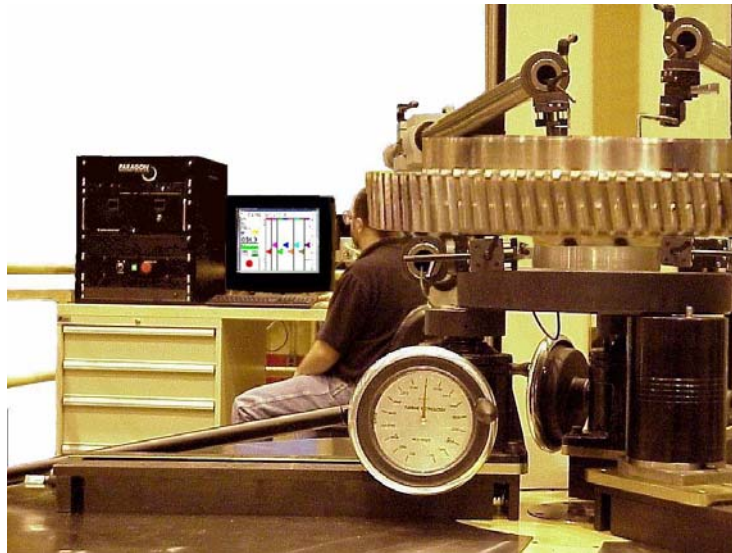


Perfect circle

High-accuracy turbine rotor measurements eliminate expensive stacking errors, writes John Sadders



Company directors generally blanch when faced with the expense of buying a made-to-order metrology system. Aside from the outlay itself, the perception exists that inspection is not a value-adding activity, and therefore is to be frowned upon in the modern corporate culture. This is realistic in so much as the culture of inspection has always been to expose errors -- but this should not disguise the fact that a good inspection solution will save money in the long term.

Take, as an example, the case of a new PC-based metrology system that accurately measures huge gas turbine components. Turbine Metrology of Kansas City, Missouri, USA, has evolved as a supplier to General Electric's massive power generation business, working within the field of circular geometry metrology. Measuring rotors for gas turbine generators is particularly important because the accurate assembly of these components has a critical impact on bearing wear - and therefore the life expectancy of the finished turbine. Early attempts to develop a system for this kind of measurement have been notoriously hit-and-miss, primarily because of the large number of data points that needed to be collected to accurately determine runout, concentricity, eccentricity, and flatness of the parts, and because of the conditions under which those measurements must be made. Viable systems have often been criticized for being painstakingly slow and/or confined to the standards room.

Spinning

The Paragon system, as Turbine Metrology's machine is known, is designed to measure the rotating parts of a turbine rotor unit. These components are up to 2.44m in diameter, 3m in length, and weigh in excess of 11 tonnes. During assembly, approximately 24 of these components are stacked up and bolted together to form the spinning core of the power generation unit. The accuracy of these components is critical to the performance of the finished unit. If each part is only a few hundredths of a millimeter out of flat, for example, the accumulated tolerances will result in a 'stack' in which the bearing surfaces are out of alignment, leading to premature bearing wear and possible catastrophic failure. Using current manufacturing methods, it is virtually impossible to build these massive parts to small enough tolerances that they can be simply bolted together without inspection.

Problem

Early attempts to perform circular geometry measurements involved small, laboratory-type machines capable of reading only one surface of the part at a time. This made the measurement and correlation of multiple surfaces a very tedious process. A few systems have been designed to measure and compare two to four surfaces in near-real time but these systems are either slow, based on flawed algorithms, or not suitable for use in a production environment. *(Continued over)*

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"The mechanical aspects of the process are difficult; these large and heavy rotors must be centered and rotated accurately enough to prevent their runout from affecting the measurements," says technical director Neill Fleeman. "But the hardest part has always been processing the enormous volume of data required to thoroughly characterize parts of these sizes while eliminating the influence of external seismic and acoustic inputs. I have seen systems that were down more than they were operating, that created larger errors than they were trying to measure, and that gave results that were based more on noise than on actual part geometry. Since restacking an assembled rotor can cost upwards of \$150,000, these measurements are critical.

Turbine Metrology set out to solve these problems by designing their new Paragon system from the ground up. The key, according to Fleeman, is the ability to collect far more samples in a single revolution. Paragon over 1.2 million samples per second, making it possible to perform all the necessary measurements in a single revolution of the part.

Runout

Paragon is designed with solid mechanical underpinnings, using purpose-built precision air bearing rotary inspection tables with runout characteristics measured in submicron units. Optical encoders are used to read the angular position of the table. Paragon can handle up to eight input channels; in the standard system, four electronic lever-type gauge heads trace the surface of the part to accuracies of .1micrometer. These components in and of themselves are capable of accurately generating a vast amount of information from a turbine rotor in a very short period of time. The problem that Fleeman then had to face was how to efficiently process this volume of information.

One option was to use a dedicated data acquisition device for data collection and a PC for running the data analysis applications. This would have driven up both the cost and the complexity of the system. Using a single PC to handle both processes, however, created another problem - the need to find a data acquisition system with the speed and accuracy required which would need little attention from the operating system of the computer on which it ran. This would allow the operating system to focus on processing the data that had already been collected. "Computing power has to be available when it is needed. Operating systems like Windows use up many machine cycles on the PC platform, and when they take control of the CPU they hold onto it for a long time. If data transfer functions were to run under Windows, the system would be vulnerable to a situation where Windows was occupied with other tasks, possibly interrupting the data flow. This would be fatal to the filter algorithms, and thus to surface data generated from them."

The solution was the Microstar Laboratories iDSC 1816 board, which combines 16-bit resolution in eight simultaneous channels of data acquisition with brick-wall anti-alias filters on each channel. The iDSC 1816 samples analog inputs at a throughput of 1.2M samples per second, with the sampling rate on each channel ranging from 8 samples to 153.6k samples per second. Onboard fourth-order analog anti-alias filters pass signals to decimation filters in the eight Sigma-Delta A/D converters.

Multitasking

This hardware converts signals to simultaneous filtered data at 153.6k samples per second on each channel. An onboard microprocessor that runs a multitasking, real-time operating system optimized for high-performance data acquisition and control applications. The intelligence on the DAP board extends the power of the Windows user interface by executing all processor-intensive routines in real time so that the software on the PC can handle more demanding applications than usual. This greatly reduces the risk of losing data, regardless of how many computer cycles are dedicated to the foreground application. The data acquisition processor continues to run the special routine that collects data from the acquisition devices totally independent of the central processor.



The net result is a system that can fully characterize the turbine rotors with respect to runout, eccentricity, concentricity and flatness by collecting 720,000 measurements in a single revolution. The manufacturer of the rotors now can accurately determine their dimensions at an early stage of the manufacturing process. Rarely will the turbine manufacturer determine that the dimensions of the piece make it impossible to use; in most cases, they will find that the rotor is within specifications and, because they will have its precise dimensions, they will be able to match it with other complementary rotors in order to produce a final assembly that will run true enough to

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