Electrohydraulic—The Most Versatile Shaker?

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ABSTRACT

Mechanical shakers are inexpensive, reliable and simple to operate, but unfortunately limited in the types of testing they are able to perform. At the opposite extreme, electromagnetic (EM) shakers are more versatile and expensive, and therefore generally limited to aerospace testing. This article discusses the less well known, but highly versatile electrohydraulic shaker and its application for vibration and shock test needs.

INTRODUCTION

Advanced technology in products and the ever increasing requirements for product reliability have created the need for both advanced vibration test techniques and additional vibration testing of existing products. Many of these test techniques are described in such documents as MIL-STD-810C and MIL-STD-781C. These vibration tests are also used as guides for a number of commercial manufacturers looking for increased product reliability. The equipment available and the application of this equipment is of extreme importance today. It must be capable of reproducing the required test accurately while still offering the versatility required to perform many different types of tests. Basically, three different approaches to the problem of vibration testing exist. I will attempt to objectively look at the uses and limitations of each.

MECHANICAL SHAKERS—PRO AND CON

Mechanical shakers are inexpensive, reliable, and easy to operate. They are reasonably satisfactory for certain tests, most notably for simulating long-term, steady vibration found in certain locations, such as aboard ships. However, their nominally sinusoidal, fixed-displacement, single-frequency-at-a-time vibration is not good simulation of "real world" complex vibrations. Also, their useful frequency range (typically 10 to 60 Hz) is severely limited. They cannot develop variable strokes needed for realistic simulation or the higher frequency capability needed for most testing. And, finally, their "nominally sinusoidal" displacement forcing function is often badly distorted with the acceleration response looking much worse.

ELECTROMAGNETIC SHAKERS—PRO AND CON

Electromagnetic (EM) shakers have accomplished much valuable testing, and have contributed greatly to the present reliability and success of our aircraft and aerospace programs. These shakers are almost without peer for very high-frequency vibration testing and calibration of accelerometers. When driven by ultralow distortion amplifiers, they produce nearly pure sinusoidal motion and strokes of a microinch or less are possible.

Electromagnetic shakers are not limited to nominally sinusoidal, one-frequency-at-a-time motion, as are mechanical shakers, but rather:

1. can be used to synthesize random vibration;
2. can be used to reproduce vibration time histories that have been stored on magnetic tape, as is popular in the automotive industry; and
3. can be used to perform certain shock tests.

The difficulty with testing large items at frequencies above 1000 Hz when item dimensions approach 48 inches (1.2 m) (or one-quarter wave length at the propagation velocity within the item) is that resonant responses are so complex that motion cannot be controlled. This difficulty has led many laboratories to attempt vibration control with multiple accelerometers and additional electronic controls that:

1. select the largest accelerometer signal; or that
2. compute an average acceleration value for control purposes.

Many MIL-STD test procedures were intended to apply only to components and small assemblies. Upper test frequencies of 500 Hz and later 2000 Hz seemed appropriate. But as test item size increases, the frequency ceiling should drop. Acoustical environment testing becomes appropriate when large test items must be tested to high frequencies. (More will be said about intense noise environmental testing combined with low frequency vibration testing later in this article).

EM shakers have some drawbacks which should be considered:

1. High cost per pound force:
   System costs per pound force, when a high-powered, low distortion amplifier is included, are very high.
2. Limited stroke:
   Strokes of only one inch (25 mm) are generally available.
3. Limited force:
   At very low test frequencies, available force may be insuffucient. Also, waveforms are apt to be poor.
4. Armature cooling presents problems.
5. Stray magnetic fields (both alternating at shaker frequency and direct) adversely affect some test items.
6. EM shakers are very heavy and hard to move from place to place between tests.