EDITORIAL

Pyroshock Testing Update

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Pyroshock testing, also called pyrotechnic shock, may be required for test items, sub-systems, and full-scale systems that must withstand an explosive event, such as an explosive charge to separate two stages in a multi-stage rocket and the resulting high-frequency (thousands of Hertz, even as high as 1 MHz), high-magnitude stress waves that propagate throughout the structure.

Pyroshock was once considered a relatively mild environment due to the low-velocity change and high-frequency content involved. Although pyroshock rarely damages structural members, pyroshock can easily cause failures in electronic test items that are sensitive to the high-frequency pyroshock energy. Since a significant number of flight failures have been attributed to pyroshock compared to other types of shock or vibration sources, the Institute of Environmental Sciences and Technology (IEST) has included pyroshock testing as one of its recommended practices. The existing IEST pyroshock practice is being reviewed and updated, and this editorial discusses some of the proposed changes.

The characteristics of the pyroshock acceleration-time history that should be simulated vary with the distance from the pyroshock event, and the magnitude may be as high as 200,000 g. The magnitude may be even higher, because it is a function of the measurement technique and digital signal processing. Three types of pyroshock have been distinguished in various documents and by various organizations. Although the differences are not always clearly defined for a particular structure, the major differences among the three are proposed for the IEST pyroshock testing recommended practice as defined here in terms of their corresponding test techniques:

- *Near-field pyroshock* – frequency control up to and above 10,000 Hz for amplitudes greater than 10,000 g. A pyrotechnically excited simulation technique is usually appropriate, although in some cases, a mechanically excited simulation technique may be used.
- *Mid-field pyroshock* – frequency control from 3,000 Hz to 10,000 Hz for amplitudes less than 10,000 g. A mechanically excited simulation technique other that shaker shock is usually required.
- *Far-field pyroshock* – frequency control no higher than 3,000 Hz for amplitudes less than 1,000 g. A shaker shock or a mechanically excited simulation technique is appropriate.

Other references, such as NASA-HDBK-7003 and MIL-STD-810, Method 517 (available on the internet at no cost), make their own definitions of pyroshock regions. Generally, pyroshock is described by frequency content, acceleration amplitude (g), distance from the pyrotechnic source of the test item and its corresponding structural response. What criteria are acceptable depend on the type of excitation source and numerous parameters. Table 1 gives a general summary of NASA-HDBK-7003 and MIL-STD-810, Method 517, pyroshock definitions as well as the definitions proposed for the IEST recommended practice.

Pyroshock Definitions.

Near-field pyroshock is close to the pyrotechnic source before significant energy is transferred to modal structural response; this type of pyroshock is dominated by propagation from the source and contains very high frequency and very high g-level energy, which is distributed over a wide frequency range and is not generally dominated by a few selected frequencies.

Table 1. Summary of existing and proposed pyroshock definitions.

Document	Region	Acceleleration Amplitude, g	Freq, Hz	Distance from Source Intense S.	Mild S.
NASA HDBK-7003	Near field	>5,000	>100,000	<6 in.	<1 in.
	Mid field	1,000-5,000	>10,000	6-24 in.	1-6 in.
	Far field	<1,000	<10,000	>24 in.	>6 in.
IEST RP Pyroshock Test Tech.	Near field	>10,000	≥10,000	–	–
	Mid field	<10,000	3-10,000	–	–
	Far field	<1,000	≤3,000	–	–
MIL-STD-810 Method 517	Near field	>5,000	>100,000	<6 in.	<3 in.
	Mid field	–	–	–	–
	Far field	1,000-5,000	<10,000	>6 in.	>3 in.

Although the near-field distances given for NASA-HDBK-7003 and MIL-STD-810, Method 517, are undoubtedly useful for the general size of NASA and military structures, respectively, the distances restrict the definitions to particular sizes. For example, the NASA definition of near-field as >5,000 g at 1-6 in. from the source implies a large structure with a great deal of structural damping, because 5,000 g is a very low value for near-field pyroshock.

For example, near-field measurements have been made with redundant instrumentation consisting of an isolated piezoresistive accelerometer and a commercial laser Doppler vibrometer. These measurements show that explosive quantities as small as 5 mg can create accelerations of almost 80,000 g at distances of 1-6 in. for small, cubic structures of about 500 in.^{3}. The NASA-HDBK-7003 document further states "in a good aerospace system design, there should be no pyroshock-sensitive hardware exposed to a near-field environment, so that no near-field testing will be required."

The NASA-HDBK-7003 document includes requirements for structures that are intended for human occupation, and this may be the origin of this near-field restriction. However, designs for unmanned NASA structures or vehicles also follow these restrictions. There are many components in near-field locations for applications other than NASA structures. Some components are deliberately put in the near-field to monitor events occurring during pyrotechnic shock. Near-field pyroshock measurements are now fairly routine, in large part due to advances made in utilizing piezoresistive accelerometers, with and without a resilient mounting (called mechanical filter), and using laser Doppler vibrometers. MIL-STD-810F states that in the near-field of a pyrotechnic device, the structure material stress wave propagation effects govern the response, and if there are no intervening structural discontinuities, the material may be expected to experience peak accelerations in excess of 5,000 g and substantial spectral content above 100,000 Hz. This MIL STD near-field definition also implies a large structure with a great deal of structural damping for the reasons stated above.

Mid-field pyroshock is characterized by a combination of wave propagation and structural resonances. The frequency content of 3-10 kHz can usually be obtained with one of the resonant fixture testing techniques discussed in the IEST pyroshock testing recommended practice and is similar to the NASA-HDBK-7003 definition that is based on measured data instead of testing techniques.

Far-field pyroshock is at a greater distance from the source where: significant energy has transferred into the lower-frequency structural response; contains lower frequency and lower g-level energy than near-field and mid-field pyroshock; and most of the energy is usually concentrated at one or a few frequencies that correspond to dominant structural mode(s). The frequency content of ≤3 kHz can usually be obtained with one of the resonant fixture testing techniques discussed in the IEST recommended practice or a shaker shock.

These proposed definitions of near-, mid-, and far-field pyroshock for the IEST pyroshock recommended practice are intended to provide broader definitions that apply to a wider range of structures and vehicles than the other references cited.

Three new resonant techniques for pyroshock simulation are proposed for addition to the IEST pyroshock testing recommended practice: full-scale tests with a resonant fixture; three-axis pyroshock simulations for mid-field pyroshock; and three-axis pyroshock simulations for near-field pyroshock. For full-scale tests, the pyrotechnic source and a portion of the adjacent structure may be replaced by a resonant plate or fixture designed so that the first mode of the plate or fixture corresponds to the dominant frequency produced by the pyrotechnic device and the associated structure. The resonant plate or fixture should be attached to the test structure in a manner that simulates the mechanical linkage of the pyrotechnic source. When this attached plate or fixture is excited into resonance by a mechanical impact, the response of the plate or fixture should provide the desired input to the test structure. A resonant fixture has successfully simulated three-axis component shock response spectra for frequencies up to 4000 Hz on a full-scale weapons structure weighing 400 lb and also may be used for satellite structures.

All pyroshock resonant fixture simulations described in the existing IEST pyroshock recommended practice require that the test item be attached to the fixture and tested in three separate axes. Also, all pyroshock simulation methods have some cross-axis response in addition to the intended in-axis response, so overtesting routinely occurs. However, in some cases all three axes may be tested with one impact on a thick resonant fixture to simulate mid-field pyroshock or near-field pyroshock. These fixtures must be designed for the specific test requirement and for specific small test items. Time history magnitudes of 1000 to 80,000 g with knee frequencies in excess of 15,000 Hz have been obtained and are demonstrated in the figures of the IEST pyroshock testing recommended practice as both acceleration time-histories and positive and negative shock response spectra calculated in one-sixth octave bands.

Comments?

The author solicits comments from practicing pyroshock professionals on the IEST pyroshock testing recommended practice in its existing form and with the proposed changes and additions described here. These comments may be made at the session to review the IEST recommended practice during the ESTECH meeting in May or directly to the author and chair of the IEST Pyroshock Testing Working Group, Vesta I. Bateman, Mechanical Shock Consulting, Albuquerque, NM. S/V

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