REDUCTION OF SHOCK RESPONSE SPECTRA USING VARIOUS TYPES OF SHOCK ISOLATION MOUNTS

by

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ABSTRACT

This experiment demonstrated how various types of shock absorbers can reduce the overall shock response spectra of a structure subjected to high impact shock. This was accomplished by measuring the acceleration on a weight dropped onto three different shock absorbers from various heights and analyzing the resulting data.

A baseline test was performed with a steel hard mount. This was followed by tests with three different soft isolation mounts; a one-half inch thick neoprene pad, a urethane rubber tube on its side, and a hydraulic liquid spring type shock absorber.

Results show that both the dominant frequencies and the peak acceleration get lower as the isolation system gets softer. This information can be valuable in the design of isolation systems.

INTRODUCTION

The shock response spectrum (SRS) is quite often used in the analysis of transient shock to help establish design criteria and test specifications. Although the peak acceleration of the SRS should not be used as a design value, it is indicative of the potential of the shock to cause damage to a structure. This is especially true when one or more natural frequencies of the structure are close to the peaks in the SRS.

It would be advantageous to attenuate the overall level of the SRS as well as the peaks and to lower the values of the frequencies at which they occur, especially the fundamental. The lowering of the frequency helps reduce the peaks, because acceleration is generally larger at the higher frequencies. An isolation system that is soft will greatly lower the peak transmitted force. When the isolator also has high damping, it will also lessen the energy reaching the system it supports and will even prevent some frequencies from being excited at all. Isolators are generally chosen to provide a natural frequency for the system that is low compared to its environment, thus providing the structure with a relatively seismic suspension.

TEST PROCEDURE

Simple drop tests were performed on various isolation mounts using a 9 pound weight dropped from 1.10 in. (29.2 ips peak translational velocity (ptv)) and 51.75 in. (200 ips ptv). The mounts tested were a ½ inch thick neoprene pad, a tubular elastomer mounting, and a hydraulic tension-compression isolator, which is described in reference [4]. Isolator baseline tests were made on a rigid steel bar.

The shock transients were measured using a Kistler accelerometer mounted to the test weight, along with a Kistler charge amplifier, Type 5116, and a Hewlett Packard 3865A data acquisition system.

All the isolation elements were statically compressed in a press to determine their static spring rates. The neoprene pad was found to have a 3,000 lbs/in. spring rate while the tubular elastomer mount (2.7 in. outer diameter, 1.37 in. inner diameter, 6½ in. long) had a rate of 2,067 lbs/in. This mount had two ½ in. x 4¾ in. x 5 in. steel plates bolted to it to insure a constant contact area for the dynamic tests. The hydraulic isolation unit was found to have a spring rate of 133 lbs/in., a preload (the amount of force which must be overcome to initiate displacement) of 150 lbs., and an available stroke of 1.5 inches. It also had a damping force relationship of $5*V^{.7}$ where V is in/sec. These values were determined by previous testing.

THEORETICAL BACKGROUND

The shock response spectrum (SRS) is extensively used to determine the potential of an input to a system to cause damage at a particular frequency. It measures the results produced by the transient rather than the actual spectral content of the signal itself [3]. The response of the structure will be dominated by the energy content of the input motion at the structure's fixed base natural frequency, each normal mode behaving like a single degree of freedom system having the same natural frequency at the mode [1].

The maximax SRS was determined by recording the maximum relative displacement of a massless, tunable oscillator at different frequencies and scaled by the factor W^2/g.

This is done by solving the following equation [5] for an undamped SDOF system:

$$z(t)\max = \frac{-1}{W_n} \int y(e)*\sin[W_n\,(t-e)]de$$

where $z(t)$ = relative displacement of oscillator to base

$y(t)$ = acceleration of base

W_n = natural circular frequency of oscillator

A damping factor of 1% of critical was used (Q = 50) which is similar to that encountered for a minimal structural damping. Damping was also needed to prevent an instability from occurring in the analysis program. This same damping value was used in every SRS calculation to ensure good comparability between results. The length of the record was held constant, because as found in reference [2], the length of the record can affect the values of the peaks.

The computer program used for the analysis was a proprietary code using QuickBASIC 4.5 (Microsoft), QuickC (Microsoft), and TSIS (Taylor Shock Isolation Simulation). TSIS is used as a "front end" menu to generate dynamic models using TUTSIM (Twente University of Technology Simulation program). TUTSIM is an analog computer simulator which is PC based that is extremely useful in solving both linear and non-linear differential equations. TSIS generated the TUTSIM model for the oscillator used to solve for the maximum g values at each frequency increment. QuickBASIC was used to pass the new spring rate and damping parameters to TUTSIM, and QuickC recorded the maximum value for each frequency.

RESULTS

The test weight was first dropped on the rigid bar from the full test height of 51.75 in. (200 ips ptv). The temporal peak g's obtained were 234 (Figure 1). The SRS shows a dominant response at 205 Hz. with a 462 g peak (Figure 2).

The next drop performed was on the tubular elastomer mount at 200 ips ptv. The peak temporal g recording was 127 (Figure 3). In the frequency domain, the SRS showed a distinct peak at 110 Hz. (232 g's, Figure 4). This is less than the amplitude of the rigid SRS at the same frequency (300 g's). At the rigid SRS peak frequency (205 Hz.), the elastomer mount decreased the equivalent g level to 207, a 55% reduction (Figure 5).

The drop on the half inch neoprene pad peaked in the time domain at 171 g's (Figure 6). The SRS peaked at 150 Hz. with 274 g's (Figure 7) and was reduced as compared to the rigid case at the same frequency (a 36% attenuation). The peak response of the rigid drop (462 g's at 205 Hz.) was decreased to 260 g's, a 44% reduction (Figure 5). Comparison with the elastomeric tube shows that the elastomer reduced the g level at the neoprene peak amplitude frequency by 21%.

The next drop that was performed was on the isolator at 200 ips ptv. This yielded a 39 g deceleration peak of the test mass (Figure 8). The drop on the isolator showed a dominant frequency of 50 Hz. with a peak at 69 g's (Figure 9), considerably less than that of the rigid bar. At the rigid drop dominant response frequency of 205 Hz., the isolator lowered the SRS to 58 g's, an 87% reduction (Figure 5). The isolator attenuated the components of the pulse that could potentially cause damage to the structure (the high frequency components).

When the neoprene pad is compared to the hydraulic isolator, the hydraulic device shows a much reduced amplitude of the SRS. The isolator g level at 150 Hz., the neoprene pad dominant frequency, is 80.4 g's, 71% less than the pad at that frequency, and the maximum SRS amplitude is reduced by 75% of that for the neoprene pad (Figure 10).

The neoprene pad was then used in conjunction with the hydraulic isolator by placing it on top of the unit. This yielded a peak temporal reading of 41 g's (Figure 11). This slightly reduced the SRS overall when compared to the isolator alone and brought out a 180 Hz. component (Figure 12). This was probably due to the neoprene pad compressing to the 150 lbs. that is required to overcome the preload. The pad serves to smooth out the SRS by reducing the higher frequency ringing caused by the initial preload and the metal to metal contact.

A low rigid drop (height = 1.10 in., 29.2 ips ptv) was performed to match the deceleration of the hydraulic isolation unit at 200 ips ptv. The accelerometer reading was 37 g's (Figure 14), close to the isolated drop's output. The overall shock response spectrum of the isolated drop (Figure 9) is slightly higher than the low rigid drop (Figure 14), but the measured energy input into the isolated system was considerably higher (kinetic energy for the isolator was 466 in-lbs., 10 in-lbs. for the rigid). The peak SRS values occurred at 50 Hz. for the isolator drop, compared to 200 Hz. for the rigid case.

Another drop was made on the isolator at the same velocity as the lower rigid drop for another comparison (Figure 15). The peak temporal acceleration was 17 g's. A great reduction in the overall spectrum was noted (Figure 16) compared to the rigid drop, and the peak g's were also reduced. The peak occurred at 155 Hz., lower than the rigid case. At 200 Hz., the g's were reduced from 63 to 30 by using the isolator.

CONCLUSIONS

The use of an isolation system, whether hydraulic, a neoprene pad, or an elastomer tube, can greatly reduce the maximax shock response spectrum of a structure subjected to a shock transient, and can also reduce the dominant frequencies which occur to the non-isolated system (Figures 5 and 10).

The compliance of the structure being isolated (in this case the structure of the nine pound weight), plays a role in the system response. However, the high energy loss and high potential energy absorption of an isolation system provides the greatest overall reduction in shock response spectra. The damping of the shock absorber, in conjunction with the low spring rate, will attenuate much of the higher frequency response of the structure.

As the SRS is a measure of how damaging a possible transient is to a structure at its modal frequencies, it is of great importance to lower the magnitudes of the spectra at these frequencies. Shock isolators provide a useful tool for this application.

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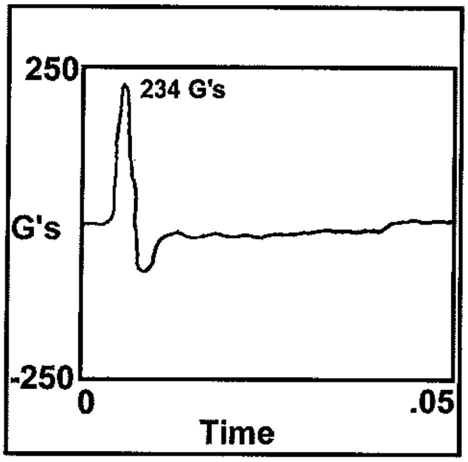
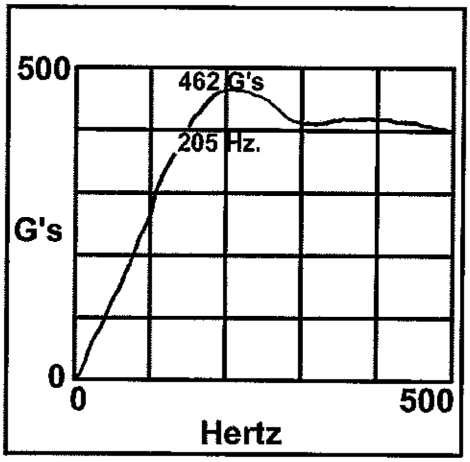


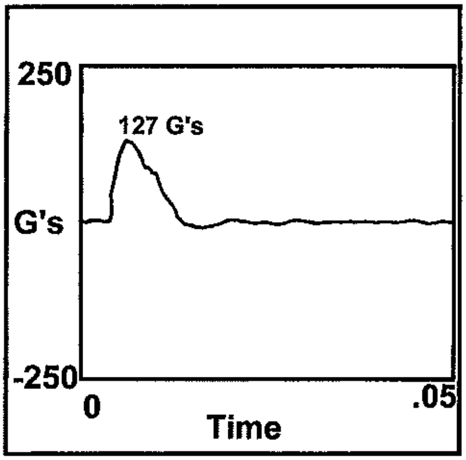
200 IPS Rigid

Figure 1



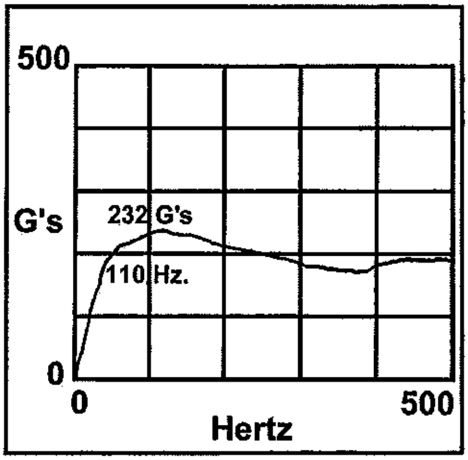
SRS 200 IPS Rigid

Figure 2



200 IPS Urethane Tube

Figure 3



SRS 200 IPS Urethane Tube

Figure 4

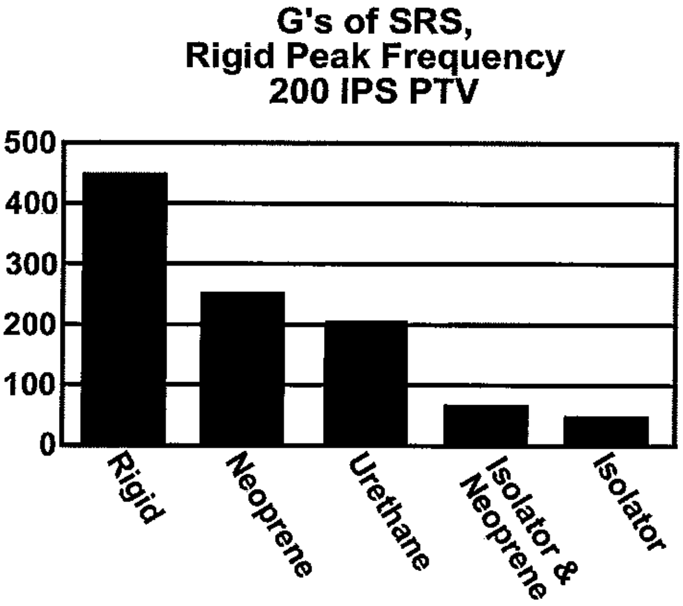
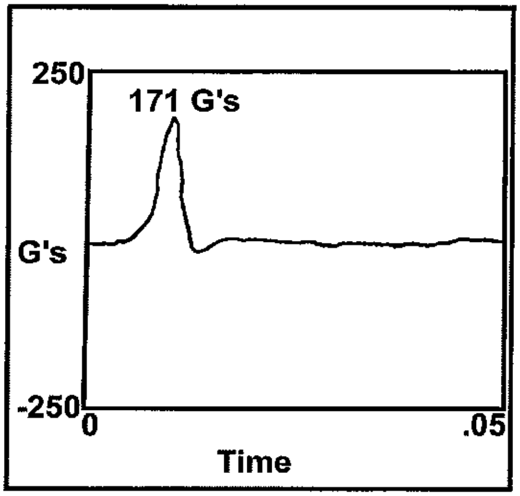
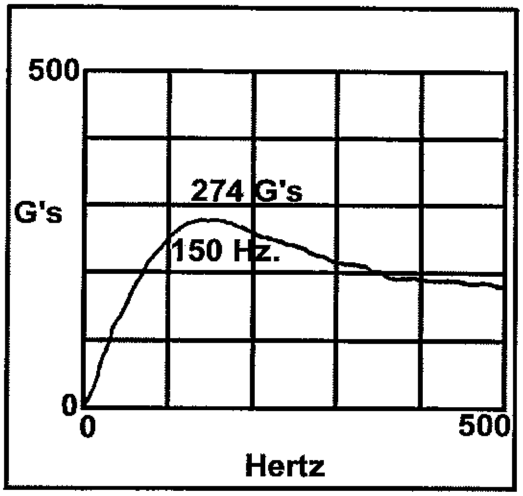


Figure 5



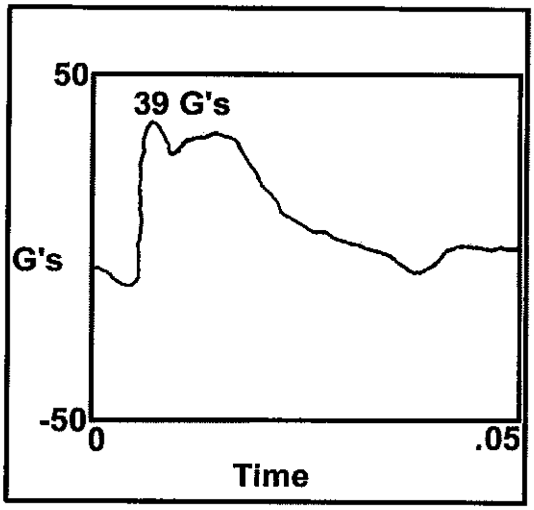
200 IPS Neoprene

Figure 6



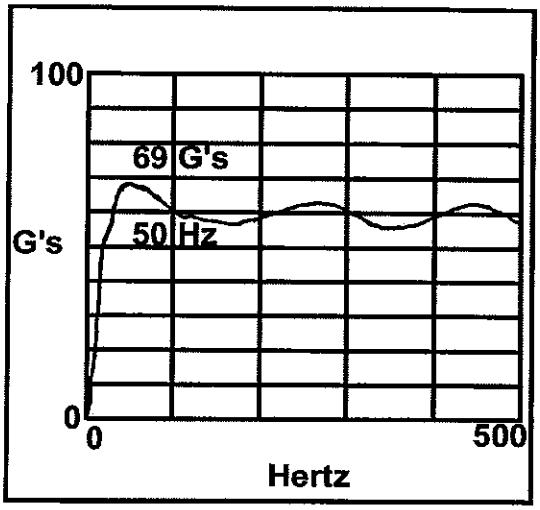
SRS 200 IPS Neoprene

Figure 7



200 IPS Isolator

Figure 8



200 IPS Isolator

Figure 9

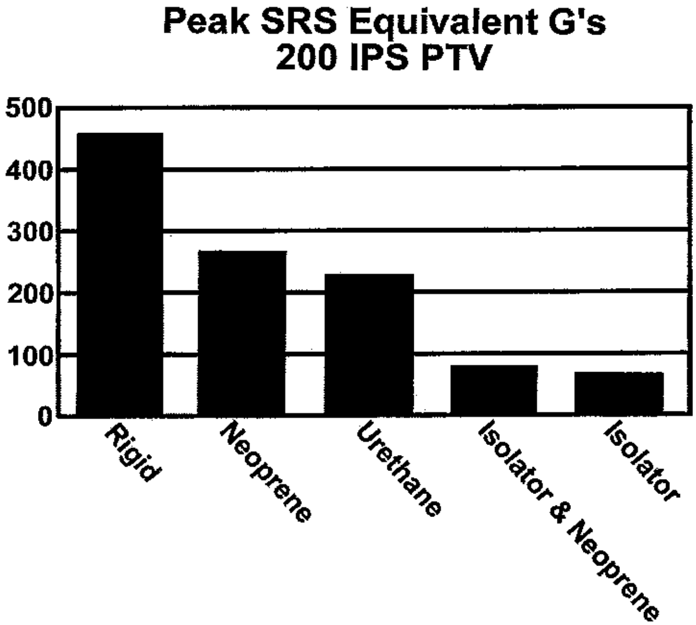
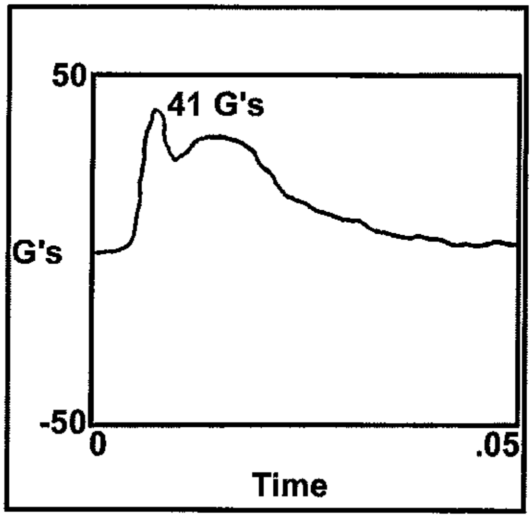
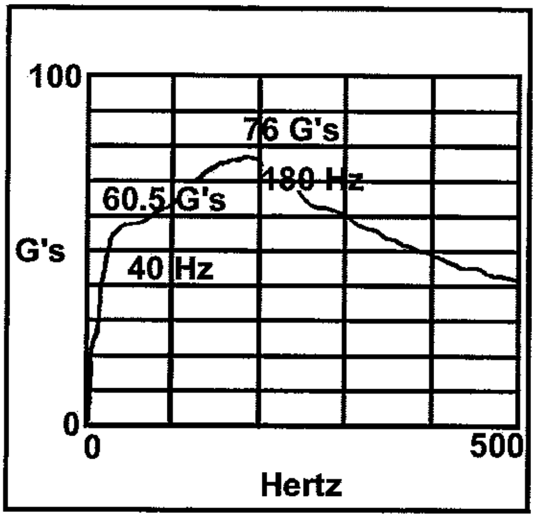


Figure 10



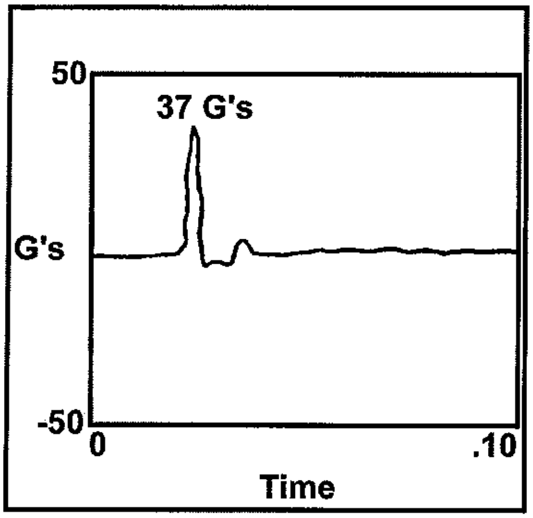
200 IPS Isolator & Neoprene

Figure 11



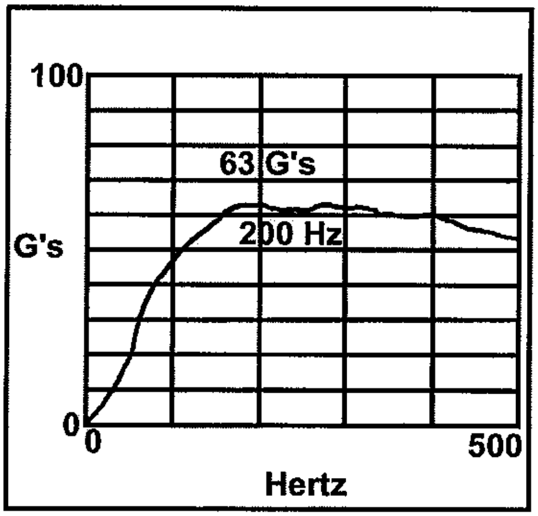
SRS 200 IPS Neoprene & Isolator

Figure 12



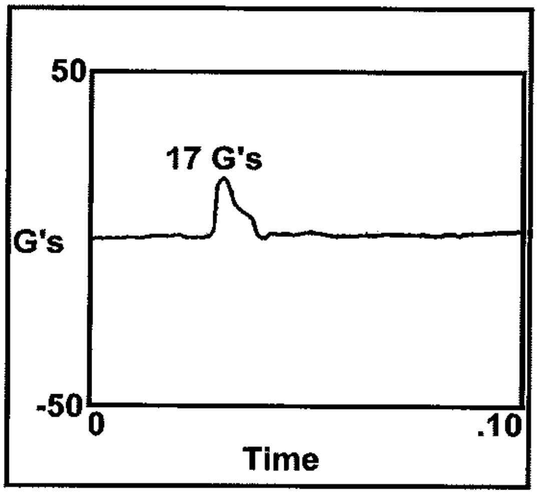
29.2 IPS Rigid

Figure 13



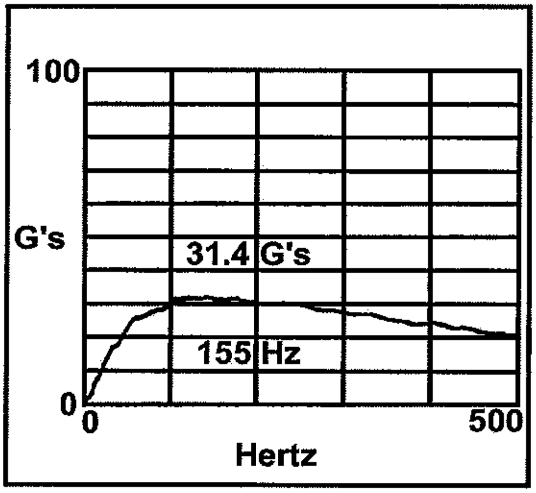
SRS 29.2 IPS Rigid

Figure 14



29.2 IPS Isolator

Figure 15



SRS 29.2 IPS Isolator

Figure 16