Equipment Vibration Problems

## tools and techniques used to solve difficult and unusual vibration problems

by:
Lyle Breaux, P.E.
Eric Luther, P.E.
Scot McNeill, Ph.D., P.E.

The most common equipment vibration problems are often solved in industry without the use of specialty engineering resources. Routine vibration problems—from machinery imbalance and misalignment to simple cases of noise and resonance—are often addressed at the plant level without help from consultants. On the other hand, some encounter noise and vibration problems that require a more in-depth approach—one that involves a combination of computer simulation, specialty field measurements, and/or advanced data analysis techniques. When these more difficult and challenging dynamics problems arise, they call on Stress Engineering Services (Stress) for expert consulting and field services.
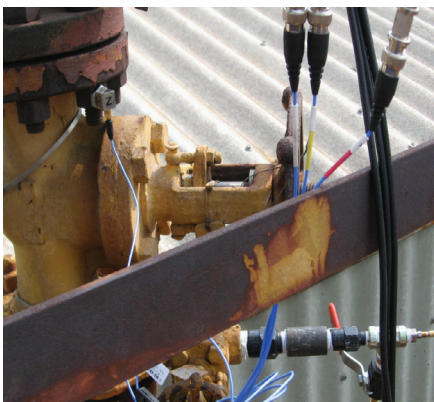
Figure 1:
Compressor piping vibration problem. Field measurement using triaxial accelerometer and dynamic pressure sensors

Field Vibration Surveys – Portable Data Acquisition

Most field vibration troubleshooting starts with basic data collection via portable, hand-held signal analyzers that are easily moved around multiple locations in the vicinity of a vibration problem. Data are typically acquired as a "snapshot in time" of a vibration signal, although modern portable analyzers can also be used as a digital tape recorder, enabling long-term and/or transient data capture. Even complicated multi-channel vibration monitoring jobs often start with a field survey to identify the best locations for mounting sensors. A field vibration survey with portable data acquisition is the simplest and fastest technique available for troubleshooting problems in the field.

Field Vibration Monitoring – Multi-Channel Acquisition

For some difficult vibration problems, long-term monitoring with multi-channel data acquisition emerges as a very powerful tool. This is certainly the case for complicated flow-induced vibration in which the vibration characteristics are intimately related to process conditions. A variety of sensor types are often used together—from strain gages and accelerometers to microphones and pressure sensors. Long-term monitoring allows our engineers to identify causal relationships between vibration characteristics and plant operating condi-

tions. Taken together, this information often points to the source of a complex vibration problem.

Experimental Modal Analysis (EMA)

EMA is often referred to simply as impact or shaker testing, and is used by our engineers in troubleshooting problems and for calibrating computer models. This is a traditional structural dynamics testing method that involves controlled loads applied to the test structure, and the analysis of the vibration (output) signals along with the measured loading (input) signals. The controlled loads are applied using shakers or impact hammers. This type of testing yields the three fundamental vibration parameters of all machines and structures: natural frequencies, mode shapes, and damping.

Figure 2:
Impact testing of a large valve system using a modal sledge hammer.
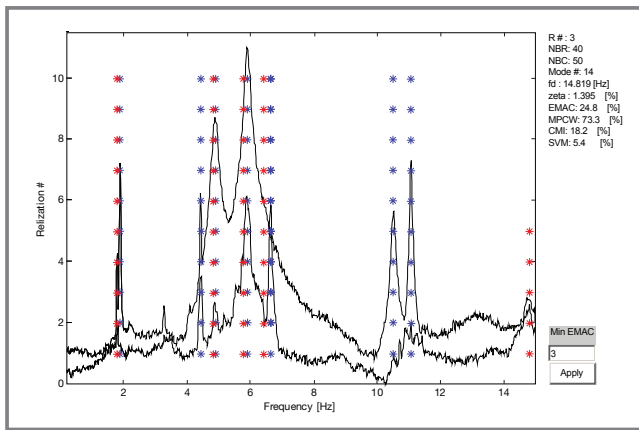
Figure 3:
Consistency diagram used during OMA to identify modal parameters.
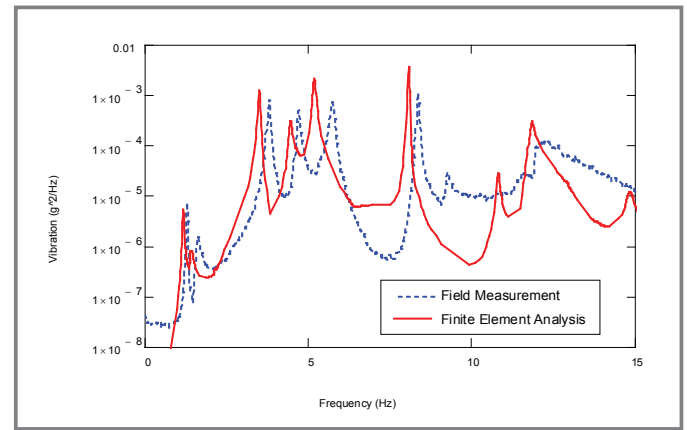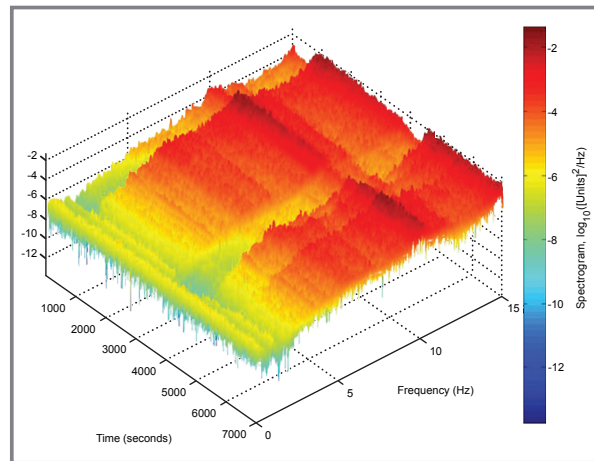

Figure 4:
Comparison of a calibrated FE model with field vibration data.

Operational Modal Analysis (OMA)

There are scenarios when traditional structural dynamics testing cannot be performed, for example, the equipment cannot be shut down, background noise levels are too high, and impact hammers are not practical or accessible, to name a few. The technique known as OMA may provide an alternative to traditional structural testing in such cases. Multiple vibration sensors are used to measure the system's normal operating vibration. Computer algorithms process the cross-correlation between the various measured signals; the result is the same natural frequencies, mode shapes, and damping, just like in EMA described above. This powerful technique is particularly well-suited for process flow-induced vibration and civil/structural vibration—situations that are dominated by random vibration signals.

Advanced Data Analysis

Troubleshooting and solving complex vibration problems often require data analysis that goes beyond simply looking at time waveforms and frequency spectra. Our engineers use advanced data analysis and signal-processing techniques to reveal the features, patterns, and nuances in measured data that aid in understanding complicated dynamics problems. Stress' expertise in system dynamics ensures that state-of-the-art analysis capabilities are at the client's disposal, from structural integrity monitoring and damage detection, to system identification using random output-only data.

Computer Simulation

Computational tools such as finite element analysis (FEA) and computational fluid dynamics (CFD) are utilized for all types of problems that Stress encounters, including those in vibration and acoustics. When the results from computer models must be accurate to within a specified tolerance, Stress engineers use actual vibration and acoustic measurements from the field to fine-tune and calibrate models. Computer models calibrated to field measurements take much of the guesswork out of FEA to better simulate real-world behavior. The dynamics of structural and machine components can be simulated under different scenarios or loading conditions that are impossible to measure in the field, or to verify solutions to vibration problems before costly modifications are implemented.

lyle.breaux@stress.com

Figure 5: Spectrogram of non-stationary random vibration
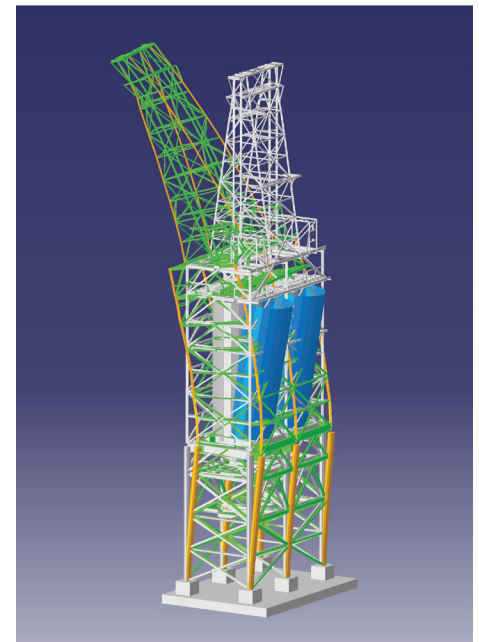
Figure 6:
Dynamic FEA result showing one mode shape of a refinery Coke Drum structure.