Amplitude Linearity Measurement and Damped Accelerometer

Technical Paper 343

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Amplitude linearity is a measure of how linear the output of an accelerometer is over its specified amplitude range. It is sometimes called amplitude non-linearity, since it specifies the deviation from perfect linearity. Manufacturers of accelerometers typically rely on several methods to measure non-linearity of the device. Here are three commonly used test apparatus and their physical characteristics:

1. Static Method - Centrifuge

- This is applicable only to accelerometers with DC response
- Test under static condition (one-sided loading)
- Input level is very accurate and controllable
- Max g level is only limited by the speed of the centrifuge
- Excitation frequency is at zero Hertz (static)

2. Sinusoidal Method - Electrodynamic shaker (suitable for only lower range devices)

- Excitation frequency is at zero Hertz (static)
- Test under dynamic condition (positive and negative loading)
- Input level is repeatable and controllable
- Max g level limited by the shaker (typically no more than 100 g)
- Excitation frequency is shaker dependent

3. Impulse Method - Pneumatic driven projectile (suitable for higher range devices)

- This is applicable to accelerometers with AC or DC response
- Test based on an impulse (one-sided loading)
- Input level is not well controlled
- Max g level limited by the velocity and the weight of the projectile
- Excitation frequency is dependent on the pulse width of the impact and the shape of the contact patch

With a typical accelerometer (undamped), measuring non-linearity by any of the above test methods is feasible due to the broad frequency response of an undamped design (Figure 1). In testing higher range accelerometers, impulse method is typically used due to its high acceleration capacity. However, with a damped accelerometer of higher g range (>100g), the use of impulse method may present a practical challenge because of its inherent high frequency roll-off (Figure 2).

Figure 1
Frequency response of an undamped accelerometer

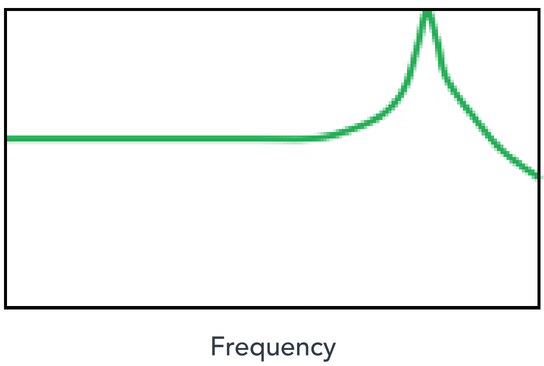
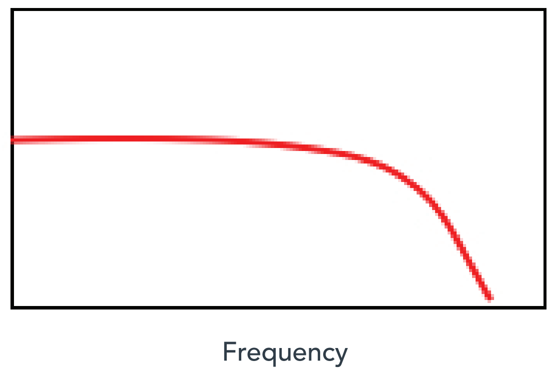


Figure 2
Frequency response of a damped accelerometer



To understand why this may be a problem in measuring non-linearity. Let's first look at the input characteristics of the impulse method. The physical construction of the impulse shock machine, typically a pneumatic driven projectile, determines the amount of energy available. The shock pulse is a function of the amplitude (g) and pulse duration (t). The maximum area under the pulse curve is fixed by the available energy of the machine. In other words, a machine can either produce higher g with short pulse duration or lower g with long pulse duration. To do both will require an impulse machine that is huge in size and complexity.

Figure 3 shows a typical input waveform created by a pneumatic driven projectile. At lower shock level (<1,000g), the pulse width is relatively long. Its frequency spectrum can be illustrated in Figure 4.

Figure 3
Time history of a lower level shock pulse

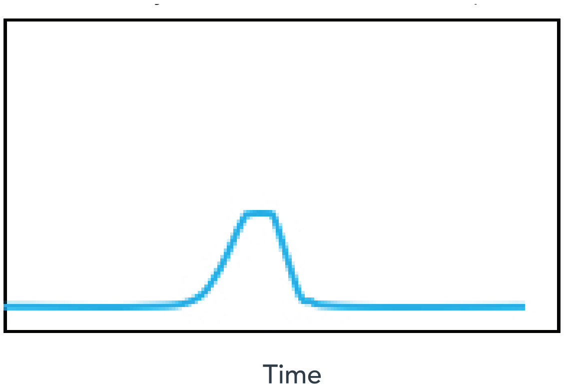


Figure 4
Frequency spectrum of a lower level shock pulse

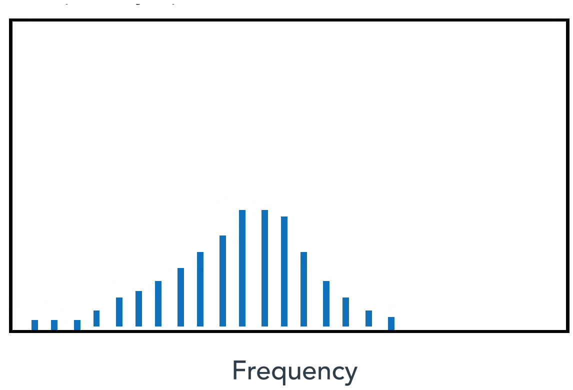
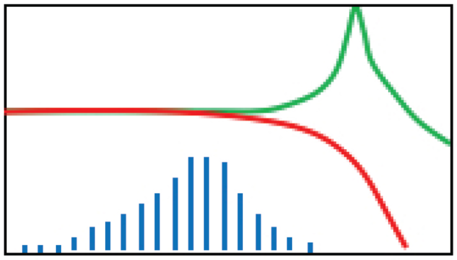


Figure 5
Bandwidth of accelerometers and input spectrum

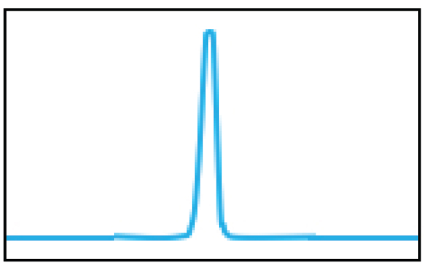


Frequency

Both damped and undamped accelerometers have the necessary bandwidth to handle all the frequency components produced by such a lower level impulse, as illustrated in Figure 5.

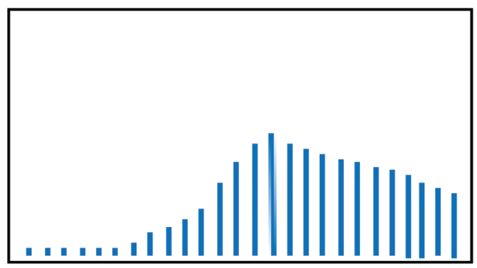
As the shock level of the impulse shock machine increases, the pulse width gets much shorter and its rise time faster. Figure 6 and 7 show the time and frequency spectrum of a higher level shock pulse.

Figure 6
Time history of a higher level shock pulse



Time

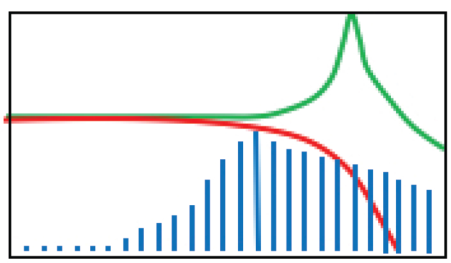
Figure 7
Frequency spectrum of a higher level shock pulse



Frequency

At higher g level, the shorter duration pulse contains much more high frequency components due to its fast rise time. In this case, the broad bandwidth of the undamped accelerometer still has no problem measuring the high frequency energy whereas the damped accelerometer, because of its higher frequency roll-off, is not able to capture all the higher frequency components. This is illustrated in Figure 8.

Figure 8
Bandwidth of accelerometers and input spectrum



Frequency

Conclusion
When the non-linearity measurement of a damped accelerometer is conducted using an impulse method, results may suggest that the accelerometer started to get non-linear at higher g levels. However, in fact, it was due to measurement errors caused by the limited bandwidth of the accelerometer. Therefore, to accurately measure the non-linearity of a damped accelerometer, a high-g centrifuge should be used where the frequency response of the accelerometer will not be a factor in the accuracy of the measurement. The test should be conducted in both positive and negative directions in order to get a complete picture of the non linear behavior of the sensor.

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