EDITORIAL

MIL-STD-810G, Change 1 Accelerometer Requirements for Shock*

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For decades accelerometer manufacturers have published specifications for accelerometers that are intended for mechanical shock measurement that includes, but is not limited to, transportation shock, pyroshock, ballistic shock, gunfire shock and other new types of shock for combined transportation and ballistic shock. The accelerometer specifications are based on low-level (10 g or other low-level) vibration sine sweeps. Additionally, the specification or calibration information is shown on plots that appear to have a linear ordinate scale that has units of decibels, a logarithmic quantity. Consequently, those experienced in shock measurement and shock measurement development have learned that for many manufacturers "an accelerometer specification document is a sales document," and not an accurate representation of accelerometer performance.

MIL-STD-810G was issued in 2008 (available for free download on the internet), and, shortly after its publication, a consensus developed in the MIL-STD-810G committee, specifically the shock subject matter experts (SME): Method 516 for Shock (SME Mike Hale, Redstone Test Center), Method 517 for Pyroshock (SME myself), Method 519 for Gunfire Shock (SME, Ron Merritt, formerly of Naval Air Warfare Center, China Lake) and Method 522 for Ballistic Shock (SME Scott Walton, Aberdeen Test Center), that accelerometer requirements had to be addressed in MIL-STD-810G, Change 1. In addition, aliasing and other signal conditioning requirements are also addressed in Change 1 as described in my editorial in the March 2013 S&V.

As an aside, the SMEs who develop the requirements for MIL-STD-810, are considered world-wide leaders in environmental testing. MIL-STD-810 is adopted virtually verbatim by NATO countries, and MIL-STD-810 SMEs participate in NATO standards meetings. In general, the SMEs for the shock standards have 30 years or more experience each in research and development in their respective areas of shock measurement and data analysis. The following paragraphs summarize the new requirements for shock accelerometers and other instrumentation in MIL-STD-810G, Change 1.

In the Instrumentation section of Methods 516 and 517, general accelerometer requirements are given. The material below summarizes these requirements. In most cases, acceleration will be the quantity measured to meet a specification, with care taken to ensure acceleration measurements can be made that provide meaningful data.[1,2] For pyroshock measurements in and close to the near field, loss of measurement system integrity is not unusual. On occasion, more sophisticated devices may be employed, e.g., a laser Doppler vibrometer. In these cases, special consideration to the measurement instrument amplitude and frequency range specifications are made to satisfy the calibration, measurement and analysis requirements. With regard to measurement technology, accelerometers, strain gages and laser Doppler vibrometers are commonly used devices for measurement.

In processing shock data, it is important to be able to detect anomalies. For example, it is well documented that piezoelectric (PE) accelerometers offset or zeroshift during mechanical shock, pyroshock, and ballistic shock,[1-4] but unfortunately accelerometer manufacturers continue to recommend PE accelerometers (with or without mechanical isolation) for all types of shock. This recommendation defies 45 years of shock measurement technology and knowledge.[1-4] A part of this anomaly detection is the integration of the acceleration amplitude time history to determine if it has the characteristics of a high-frequency velocity trace and the physics of the test environment without further filtering or other manipulation of the data. In addition, instrumentation to measure test item function may be required. In this case, it is obtaining suitable calibration standards and adhering to them.[5,6]

For accelerometers further requirements are to ensure amplitude linearity: It is desired to have amplitude linearity within 10%, from 5% to 100% of the peak acceleration amplitude required for testing. Also, in response to manufacturer's comments about MIL-STD-810 requirements, the MIL-STD-810 has addressed their comments with the following requirements.

Since mechanically isolated PE accelerometers also show zeroshift, there is risk to not characterizing these devices at 5 percent of the peak amplitude. To address these zeroshifts, high-pass filtering (or another data correction technique) may be required. Such additional post-test correction techniques increase the risk of distorting the measured shock environment and are not recommended.

It is recognized that almost all mechanically isolated accelerometers have both non-linear amplification and non-linear frequency content below 10,000 Hz. To understand the non-linear amplification and frequency characteristics, it is recommended that shock linearity evaluations be conducted at intervals of 20 to 30% of the rated amplitude range of the accelerometer to identify the actual amplitude and frequency linearity characteristics and usable amplitude and frequency range. To date, manufacturers publish characteristics of these devices based on models, vibration sweeps, or long duration shock pulses;[7] the MIL-STD-810 committee has placed a requirement on time domain shock pulse durations and the corresponding frequency domain representations. The shock pulse duration for the evaluations is specified by a calculation as:

$$T_D = \frac{1}{2f_{max}}$$

where T_D is the duration (baseline) of the acceleration pulse, and f_{max} is the maximum specified frequency range for the accelerometer. For near-field pyroshock, f_{max} is 100,000 Hz. For mid- and far-field pyroshock as well as mechanical shock in Method 516, f_{max} is 10,000 Hz. If Hopkinson bar testing is used for these evaluations, then care must be taken to ensure that a non-dispersive pulse duration is used.[5] In absence of techniques for addressing 100,000 Hz characterizations and considering duration limitations associated with non-dispersive reference requirements, a Hopkinson bar, with for example a 0.75-inch diameter, may be used with a 20-microsecond reference pulse. The roll-off in frequency response of this greater-than-nominal duration reference must be considered in evaluating linearity. The requirements for shock amplitude and duration are subject to the usual shock tolerance requirements of ±15%. In addition, it is recognized that the lower limit for Hopkinson bar testing is usually 5,000 g. Therefore, to span the full accelerometer range as defined above, it may be necessary to use more than one calibration apparatus; i.e., a drop-ball calibrator as well as a Hopkinson bar. To correlate the physical parameters of a shock test with an accelerometer measurement (by integration of the acceleration), response below 2 Hz is required, and a PR accelerometer measurement is required.

Additionally, a flat response within ±5% across the frequency range of interest is required. Since it is generally not practical or cost effective to conduct a series of varying pulse width shock tests to characterize frequency response, a vibration calibration is typically employed. For the case of a high-range accelerometer with low output, there may be signal-to-noise issues associated with a low-level vibration calibration. In such cases, a degree of engineering judgment will be required in the evaluation of frequency response.

The sensitivity of a shock accelerometer is expected to have some variance over

*Scheduled for Publication 15 April 2014 its large-amplitude dynamic range. If the sensitivity is based on the low-amplitude vibration calibration, it is critical that the linearity characteristics of the shock-based amplitude linearity be understood so that an amplitude measurement uncertainty is clearly defined. Ideally, vibration calibration and shock amplitude linearity results should agree within 10% over the amplitude range of interest for a given test. Transverse sensitivity should be less than or equal to 5%. The measurement device and its mounting will be compatible with the requirements and guidelines provided[8] and other manufacturer's requirements.

Unless it is clearly demonstrated that a PE accelerometer (mechanically isolated or not) can meet the mechanical shock and pyroshock requirements and is designed specifically for a one-sided shock pulse and oscillatory shock, respectively, PR accelerometers shall be used for high-intensity pyroshock events. PE accelerometers may be used in scenarios in which levels are known to be within the established (verified through calibration) operating range of the transducer, thereby avoiding non-linear amplification and frequency content.

Additional requirements are necessary for pyroshock measurement, especially near-and mid-field pyroshock. Slew rate specifications for signal conditioning and data acquisition systems are also important because slew rate contamination can alter the low frequency content of the data, add erroneous frequency content and become part of an erroneous specification. To prevent distortion caused by spurious electrical noise, the data recording instrumentation shall be capable of recording a signal of one-half, full-scale voltage in 1 microsecond without slew rate distortion. For example, if a system is capable of +10 volts full scale = 20 volt peak-to-peak, then a slew rate of 10 volt/µsecond is required.

Exceptions to these criteria shall be documented and sufficiently justified to prove that digital aliasing and other contamination of the data has not occurred. A noise gage[8] is required for all pyroshock testing. The shock response spectra for pyroshock data are to be analyzed for the extended bandwidth of 10 Hz to 100,000 kHz (or higher) to examine the low frequencies for data contamination and to ensure the high-frequency content has been captured. An appendix demonstrating common pyroshock data anomalies has been added to Method 517 to assist in the interpretation of pyroshock data.[9]

References

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