Material Testing Systems Optimized by the Use of Moving Magnet Linear Motors

By Kirk Biegler
EnduraTEC Systems Corporation

Executive Summary

Significant advances in linear motor design accomplished by the product development teams of the Bose® Corporation and EnduraTEC Systems Corporation now allow for the development of high performance material test systems. This linear motor technology has been introduced in a new product family, the ELF™ (ELectroForce™) Series.

Introduction

Significant advances in linear motor design accomplished by the product development teams of the Bose® Corporation and EnduraTEC Systems Corporation now allow for the development of high performance material test systems. This linear motor technology has been introduced in a new product family, the ELF™ (ELectroForce™) Series.

Whereas previous material test systems utilized mechanical screw drives, hydraulic actuators, pneumatic actuators, or voice coil designs, this new test system uses a patented linear motor design based on a fixed winding and moving magnet assembly. A flexure support guidance system for the moving magnet eliminates the friction associated with traditional bearing/seal assemblies. The new design provides for better efficiency, long-term durability and improved fidelity. The result is a higher performance, more precise test instrument that has cleaner and quieter operation, and a predicted maintenance-free life of more than 10 billion cycles.

Historical perspective

Material test systems have evolved significantly. Leonardo Da Vinci's notebook shows a simple tensile test system that consisted of a basket hanging from a wire made of the test material. Rocks were added until the specimen broke. August Wohler created a simple rotating beam tester to study the fatigue failures of early railroad axles. It provided only simple sinusoidal loading with the load being applied through a spring mechanism.

Today's test systems use computer controls to accurately recreate complex test conditions and monitor the material reactions to the test. So why introduce a new motor technology to material test systems? Aren't the current ways of exciting a sample sufficient? While current technologies have been adapted for a wide range of testing, they are limited in some areas and often provide a poor tradeoff between performance, reliability, cost, and ease-of-use.

The most widely used technology is the mechanical screw driven test system. Often referred to as ElectroMechanical (EM) test systems, they have been optimized for large strain, monotonic tension or compression tests but are sometimes used for slow cyclic testing. The test speed and frequency are limited by the inertia and backlash of the loading mechanism.

Servohydraulic (SH) test systems can be configured for a wide range of test conditions including frequencies to several hundred hz, displacement rates to 25 m/s, and forces to over over 1000 tons. They are relatively complicated with many mechanical components required to make the system work (pump, filtration, cooling systems, hoses, control manifolds, servovalves, actuators, etc.) with working pressure in the range of 200-350 bar (3000-5000psi). These components also make them expensive to purchase and maintain. Maintenance is required on a monthly basis if the test system is used continually. Leaks at the many seals are not uncommon and can make it difficult to maintain a clean test environment.

Servopneumatic (SP) test systems are used for lower frequency (up to 10 hz) tests. The force capacity is usually limited to 10kn (2000lb) due to the need for a large piston area at the lower 7 bar (100psi) pressure level. The mechanical components for the servopneumatic are similar to the servohydraulic but less expensive since they are designed for much lower pressures. In addition, the energy source (pressurized air) is often already available in the laboratory and is easier to install and maintain. Leaks, while a maintenance issue, are not typically a cleanliness issue.

Some low force test systems use a voice coil linear motor technology for force generation. Often referred to as electrodynamic testers, voice coil driven systems are clean, cost efficient devices and are typically optimized for high frequencies. The available force is low ($<$ 20N) due to difficulties in removing the heat generated in the moving voice coil.

Linear Motor Design

The ELectroForce linear motor design uses two magnets that are placed in an electromagnetic field. With this approach, the magnets move while the field remains stationary (See Figure 1).

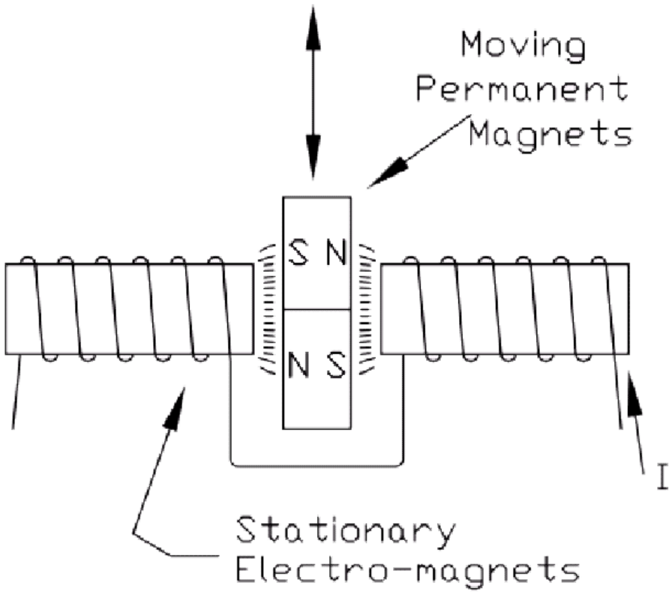

Figure I - ELectroForce Motor Design

The friction-free bearing design (patent-pending) used in the ELectroForce Series Instruments uses a flexure assembly that provides both long travel and high lateral stiffness. The flexure provides infinite fatigue life since it is designed to operate below its fatigue limit.

There are several advantages to this approach:

1. **Wide range of forces.** The ELF 3200 design has been proven to provide force control in the milligram range and the ELF 3400 is available in motors up to 9000N (1000lb) capacity.

2. **Wide range of displacements.** The ELF 3200 linear motor provides up to 13mm of displacement (+/-6.5mm) and has been shown to control 20 nanometer steps with while the ELF 3400 linear motor provides up to 25 mm of displacement (+/-12.5 mm).

3. **High fidelity.** The moving mass is low which permits both low and high velocities as well as a wide range of frequencies and amplitudes with exceptionally low distortion.

4. **Quiet operation.** At normal operating conditions the system is quieter than a desktop personal computer. When operating at extreme forces and/or frequencies, a cooling fan runs at a slightly higher noise level.

5. **No maintenance.** The motor has extremely high durability. This is evidenced by inhouse tests at the Bose Corporation where several of these motors have been running six years at 60 Hz accumulating some 11 BB cycles each. There are no seals or filters to change, no mechanical components to replace.

6. **High efficiency.** The only power supply needed for this motor is a standard 110/220V wall outlet. The power used by an ELectroForce test instrument is a fraction of what is needed to operate a servohydraulic test system.

7. **Clean operation.** There are no lubricants or hydraulic oil. The flexure support system does not generate any debris that can contaminate the test environment.

The ELectroForce Series fills a large gap in the low to medium force (mN to 9000N) capacity test systems for dynamic testing. Traditional electrodynamic test systems do not have the combination of force and displacement required for dynamic mechanical characterization or for the fatigue testing of typical material specimens. Servohydraulic systems do not provide the required fidelity, are expensive and energy inefficient, require considerable maintenance and are prone to leaks. Although cleaner, more efficient and more affordable than SH systems, servopneumatic test systems lack the fidelity and frequency response required for many tests. required fidelity or are not cost effective and they always require excessive maintenance.

Summary

The linear motor design used in the ELectroForce Series is the result of over a decade of research. It utilizes an advanced electromagnetic design combined with a friction-free bearing design. The combination of these two elements provides performance, precision and durability that is unmatched using other traditional technologies. This enables the ELectroForce Series to perform traditional tests at a much higher level of performance and accuracy and new tests that were not possible with previous generations of test instruments.

EnduraTEC
Life Enhancing Test Solutions
5610 Rowland Road, Minnetonka, Minnesota 55343 USA
PH: 952•278•3070 FAX: 952•278•3071
Email: info@enduratec.com Web Site: www.enduratec.com