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CONSIDERATIONS ABOUT THE ACTUAL STAGE OF LINEAR ELECTRIC MOTORS WITH MOBILE COIL

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Abstract **– The present paper is meant to be a short presentation of the actual stage of linear electric motors with mobile coil, also calls „voice-coil actuator". The author show some theoretical consideration regarding these actuators like design consideration, characteristics and performance specifications of this motors and domains of applications of voice-coil motors. It is also presented the examples of voice-coil actuators and future of these motors.**

Keywords: *mobile coil type actuator, movable coil actuator, moving-coil actuator, swing type actuator, linear voice-coil actuator, rotary voice coil actuator.*

1. INTRODUCTION

The studied actuators been part of the machine class to induced without iron (Axem motors, motors to induced bell, etc.), besides, the studied structure is destined to produce a linear movement. One also calls him „voice-coil actuator", that is to say actuator of loudspeaker. It is also calls mobile coil type actuator, moving-coil actuator, movable coil actuator or swing type actuator. It is indeed one of its domains of application, the other being, the practice of the magnetic heads of hard drives and various direct practices where of high dynamic performances are required, for example, in the industry of circuits integrated for the soldering of connections (bonding). A particularity this actuator is the absence of alternate magnetic poles, says the flux otherwise is homopolar this drives to a magnetic circuit of pipeline of the flux relatively sub dimensioned and whose measurements become prohibitive for the big values of effort, it limits applications to the weak measurements (lower to about ten centimeters) [1].

2. DESIGN CONSIDERATION

Aluminium was widely used in the speaker industry due to its' low cost, ease of bonding, and structural strength. When higher power amplifiers emerged, especially in professional sound, the limitations of aluminium were exposed. It rather efficiently transfers heat from the voice coil into the adhesive bonds of the loudspeaker, thermally degrading or even burning them. Motion of the aluminium bobbin in the magnetic gap creates internal eddy-currents in the material, which further increase the temperature, not helpful to long-term survival. In 1955, DuPont developed Kapton, a polymide film which did not suffer from aluminium's deficiencies, so Kapton, and later Kaneka Apical were widely adopted for voice coils. As successful as these dark brown plastic films were for many voice coils, they also had some less attractive properties, principally their cost, and an unfortunate tendency to soften when hot. Hisco P450, developed in 1992 to address the softening issue in professional speakers, is a thermoset composite of thin glassfibre cloth, impregnated with polyimide resin, combining the best characteristics of polyimde with the temperature resistance and stiffness of glass. It can withstand brutal physical stresses and temperatures up to 300ºC.

The actual wire employed in voice coil winding is almost always copper, with an electrical insulation coating, and in some cases, an adhesive overcoat. Copper wire provides an easily manufactured, general purpose voice coil, at a reasonable cost. Where maximum sensitivity or extended high frequency response is required from a loudspeaker, aluminium wire may be substituted, to reduce the moving mass of the soft-parts (cone-coil structure). While rather delicate in a manufacturing environment, aluminium wire is about one third of the mass of the equivalent gauge of copper wire, and has about two thirds of the electrical conductivity. Copper-clad aluminium wire is also used, allowing easier winding, along with a useful reduction in coil mass compared to copper.

One manufacturer uses anodized aluminium flat wire, which is effectively insulated against shorting between turns of the coil, so is not subject to dielectric breakdown as is the case with various enamel coatings used on most voice coils. This creates lightweight, low-inductance voice coils, ideally suited to be in small, extended range speakers. The principal power limitation on such coils is the thermal softening point of the adhesive that bonds the wire to the bobbin.

3. VOICE COIL ACTUATORS BASICS

Voice coil actuators and motors generate force when subjected to an electrical current or magnetic field. The coil within the motor is the only moving component and is usually attached to a moveable load with a device such as a voice coil valve. This design permits high-speed motion and accurate positioning. Voice coil motors are an effective alternative to electromechanical components such as servomotors. Voice coil systems don't produce motion with gears or screws, nor do they generate heat. There are two basic types of voice coil products: linear and rotary. Linear voice coil actuators and linear voice coil motors provide precision, linear motion over short distances. Rotary voice coil actuators and rotary voice coil motors provide precision, circular motion over short angles. Both types of voice coil products are used in many types of control applications, from drive mechanisms in computers to robotic assembly lines.

Performance specifications for voice coil actuators and voice coil motors include force constant, peak force, linear stroke, torque constant, and peak torque. Force constant is the force that voice coil actuators and voice coil motors develop per ampere-turn of coil excitation. It is specified in pounds per amp (lbs/amp) or in Newtons per amp (N/amp). Peak force is the maximum, continuous force developed by a linear voice coil actuator or voice coil motor. Torque constant is the torque a voice coil motor develops per ampere of coil excitation. Angular stroke is the maximum angle of displacement for rotary voice actuators and rotary voice coil motors. Peak torque is another important parameter to consider when selecting a rotary voice coil device. Electrical time constant is the time it takes the current to reach 63.21% of its final value when the actuator is subjected to a step input voltage.

The name "voice coil" derives from the origins of the earliest designs, which were scaled up from the drive mechanisms of cone speakers. That form, shown in Figure 1, continued in use for some twenty years but is rarely seen today. About 1971, a newer form appeared, using a shorter coil and longer magnet section (Figure 2). It had a much smaller, lighter coil, and was capable of higher acceleration, shorter settling time, and better linearity of performance. Since that time a great many improvements have been discovered, and new developments continue to occur [3].

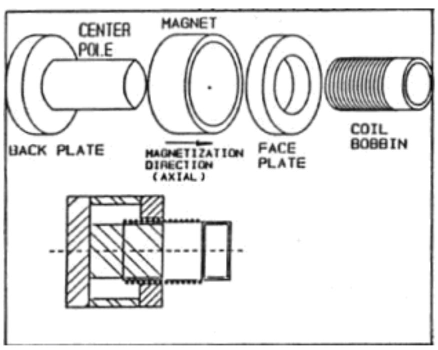

Figure 1: Original voice-coil motor
(long-coil and short gap design).

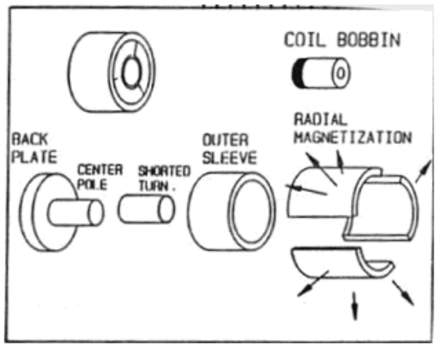

Figure 2: Voice-coil motor
(short coil and longer magnet section).

The design of these deceptively simple-looking devices is more challenging than it might seem at first. Almost any design can be made to work, but not very well. Second-order effects immediately become important and must be dealt with early in the design.

A voice coil is a single-phase, two-wire device that does not require commutation. Changing polarity of the applied excitation reverses the direction of movement. In a closed-loop servosystem, the position sensor sends feedback signals to the drive electronics. The sensor can also be used in open-loop systems when the developed force can be accurately adjusted by controlling the applied power.

The single phase linear voice coil actuator allows direct, cog-free linear motion which is free from the backlash, irregularity, and energy loss that result from converting rotary to linear motion. Rotary versions of voice coils provide such smooth motion that they are becoming the preferred device in applications requiring quick response, limited angle actuation, such as gimbals assembles [4].

In its simplest form, a linear voice coil consists of a tubular coil of wire within a radially oriented magnetic field, as shown in Figure 3.

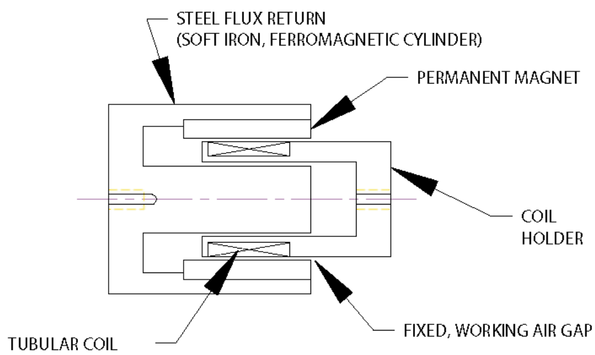

Figure 3: Linear voice coil actuator.

Permanent magnets lining the inside diameter of a ferromagnetic cylinder produce the field. The magnets are arranged so the sides "facing" the coil are the same polarity. The core of ferromagnetic material completes the magnetic circuit. It sits on the coil's axial centerline and is connected on one end to the permanent magnet. When current flows through the coil, it generates an axial force on the coil and produces relative motion between the field assembly and coil, providing the force is enough to overcome friction, inertia, and other forces from loads attached to the coil.

In some cases the axial length of the coil exceeds that of the magnet, by the amount of coil travel. In other cases the magnet is longer than the coil, by the travel length. The long-coil configuration provides a superior force-to-power ratio and dissipates heat better, compared to the short-coil configuration. The short-coil, however, has a lower electrical time constant, smaller mass, and produces less armature reaction. Neither arrangement provides a perfectly linear force-vs-travel characteristic. An armature reaction results from current in the coil and alters the level of flux in air gap. Current through the coil in one direction decreases air gap flux, and current in the opposite direction increases it. Applications calling for a more linear force-vs-position characteristic may use two actuators working in concert. Here, one actuator pulls when the other pushes, and vice versa.

BEI has developed a flux-focus technique which enables the manufacture of actuators with air gap flux densities equal to or greater than the magnet residual value. Actuators based on this technique contain a magnet in the form of a hollow cylinder with one end closed, as illustrated in Figure 4.

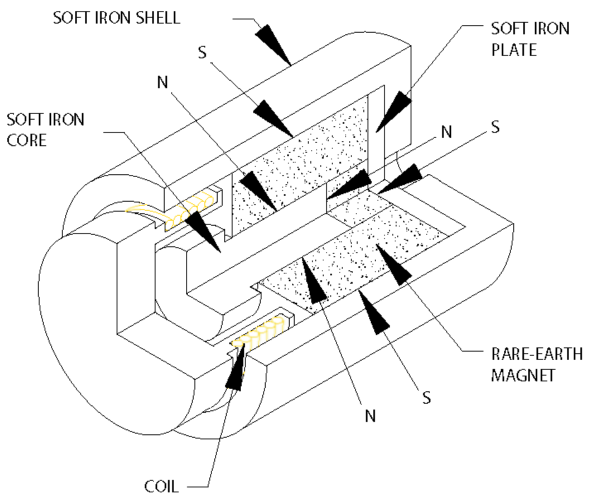

Figure 4: Actuator with flux-focus technique.

The cylinder interior (including the closed end) forms a north pole. The outside of the cylinder forms a south pole. The magnet is surrounded by a tight-fitting, cylindrical shell of soft iron that also has one end closed. The open end of the soft shell extends beyond the open end of the magnet. A cylindrical core, generally fabricated of soft iron, fits tightly inside the magnet and extends beyond its open end. An annular space between the inside face of the shell and the outside face of the core forms an air gap in which the cylindrically shaped coil is free to move axially.

4. EXAMPLES OF LINEAR AND ROTARY ACTUATORS

Linear voice coil actuator (BEI Kimco's LA16-27-000A), presented in Figure 5, is housed with its own bearings and can be used as a standalone component for such applications as valve control (pressure and flow), laser beam steering, auto-focus in optical applications and tension control in textile applications. Linear actuators are also used in factory automation applications like inspection, metrology, packaging, machine tool processing, pick-n-place equipment and optical systems. Rotary actuators such as presented in Figure 6, from BEI Kimco (RA29-11-002A) are ideal for limited angle motions, such as Z-Stages in X-Y-Z positioning equipment, site stabilization, and fin control on aircraft and missiles [4].

Figure 5: Linear voice coil actuator.

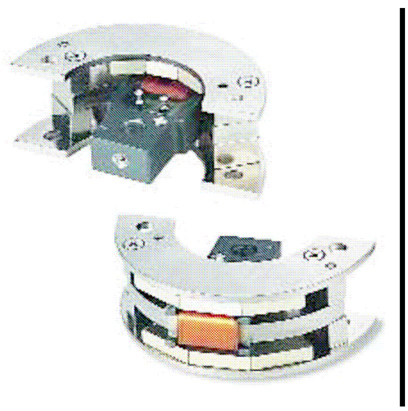

Figure 6: Rotary actuator.

In [1] there are presented inventions regarding linear electric motors with mobile coil. The author has built an electric motor with mobile coil in short-circuit, with variable height [2], presented in the Figure 7. The motor has settled on the column a fixed coil which deals just half from the height of the column and which operates by intermedium of the electrodynamics forces about of a mobile coil in short-circuit, materialized from several boulder stones, mount butt, existing the possibility of intake or take-out these boulder stones, what modifies the height of mobile coil and therefore, the eccentricity among the fixed coil and the mobile coil too.

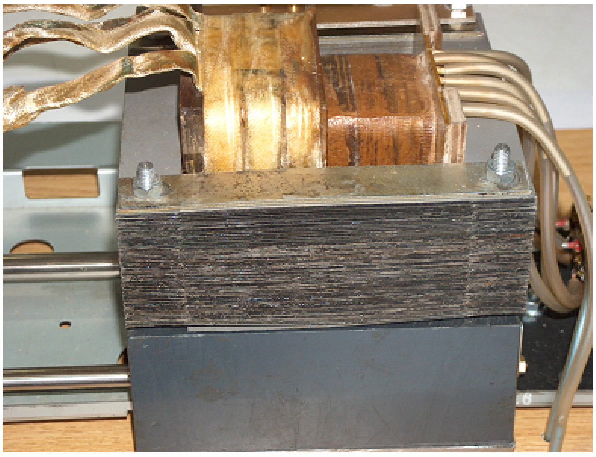

Figure 7: Electric motor with mobile coil in short-circuit.

5. FUTURE OF VOICE-COIL ACTUATORS AND MOTORS

There are two major standards with which voice coil actuators and voice coil motors must comply: RoHS and WEEE. Restriction of Hazardous Substances (RoHS) is a European Union (EU) directive that requires manufacturers of electronic and electrical equipment sold in Europe to demonstrate that their products contain only minimal levels of the following hazardous substances: lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyl and polybrominated diphenyl ether. RoHS became effective on July 1, 2006. Waste Electrical and Electronics Equipment (WEEE) is an EU directive that is designed to encourage the reuse, recycling and recovery of electrical and electronic equipment such as voice coil actuators and voice coil motors. WEEE establishes criteria and requirements for the collection, treatment, recycling and recovery of this equipment. It also makes producers responsible for financing these activities. For their part, retailers and distributors must provide a way for consumers to return used or obsolete equipment without charge. WEEE became effective on August 1, 2005.

6. CONCLUSIONS

The linear motors with mobile coil offer excellent control characteristics where linear actuation is required over short distances with electronic control systems. Comparison of the force characteristics vs. displacement, and vs. current, for voice coil devices and solenoid actuators shows the difference between these devices. The flat force characteristic exhibited by the voice coil motor lend this to applications requiring precise control of force or position such as control valves, or lens and mirror positioning systems, whereas the sharp increase in developed force as the pole faces approach one another in a solenoid device makes these difficult to control.

In general, voice coils are popular in applications that need proportional or tight servocontrol and high accuracy. But they are also replacing conventional solutions in low-accuracy positioning applications, where increasing speed or control is necessary, such as in the textile industry. Other popular applications include precision valve control in medical systems, mirror and lens positioning in optical systems, acting as linear drives for compressors and pumps, vibration dampening or sight stabilization in military applications, and generating vibration in fluidized beds and flight simulators. Voice coils are also being used in multiaxis spherical systems and other complex motion devices, including six-degrees-of-freedom optics.

Acknowledgments

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