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Automotive Brake Testing

using the WaveBook™

Automotive

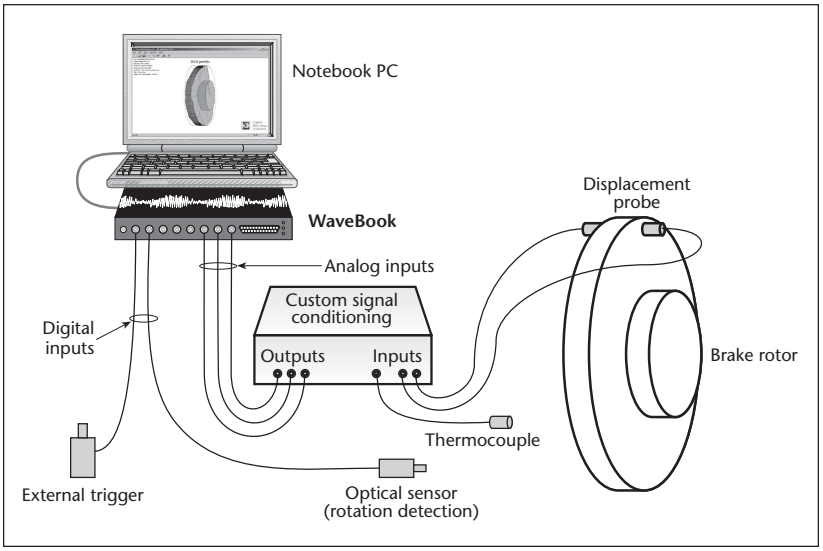
Application Note #87

Application Summary

Automotive braking systems are designed for high reliability and are constantly monitored with data from warranty returns. Because brakes are one of the most safety-critical items on a vehicle, the OEM component manufacturers take these warranty returns seriously. All returned units are thoroughly examined for signs of abnormal wear and manufacturing or material defects, but most often, the parts prove to be flawless: the alleged fault lies elsewhere. Brake suppliers have invested enormous sums of money on test equipment to validate brake reliability, durability, and life for ensuring the utmost safety, so analyzing and testing returned units that are good is an expensive, time-consuming process. In spite of the high cost, the OEMs continue to examine these returns for such features as run-out and thickness variations, but at the same time, they are constantly upgrading the test gear to make measurements and analyses more accurate and faster.

Potential Solution

For a relatively long while, most tests were conducted on braking systems on a component-by-component basis, which amounted to testing on a relatively static, bench-top system. The typical measurement process involved dial indicators and calipers to check for run-out and thickness. A more expensive dynamic test conducted in the lab involved a precision spindle and a controller to rotate it at a constant speed while measuring run-out with linear variable differential transformers (LVDTs), signal conditioners, and a read-out device that allowed technicians to manually measure and record the roundness, flatness, and thickness of brake discs.



The system block diagram for dynamic brake testing of warranty returned parts is relatively simple and perhaps belies the importance and significance of the test. However, the IOtech WaveBook measurement system equipped with Digital Metrology's custom analysis software can detect displacements in microns and sort out the very few truly defective parts from the greater number of misdiagnosed parts.

IOtech's Solution

Recently, however, one OEM brake supplier, Bosch Braking Systems of Farmington, Mich., began looking for a better way to measure brake geometry and to lower inspection costs by increasing brake component throughput without compromising the accuracy and thoroughness of the test. Robert McNaughton, Manager, Metrology/Technical Services, at Bosch, contacted Mark Malburg of Digital Metrology Solutions, Columbus, Indiana, a metrology consultant dealing with surface and form measurement and analysis, to assist in the design and development of a new testing and analysis system. The initial system was intended to test a single wheel on the vehicle – without removing components. Malburg recommended the IOtech WaveBook™ and a special capacitive sensor purchased by Bosch along with a custom signal processor package to replace the existing test and measurement system. Signal conditioners scale and filter the output of the capacitive sensors or LVDTs to provide the WaveBook with noise-free voltage signals. Malburg used the IOtech software drivers, but wrote the math-intensive instrumentation software in Visual C++™ that was necessary to take the measurements, analyze the data, and control the system.

The new system eliminates the need for speed control, and it can measure not only roundness, flatness, and run out, but also relative thickness, parallelism, and other parameters on a brake disc and caliper assembly while spinning wheel-brake assemblies on the vehicle. The WaveBook records units of measurement that are in the microns.

One problem discovered was tilted parts, which resulted in uneven disc wear that left two thin-to-high spots. These anomalies produce audible oscillations plus multiple harmonics, which are annoying and indicate the malfunction. Another problem came from unbalanced rotors that had to be replaced. Before the IOtech system was used, the brakes were removed from a vehicle, sent to a lab for tests, and the data recorded and analyzed. The process took about a week. With the new system in the field, a vehicle is put on a hoist, the wheel is spun, and the data is recorded and analyzed within about 5 minutes, a remarkable reduction in time, labor, and ultimate cost.

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Further studies include analyzing different frequencies and harmonics generated by the shape of the brake. Investigators can detect discs that have two or three lobes just from the frequency it generates. This produces an extremely shaky ride. "Now, researchers understand the relation between orientation and thickness variations," says Malburg. "The biggest issue is the thickness variation, because the caliper can slide back and forth a little to accommodate a slightly warped (potato-chip shaped) disc. But eventually it wears to the point where the disc has thick and thin spots that produce the shaky ride."

The test rig graduated from the hoist and garage setting to being used on a vehicle running over the road, a bigger challenge. But because the WaveBook can operate from the vehicle battery, this portability let McNaughton install the data acquisition system relatively easily. Moreover, the advantage of eliminating speed from the equation let researchers measure actual on-road variables on all wheels simultaneously with the WaveBook expansion module. "Because all wheels don't turn at the same speed while cornering, for example, the challenge was finding the relationship between the wheel position and the displacements. Picking up the speed of an individual wheel allows me to interpolate backward to determine the values of the displacements at the actual positions on the rotor," says Malburg.

"Another significant benefit was derived from the new data acquisition and measurement system at another level," says McNaughton. "We installed similar systems all the way from the development lab through the production line and to the dealerships to provide us with much more uniform, in-depth data for diagnosis and analysis. Each department can now submit their data in a common format, which helps considerably in decision-making."

Conclusion

Bosch Braking Systems in cooperation with Digital Metrology Solutions, designed a measurement system for evaluating brake components returned under warranty. The new system using an IOtech WaveBook and capacitive or LVDT displacement sensors moved the static test from the lab bench to a garage hoist or the highway where dynamic tests can be run on actual vehicles. This reduces the test time from weeks to minutes: It eliminates the time and huge expense needed to remove the components from the vehicle, run the bench test, and return the parts to the point of origin. The new test system produces more in-depth data in a uniform format, and is remarkably faster and much more accurate.

WaveBook Series

The WaveBook/516E™ digitizer offers multi-channel waveform acquisition and analysis for portable or laboratory applications. The WaveBook includes 8 built-in channels expandable up to 72 channels of voltage, accelerometer, microphone, strain gage, thermocouple, position encoder, frequency, high voltage, and other signal types. For applications beyond 72 channels, up to four WaveBooks can be combined within one measurement system, for a total capacity of 288 channels. You can also add up to 854 thermocouples, without consuming measurement bandwidth of the WaveBooks, using the WBK40™ series, and DBK90 signal conditioning options. The 12-bit WaveBook/512A™ and 16-bit WaveBook/516A™ attach to the WaveBook/516E via their built-in parallel port interface. Other than the interface, the WaveBook/512A and WaveBook/516A are identical to the WaveBook/516E.

Features

- PC connection via Ethernet
- 12-, and 16-bit/1-MHz A/D
- 1 µs/channel scanning of any combination of channels
- Single and multichannel analog triggering with programmable level & slope
- Digital TTL-level and pattern triggering
- Pulse trigger and external clock
- Programmable pre- and post-trigger sampling rates
- Sixteen digital inputs can be scanned synchronously with analog signals
- Operable from AC line, a 10 to 30 VDC source, such as a car battery, or optional compact rechargeable battery module
- Expandable up to 288 high-speed channels
- SYNC connection allows multiple units to sample synchronously
- Add up to 854 lower-speed thermocouple channels
- DSP-based design provides real-time digital calibration on all channels

Signal Conditioning

- ICP® dynamic signal inputs
- Strain gages
- Programmable filtering
- Simultaneous sampling
- Quadrature encoder inputs
- Pulse/frequency measurements
- Thermocouples
- High-voltage measurements
- Vehicle bus network

Software

- Includes WaveView™ for *Out-of-the-Box*™ setup, acquisition, & real-time display:
  - Scope mode for real-time waveform display
  - Logger mode for continuous streaming to disk
- Optional eZ-Analyst™ for real-time spectrum analysis
- Export data in third-party formats
- Includes support for Visual Basic®, C/C++, LabVIEW®, MATLAB®, and DASYLab®
- ActiveX/COM development tools