Voice Coil Actuators & Their Use in Advanced Motion Control Systems

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Voice coil actuators are direct drive, limited motion electric motors. They employ a permanent magnet field assembly in conjunction with a coil winding to produce a force proportional to the current applied to the coil. These two-terminal, non-commutated electromagnetic devices are used in linear and rotary motion systems requiring high acceleration, high frequency actuation, and linear force or torque output. Typical applications for voice coils Include mirror and lens positioning in optical systems, head positioning in computer hard disk drives, high-accuracy machine-tool positioning, precision valve control in medical and industrial devices, and linear drives for cryo-coolers and other pumps.

In its simplest form, a linear voice coil actuator is a tubular coil of wire situated within a radially-oriented DC magnetic field, as shown in Figure 1. This DC field is produced by permanent magnets embedded on the inside diameter of a ferromagnetic cylinder, arranged so that the magnets facing the coil are all of the same polarity. An Inner core of ferromagnetic material set along the axial centerline of the coil, joined at one end to the permanent magnet assembly, is used to complete this basic magnetic circuit.

When current is applied to the circumferentially-wound coil, it interacts with the DC field of the permanent magnet assembly via the Lorentz Force Principle to create an axial force between the coil and magnet assemblies. The polarity of the current-producing voltage applied to the two terminals of the coil dictates the direction of the axial force upon the coil, while the magnitude of the force on the coil is proportional to the current.

The BEI patented voice coil actuator designs, by virtue of their ultra-high-efficiency magnetic circuits, provide considerably higher force outputs from smaller-diameter packages than the basic voice coil actuator embodiment. These patented actuator designs are the proper solution for many high-acceleration, space-limited requirements. The power supply used to drive a voice coil actuator must provide sufficient current to meet the application's force requirements. It must also provide sufficient voltage to overcome the back EMF at maximum coil velocity and to allow for the resistive and inductive voltage drops across the winding. The coil

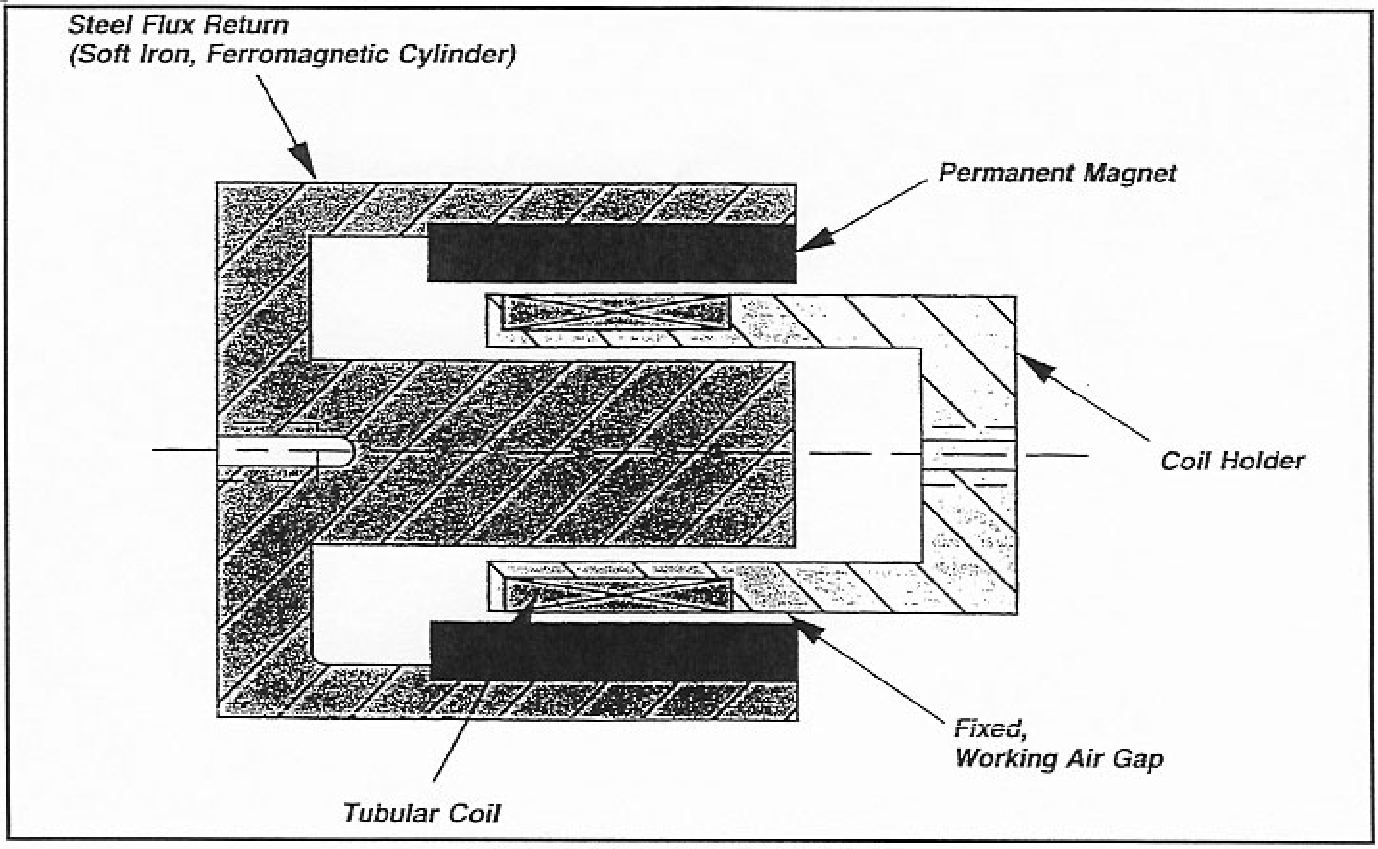


Figure 1 - Linear Voice Coil Actuator

resistance (Ohms) and force sensitivity (Newtons/Ampere) of the voice coil actuator can be impedance matched to most DC power supplies, provided enough volt-amps are available to do the work required for the application.

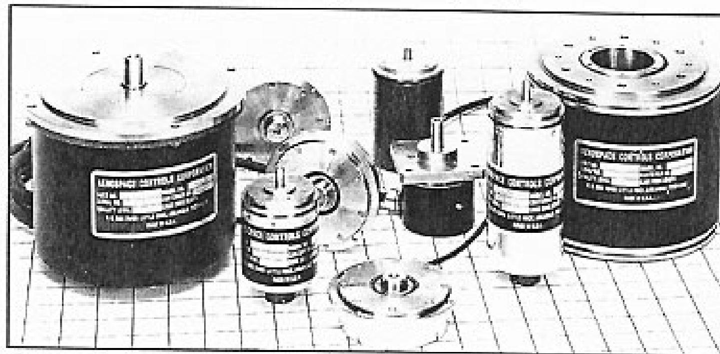
Many applications of voice coil actuators require precise servo control, and, therefore, a closed-loop control system. There is a wide variety of position, velocity, and force transducers which can be used as feedback devices in voice-coil-based servo systems. Most common are optical encoders, contact and magneto-resistive potentiometers, LVDT's, and load cells. Voice coils provide cog-free, hysteresis-free motion capable of infinite sensitivity, limited only by the feedback sensor used to close the control loop.

Voice coil actuators are being employed in an increasingly-wide variety of applications. Their ease of control, fast actuation, smooth response, high reliability, and high efficiency in converting electrical to mechanical energy make them an ideal replacement for conventional electric motors and hydraulic and pneumatic actuators.

Linear voice coils are used for speakers because of their flat response over a wide frequency range. Other voice coil applications requiring high frequency operation Include linear cryo-coolers, refrigerators, and various other pumps, where the actuators are operated in resonance against a gas spring to provide the necessary compression for the particular cooling cycle employed.

The smooth, precise, hysteresis-free, cog-free response of voice coil actuators make them ideal for the control of many types of valves and machine tools. Because there is no contact between moving parts (i.e., the coil and field assemblies), voice coil actuators are more reliable than hydraulic or pneumatic valves. Voice coils are also free of the hysteresis inherent in other types of actuators, thus making them easier to control.

Voice coil actuators are rapidly becoming the preferred drive system for precision optical and machine tool systems. The smooth, fast, cog-free motion provided by voice coils make them ideal for positioning mirrors, lenses, and tools in tightly-controlled servo loops. The electrical and mechanical simplicity of these actuators allow for high reliability and high energy conversion efficiency. Systems designers are continuously finding new and creative ways to incorporate voice coil actuators in their devices.



About the Author

Mr. Anthony C. Morcos is a Senior Magnetics Engineer for BEI Sensors and Systems's Kimco Magnetics Division In San Marcos, California. He joined the Kimco Magnetics Division in July, 1989. He is responsible for the design of linear and rotary actuators, magnetic bearings, and specialty magnetic devices. Prior to joining BEI, Mr. Morcos was an Electrical Engineer at Hughes Aircraft Electron Dynamics Division in Torrance, California. There, he designed and analyzed advanced magnetic circuits for the focusing of electron beams for traveling wave tubes (TWT's). Prior to joining Hughes, Mr. Morcos was involved in graduate research at the University of Dayton Magnetics Laboratory. There he participated in the development of rare-earth permanent magnet alloys under the tutelage of Dr. Karl Strnat. Under a U.S. Army Research Office Fellowship, Mr. Morcos worked at the U.S. Army Research Lab, Fort Monmouth, New Jersey with Dr. Herbert Leopold to design and analyze novel magnetic circuits for bending and focusing high-energy electron beams. Mr. Morcos has a Master of Science in Electrical Engineering (honors) from the University of Dayton. He is a member of Tau Beta Pi. He is also the author of several papers on the design and analysis of magnetic circuits and the measurement of magnetic fields and forces.

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