The Virtual Plant Vibration Analyst

A New Method for Troubleshooting Your In-plant Machinery

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This technical paper introduces a vibration analysis troubleshooting method recently employed during a training session with Honeywell Corporation at their Kansas City, Missouri, facility. Honeywell maintenance personnel wanted an effective on-the-job training method that would allow them to implement Operating Deflection Shape (ODS) Analysis throughout their department. What resulted is considered a methodology for performing more complex vibration analysis and diagnostics via the phone and internet with a more experienced analyst, without that analyst ever having to set foot in their facility. Here is how the process works:

- Initial phone and internet contact provide the virtual analyst with detailed operating and design information on the problem machinery.
- The analyst builds a computer model of the machine and documents locations where data collection is required.
- A route is built (in this case, for the SKF Microlog CMVA 40) in the ODS software to be downloaded to the data collector.
- The ODS model, route and data collection locations are transferred via the internet to the customer site.
- The customer collects the specified measurements and uploads them to the ODS analysis software.
- The customer also transfers the data via the internet to the off-site virtual analyst.
- The virtual analyst processes the data, creates animations and composes a detailed report for the customer.
- The customer can perform the same analysis on-site and gain valuable on-the-job training, all within the supervision of the virtual analyst.

Initial contact for this job was with the Honeywell Corporation in Kansas City, Missouri. The Honeywell predictive maintenance group, like many companies, have several Level I and Level II analysts and are taking the next step in vibration diagnostic capabilities, namely Experimental Modal and Operating Deflection Shape (ODS) Analysis. The vibration industry is rapidly progressing in ways that allow plant vibration technicians to perform analysis and troubleshooting that, in the past, were reserved for engineers and outside consultants.

Most portable data collectors can perform “single channel” ODS analysis and simple “bump” natural frequency testing. For single channel ODS applications, there is an additional complication of requiring a 1x r/min shaft trigger. The relative phase has significance only as related to a specific shaft in a multiple shaft system train. Thus each shaft requires a reference trigger for phase to be meaningful.

“Multi-channel” data collectors can perform ODS FRF and Experimental Modal Analysis (EMA). This ODS FRF analysis removes the need for an external trigger source and allows the analysis of virtually *any* frequency in the spectrum.

Additional capabilities are gained with “route-capable” multi-channel SKF Microlog units like the CMVA 40 and CMXA 50 that can be programmed directly from advanced analysis software like MEscope VES. Both the download and the upload process via the SKF Microlog are automatic without user intervention to modify either the measurement parameters or route point selection. It is this performance uniqueness that is essential to the successful application of remote (or virtual) analysis.

Fig. 1. Photos of problem machine.

For the Honeywell application, the customer requested additional training on the MEscope VES software. A detailed step-by-step model construction guide (the MEscope Workbook) was provided along with the completed model shown in **fig. 2**. A series of digital photos helped in the model construction and the accessibility of locations on the structure for making measurements. Measurement location as well as direction (±) is extremely important for any phase analysis like ODS.

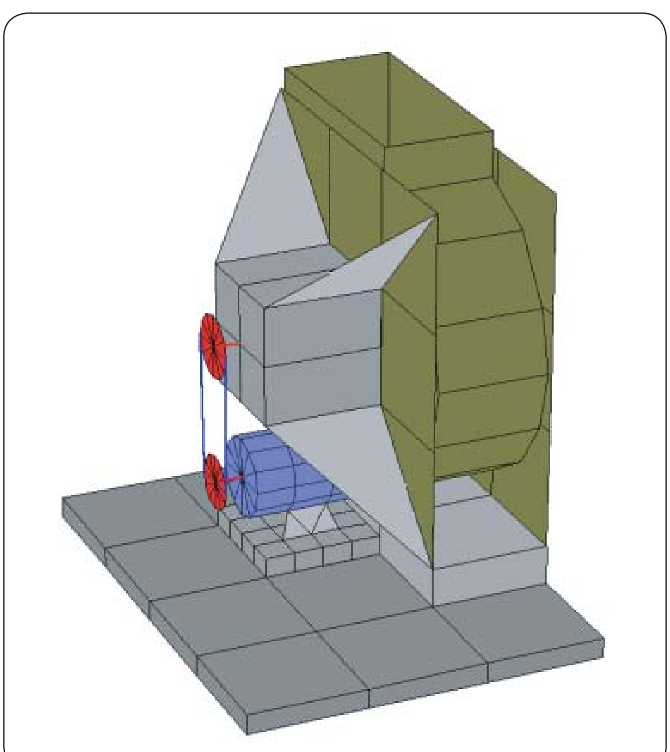

Fig. 2. MEscope ODS analysis computer model.

Definition: operating deflection shape

An operating deflection shape is measured with the machine at its normal operating condition. This analysis measures the machines' response at a specific time or frequency. Both amplitude and phase information are collected at various locations on the structure and, via special software, the vibrating "shape" or response of the machine can be animated. These animations show the analyst "how" the machine is moving during normal operation. Note that this is not a resonant response of the machine, but its operational response. The forces within the machine are responsible for the motion or shape of motion measured with this analysis tool. For example, the unbalance response of any rotating system will produce a response or driving force at 1x r/min. Misalignment and looseness generally produce synchronous multiples of running speed (2x r/min, 3x r/min, etc.).

Machinery information such as operating speeds, belt and sheave information, blade, vane or gear tooth counts, and past structural modifications to the original design are all acquired in the initial phone conversations.

The data collection points and directions were defined based on experience with machinery and how beam, plate and shell structure will bend, twist and deform under vibration loadings. The main concern is taking enough measurements to accurately "visualize" the motion. Another concern is properly measuring across bolted interfaces such that relative motion of the joints can be seen (if present).

The measurement points were logged into a "route" in the MEscope software to be downloaded to the customer's SKF Microlog CMVA 40 data collector on-site (→ **fig. 3**). The analysis is as simple as collecting monthly condition monitoring data. For this analysis, two routes are specified. The first collects a velocity FFT spectra at each measurement location. This provides an accurate amplitude response all over the structure. The second route collects a transfer function between each measurement location and a reference location. This step provides the relative phase relationships across the structure and the reference source for animation.

Prior to the ODS analysis, Honeywell vibration analysts were convinced that their problematic fan had a structural resonance problem. Several modifications to the structure failed to completely resolve the vibration issues. Full Spectrum Diagnostics was asked to also design a tuned vibration absorber (TVA) to be installed, if required. The TVA was designed and tested for effect analytically in the MEscope VES software as a part of this vibration investigation.

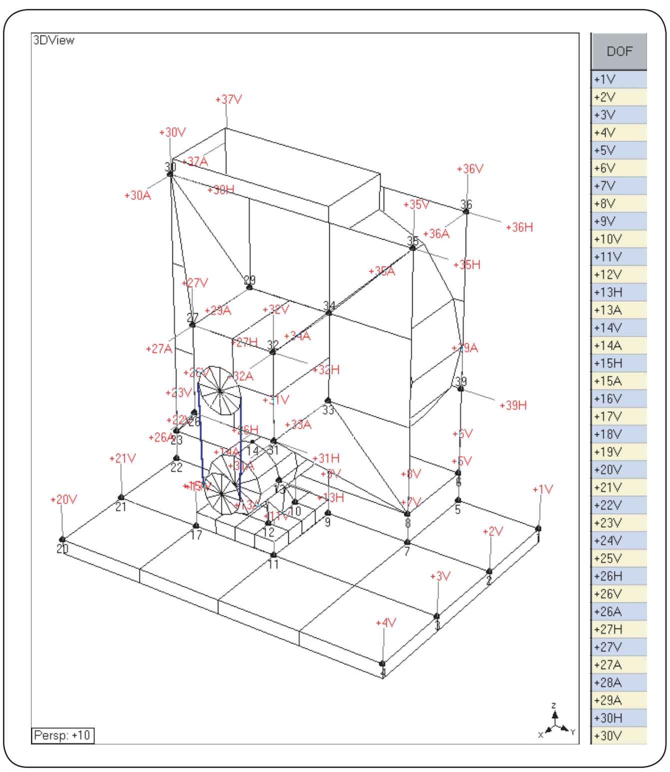

Fig. 3. SKF Microlog CMVA 40 route measurements.

When the data was collected and transferred back to the virtual analyst, several unforeseen problems were detailed in the structural animations. **Fig. 4** shows a soft or weak location in the support frame on the backside of the fan that is suspected of inducing the dominant vibration problems in the fan. This realization prompted the customer to "re-think" its initial position on installing a TVA to the structure.

Additional problems were noted when animating the 2x fan and 3x fan harmonics. Obvious belt alignment and tension problems resulted in axial vibration and torsional response of the fan bearing support structures (→ **figs. 5** and **6**).

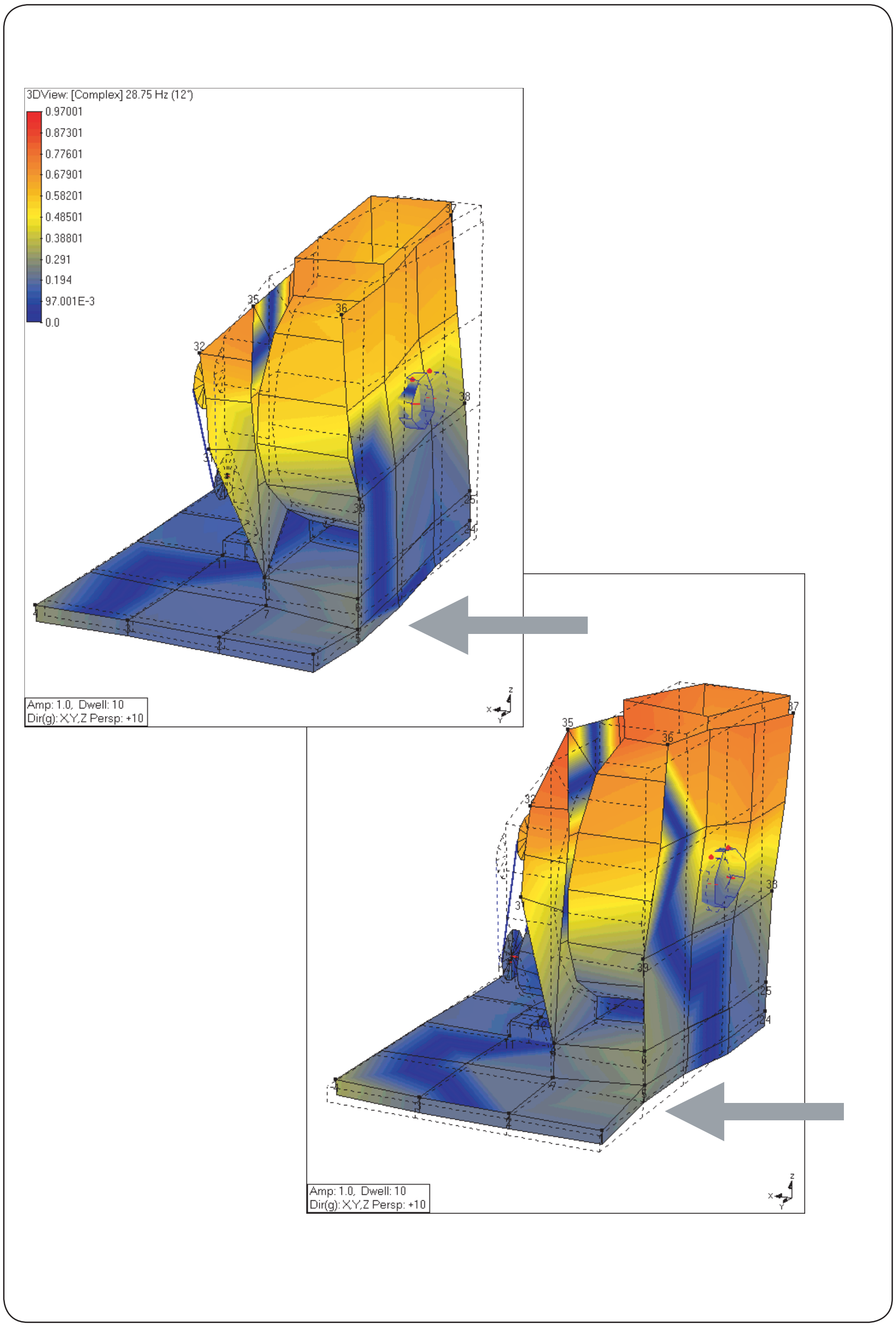

Fig. 4. Animation shapes at 1x r/min of fan.

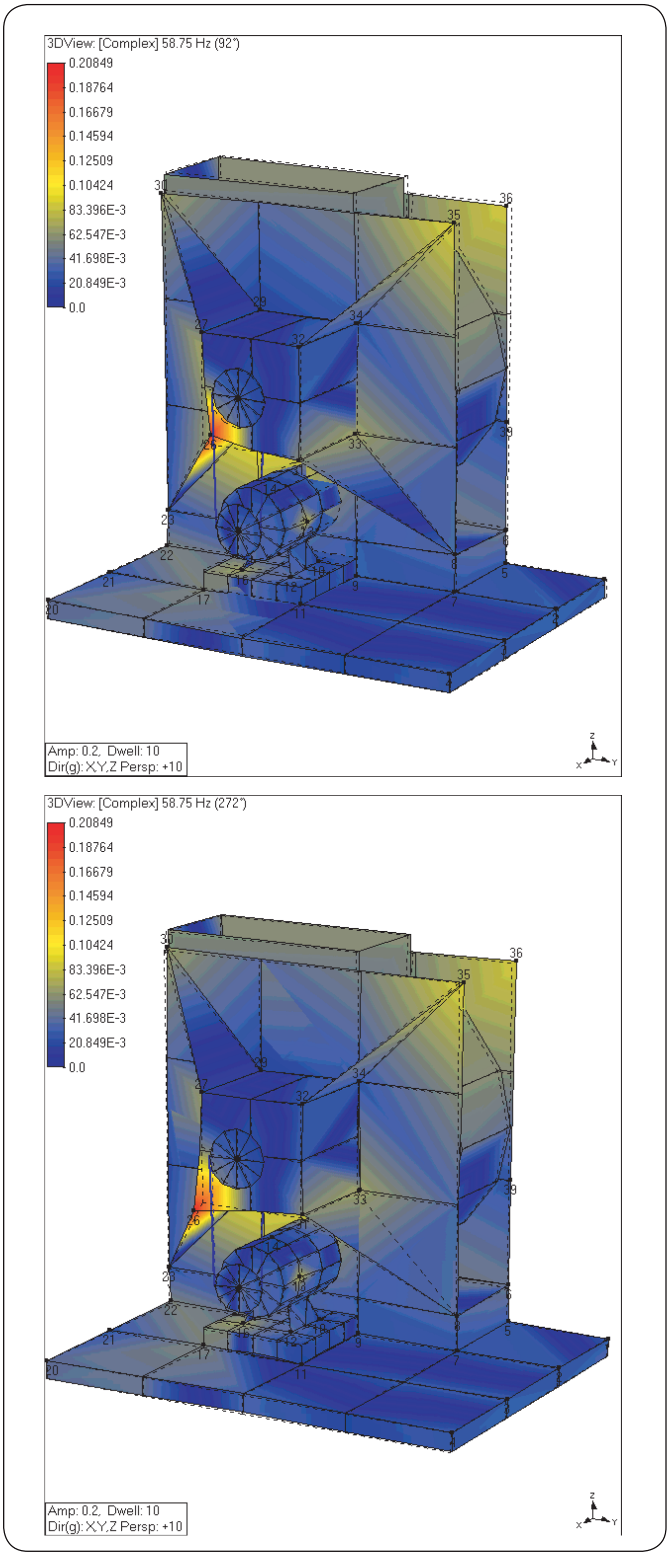

Fig. 5. Animation shapes at 2x r/min of fan.

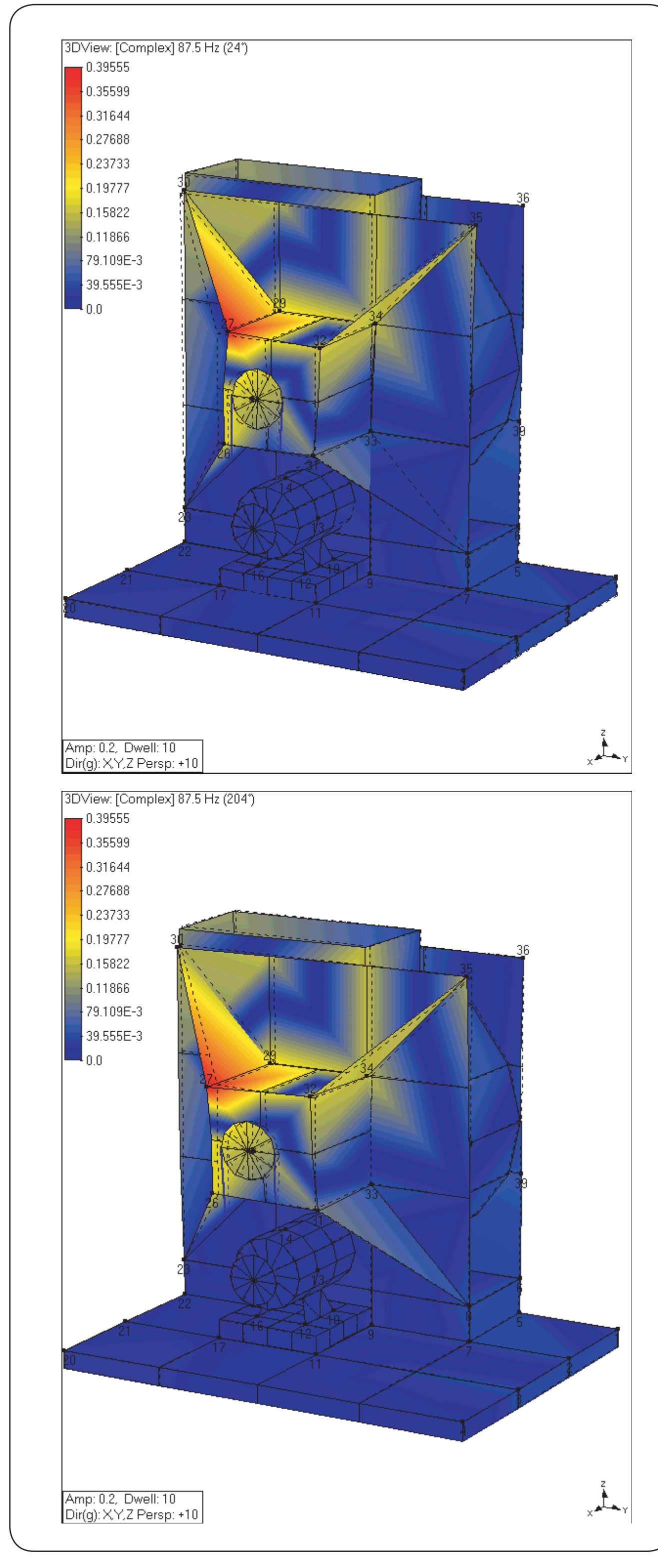

Fig. 6. Animation shapes at 3x r/min of fan.

The most powerful component of Operating Deflection Shape Analysis is that it is predominantly **visual**. Of course a series of vibration spectra are collected and can be reviewed by the analyst, but it is the animation that provides that greatest impact. Animations allow the interpretation of hundreds of measurements simultaneously at specific fault frequencies. The visual presentation through animation movies allow vibration concepts to be easily recognized up and down the management chain.

Along with a complete series of machinery animations, the customer is provided a detailed diagnostic report with conclusions and recommendations that can be a stand-alone guide for vibration reductions, or information that can complement the internal diagnostic investigation within the plant.

The future of vibration analysis is sure to continue to change with leaps and bounds, but current capabilities are available now to enhance your vibration program. You may not have the expertise for advanced analysis, but you likely have the required tools to perform the tasks (if not with a little help).

Operating Deflection Shape Analysis and Experimental Modal Analysis are the logical next steps in the evolution of the Level II Vibration Analyst. The concept of a virtual analyst to help you along the way may be your best on-the-job training option.

Biography

Dan Ambre, P.E. is a Mechanical Engineer and founder of Full Spectrum Diagnostics, PLLC, a full service predictive maintenance consulting company. Dan specializes in resonance detection, Experimental Modal Analysis and Operating Deflection Shape machinery diagnostics. Full Spectrum Diagnostics provides vibration analysis level I, II and III training and certification, as well as training in advanced diagnostic techniques. Dan is a certified software representative for Vibrant Technology, Inc., the creators of MEscope VES and SKF Machine analysis tools. He also provides MEscope software training targeting the in-plant vibration analyst. Please visit his web site at www.fullspec.net, or email him at modalguy@aol.com.

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Jerry Bryant is currently a Millwright and Level II Vibration Analyst with Honeywell FM & T, Kansas City, Missouri. He has over 30 years of combined maintenance experience from the US Navy, the paper, aluminum and fiberglass industries. His four years of vibration experience are with SKF products, and he has been performing Operating Deflection Shape analysis on machinery for just over one year.

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