Proving HALT/HASS Machine Effectiveness Using Fatigue Spectrums

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Introduction

It has been shown that pneumatic hammer excited screening machines exhibit significant intensity variability across their product mounting table surface. It has also been shown that this variability results in large differences in loading intensity g^2/Hz. In turn, this causes variability in fatigue accumulation needed to precipitate defects. This paper illustrates a method of using a fatigue spectrum to measure both the overall (global) and specific frequency (micro) effectiveness of a screening machine to rapidly induce fatigue at the defect sites.

Problem

Measurements of pneumatic hammer screening machines have produced data showing a large degree of intensity variation as a function of table position, which is inherent with these machines.[1,2] Intensity variations as great as 35:1 in gRMS have been documented when all three axis of vibration are compared. These variations are due to differences in Power Spectral Density, (PSD) of acceleration loading power g^2/Hz.

The prime purpose of vibration during HALT/HASS processes is to cause defects to "precipitate." The cause of this precipitation (a failure of a defective component) is fatigue that is accumulated due to repeated stress loading cycles.

It should be obvious that the stress should be uniformly distributed amongst the products being screened to insure uniform accumulation of fatigue. Uniformity reduces the possibility of under and over testing which shows up later as field failures.

Unfortunately, the metric employed by many HALT/HASS procedures for control of the process is the highly variable gRMS. One should expect similar variability in the screen results.

A Method For Measuring Machine Effectivity

In 1995, Allan Piersol and this author published a new method for characterizing vibration induced damage potential, DP(f)[3]. The DP(f) has recently been validated by a leading expert in vehicle testing.[4] The DP(f) is a compensated velocity spectrum. The stress loading cycles that produce fatigue relate to the velocity of the first bending mode of a vibrating element.[5] As such, the velocity spectrum DP(f) is a tool for its measure.

The spectrum is compensated for those physical parameters that control fatigue accumulation, namely the duration of the stress loading time, the materials fatigue S/N β constant, and the vibrating element's damping ζ.. The magnitude of the damage potential will increase with time of exposure.

The physical measurement is simplified since strain measuring devices are not necessary and typical acceleration sensors may be used.

Application Example

An experiment was performed with two pneumatic screening machines produced by the same manufacturer. The machine tables were the same physical size, but the hammer arrangements were different. Each machine was instrumented by an accelerometer attached to the vibration table with the sensitive axis of each in the Z direction (vertical to the table surface). Each was positioned at the same relative table location. The two machines were then set to operate at 10 gRMS. The resulting Damage Potential spectrum plots were produced using an exposure time of 60 minutes, and the same values of β and ζ. The plots are overlaid for comparison and printed out. This printout can be seen in Figure 1, below.

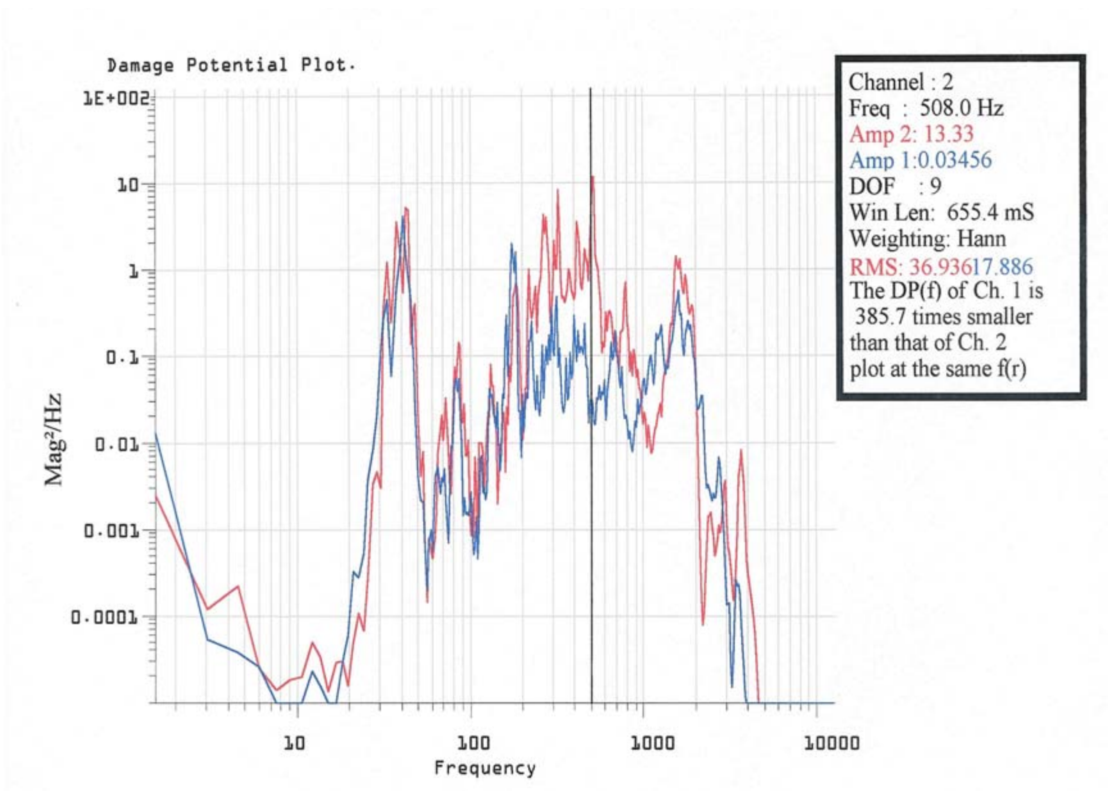

Figure 1. Overlaid plots of Damage Potential for two ESS screening machines, both at 10 gRMS, showing a difference of 2X in fatigue potential for an exposure time of 60 minutes.

To evaluate the damage potential spectra, two useful relationships exist. The first is the fRMS, similar to the gRMS of the PSD, and which is considered a “global” metric. It gives the relative fatiguing potential over wide spectral bandwidths of the DP(f), but must be used with care when comparing different spectrums. The second is the actual damage potential at a specific f_r of a resonating component. The term given to this narrowband measure is “micro” value.

In addition to the global variation of 2:1 between machine 2 and machine 1, shown in Figure 1, there are large differences in the micro values of damage potential at specific f_r frequencies. This can be seen in the differences in magnitude at certain frequencies between the two plots in Figure 1. As an example, a cursor has been located at a theoretical component resonant frequency f_r of 508 Hz. The difference in fatigue magnitude between the two machines at this frequency is seen to be 385.7:1 as indicated in the data block of the figure. In simple terms, if a component’s f_r were at this frequency, machine 2 would cause 386 times more fatigue accumulation than machine 1 in the same screen time. This illustrates a large potential for under/over test for components due to loading variability.

Conclusions

There are several conclusions that can be drawn from this experiment:

1. That gRMS is not an indicator of potential fatigue.
2. The variability in table loading intensity and resulting fatigue potential are relatable.
3. Due to machine design, hammer performance, damping, etc., similar machines at the same gRMS loading intensity do not produce the same fatigue.
4. Different machine effectiveness can be measured and compared using the global DP(f) spectrum.
5. Specific defect f_r can be measured and compared using the micro DP(f).

References

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