Military Aircraft Modal Testing
using the ZonicBook

Application Summary

Military aircraft, rotorcraft, and selected fixed-wing aircraft are often adapted to accommodate a wide variety of armament and other accessory gear that they were not originally designed to handle. The nature of continually changing peacetime and battlefield requirements puts a severe demand on engineers to make these components fit and operate efficiently and safely within a limited development time. Although the aircraft are generally designed to handle the additional payload, placing new components where they will not interfere with vehicle performance is paramount. For example, the airframe and wing structures are critically supported and reinforced, and any extra weight or a vibrating load in the wrong place could cause early failures.

Although this type of military helicopter is primarily used as a troop carrier, it can be retrofitted to serve medical missions, search and rescue operations, and armed escorts. Also, it can be equipped for warfare use with several missiles, various kinds of guns, 20-mm cannons, rockets, and other components. To ensure that these added components are properly located and do not alter the dynamic behavior of the craft or generate unacceptable vibrations, structural engineers use IOtech data acquisition systems to conduct modal tests on the ground and other vibration tests in flight. [Photo Courtesy of U.S. Army]

Potential Solution

Structural engineers perform special tests to ensure that the retrofitted components are properly mounted and secure and the aircraft are safe. The engineers typically use multi-channel data acquisition systems and accelerometers for modal analysis to measure vibrations before and after the components are mounted.

IOtech's Solution

Structural dynamics engineers in the aircraft industry have preferred IOtech ZonicBooks for several years to conduct modal analyses for several reasons: small size, portability, accuracy, sampling speed, and quick and easy set up. They also like the eZ-Analyst software because it is easy to use and lets engineers manipulate the data in many ways.

Rotorcraft industry engineers explain that helicopters are especially susceptible to vibrations generated by the aerodynamics of rotating main and tail rotors at discrete excitation frequencies that relate to the number of blades and rotational speed. When new components are added to a helicopter, especially at an extremity such as the tailboom or wings, the engineers conduct modal tests to ensure that resonances are not present and that the vibrations are not high enough to adversely affect the fatigue life of structures and components, which in turn, can cause early failures.

"For example, we currently use the ZonicBook to look for resonances using modal tests," says one engineer. The different payloads, which include sophisticated electronic components, put a stress on the wings and struts. The combination of fixed with rotating components such as the main rotor can set up some severe vibrations. For example, on one particular aircraft, a new component had to be installed on the tip of the wings. "We conducted some impact tests to see if we had any resonance problems with wing frequency and rotor frequency," says the engineer. "Sometimes a resonance does appear, but it might be of such low amplitude that it presents no problem. Textbooks usually warn that resonances must be avoided; however, on some craft, a few resonances can be tolerated when they appear during a transient condition such as during rotor speed

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ramp up. But no resonances are allowed to exist within the rotors operational speed envelope. Otherwise, components need to be redesigned or vibration isolation must be added. It is not unusual for a helicopter to carry several hundred pounds of vibration isolation equipment."

The modal testing usually takes two to three hours; but modal analysis takes longer, and the time depends on the specific problem. An 8-channel system uses the first channel as reference, which may be an impact force or random or sinusoidal excitation. For relatively small and stiff structures, impact testing yields satisfactory results. The other 7 channels (the eZ-Analyst software can support up to 56 channels) measure accelerometers strategically placed around the wings, struts, and other structures. When more than 7 channels are needed in one test, the accelerometers are relocated and the modal testing continues in the same manner.

"After the ground vibration tests are performed and flight safety is met, up to 56 channels of dynamic signal measurements can be taken with the ZonicBook on board. Its compact size and

ZonicBook/618E

Vibration analysis and monitoring has never been easier than with the ZonicBook/618E and eZ-Series analysis and monitoring software. The ZonicBook leverages 30+ years of experience providing vibration measurement solutions. The ZonicBook hardware is the signal conditioning and acquisition engine, while the eZ-Series software in the PC defines the specific analysis and monitoring features of the system. The ZonicBook's architecture makes expansion beyond the eight built-in channels less expensive than other suppliers. You can expand the ZonicBook in 8-channel increments up to 56 channels, and each additional 8 channels are approximately one third the cost of the first 8 channels. *All* channels in a ZonicBook system are measured synchronously, providing 1 degree phase matching between channels.

Features

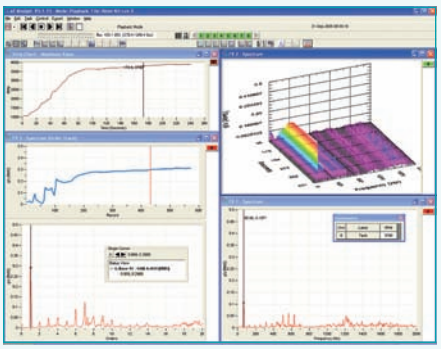
- 8 dynamic input channels, expandable up to 56 channels
- 4 tachometer channels for rotational measurements
- High-speed Ethernet connection to for continuous recording
- eZ-Series software packages address a wide variety of vibration monitoring and analysis applications
- TEDS support for accelerometers

Software Overview

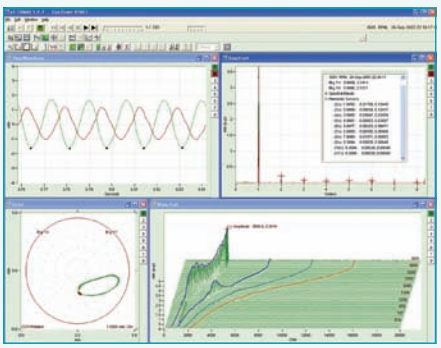
Four software packages are available for the ZonicBook, each tailored to a particular vibration measurement and analysis application. Choose the package that suits your application now, and upgrade to additional packages as your requirements evolve.

- **eZ-Analyst** provides real-time multi-channel vibration analysis, including overlay of previously acquired data while acquiring new data, strip charts of the throughput data files, cross channel analysis, and direct export to the most popular MODAL analysis packages, ME Scope and Star Modal.
- **eZ-TOMAS & eZ-TOMAS Remote** are highly sophisticated, yet easy-to-use tools for the monitoring and analysis of single or multiple machines, which allows the user to assess the reliability and operation of his process, and the critical machines pertaining to his process. Notification of faults are displayed locally, but can also be sent via text message or email, allowing the user to be notified of any problem regardless of his location.
- **eZ-Balance** is used to balance rotating machinery with up to seven planes. A balance toolkit, including Split Weight calculations, supports the balance process. The balance vectors are displayed on a polar plot so the user has a visual indication of the improvement. Time and spectrum plots show detailed vibration measurement during the balance process.
- **eZ-NDT** package is exclusively used in production applications to determine the quality of composite-metal products at production rates of 1 part per second.

The ZonicBook/618E with eZ-Series software and your PC makes a real-time, portable vibration analysis monitoring system



eZ-Analyst adds real-time continuous and transient data acquisition in the time, frequency, or order domain



View Time-Domain, Spectrum, Waterfall, and Trend simultaneously on one screen with eZ-TOMAS

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design for portability are perfect qualities for the job, and its ability to run from a 12V battery makes it ideal for flight tests," claims the engineer.

Acceleration and vibration are often recorded during flight. The wiring and sensor installation for up to eight channels can take as long as two hours. The ZonicBook can be simply strapped down in the passenger seat or fastened to the floor with Velcro. It can be operated by the flight test engineer or from a remote location, such as the co-pilot using an on-off remote switch. Flight measurements from all accelerometers at a given flight maneuver can made by running the analyzer continuously for about 60 seconds, or by partitioning it into several bursts to obtain the desired resolution. The amplitudes typically fall in the range of 0.02g pk-pk to 0.7g pk-pk in the cabin, but they can be as high as 5g pk-pk at extremities. Typically, the frequency range of interest is one to 100 Hz, which encompasses several harmonics of the main and tail rotor. For rotating shafts the frequency range is much higher, such as 200 Hz and beyond. These measurements are needed for an Airworthiness Release of the new component or a redesign if necessary.

The eZ-Analyst software is also used for flight vibration measurement. "The eZ-Analyst software is easy to use and provides all the data I need to conduct a successful analysis," says the engineer." I particularly like its ability to let me manipulate the data in any manner I like. We use the ZonicBook and eZ-Analyst software for all the helicopters and a number of fixed-wing aircraft as well."

Conclusion

Structural dynamics engineers frequently retrofit military helicopters and fixed-wing aircraft with a variety of weapons and electronic systems that could potentially alter the dynamic behavior of the platform structure and generate unacceptable vibrations. To keep the aircraft safe, however, engineers use an IOtech ZonicBook and accelerometers to perform ground modal and flight tests that locate any trouble spots so they can be fixed, immediately and effectively.

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