Selecting vibration-isolation tables for sensitive apps

Although air tables have been around for the better part of a half-century, negative-stiffness systems offer new, useful abilities

BY JIM McMAHON
Minus K Technology
Inglewood, CA
http://www.minusk.comn

For almost 40 years, pneumatic vibration isolators have been the mainstay for stabilizing industrial and academia's most critical micro-engineering instrumentation. However, just as technology has been steadily migrating from micro to nano, so has the need for more precise vibration isolation in microelectronics fabrication, industrial laser/optical systems, and biological research.

These so-called "passive system" air tables are now being seriously challenged by the negative-stiffness vibration isolators. Able to effectively isolate vibration in diverse and challenging environments, negative-stiffness isolation is rapidly gaining popularity in industrial and laboratory environments.

Air table applications

An isolator is used to solve a problem, and how bad the problem is determines the solution you need. Since the 1960's, air tables have been used for isolation. Basically cans of air, they are still the most popular isolators used. But, air tables with resonant frequencies at 2 to 2.5 Hz can typically only handle vibrations down to about 8 to 10 Hz, not quite low enough for optimum performance with modern nano-equipment. Also, greater isolation efficiencies are needed in the frequency ranges air isolators can handle.

For purposes of clarity in scanning probe microscopes and interferometers, air tables are an inefficient isolation solution. The air systems have been adequate up until a few years ago, when better isolation was required for finer measurements.

Because of its very high isolation efficiencies, negative-stiffness vibration isolation systems enable vibration-sensitive instruments such as scanning probe microscopes, micro-hardness testers, profilers and scanning electron microscopes to operate in harsh conditions and severe vibration environments that would not be practical with top-performance air tables and other pneumatic isolation systems.

How negative stiffness works

Negative-stiffness isolators employ a unique — and completely mechanical — concept in low-frequency vibration isolation that was invented by Dr. David L. Platus, the founder of Minus K Technology. With this technology, vertical-motion isolation is provided by a stiff spring that supports a weight load, combined with a negative-stiffness mechanism. The net vertical stiffness is made very low without affecting the static load-supporting capability of the spring.

Beam-columns connected in series with the vertical-motion isolator provide horizontal-motion isolation. The horizontal stiffness of the beam-columns is reduced by the "beam-column" effect. (A beam-column behaves as a spring combined with a negative-stiffness mechanism.) The result is a compact passive isolator capable of very low vertical and horizontal natural frequencies and very high internal structural frequencies.

The isolators (adjusted to 1/2 Hz) achieve 93% isolation efficiency at 2 Hz; 99% at 5 Hz; and 99.7% at 10 Hz (see *Fig. 1*).

Negative-stiffness features

Since negative-stiffness isolators are a relatively new technology, the features they offer can be understood in contrast to the more familiar air tables. There are several significant areas in which negative-stiffness systems offer new capabilities:

Low-frequency perturbations

All isolators will amplify at their resonant frequency, and then they will start isolating. Air tables typically amplify vibrations in a range of 2 to 7 Hz because of that is where their natural resonance frequency occurs. Any vibration in that range could not only fail to be mitigated, it could be amplified. The low cycle perturbations would come through to the instrument. Negative-stiffness isolators resonate at 0.5 Hz, a frequency at which typically there is almost no

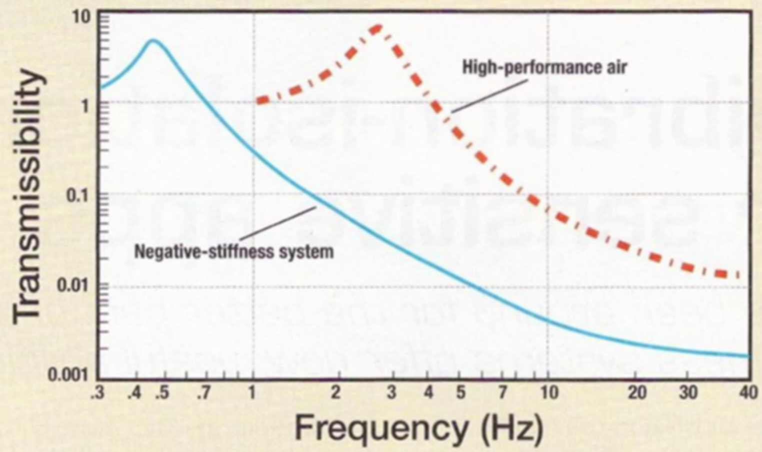

Fig. 1. Due to their lower resonant frequency, negative-stiffness isolators provide better isolation at low frequencies than air tables do.

energy present to amplify — it would be very unusual to find significant vibration at 0.5 Hz.

Image clarity
Compared with top-performance air tables, negative-stiffness vibration isolation can reduce vibration noise levels in atomic-force microscopes, for example, by a factor of 2 to 3 — particularly significant in the sub-angstrom range and results in clearer images and features not discernable with pneumatic isolation systems.

Severe vibration
As use of nano-equipment becomes more prevalent, lab sites are being set up in much more severe vibration-prone environments, such as upper floors of buildings and clean rooms. Such severe vibration locations are too extreme for current pneumatic isolators to effectively do their job. Negative-stiffness isolators perform well in such environments, producing better images and data.

Harsh environments
Air tables are not particularly compatible when it comes to operating in vacuums, extreme high and low temperatures, and radiation. Yet these harsh operating environments are often necessary when conducting research and testing, such as with cryogenic chambers in semiconductor research.

All metal negative-stiffness systems can be configured that are compatible with high vacuums and other adverse environments, such as extreme high and low temperatures, and radiation. With vacuums, for example, negative-stiffness isolators can be used right inside the vacuum chambers. This offers other advantages such as much lower payload weights, more compact systems, and eliminates problems associated with vacuum chamber feed-through.

Compressed air
Unlike air tables, negative-stiffness isolators do not require a constant supply of compressed air. Compressed air requires either a dedicated air line to be plumbed into a lab, a tank of pressurized gas, or a small compressor.

Even if a dedicated compressed-air line is already available, an air table's location is still limited by the length of the air line. As for large tanks of compressed gas, they have to be mounted very securely to minimize danger, and changing tanks can be difficult and inconvenient. Compressors, on the other hand, are *sources* of both mechanical and acoustic noise , making them very poor choices from a vibration standpoint.

Equipment location choices
Air tables, especially high-performance units, are bulky structures that can take up a lot of lab space. This can become a limiting factor when laying out the equipment in your lab. Negative-stiffness isolators are available in high-performance bench top configurations, considerably more compact than air tables and easy to move around. They are also available as workstations, tables, and floor platforms where these configurations are required.

Load adjustment
Low-frequency passive vibration isolators are somewhat sensitive to small changes in weight loads. Pneumatic systems utilize leveling valves to mitigate the problem.

Negative-stiffness isolators provide a very simple manual adjustment to accommodate variations in weight loads. For applications where manual load adjustment is not practical they provide an auto-adjust system that maintains the isolator in a precise vertical equilibrium position.

Multiaxes isolation
Consider the case of scanning probe microscopes (SPMs), which have vibration isolation requirements that are unparalleled in the metrology world. The vertical axis is the most sensitive for most SPMs, but they can be quite sensitive to vibrations in the horizontal axes too.

To achieve the lowest possible noise floor, on the order of an angstrom, isolation is always used. Benchtop air systems provide limited isolation vertically and very little isolation horizontally. Negative-stiffness isolators provide increased isolation performance and have the flexibility of custom tailoring resonant frequencies vertically and horizontally.

Maintenance and expense
Because negative-stiffness isolators utilize simple elastic structures and viscoelastic materials that deform, their isolation performance does not degrade with micromotions typical of laboratory floors and fabrication rooms, as do conventional pneumatic isolators.

Negative-stiffness isolators are comparably priced to air isolators or lower for many applications. ■

For more information on negative-stiffness isolation, visit http://www2.electronicproducts.com/-article-olrc02-oct2007-html.aspx.