

Figure 1. A **Basic Halbach Array** consists of permanent magnets oriented in a sequence of quarter turns chosen to concentrate the magnetic field on one side. The motion of the array along a wire coil gives rise to an electromagnetic repulsion that can be exploited for levitation.

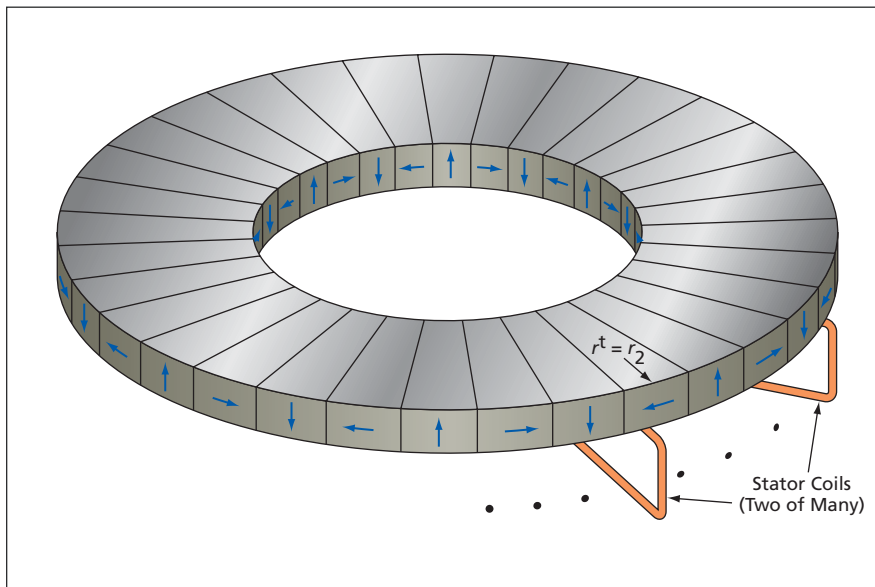


Figure 2. An **Axial Halbach Magnetic Bearing** includes a symmetrical disk version of the Halbach array of Figure 1 plus multiple stator coils in a symmetrical array below the magnet disk. For simplicity, only two of the stator coils are shown.

A basic Halbach array (see Figure 1) consists of a row of permanent magnets, each oriented so that its magnetic field is at a right angle to that of the adjacent magnet, and the right-angle turns are sequenced so as to maximize the magnitude of the magnetic flux density on one side of the row while minimizing it on

the opposite side. The advantage of this configuration is that it makes it possible to approach the theoretical maximum force per unit area that could be exerted by a given amount of permanent-magnet material. The configuration is named after physicist Klaus Halbach, who conceived it for use in particle accelerators.

Halbach arrays have also been studied for use in magnetic-levitation (“maglev”) railroad trains.

In an axial Halbach magnetic bearing, the basic Halbach arrangement is modified into a symmetrical arrangement of sector-shaped permanent magnets in a disk on the rotor (see Figure 2). The magnets are oriented to concentrate the magnetic field on one of the axial faces of the disk — the lower face in Figure 2. The stator coils are mounted in a symmetrical arrangement below the disk.

At a given radial and axial coordinate relative to the disk, the magnetic flux along any given direction varies approximately sinusoidally with the azimuthal angular coordinate. When the disk rotates, the temporal variation of the magnetic field intercepted by the stator coils induces electric currents, thereby generating a repulsive electromagnetic force. The circuits of the stator coils may be terminated with external inductors, the values of which are chosen to modify the phase shifts of voltage and currents so as to maximize the axial repulsion. At and above a critical speed that depends on the specific design, the repulsive force is sufficient to levitate the rotor. During startup, shutdown, and other events in which the rate of rotation falls below the critical speed, the rotor comes to rest on an auxiliary mechanical bearing.

*This work was done by Dennis J. Eichenberg, Christopher A. Gallo, and William K. Thompson of Glenn Research Center. Further information is contained in a TSP (see page 1).*

*Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steve Fedor, Mail Stop 4-8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18066-1.*

## ✱ Compact, Non-Pneumatic Rock-Powder Samplers

**Tool bits for ultrasonic/sonic drill/corers are modified to trap small particles.**

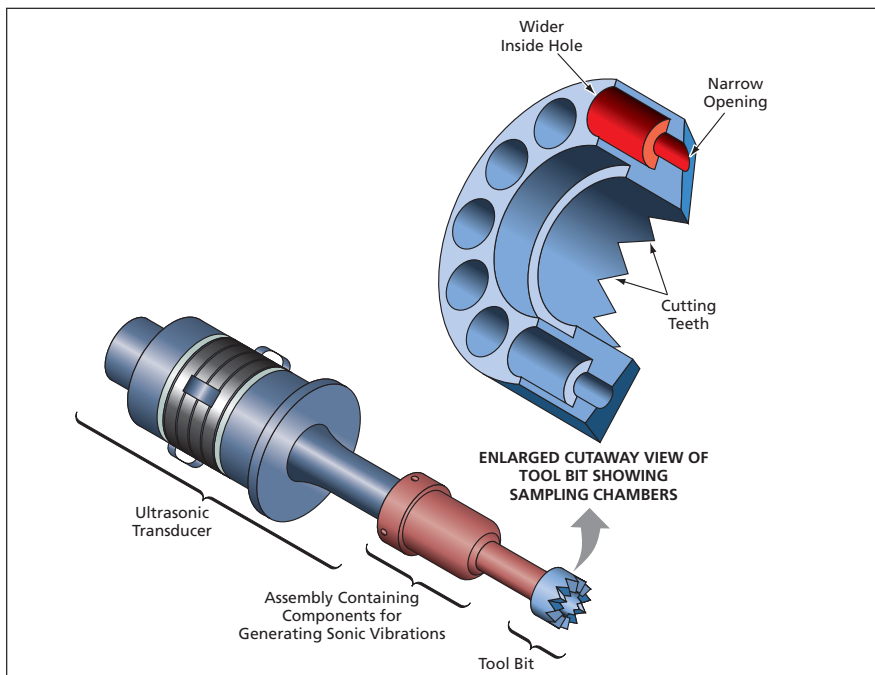
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Tool bits that automatically collect powdered rock, permafrost, or other hard material generated in repeated hammering action have been invented. These tool bits are intended primarily for use as parts of ultrasonic/sonic drill corers (USDCs) and related apparatuses, which have been reported in numerous prior *NASA Tech Briefs* articles. A USDC is based on the concept of a

miniature, lightweight, low-power, piezoelectrically driven hammering mechanism that is excited with a combination of ultrasonic and sonic vibrations that enable its tool bit to bore into rock or other hard, brittle material with very little applied force. There are numerous potential applications for such apparatuses in geological exploration on Earth and on remote planets. Typi-

cally, in such an exploration, the purpose served by a USDC is to cut samples of fragmented rock from one or more depth(s).

The present invention pertains to the special case in which it is desired to collect samples in powder form for analysis by x-ray diffraction and possibly other techniques. In one prior approach, rock fragments generated by a USDC or



**Sampling Chambers** consisting of narrow openings leading to wider inside holes are incorporated into the tool bit of an ultrasonic/sonic drill corer.

other apparatus were first collected by some independent means, then placed into a chamber in the same or a different USDC or USDC-like apparatus, wherein the fragments were crushed into powder. In another prior approach, powder generated at the cutting face of a USDC tool bit was blown into a collec-

tion chamber by a pulse of pressurized gas. The present invention eliminates the need for both the mechanical collection equipment and the crushing chamber of the first-mentioned prior approach and the pneumatic collection equipment of the second-mentioned prior approach, so that it becomes possi-

ble to make the overall sample-acquisition apparatus more compact.

A tool bit according to the present invention (see figure) is hollow and includes holes at or near its cutting tip. Some of the powder kicked up during cutting enters the interior of the tool through the holes. To make the tool more effective in trapping the powder that enters, the holes are tapered (e.g., stepped as in the figure, or else conical), with narrow openings leading to wider inside holes. The narrow openings prevent the entry of wider rock fragments. The collected powder is retained in the tool until needed for analysis. To dispense the powder for analysis, the USDC actuator is simply turned on to shake the powder out through the holes into a suitable receptacle. Experiments have shown that the powdered rock generated by use of a tool bit of this type has essentially the same particle-size distribution, suitable for x-ray diffraction studies, as does powdered rock generated by a commercially available laboratory rock-crushing mill.

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