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Measured Hammer-Tap Inputs

An instrumented hammer test does not require an idealized single half-sine waveform. When the complete force and response are measured accurately, crest ripples and separated contacts remain known inputs. Force shape changes excitation, but does not inherently invalidate the record. Adequacy depends on measurement accuracy, bandwidth, signal-to-noise ratio, and coverage of the test objective.

Background: What the Hammer Actually Measures

Hammer tests support modal analysis [2–4] and can precede pyroshock testing [6]. Figure 1 compares a half-sine, maintained-contact rippling, and separated contacts. During a zero-force interval, the structure continues to vibrate; re-contact acts on that vibration.

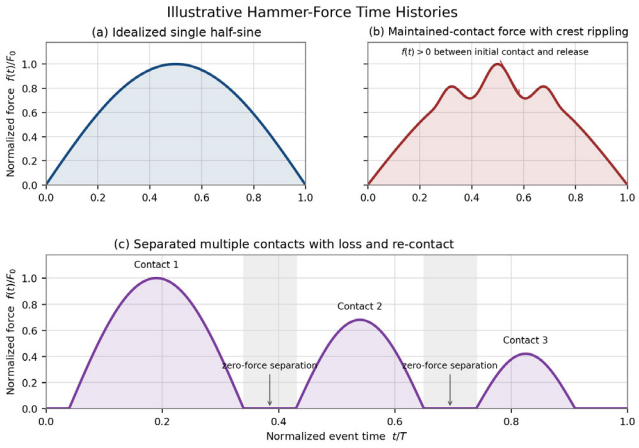


Figure 1. Illustrative force histories (not test data): (a) half-sine; (b) maintained contact; (c) separation and re-contact.

Issue: Waveform Appearance Is Not a Validity Criterion

The general governing equation which includes $g(x, \dot{x})$ that represents nonlinear stiffness, damping, friction, joint slip, gaps, or contact accepts measured force f(t) without a halfsine requirement. Set g = 0 for a linear structure; its response follows by convolution. For a nonlinear structure, integrate continuously through all contacts, retaining displacement and velocity [5].

$$\mathbf{M}\,\ddot{\mathbf{x}}(t) + \mathbf{C}\,\dot{\mathbf{x}}(t) + \mathbf{K}\,\mathbf{x}(t) + \mathbf{g}(\mathbf{x}, \dot{\mathbf{x}}) = \mathbf{b}\,\mathbf{f}(t)$$

If an exact model and test article receive the same force and initial conditions, uniqueness gives identical responses for each bounded measured history. An approximate model can show different errors as inputs excite different frequencies, amplitudes, or nonlinear states. See [1] for the exact-model derivation.

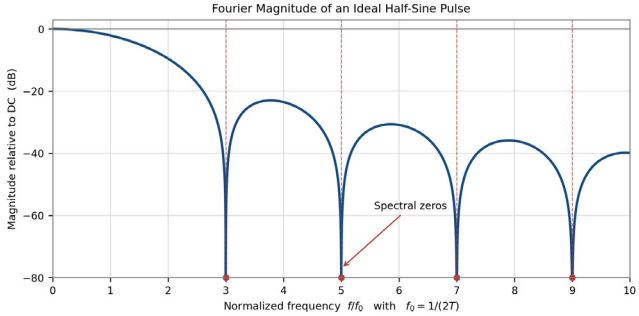


Figure 2. Ideal half-sine Fourier magnitude normalized to DC; zeros are inherent to the pulse.

Analysis: A Half-Sine Is Broadband, but Not Flat

Figure 2 shows that a finite half-sine is broadband but contains spectral zeros at $f/f_0 = 3, 5, 7, \ldots$, with $f_0 = 1/(2T)$ for pulse duration T. Its appearance alone cannot establish adequate excitation.

Analysis: Spectral Content Is Determined by the Measured Force History

Figure 3 normalizes each spectrum to its own DC value. Crest rippling adds content and can fill half-sine notches. Timing between separated contacts creates deterministic interference. For adequacy, inspect the unnormalized measured spectrum and response signal-to-noise ratio.

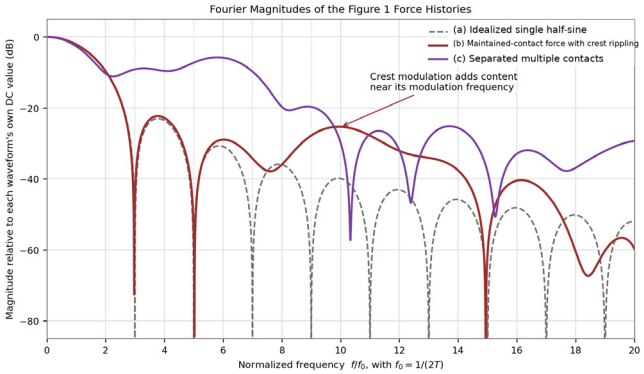


Figure 3. Spectra of Figure 1 histories; pulse shape and contact timing determine their peaks and notches.

Recommended Practice: Evaluate Test Adequacy Against the Intended Objective

- Measure the complete applied force with adequate bandwidth, calibration, dynamic range, and time synchronization.
- Verify that the response measurements have adequate bandwidth and signal-to-noise ratio and are not clipped or saturated.
- Confirm that the excitation covers the frequency, amplitude, and nonlinear-response ranges required by the intended test objective.
- Reject or repeat a test only for an identified measurement, excitation, or coverage deficiency.

Conclusion

Half-sine appearance neither establishes validity nor guarantees adequacy. Judge each hammer test by its purpose and by accurate, complete force and response measurements over the required range.

References

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