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New Electro-Magnetic Shaker Technology

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There was a time when vibration testing was something that was conducted in R&D laboratories. Small shakers were often used to test items – such as aerospace components – at low levels of vibration for relatively short periods.

Today, throughout the aerospace, automotive and electronics industries, shakers are used in both laboratory and production environments to test heavy loads at high stress levels over long periods. The testing regime invariably involves shock testing, as well as traditional sine and random testing, often at rates of up to 500 shock pulses in a single session. When looking for a point of failure of a missile, torpedo or an automotive assembly, testing may continue until the product breaks. You don't really want the shaker to break as well.

Hence, the need for robust, highly reliable machines that can operate at high force levels for long periods. The new V875-240 shaker model from Ling Dynamic Systems (LDS) has been developed to meet this requirement with an advanced lightweight armature assembly suitable for high acceleration shock transients of heavier payloads.

The air-cooled V875-240 is rated at 8000 lbf (35.5 kN) with a peak acceleration for swept sine of 175 g and shock acceleration of 462 g. Designed to test payloads typically from 2 to 44 lb (1 to 20 kg), the new model features a relatively small 9.4 in. (240 mm) lightweight armature (complementing the 440 mm and 640 mm armatures on existing V875 shakers). The new lightweight armature assembly, lightweight suspension and an aluminium guide shaft minimize the moving mass (only 45 lb/21 kg) to deliver significantly higher acceleration capabilities than competitive systems and the ability to sustain many hours of full level excitation. The LDS V875-240 is designed for vibration testing of a wide range of products, from airbag impact sensors and PC peripherals to military avionics.

New High Force Shaker. The new V875-240 meets today's requirements for high performance vibration testing. However with the totally new High Force Shaker, code-named V9, LDS design engineers have gone right back to the drawing board. The V9 (patent applied for) which is in the final stages of development, combines proven coil technology with advanced carbon fiber armature construction and a radical new concept in shaker structure.

The new shaker will have a maximum sine force rating of around 22,500 lbf (100 kN) as against 20,000 lbf (89 kN) for the V964, the nearest force-comparable LDS

Figure 1. The photo shows the lightweight armature and suspension arrangement on the V875-240.

product. A velocity limit of 126 in./sec (3.2 m/sec) has been achieved, compared to a maximum of 78.7 in./sec (2 m/sec) for all previous designs and displacement capabilities for testing can reach 3 in. (75 mm) peak-peak. That is a major advance over the 2 in. displacement that is now common on most electromagnetic shakers. Yet, the use of composite materials in the armature and the unique field coil design means that the shaker can be much more compact for a given force rating. Armature mass on the V9 is only 106 lb (48 kg), compared to 130 lb (59 kg) on the V964.

LDS has achieved this striking enhancement of performance by a fundamental redesign of the basic structure of the shaker. In a conventional shaker there is one flux gap with two field coils running in opposition to provide the motive force. One problem with this arrangement is that the armature structure has to be long and webbed in order not to disturb the magnetic fields.

For the V9, LDS has effectively turned the design inside out, with two magnetic gaps driven by one field coil. The magnetic field generated within the two gaps is concentrated within the shaker by the addition of two coils near the air gap, ensuring a very low stray field.

The two-gap design has many advantages. The armature can be lighter and of any shape and displacements can be increased within the same size of body. Because the magnetic flux gap is not so heavily saturated, higher velocities are achievable. The body of the shaker itself can be much more compact and maintenance is dramatically easier than on earlier shakers. In fact, the armature can be removed without having to dismantle the whole machine. You simply disconnect eight roller mountings and the top and bottom lead-out junction terminal and pull the armature out. The armature on the V9 can be replaced in an hour. That compares with a whole day of work for an armature change on most shakers.

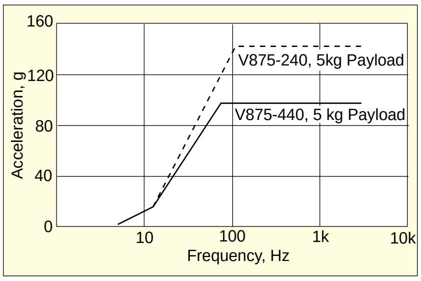

Figure 2. Sine performance of the V875-440 and V875-240 with an 11 lb (5 kg) payload.

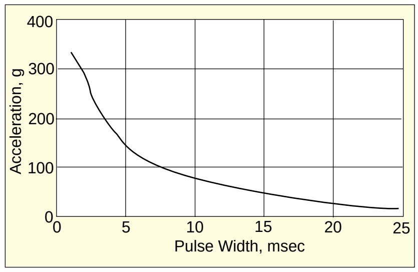

Figure 3. Shock performance of the V875-240 with an 11 lb (5 kg) payload.

Figure 4. The photo shows the armature and suspension arrangement on the V9 High Force Shaker.

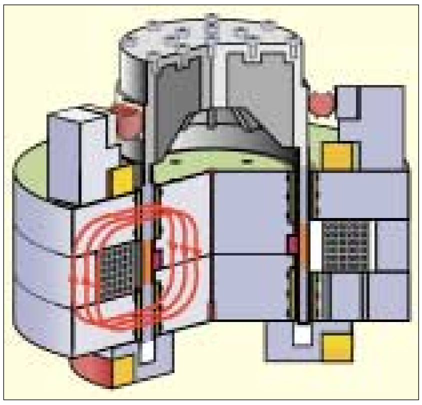

Figure 5. Section through the V9 High Force Shaker.

Due to the open construction of the V9, it is possible to visually inspect all of the internal moving parts without special tools. Removing the top cover gives access to the upper suspension, optical position sensor and electrical lead-out junction terminal. By rotating the shaker body to the horizontal position, it is also possible to observe the bottom winding of the moving armature and lower electrical connector.

The V9 armature design builds on

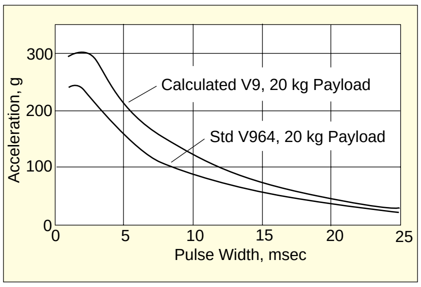

Figure 6. Shock performance comparison of the existing V964 and a V9 with a typical 44 lb (20 kg) payload.

proven composite technology and LDS' experience in using resin bonded carbon fiber, advanced adhesives and reinforced coil wire to provide the strength and robustness needed for the high acceleration conditions of shock testing. But, it is designed and manufactured in a new way to deliver even greater strength and longevity. The new armature has a carbon fiber backbone or spine bonded to the inside of the hollow aluminum coil. The direction of the coil is reversed between the upper and lower windings.

Keeping cool. Around the armature is a wrapping of more carbon fiber. Demineralized water is passed through the coil to keep the armature cool. There is no need for a fan and no hot air that has to be dispersed into the working environment.

All water-cooled shakers can be certified to Federal Standard 209, Class 100,000 for operation in clean room environments. On the V9, even the shaker body is water cooled to reduce heat build up near the magnetic field when operating over lengthy periods of time. The ability of water-cooled shakers to efficiently dissipate heat means that they can be safely used to test payloads containing hazardous fuels or propellants.

Tim Bidwell, a mechanical engineer at LDS, sees the V9 as a real advance in shaker technology. "The new moving coil arrangement is a truly elegant solution," he says. "The armature assembly is simple and robust, using a load support system that does not require a rolling seal. This simpler design improves the ease of servicing with improved accessibility and fewer parts within the shaker body." The combination of composite materials and innovative design means that the V9 is robust and reliable in the high acceleration conditions of shock testing. And the V9's water cooled, wound coil design delivers good low frequency performance while using relatively modest amplifier output.

Power Amplifier. The (IGBT) Insulated Gate Bipolar Transistor technology in the LDS digital amplifiers that drive the V9 delivers new levels of performance and efficiency, with a switching frequency of 150 kHz. Self-contained 8 kVA power modules, rated at 80 amperes each, operate in parallel to provide electronically controlled equal current sharing. This system minimizes overloading and delivers maximum efficiency in both random and shock conditions. In the high stress condition of shock testing, in particular, reliability is best achieved by minimizing the power required from each module by this method of electronically forcing power sharing.

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COVER

An Anglo-French Storm Shadow/Scalp EG airborne cruise missile being prepared for vibration testing at the MBDA Environmental Engineering Laboratory at Stevenage, United Kingdom. A support fixture on the right is used for horizontal testing. The fixture, which is held in place with temporary weights, rests on hydrostatic bearings. The laboratory is able to measure, analyze and synthesize a great variety of environments, including shock, vibration, acoustic, EMC and all climatic conditions. MBDA recently completed a modernization program of one of their large drive-in test chambers. The new chamber is equipped with two LDS low-profile V964Ls vibration test systems coupled to two 110 kVA switching power amplifiers producing an individual system sine force of 18,000 lb. *(Photo courtesy of MBDA Limited, a wholly owned subsidiary of MBDA S.A.S., a company owned by BAE Systems, EADS and Finmeccanica.)*