Wind Tunnel Rotor Blade Testing

Aerospace

using the DaqBook®

Application Note #70

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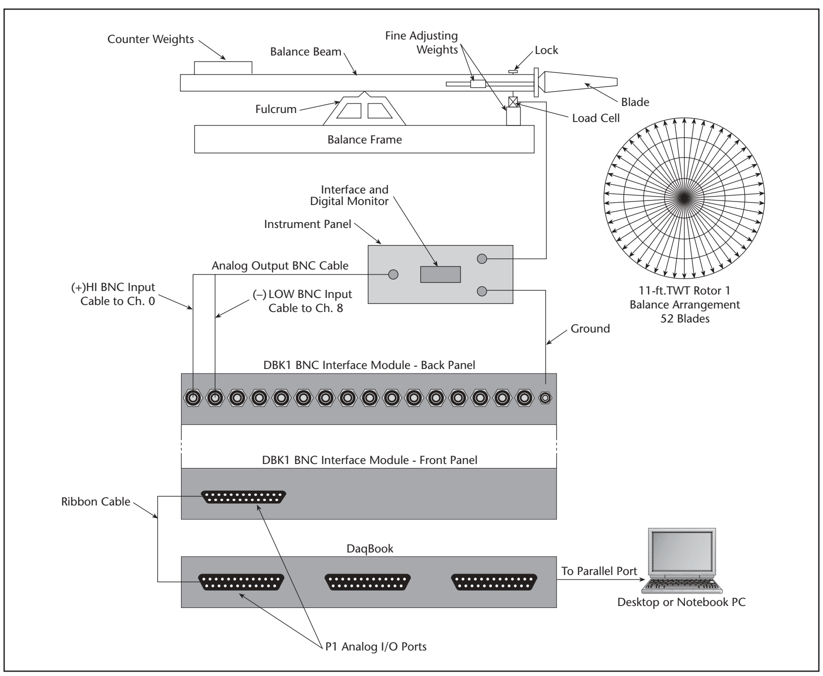
Application Summary

NASA's large compressors used in high-speed wind tunnels for aerospace applications typically contain rotor blades approximately four feet long. Eccentric or unbalanced compressor blades of this size can vibrate and produce audible noise, damage bearings, and are less efficient than well-balanced ones. The NASA Ames Research Center, Moffett Field, Calif., has come up with a highly accurate technique of optimizing sets of 52 rotor blades per stage for three-stage compressors to ensure an optimally balanced rotor.

The method automatically acquires each blade's moment-weight data and replaces the previous, highly repetitive manual process that is quite prone to operator errors. Moreover, it automatically corrects dc offsets without recalibrating the balance flexure beam after every 10 acquisitions. It also sorts the blade moment-weight data by stage number so the blades don't have to be physically presorted before acquiring the moment weight. This method eliminates the more traditional way of assembling rotors from random sets of blades and performing a painstaking, trial and error balancing procedure by adding or subtracting blade mass.



The balance flexure beam assembly is rigged to statically measure the moment weight of the compressor blades, one at a time. The output of the digital monitor connects to a DBK1 interface, which, in turn, connects to the IOtech DaqBook to collect the data. The graphics file for all the rows of blades are posted on a Microsoft Word document and printed out graphically for sorting and positioning the blades.

The system comprises two individual processes, a moment-weight data acquisition and a balance computation. The equipment that selects the blades includes a beam balance that holds an individual blade and measures its weight and center of gravity (cg). The data is stored in a data acquisition system, and software determines which blades are to be used in a set and their specific location on the rotor assembly. This is a static test that does not require a particularly fast sampling speed, but does require high accuracy and easy commissioning.

Potential Solution

Initially, test engineers used a digital readout box connected to a load cell to measure the moment weight. The operator placed a blade on the balance beam and recorded the digital readout value on a sheet of paper. The operator had to test each blade, and then an engineer manually entered the data into a computer to calculate the optimum blade arrangement. Sometimes the operator had to add or remove mass when the balance did not meet the specified tolerance of 1%.

IOtech's Solution

In order to improve the accuracy and reduce the physical resources to perform rotor balance, Nhan Nguyen, a NASA aeronautics facility engineer, developed a method to automate the process. After evaluating several data acquisition systems and supported by recommendations from NASA instrumentation engineers, Nguyen selected an IOtech DaqBook® to collect the moment weight data and wrote a software module to calculate the optimum arrangement of the blades on the compressor rotor discs. The new optimization method arranges rotor blades to meet a much tighter tolerance of 0.05%, which eliminates the need of altering the mass.

The blade balance system includes a balance flexure beam assembly equipped with a load cell, a digital monitor, an IOtech DaqBook data acquisition system, and a personal computer. The balance flexure beam measures the reaction force due to the moment of the blade cantilevered out at one end of the balance beam. The reaction force is registered with a 50-lb load cell. The load cell connects to an instrument panel that conditions its output signal. The load cell voltage signal is then scaled and displayed on a digital monitor.

The load cell provides a differential or bipolar signal to the instrument panel and digital monitor indicating either compression or tension. Shielded BNC cables and a ground wire from the bipolar output of the instrument panel connect to two inputs and ground terminal of the IOtech DBK1™ interface module. The positive signal connects to channel 0 and the negative output connects to channel 8. The output of the DBK1 connects to the DaqBook, and the DaqBook connects to the laptop computer.

The DaqView software that is included with the DaqBook is easy to use and understand, claims Nguyen. "You don't have to spend a lot of time reading the manual to use the software; it's pretty intuitive." He uses it to set up the parameters and conditions to acquire the data, and perform averaging and triggering, but for a completely automated process, it requires a different kind of software interface. "I'm using the DaqLink macro that lets me acquire data in the Excel® environment," says Nguyen.

Nguyen developed the custom data acquisition and balance beam software using MATLAB® GUI capability to control the DaqBook for acquiring the moment weight data. The MATLAB program also interfaces with Microsoft Excel and Word software using ActiveX for data output and storage. "MATLAB is used," says Nguyen, "because we acquire and optimize the data in a certain way to provide us with the best balance arrangement for the set of blades. I rely on MATLAB primarily for number crunching." And because ActiveX interfaces MATLAB to other software, Nguyen uses it to open a channel between MATLAB and Excel to communicate with the DaqBook.

The main program for the automated blade balance system is a MATLAB file. The program controls various high-level functions such as file creation and opening. It lets the user select either data acquisition or balancing. The balance weight program dispatches a MATLAB subroutine to perform moment weight data acquisition, and a MATLAB function to perform balance optimization. In turn, one subroutine calls another MATLAB function repeatedly to perform the actual data acquisition, and yet another to compute the imbalance vector during optimization iterations. The output of the system is a graphics file posted in a Word document and printed out graphically to show individual blade locations.

Conclusion

NASA Ames facility engineer Nhan Nguyen uses the DaqBook to statically balance rotor blades for a high-speed compressor. Although the Ames Research Center houses the world's largest wind tunnel, measuring 80 x120-ft, the compressors discussed here drive 11 x 11-ft transonic wind tunnels for testing aerospace components. Nguyen developed the moment weight beam balance fixture and configured the data acquisition hardware and control software to automate what was once a highly labor-intensive and time-consuming manual process. The new method is more accurate and faster than the previous manual method.