THE EFFECT OF MASS LOADING ON THE SENSITIVITY OF SHOCK ACCELEROMETERS

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1. INTRODUCTION

Mass loading affects the sensitivity of accelerometers. The mass loading effect can be corrected using mass loading correction curves published by manufacturers [1]. These curves, however, are only applicable to the sinusoidal acceleration below 500 m/s^2. The mass loading effect on the sensitivity of accelerometer Endevco 2270 in shock calibration, from 500 m/s^2 and up, is investigated using a vibrometer. The output waveforms of the accelerometer and vibrometer are compared in this study. Since the output waveform of the vibrometer is an integration of the acceleration waveform, small changes in the peak value of the acceleration waveform are masked by the acceleration waveform shape changes between measurements. Thus, the mass loading effect cannot be determined from the direct output of the vibrometer. Traditional differentiators that can convert the velocity output to acceleration suffer from noise. To overcome the noise problem, digital signal processing techniques are used. Existing filtering algorithms [2], [3] are not suitable for this application because of the rapid change of acceleration in shock calibration and the requirement for precision measurement.

The aim of this paper to present a new method for conversion of a velocity signal to an acceleration signal. With this method, the sensitivities of an Endevco 2270 accelerometer for two different mass loads at a shock level of 10,000 m/s^2 are measured. The mass loading effect in shock calibration for this accelerometer is then obtained.

2. METHOD

Signal quantization can represent a significant limiting factor in converting velocity signals to acceleration signals. Additional conversion errors are introduced when the velocity signal is subject to added noise prior to quantization. Reduction of these effects is the main task in determining the mass loading effect using the vibrometer output.

2.1 Data Acquisition

A data acquiring program is implemented using Visual Basic 6. Raw sample data from a digital oscilloscope Tektronix TDS 240L as shown in Figure 1 are transferred to a PC via GPIB and saved in a file that Matlab can read. The sample values are integers that correspond to the output of the A/D converter. The sample values are kept in integer format through rounding during the data processing to eliminate the numerical error introduced by calculations.

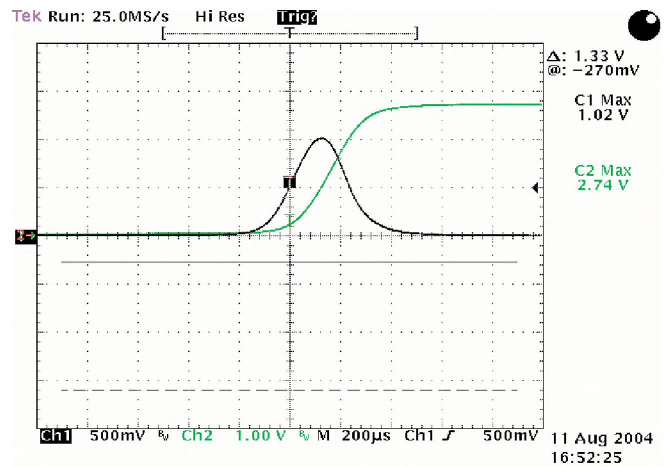

Figure 1: Acceleration (Ch1) and velocity (Ch2) signals.

2.2 Data Filtering

The velocity signal is first filtered through an analog low-pass filter (cut off, 5 kHz) prior to quantization. The quantized velocity signal (as an integer sequence) is then filtered through a median filter of variable length.

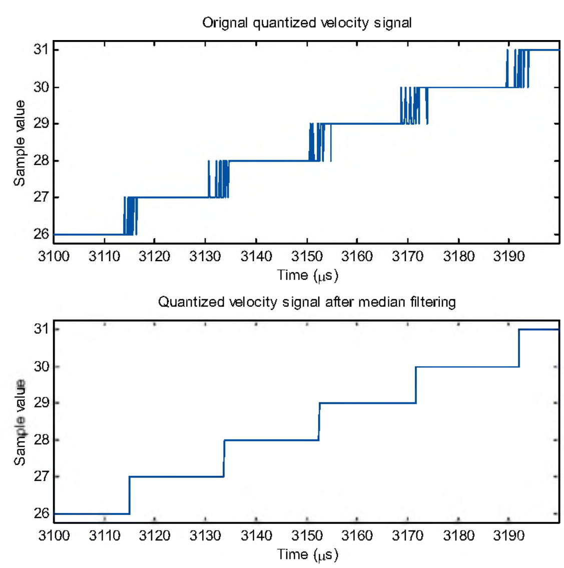

Figure 2: The effect of median filtering of a signal.

The length of the median filter is adaptively determined so that the power of impulsive noise in the filtered signal is minimized. Figure 2 shows a portion of the quantized velocity signal before and after median filtering.

2.3 Rate Estimation

The filtered velocity signal is close to the ideal output of an A/D converter: a stepwise function in time. The differentiation of such a signal creates zeros and impulses in the resulting acceleration signal. The stepwise signal could be smoothed before differentiating by either low-pass filtering or least squares curve fitting. This process, however, would result in a distorted acceleration signal and would generates a large error in acceleration peak estimation. A new method is proposed here, based on the assumption that the change rate (acceleration) of velocity within adjacent quantization levels is constant. That is, the stepwise signal can be replaced by a piecewise signal consisting of line segments. Each line segment connects the midpoints of two adjacent steps in the stepwise signal (velocity signal). The midpoint for a quantization level is estimated by finding a step at that level that has the greatest length. Other steps at that level are not considered, so that the noise has little effect on the midpoint estimation. As an example, the estimated change rates for a velocity signal using this method are shown in Figure 3 by crosses.

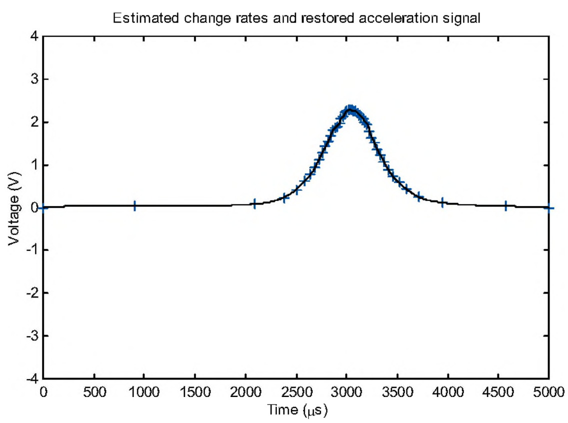

Figure 3: An example of a restored acceleration signal.

2.4 Acceleration Restoration

The acceleration signal is restored using cubic spline interpolation [4] from the discrete change rates estimated from the stepwise velocity signal. The restored acceleration signal using the estimated change rates is shown in Figure 3 by the solid line. The peak acceleration is then estimated from the restored acceleration signal.

3. RESULTS

Using the proposed method for converting velocity signals to acceleration signals, the sensitivities of an Endevco 2270 accelerometer (S/N CB18) for two different mass loads at are measured. The accelerometer is mounted on an anvil of a shock generator (Endevco 2925 POP) with the dummy mass loads on top of it. A vibrometer (Polytec OFV 050) is used to measure the velocity of the accelerometer. The output of the accelerometer, which is affected by mass loading, is compared with the acceleration signal converted from the velocity output of the vibrometer. The measured sensitivity of the accelerometer, normalized to the peak acceleration determined using the vibrometer, is shown in Figure 4 for 0 g and 200 g mass loads at accelerations of 10,000 m/s^2 ± 300 m/s^2. The dashed lines in Figure 4 indicate mean values for ten repeated measurements. The difference due to mass loading for this case is about 1.5%.

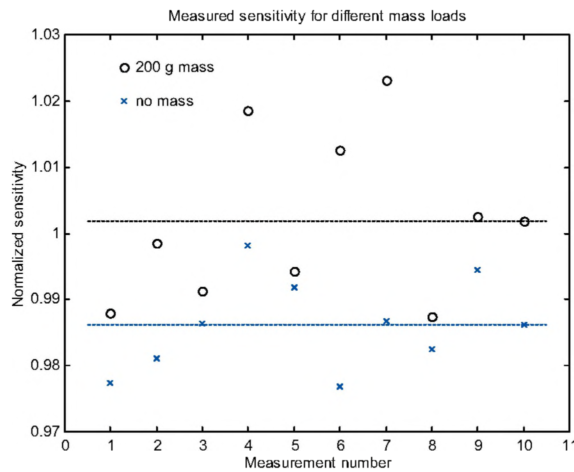

Figure 4: Measured sensitivity for 0 g and 200 g mass loads.

4. DISCUSSION

Mass loading affects the sensitivity of an accelerometer in high shock calibration. The variance of the measured sensitivity is mainly due to the resolution limitation (8-bit) of the A/D converter in the digital oscilloscope. Therefore, fine tuning of the proposed conversion algorithm may not lead to any significant improvement. The next task is to determine the mass loading effect at a number of different mass loads and shock levels.

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