsheets. The consequence of this focus has not allowed tire manufacturing quality analysis to keep pace with Business Intelligence (BI) technology developed specifically for and proven effective by analysts in the retail and financial industries. This trend is reminiscent of the slow movement of computers to the factory floor following their introduction to the "top floor" financial departments of business and industry during the 1980s.

This paper will discuss two specific limitations imposed by traditional data acquisition methodology and tools currently used by many in the industry to analyze tire test data, and how the adoption of current Manufacturing Intelligence (MI) methodology and tools (based on BI principles) can overcome those limitations to allow quality engineers to spend less time tracing problems back to their root cause and more time fixing them.

Lack of Agile Analytics

Over the years, integration between plant data systems, along with serialized barcoding of products, has allowed tire manufacturers to provide product traceability. Tire test results from the final finish department can include enough information about upstream processes (like build machine and curing press cavity/mold identification) to give first responders some ideas about where to go next when troubleshooting degrading tire yields.

But to identify trends, first responders are still typically using tools like tabular reports, traditional bar graphs, and other SPC charts. The use of these tools makes finding trends (other than obvious or highly variant ones) a labor-intensive effort that often requires them to already know what they are looking for.

Contrast that method with the use of dashboard, heat map, and drill-down tools commonly offered by BI vendors.

Figure 1 is an example of a dashboard designed to monitor performance of a plant based on the data acquired from the final finish department. The plant has identified several Key Performance Indicators (KPIs) that provide insight into the success of various aspects of the manufacturing process. These metrics are displayed visually, along with the context of acceptable ranges and goals.

KPIs can be designed around both industry standards and the tire manufacturer's unique expert knowledge about their particular products and processes. This approach allows this expert knowledge to be disseminated throughout a department, plant, or even the enterprise, keeping trends, goals, and any adjustments visible.

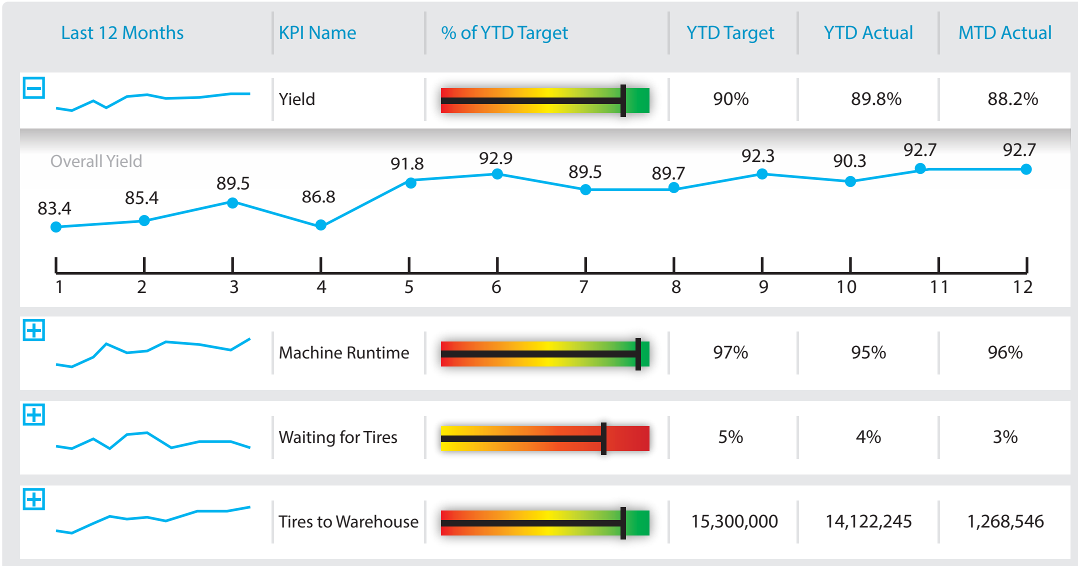
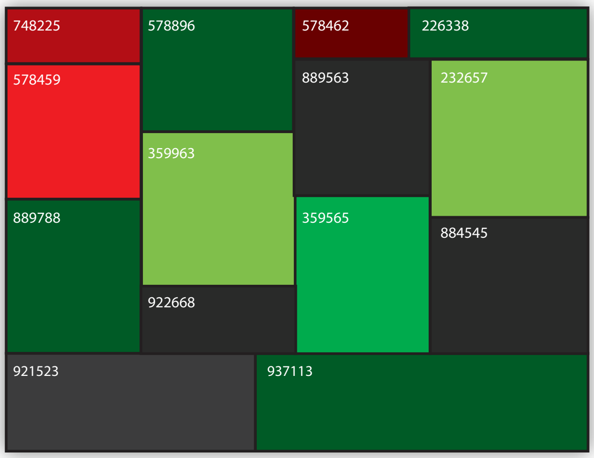


Figure 1

In *Figure 2*, each of the reports is showing information about the yield of various Tire Codes. The total number of tires tested along with the yield (the percentage that have passed inspection) is represented in each.

The difference is that the heat map is providing contextual information visually. The total area of each rectangle represents the number of tires tested for each Tire Code and is relative to the entire set of tires tested. The color of each rectangle represents the yield of each Tire Code. The coloring is scaled so that acceptable yield percentages are in the green range and substandard yield percentages are in the red range. As a result it's immediately clear which Tire Codes have low yields and whether they account for a significant portion of tires tested. Even without this explanation, the visual clues are so strong that most viewers will have immediately assumed that the bigger and redder the box, the "bigger and badder" the problem.



Tire Code	Quantity	Yield
232657	1064	98%
359565	688	94%
359963	976	97%
578459	745	75%
578462	231	88%
578896	697	92%
748225	284	85%
884545	752	90%
889563	739	90%

Figure 2

Once an exception has been identified, the next step is to start drilling down into root causes so that it can be corrected. The responding quality engineer will want to know more about the specific measurement tests which have caused the tires to fail and the history of those tires throughout the plant. In the drill-down tool in *Figure 3*, the user can select test results along with upstream departmental information and visualize the contributions of each piece to the whole.

The query is initially limited to a Tire Code identified as having a low yield, and in the first column, there are two sets of tires, those that passed and those that failed, along with their total contribution, 75% success, and 25% failure. We're going to take a look at the history of the failed tires first, but we may want to compare that to the history of the tires that passed as well. Once the set of failed tires is selected from the first column, the second column is automatically populated with the various causes of failure and their percentage contribution to the set of failed tires.

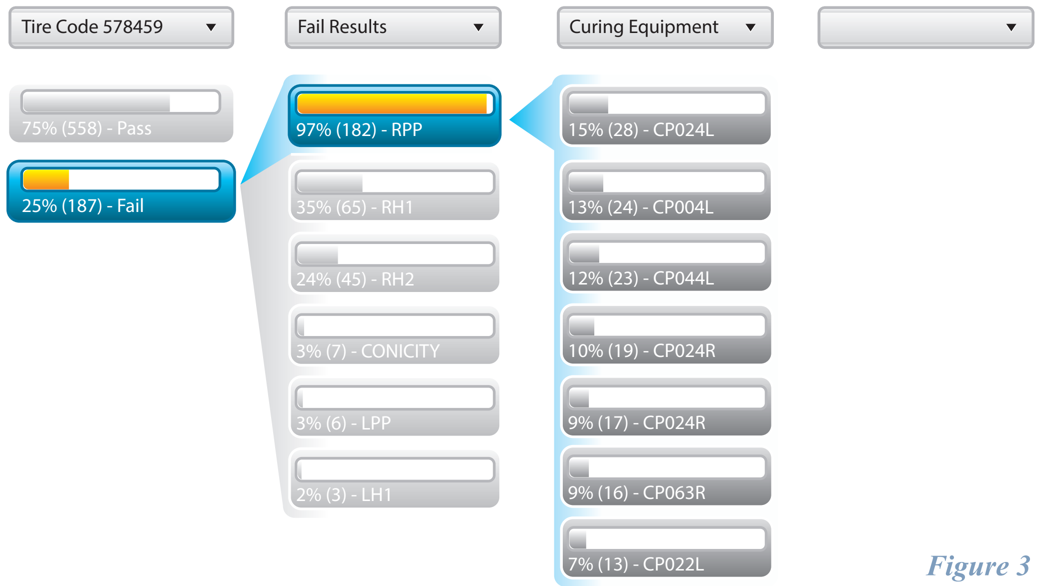


Figure 3

The second column leaves no doubt that the leading contributor to testing failure is an out-of-range radial peak-to-peak (RPP) measurement. Now the third column can be set to investigate equipment from various upstream departments. In the first image, the user has selected the Curing Equipment and it is clear that many different curing presses contributed fairly evenly to the set of tires with a failed radial peak-to-peak, eliminating the possibility that the root cause is related to a particular curing press needing maintenance or adjustment. This high-level check of that department allows the user to quickly move on to other possible causes.

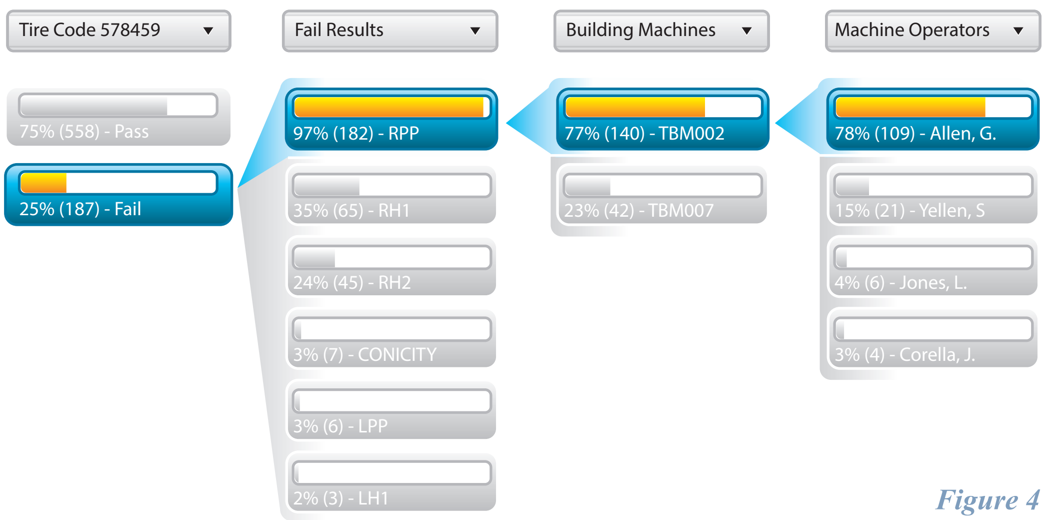


Figure 4

In *Figure 4*, the user changes selections so that the tire Building Machines are selected, and in this department, there is a much smaller group of contributing equipment. This lead is more promising and the user can choose to investigate further, in this case checking the distribution of Machine Operators.

This tool is designed to be fairly free-form and presents data in ways that can help direct the user's attention to the largest contributing factors to a problem. In practice, an experienced quality engineer may have a set of initial questions that should always be answered at the start of an investigation and will lead to follow-up questions. In that case a preconfigured dashboard can be designed around the most useful questions and shared with other engineers who are performing in a similar role.

Some aspects of the visual tools presented in this section can be implemented in the final finish department based on the typical data on hand, but getting to the root cause with the drill-down tool is not easy due to the second limitation: current scope of data available to the final finish department.

Limited Scope of Data

While acquiring more data within a tire's test result has made it possible for a plant to identify trends of interest, only a small part of a tire's total history is provided within a typical final finish department data acquisition system. Efficiently drilling down to discrete upstream contributors requires quick and easy access to details maintained within disparate departmental databases. For example, the final finish product traceability record for a tire may include a curing press cavity and mold ID, but the only way to find out the last time the mold was cleaned is to look at data maintained exclusively within the curing department.

So, looking at typical final finish test data initially limits the quality engineer to a narrow picture of the upstream processes that contributed to the final product. To perform agile, advanced product and process analysis, the information in disparate databases must be readily accessible.

To fill the basic need for increased data availability, some tire manufacturers have turned to grant direct access to operational databases so their quality engineers can import specific information from different databases into local user spreadsheets. Within the spreadsheet, quality engineers then typically apply a variety of sorting methods or specialized functions to look for root cause associated with problems they have identified.

This approach makes the data available without any initial investment into data preparation, but a database designed for running day-to-day manufacturing operations differs in many aspects from an ideal source for analysis.

Operational databases are generally OLTP (on-line transactional processing) and are designed for efficiently processing a large number of small transactions in real-time. They are designed to handle mission-critical tasks in the production environment. Any user-friendly components, like summary tables and denormalized views, must be added to these databases without interrupting their primary functionality. After a few basic usability additions, users may be left to join data on their own within their spreadsheets and accept long response times to queries lacking supporting summary information. The end-user may eventually become adept at database table manipulation or may have to rely on the IT department to write specialized reports when new questions are being investigated.

A consequence of this approach is "spreadmart," an environment where users and departments create their individual silos of disconnected data, as they manually do their tedious data integration. After data is imported into spreadsheets for manipulation, information is often irrevocably separated from its source. It's difficult to collaborate and it's difficult to validate the results against a central source of truth.

By contrast, a data warehouse for MI is generally OLAP (on-line analytical processing) and is designed to organize and aggregate data into a logical and responsive analytical tool. This is achieved through a specialized structure. An OLAP data warehouse contains one or more multi-dimensional datasets called cubes. Each dimension in a cube contains a set of related descriptive information. For example, a time dimension usually contains a calendar hierarchy of Year, Month, Date, and Time, and a Curing Press dimension might contain a list of the presses in the plant along with descriptive attributes such as press size and type, current recipe, bladder and mold ID, and date of last mold change. These dimensions form the structure for the values of interest, referred to as Measures. Measures are usually numeric data points, such as the number of tires cured and the measurement values from various temperatures and pressures monitored during the cure. In practice, there can be many more than 3 dimensions in a data cube, but the physical cube shape is a good visual analogy for understanding how OLAP data warehouses organize data within a multi-dimensional framework.

An OLAP data warehouse is not designed to be real-time. Instead, it will be processed periodically at intervals determined by the needs of the organization and the amount of time required to build the warehouse. This could mean hourly, by shift, or daily. Mission-critical production data may be updated more frequently. Once it has been processed, the result is a centralized location where disparate data sources have been integrated and enhanced with additional aggregations, business rules, and KPIs so that users can quickly access understandable, contextual information.

	OLTP	OLAP
Function	Process operational transactions efficiently and accurately	Provide user-friendly data prepared for complex analysis
Update Schedule	Real-time	Periodic
Data Source	OLTP databases store original data	Built from OLTP databases
Integration	Each database is specialized to its own function and not integrated with others	Integrates data from disparate OLTP databases
Reporting	Real-time snapshot data with limited scope, or standardized summary tables	Flexibly supports complex queries with wide scope
Size	Only what is required for operational functionality	Retains history and adds aggregations, taking up more space than OLTP

Tire Test Data: Using MI for Product/Process Improvement

MI provides proven methods for data preparation and access which are scalable throughout an enterprise, from use within a single department to an entire plant, and across the enterprise as a whole. Focused teams, managers, and executives can all benefit from access to efficient MI tools. A well-designed data warehouse can service self-directed investigation or supply fast response times on role-specific preconfigured reports and dashboards.

Earlier we saw an example of how a first responder to degrading yield might use intuitive visualizations to identify the problem and a self-directed investigation of upstream data to react to it. In the long term, proactive studies of tire test results could actually benefit the most. Quality engineers will be able to take a self-directed investigation to new levels when they have a responsive set of tools for reviewing process data along with correlating results.

Once the task of pulling out relevant information is made into a simple procedure, engineers can use the time savings to ask additional questions or to pursue more complex analysis. Manufacturers already have experience with changes that may seem subtle, like finding the optimal angular placement of a green tire within the curing mold, that have led to improvements in yield. When testing a high volume of tires, even a small percentage increase in yield can lead to a significant improvement in a metric like Overall Equipment Effectiveness (OEE). In this stage of analysis, test data is used to optimize procedures that are already considered acceptable but can be improved.

Some types of procedural analysis may require additional data collection, but many questions could be answered by data that is already collected but has been logistically difficult to correlate to final finish test results. For example, while materials must always be used before their defined expiration date, a quality engineer may wonder if there is an optimal time to use a new material that will correlate to the best yield results. The required supporting data is already collected, but in many plants, the technical effort to integrate the data from multiple departments for this analysis could be prohibitive.

This is where an engineer can turn to a drag-and-drop ad-hoc query tool to compile supporting data and look for trends. Not only is the data available, but there is no SQL knowledge required to access it. Many front-end tools make this possible. *Figure 5* shows a typical setup, where the OLAP cube is laid out with its structured multi-dimensional content, which can be dragged onto filters, rows, and columns in a workspace. Visualization tools can be applied to the data to facilitate trend-spotting.

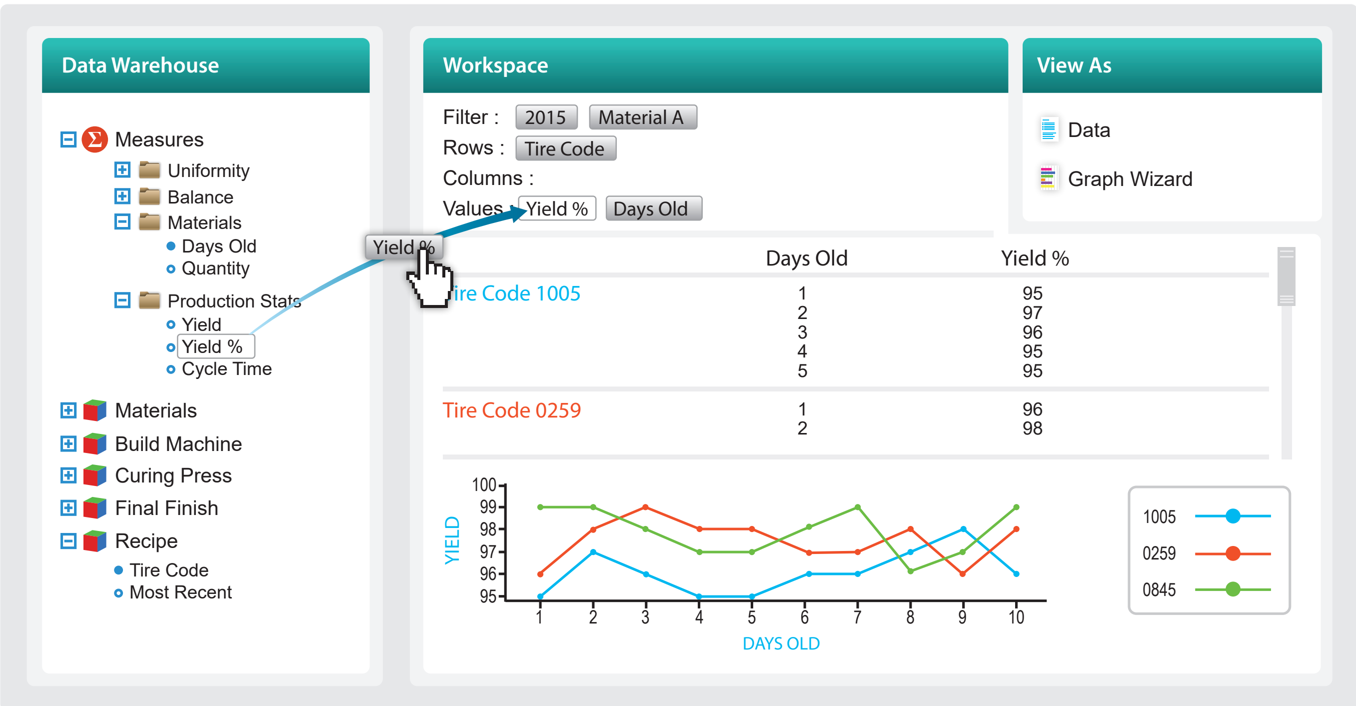


Figure 5

With this kind of data empowerment, engineers will be able to pursue questions that had been too logistically difficult in the past. If even one answer leads to a process improvement, it can mean a significant gain for the overall yield.

Implementation Considerations

The decision to implement MI practices for final finish test data is an enterprise decision requiring integration with the upstream departments' data. Plant and Corporate IT departments need personnel with the availability and the skillset for managing the data warehouse. Generally a team devoted to MI is a necessity, and they will work with the existing IT department to design the implementation and gather changing requirements from different departments. MI vendors must have a good understanding of tire data to make an investment cost-effective.

Part of the initial design will involve dedicated hardware for the new analytical system. The warehouse is an integrated, re-structured copy of data that originates from many other locations. It contains aggregations and often retains more history than an operational database, making its total size larger than the sum of its parts. Many users may be accessing the system at once with complicated questions, and the response time of the system will directly impact their success. The design stage must include careful consideration of data size and usage to ensure that dedicated hardware is sufficient for the workload and scalable with increases in workload.

As with any new tools, users will need some information and training on how to use them. Depending on their role their usage may vary greatly. Some users will continue to use prepared reports that have new intuitive features, better response time, and integrated data. Quality engineers will additionally require an overview of the new availability of data and the tools they can use to pursue their self-directed inquiries. The goal is to provide them with tools that are more intuitive and complete than what they may have had access to in the past.

After the initial design and deployment, a continuous improvement plan should be in place. As products and processes evolve the system must evolve with them. The insights gathered by analysts from their MI tools can be used to design new KPIs and rules that are fed back into the system to propagate the knowledge. A review of common queries can inform new targeted aggregations.

Summary

Testing Innovation in the tire industry comes from experience, creativity, and technology. While experience provides the expertise necessary to identify problems, technology is the key to efficiently using that expertise to quickly identify and solve those problems.

How MI is designed for effectiveness (right-time queries) instead of efficiency (real time queries) enables agile analysis that can foster the creativity necessary to provide breakthrough improvement. This has been proven in the retail and financial industries, and the time is right to prove it in the tire industry.