Introduction to Actuators

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This Lecture Contains

- Why Energy Conversion is needed?
- Energy Conversion in Actuators
- Electrohydraulic (EH) Actuators
- EM based Actuators
Physical Process involving a combination of Mechanical, Fluid, Thermal, Chemical, Electrical Components/Subsystems

- Actuators
- Power Modulation
- Energy Conversion

- High Power

- Sensors
- Energy Conversion

- Signal Processing
- Electronics, Software
Why energy conversion is needed?

- Fully mechanical systems are possible eg. Store energy in spring (PE) or in Flywheel (KE) and extract as required – toys. However, for such a system:
  - closed loop system development is not generally possible
  - energy could not be transferred to a long distance - loss is quite high
  - It will not be green, clean and economic
Energy Conversion in Actuators

- Electromagnetic: eg. Motors
- Electro pneumatic/Electro-hydraulic
- Electrostatic: MEMS based
- Piezoelectric: eg. PVDF
- Magneto-strictive: Terfenol-D
- Phase-Change related: NITINOL

MEMS based Electrostatic Actuator
Example of an EH-Actuator

[Diagram of an EH-Actuator system including: Hydraulic Power Supply, Servo Controller, Flow Control Valve, Linear Actuator, Load, Displacement Transducer, and Seals with direction of piston movement.]
The flow path of such a system could be expressed as:

Motor -> Pump -> Spool Valve/ Poppet Valve ->
Accumulator/Pressure Release System -> Loading/Return
Electromagnetic energy conversion

Magnetic field has high energy density than the electric field

Magnetic flux density \( B = \mu H \)

Lorenz's Law

Force realized by a current carrying conductor of length \( L \)

\[
F = I \times B; \\
|F| = Bli
\]

Faraday's Law:

Motion of a conductor in a magnetic field will produce EMF

\[
E = -\frac{d\varphi}{dt} = BLv
\]
Types of EM based Actuator

- Solenoids(EM) /EH/EP actuator
- DC Motors (with bruss/ brussless)
- AC Motors (synchronus/)
- Stepper Motors
A solenoid is a long wire, wound with a helical pattern, usually surrounded by a steel frame, having a steel core inside the winding.

When carrying a current "i ", the solenoid becomes an electro -mechanical device, in which electrical energy is converted into mechanical work.
Efficiency of a solenoid depends on: Geometry, Electrical Configuration and Magnetic permeability of the three subsystems - core, plunger and housing.

The plunger is free to travel in the center of the winding in a linear mode. When the coil is driven by an electric current "i", a magnetic force is created between plunger and the end core, causing the plunger to move. The higher the permeability of steel used, the better will be the performance.

It is essential for a solenoid to lose its magnetic force as fast as possible when the input electrical power is removed. This is to allow the plunger to resume its original position. Any remaining magnetic field is residual magnetism.
To obtain the optimum performance, reliability and life of a solenoid, selection considerations should include the following factors:

1. **Force or Torque**

   Pull, push or rotary load, developed by plunger when the coil is activated by an external voltage.

2. **Stroke**

   The distance a plunger must travel before it is stopped.

   The force versus stroke relationship must be known for any particular solenoid to be used. This relationship is usually shown as a characteristic curve.
The speed of an AC motor depends on the following variables:

- The fixed number of winding sets (known as poles) built into the motor, which determines the motor's base speed.
- The frequency of the AC line voltage.
- The amount of torque loading on the motor, which causes slip.
Special References for this lecture

- www.howstaffworks.com
- Modern Control Systems – Dorf and Bishop Addison-Wesley