SHOCK AND VIBRATION RESPONSE SPECTRA COURSE
Unit 23. Integration of Accelerometer Data to Velocity

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Introduction

Pyrotechnic shock data is difficult to measure accurately. Saturation effects, which are explained in this report, may degrade the data. A saturated signal must be either discarded or repaired.

The present Unit focuses on diagnosis methods. Future Units will cover repair techniques.

A specific diagnosis technique is to integrate the accelerometer signal to velocity.

A velocity signal which diverges from the zero baseline indicates a poor accelerometer signal.

A velocity signal which oscillates about the zero baseline tends to indicate a good accelerometer signal although, additional criteria must also be satisfied.

Baseline Shift

Numerous problems can affect the quality of accelerometer data during pyrotechnic shock events. A baseline shift, or zero shift, in the acceleration time history is perhaps the most common error source.

Chu notes in Reference 1 that this shift can be of either polarity and of unpredictable amplitude and duration. He has identified six causes of zero shift:

a. Overstressing of sensing elements
b. Physical movement of sensor parts
c. Cable noise
d. Base strain induced errors
e. Inadequate low-frequency response
f. Overloading of signal conditioner.

Accelerometer resonant ringing is a special example of causes "a" and "e.” This is a particular problem if the accelerometer has a piezoelectric crystal as its sensing element.

A piezoelectric accelerometer may have its amplification factor Q well above 30 dB at resonance. This resonance may be excited by high-frequency pyrotechnic shock energy. Resonant ringing causes higher element stresses than expected.

Chu notes that this may cause the signal conditioner to overload, as follows

> When a signal conditioner attempts to process this signal, one of its stages is

> driven into saturation. Not only does this clipping distort the in-band signals momentarily, but the overload can partially discharge capacitors in the amplifier, causing a long time-constant transient.

This overload causes zero shift in the acceleration time history. This shift distorts the low-frequency portion of the shock response spectrum.

Piersol gives criteria for determining whether a signal has a zero shift in References 2 and 3. Briefly, it involves integrating the acceleration time history to obtain a velocity time history. The velocity time history is then inspected for any unexpected net change.

Examples

Good Signal

An accelerometer signal from a pyrotechnic shock test is shown in Figure 1. The acceleration signal oscillates about the zero baseline. This is a good sign, but further analysis is needed to validate the signal.

The velocity time history is shown in Figure 2. The mean value tends to drift in the positive direction with time. The velocity criterion is not met in the ideal sense. Nevertheless, the velocity signal is stable. For practical purposes, the velocity signal is considered good.

The shock response spectra are shown in Figure 3. The positive and negative spectral curves are nearly equal. This agreement completes the signal validation.

Saturated Signal

An accelerometer signal from a separate pyrotechnic shock test is shown in Figure 4. The signal appears well behaved at first inspection.

The velocity time history is shown in Figure 5. The signal clearly diverges from the zero baseline. This divergence represents some form of saturation. For example, the accelerometer's own natural frequency may have been excited.

The corresponding shock response spectra are shown in Figure 6. The positive and negative spectra diverge at certain natural frequencies. For example, the difference is 6.6 dB at 250 Hz.

Comparison

The good signal in Figure 1 had a peak acceleration of 110 G. The saturated signal in Figure 4 had a peak acceleration of 12,000 G. This difference is not coincidental. The probability of saturation tends to be proportional to the input level. The frequency content is also important in this regard.

Data is precious, even if it is saturated. Some filtering or trend removal technique could be used to remove the spurious signal from the saturated accelerometer time history in Figure 4. These techniques will be covered in future Units.

Preventative Solution

An analog lowpass filter can be placed before the first input stage of the signal conditioner to prevent overloading the electronics. Note that this filter can also be used to prevent aliasing, as discussed in previous Units.

A more effective solution, however, is to use an accelerometer which has a mechanical low pass filter. The purpose of this filter is to prevent excitation of the accelerometer natural frequency. The mechanical filter is located between the accelerometer and the measurement surface.

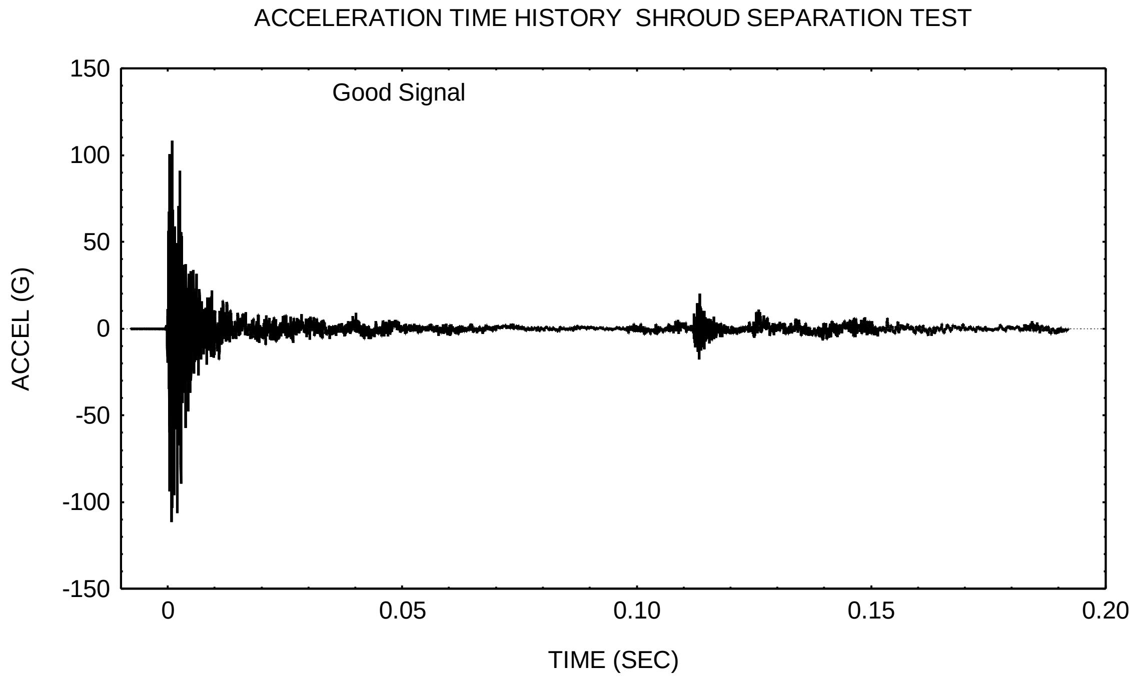

Figure 1.

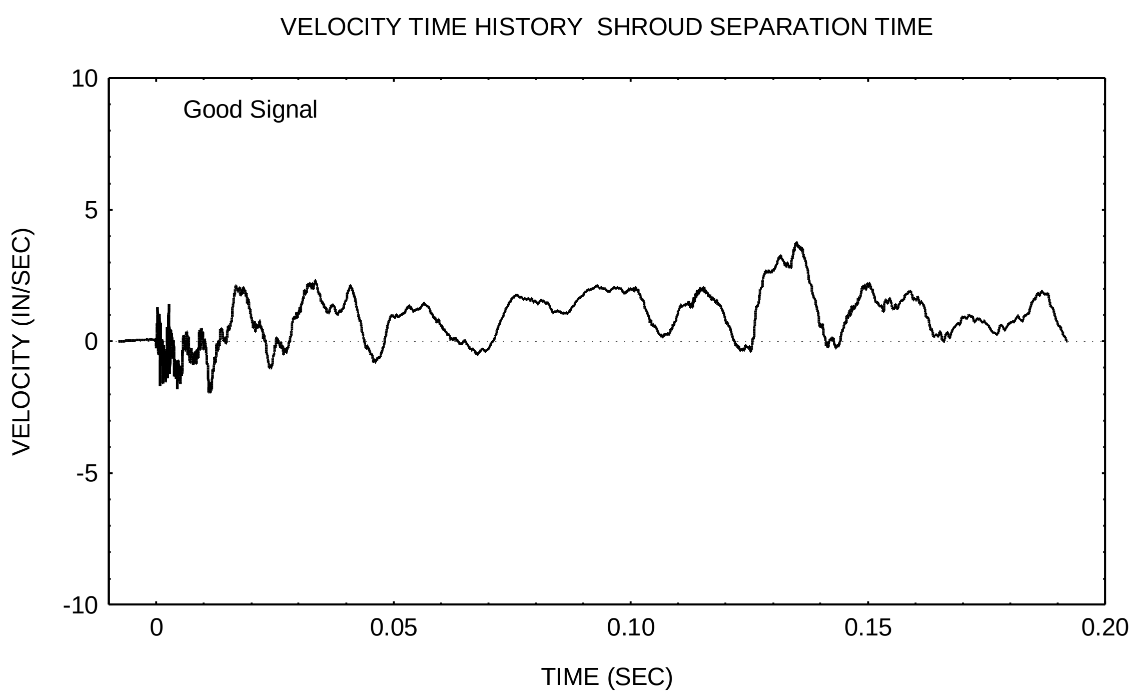

Figure 2.

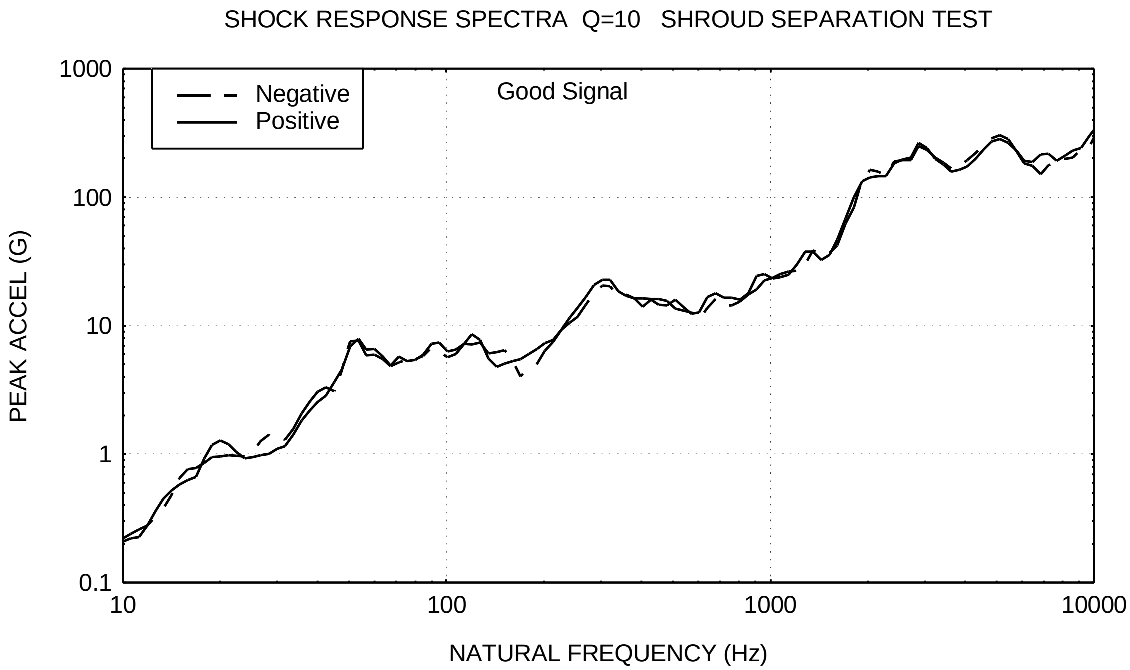
SHOCK RESPONSE SPECTRA Q=10 SHROUD SEPARATION TEST
Negative
Positive
Good Signal
PEAK ACCEL (G)
1000
100
10
1
0.1
10
100
1000
10000
NATURAL FREQUENCY (Hz)

Figure 3.

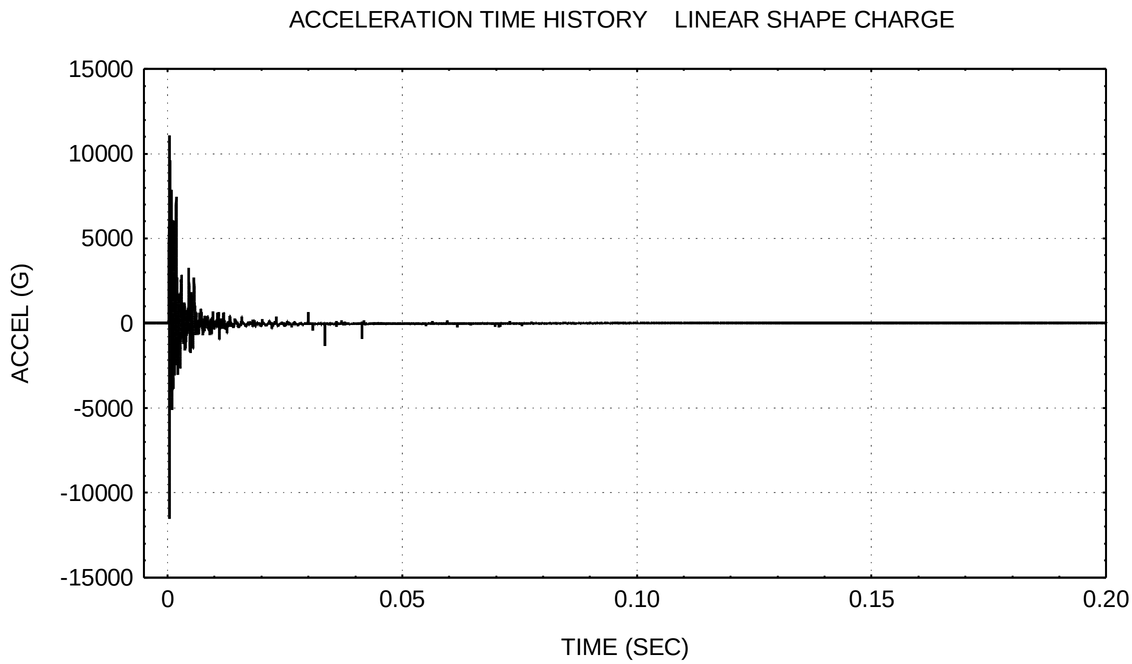

Figure 4.

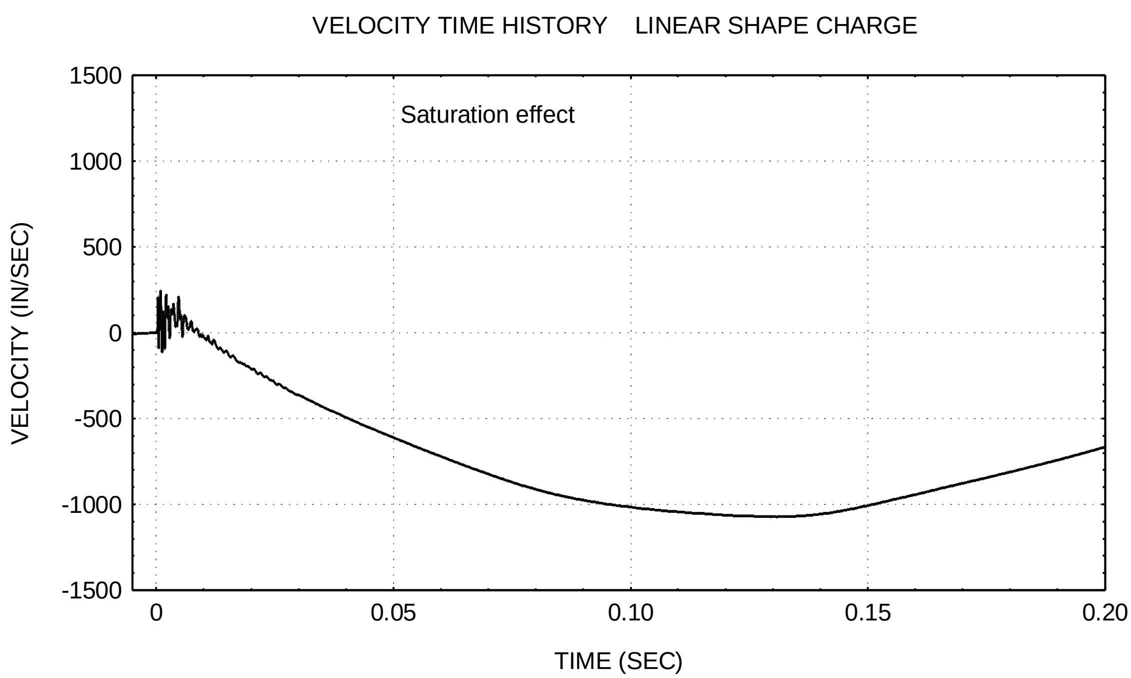

Figure 5.

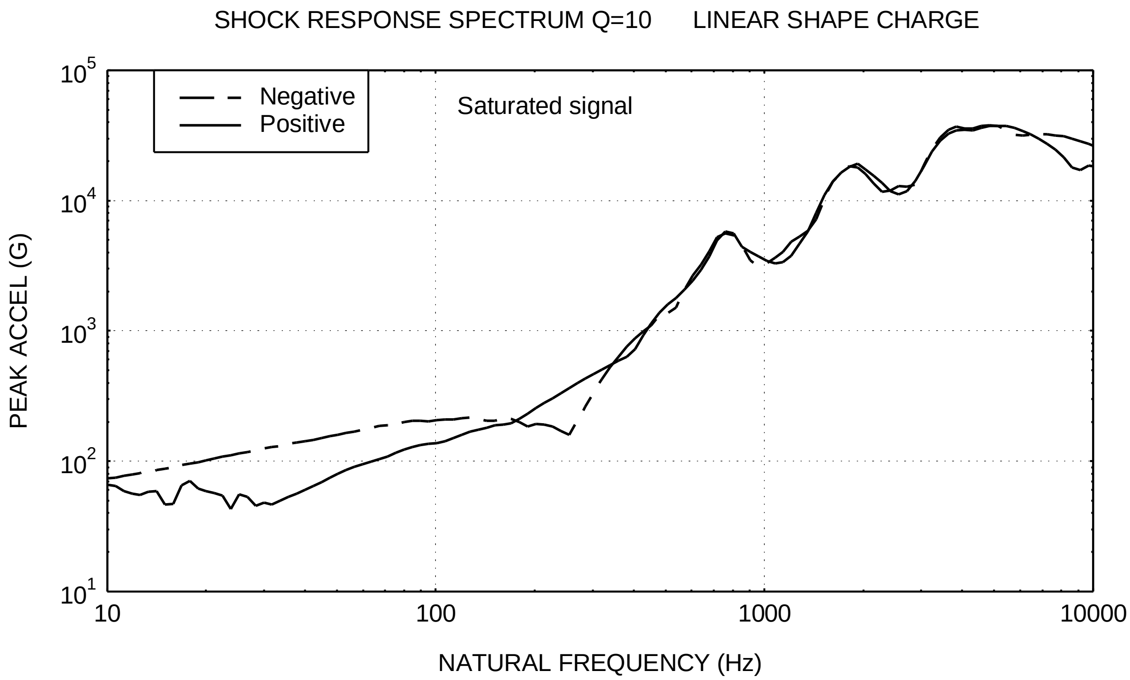

Figure 6.

References

1. Anthony Chu, "Zero Shift of Piezoelectric Accelerometers in Pyroshock Measurements," Paper presented at the 57th Shock and Vibration Symposium, 1986.

2. Allan Piersol, "Pyroshock Data Acquisition and Analysis for U/RGM-109D Payload Cover Ejection Tests NWC TP 6927," Naval Weapons Center, China Lake, CA, 1988.

3. Allan Piersol, "Recommendations for the Acquisition and Analysis of Pyroshock Data," Sound and Vibration; April 1992.

Homework

1. File rv_sep.txt is an acceleration time history with dimensions: time(sec) and accel (G). It represents measured flight data from the re-entry vehicle separation of a suborbital rocket vehicle. Linear shape charge was the source device. The measurement was made near the source. Integrate the signal to obtain velocity. Multiply by a scale factor to convert the amplitude to either (inches/sec) or (meters/sec). Also, calculate the shock response spectrum. Did saturation occur? Note: use programs integ.exe and qsrs.exe from previous Units.