What is an Induct-A-Ring Shaker?

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Conventional electrodynamic (ED) shakers use the same basic design configuration as a loud speaker – an AC voice coil suspended in a DC magnetic field that is driven by an audio amplifier to produce vibration (sound). All conventional ED shaker designs have used this basic design configuration, just beefed up to industrial strength proportions. Therefore most of today's conventional shakers use a multiturn, wound armature coil (air cooled or sometimes water cooled) that interacts with a fixed DC magnetic field (produced by field coils) to develop output force when the driven armature coil receives AC current from a power amplifier.

This "moving driver coil" design philosophy completely dominated ED shaker development up until about 1970, when two important things happened. First, Unholtz-Dickie engineers developed a line of solid-state (low-voltage/high-current) power amplifiers that soon replaced the earlier high-voltage/low-current vacuum tube amplifier designs. Then in concert with development of the new power amplifier, Unholtz-Dickie engineers came up with a breakthrough shaker design that moved the driven AC coil from its original position on the moving armature frame to a stationary location within the ED shaker iron structure, but closely surrounding the bottom half of the moving armature. As shown in Figure 1, the lower section of the armature was changed to a solid-metal, single-turn coil made from an aluminum forging. In this new shaker design, the power amplifier delivers AC current to the relocated *stationary* driver coils (called stators). These stator coils then *induce* AC voltages into the single-turn armature ring they surround. This inductive coupling action produces AC currents in the armature ring, delivering AC force output at the moving armature.

This armature design was named "Induct-A-Ring" and was put into production by UD in the early 1970s. Since then, the UD Induct-A-Ring shaker family has grown into a formidable lineup of vibration test systems rated from 15,000 lbf to 55,000 lbf (67-245 kN) and now available with up to a 3-inch (76-mm) peak-to-peak stroke. UD is the only electrodynamic shaker supplier offering Induct-A-Ring armatures.

Wound-Coil Armatures. Conventional shakers use a wound coil assembly attached to the lower frame of the moving armature. In many high-force shakers, the power amplifier must deliver 1,000+ amperes of AC current to this moving coil to generate rated AC force output. A conventional driver coil winding is typically made with hollow tubular wire that must be water cooled to achieve sufficient heat transfer to cool the armature coil. As a result, this "wound coil" configuration requires a high current carrying linkage between the moving coil and the stationary shaker body, along with flexible hose linkages to deliver cooling water into and out of the coil.

At low frequencies, both of these linkages (current and water) are flexed up to the full stroke rating of the shaker. And at higher frequencies, they are subjected to large accelerations (high g inputs) that can occur at the resonant frequencies of these linkages. Current linkages and water-cooling hose assemblies are the proverbial "Achilles Heel" of a wound-coil armature and are the cause of many armature failures.

Also, the wound driver coil consists of multiple turns of wire held together with many epoxy joints. These epoxy joints are potential failure sites due to fatiguing of the joints or voltage breakdown (shorting) between adjacent wires. To remain within the temperature limits of the epoxy, the coil temperatures must be kept under approximately 250° F (121° C).

Induct-A-Ring Armatures. The Induct-A-Ring Armature (IAR) uses a solid metal cylinder (ring) as the moving coil, with an approximate 0.5-inch (12.7-mm) wall thickness. The force-generating AC currents in the IAR single-turn coil are produced by induction, eliminating the need for current-carrying linkages between the armature and the shaker body.

The solid metal ring has uniformly distributed electrical properties along its circumference. When induction occurs, any unit length along the ring has a voltage induced in it that is proportional to the length of that segment. That same conductive segment has an electrical impedance Z that is proportional to its length. The distributed voltages E summed along the length of the ring's circumference produce a current flow in the single-turn ring. But note that the voltage potential between any two points on the ring's circumference is equal to the induced voltage rise minus the IZ drop that occurs when the induced current flows in that same segment.

The end result is that the net voltage on the Induct-A-Ring coil itself is zero at all times, even at full shaker output, or a zero-voltage armature coil. This extremely important design factor means that the armature ring requires no electrical insulation from ground, and since all the current is conducted by the one-piece ring, the need for epoxy-bonded coil wires is eliminated. With no electrical insulation or epoxy joints to worry about, the current-carrying areas of the ring can be operated at 600° F (315° C) and higher without concern. The resulting high surface temperature of the ring actually becomes an advantage, allowing extremely effective heat transfer with simple forced-air cooling, eliminating the water hoses and fittings required by conventional wound-coil armatures.

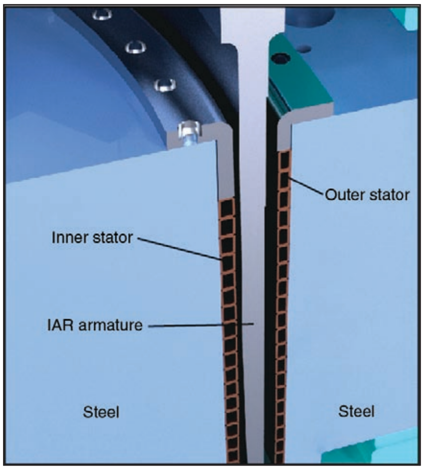

Figure 1. Cutaway view of the Induct-A-Ring shaker.

In summary, how do Induct-A-Ring shakers improve the state-of-the-art? These shakers:

- Eliminate the need for current and cooling-water linkages to the armature.
- Greatly improve the armature's mechanical ruggedness by using a one-piece, solid-metal driver coil.
- Eliminate any voltage potential between the armature and the shaker body.
- Increase armature acceleration limits to 220 g peak sine, 170 g RMS random and 600 g peak classical shock pulse
- Provide significantly higher armature resonant frequencies than wound-coil designs; i.e. 2,200 Hz for the 25,000 lbf (111 kN) T2000 IAR armature and 2,000 Hz for the 40,000 lbf (178 kN) T4000 IAR armature)

Shaker FAQs

Q: How big are Induct-A-Ring armatures?

A: Two sizes: 17.5 inches in diameter and 25.5 inches in diameter (444 mm and 648 mm respectively).

Q: What kind of low frequency output can you get with Induct-A-Ring shakers?

A: Although operation to absolute DC is not possible, the useable low frequency range

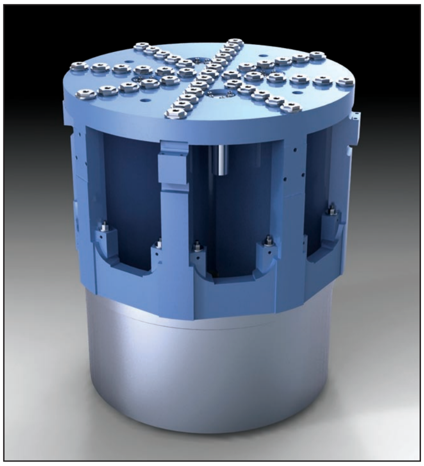

Figure 2. T4000 Induct-A-Ring armature.

limit for all T2000/T4000/T5000/T5500 shakers is 2 Hz. Full-rated stroke is specified down to 5 Hz. Two-inch (51 mm) peak-to-peak standard and 3-inch (76-mm) peak to peak is optional. Note that 3-inch (76 mm) peak-to-peak is standard on the T5500. IAR shaker low-frequency performance meets or exceeds that of most wound coil shakers.

Q: What about high-frequency performance?

A: IAR armatures have significantly higher resonant frequencies than comparable wound-coil designs. The IAR's high-frequency performance advantage is tied to its solid-metal construction and lack of epoxy joints in the moving armature. As a result of these superior frequency response numbers, the T4000/T5000/T5500 shakers deliver full-rated force to 2 kHz, while some T2000 system configurations deliver full rated force to 3 kHz.

Q: Why do IAR armatures have higher max-g ratings than wound-coil armatures?

A: The standard IAR armature structure is comprised of a solid-metal, forged ring that is bolted rigidly to its upper web casting, producing a mechanically preloaded metal-to-metal interface joint as shown in Figure 2. This solid-metal assembly contains no epoxied windings, current-carrying flexures or water-cooling hose fittings. Consequently, the solid-metal IAR armature can tolerate extreme vibration and shock g-levels that typically destroy wound-coil armatures of other shakers.

Extreme Performance. Figures 3-5 show examples of extreme testing conditions performed by IAR shakers. For conventional wound driver-coil shakers, these tests get put into the category of "armature breakers," but UD's Induct-A-Ring technology has changed that.

Please visit www.udco.com for additional information on Unholtz-Dickie products.

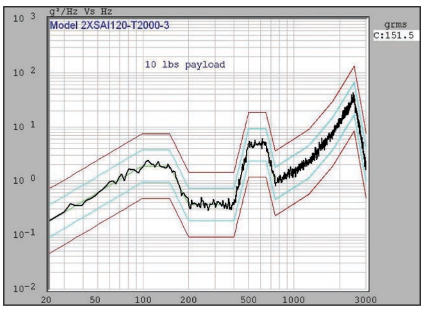

Figure 3. Random vibration test – 150 g overall with 10 lb payload.

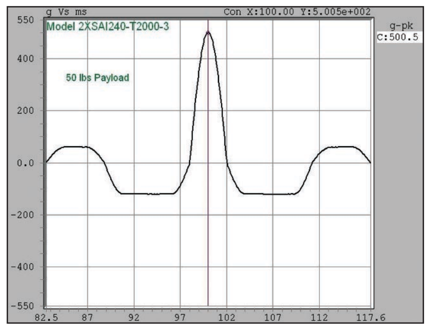

Figure 4. Classical shock test – 500 g peak, 4-msec half-sine pulse, with 50 lb payload.

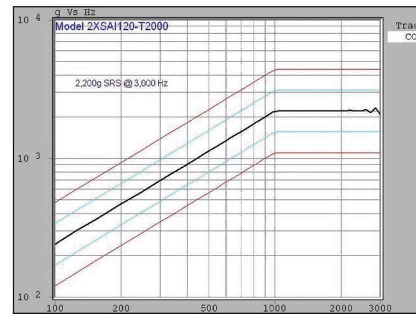

Figure 5. SRS shock test – 2,200 g SRS at 3,000 Hz.