Improving SRTD Testing with Resonance Phase Settings

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The use of automatic phase/frequency control for sine resonance track-and-dwell (SRTD) tests is proposed. the technique makes fatigue tests consistent with real-life excitations.

Traditionally, when test engineers performed SRTD tests, they have controlled the frequency of the resonance with little concern for its phase. There is some good reasoning to this. Since a resonance occurs when a material's vibrations are reinforced (constructive interference) by the "reflected" waves in the material, it can be assumed that the ideal phase value for a resonance is 90º. Consider a cantilever beam fastened to a shaker on one end; other end perhaps with a mass attached is free to vibrate in its fundamental mode. The end of the beam is at its peak amplitude, while the shaker head is at its equilibrium position (see Figures 1 and 2). Therefore, controllers would often set the default phase setting for a resonance to 90º.

In reality, however, this theoretical phase value of 90º could be different. The phase value may be affected by the location of the accelerometer or due to a lag in the mesurement instrumentation. When these real-life factors are considered, the test engineer should be concerned about the phase value of the resonance.

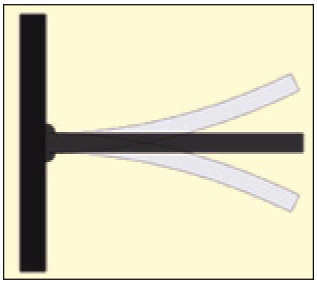

Figure 1. Resonating cantilevered beam – profile.

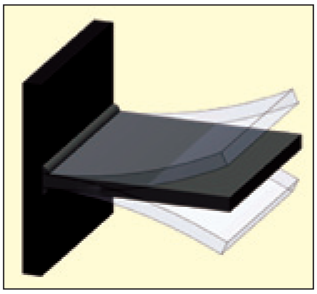

Figure 2. Resonating cantilevered beam – 3D.

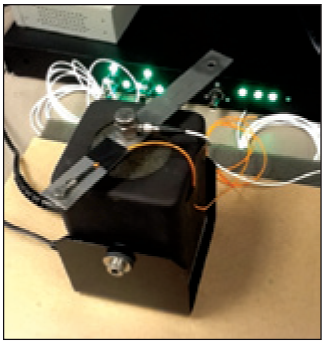

Figure 3.Tear-drop accelerometer attached to beam's "short arm."

In addition, there is a significant difference between how a fatiguing product affects frequency-tracking versus phase-tracking tests. When a product begins to fatigue, the frequency values of its resonances will decrease, but the phase values for the resonances will not. So if one uses frequency-tracking SRTD, then when the product begins to fatigue, the test will no longer be dwelling at the resonance of the product, because that resonance value has changed. But if one uses phase-tracking SRTD, when the product begins to fatigue, the test will continue to maintain the same phase but allow the frequency value to adjust to the changing resonant frequency of the product. Therefore, phase-tracking is advantageous, since it allows the test's frequency value to match the changing resonant frequency.

For these two reasons (real-life phase values are not always 90º; and phase-control allows the test frequency to match the changing resonant frequency of the product) test engineers ought to consider utilizing a phase-tracking control method for SRTD tests.

Vibration Research has developed a method that allows the test engineer to manually select and automatically track the phase value to produce the maximum transmissibility value at a particular resonance (the transmissibility value is the value that gives the most damaging acceleration to the product). This method is advanced user-defined SRTD phase-tracking control.

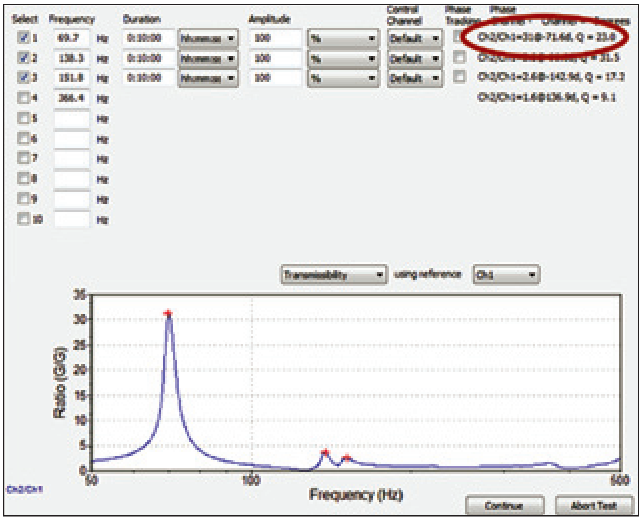

Figure 4. Resonance table for metal beam (long arm), showing fundamental resonance at 69.7 Hz with peak transmissibility of 31 G/G and a phase of –71.6º.

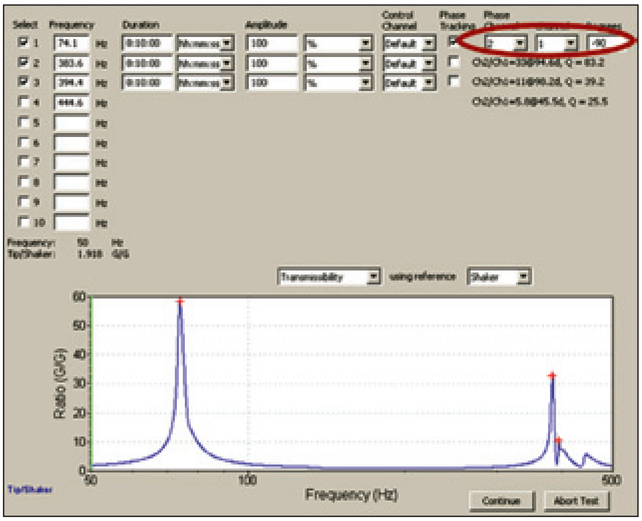

Figure 5. Phase-tracking setting selected for lawnmower blade test; phase is automatically set to 90º.

Resonance Tracking Methods

There are a few options available to the test engineer for sine-resonance, track-and-dwell testing. To understand these options, consider a swept-sine test that was conducted on a thin metal beam where acceleration was measured at the end of the beam (Figure 3).

In this case, a resonance table was produced from the swept-sine test indicating that the fundamental mode of the long arm had a resonance at 69.7 Hz, where the measured transmissibility value was 31 G/G, and the measured phase was –71.6º (Figure 4).

Phase-Tracking: 90º Default. Since the theoretical phase of a linear spring-mass system is 90º, many controllers will set the

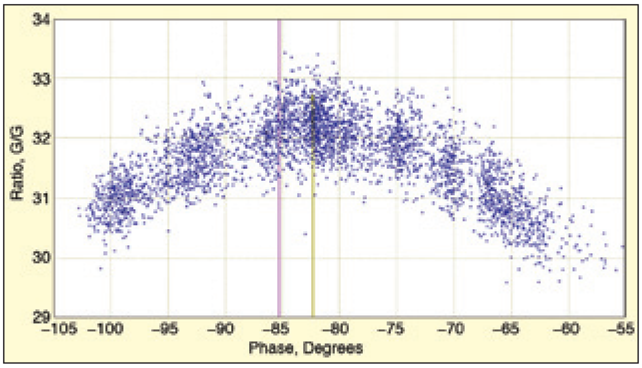

Figure 6. Transmissibility metal beam tip (long end of beam) to shaker head vs. phase of resonance. Standard SRTD predicts a phase of –71.6º (peak transmissibility of 31 G/G) and the phase tracking sets phase to default of –90º; meanwhile, a new feature, advanced user-defined SRTD phase-tracking control, allows adjusting phase to –82.5º to obtain the true peak transmissibility (32.4 G/G).

Figure 7: Thin metal beam attached to shaker.

Figure 8: Lawnmower blade attached to large shaker.

phase automatically to 90º. With Vibration Research's VibrationVIEW software, the test engineer can choose to set the phase automatically to 90º by clicking on the "phase-tracking" checkbox (Figure 5). In this case, the SRTD test will lock the phase to 90º and allow the resonance frequency to drift slightly as the test proceeds to dwell at the resonant frequency.

Resonance Frequency Track-and-Dwell Using the Measured Phase Value. Commonly in SRTD testing, the test engineer will control the resonance frequency (resonance track), since it is important to test the product *at* its resonance frequency. In this case, the controller tries to accurately measure the phase of the resonance during the swept-sine test. This measured value (example, –71.6º) is recorded in the resonance table (Figure 4). This measured value, however, may not be entirely accurate. The inaccuracies are due mostly to the lag in measurement instrumentation. Therefore, the phase results from one swept sine may differ (sometimes significantly) from the phase results of a different swept sine.

Table 1 shows a series of swept-sine tests that were conducted where very similar resonance frequencies and transmissibility values were produced, but the phase values were quite different

Table 1. Results of variety of swept-sine tests on thin metal beam; note variability of measured resonance phase.

Sweep Method	Sweep Rate, oct/min	Resonance, Hz	Resonance Transmissibility, G/G	Resonance Phase, °
Up	3	70.6	32	–91.5
Up	3	70.8	32	–101.0
Up	3	70.5	32	–79.1
Up	3	70.6	32	–90.3
Up	3	70.5	32	–79.7
Up	3	70.6	32	–89.9
Up	3	70.8	32	–102.9
Up	3	70.6	32	–89.6
Up	3	70.6	32	–88.4
Up	3	70.5	32	–78.9
AVG	3	70.61	32	–89.22
STDEV	0	0.110	0	8.53

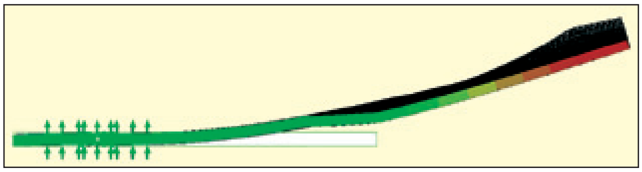

Figure 9: CAD display of lawnmower blade.

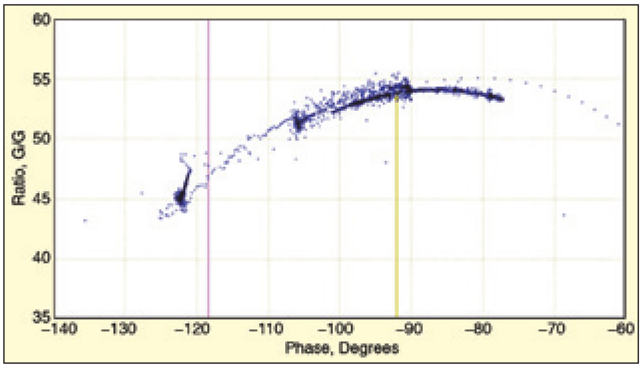

Figure 10: Screenshot of VibrationVIEW software showing use of advanced user-defined SRTD phase-tracking control to obtain higher peak transmissibility; peak transmissibility occurs around –90º and not the predicted –105º.

(see Table 1 – 8.53 degree variance in sweeps). If the test engineer desires to dwell at a specific resonant frequency, then this technique is commonly used even though the measured phase value may be off from the true phase value. In addition, this method dwells at a particular frequency with the goal of meeting the resonant frequency. However, the resonant frequency may change slightly as the product fatigues.

Manual Phase-Tracking Control. In the "metal beam" test example, the actual phase of the resonance that produced the peak transmissibility was not the default value (–90º) or the predicted value by the software (–71.6º). As can be seen in Figure 6, the *peak* transmissibility was a completely different value (–82.5º).

Since the true phase of the resonance may not be the default value of 90º, a test engineer may not want to use Option 1: phase-tracking at the default value. Since the resonance frequency of the test product may change as it fatigues, it may not be desirable to conduct SRTD testing by using Option 2: resonance frequency track-and-dwell while using the measured phase value. With Vibration Research's newest VibrationVIEW software, the test engineer will be able to adjust the phase value during the test to help obtain the highest peak transmissibility. This method is valuable because it allows the test engineer to dwell at a resonance using the correct phase value while allowing the frequency value to adjust slightly for changes that occur in the product's resonance as it fatigues.

Metal Beam and Lawnmower Blade Tests

The effect of *phase tracking* on the peak transmissibility can be shown from experimental results. One test conducted on a simple product was the "thin metal beam" test (Figure 7). Resonance data were collected from both the "short arm" and the "long arm." A second test was conducted on a more complex beam – a lawnmower blade that had a twist in the beam (Figures 8 and 9). The lawnmower blade was specifically chosen because it resembles a "turbine blade," an object that tends to be a nonlinear system.

Experimental Results

Thin Metal Beam. When the advanced user-defined SRTD phase-tracking method was used with a thin metal beam, the phase was manually adjusted to –82.5º. The SRTD test then dwelt at that phase value, applying to the product a peak transmissibility of 32.4 G/G. The resonant frequency-tracking method would have set the resonant frequency to 69.7 Hz and would have dwelt there with a phase value of –71.6º. This would have produced approximately a peak transmissibility of 31 G/G. The advanced user-defined SRTD phase-tracking method gives approximately a 4.5% increase in the peak transmissibility value compared to the resonant frequency-tracking method (see Figure 6).

Lawnmower Blade. When the advanced user-defined SRTD phase-tracking method was used with the lawnmower blade, the phase was manually adjusted to –92°. The SRTD test then dwelt at that phase value (resonant frequency of 71.6 Hz). At this phase setting and frequency setting, the product experienced a peak transmissibility near 54 G/G. The *resonant frequency-tracking* method would have set the resonant frequency to 72.5 Hz and would have dwelt there with a phase value of –105°. This would have produced approximately a peak transmissibility of 51 G/G. The advanced user-defined SRTD phase-tracking method gives approximately a 5.9% increase in the peak transmissibility value compared to the resonant frequency-tracking method (Figure 10).

Conclusions

Consequently, the results of these tests indicate that the test engineer ought to manually control the SRTD phase-tracking to find the most accurate location for the peak transmissibility of a resonance. To obtain a phase of the resonance that will provide the highest possible transmissibility level for that resonance, the test engineer should use a manual control feature to "tweak" the *phase* as necessary to obtain the highest possible transmissibility level for that resonance.

This will serve as an improvement over the traditional phase-tracking tool or the resonant frequency-tracking method. A new add-on feature from Vibration Research in its VibrationVIEW Software (Version 11) is the advanced user-defined SRTD phase-tracking control that allows the test engineer to *manually* find the peak transmissibility at a particular resonant frequency by adjusting and controlling the phase value.

Test engineers would benefit from using Vibration Research's VibrationVIEW software with the add-on feature, advanced user-defined SRTD phase-tracking control, to conduct the most precise test that maximizes the transmissibility value. S|V

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