Unit 3: Actuators

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based on

Electrical Motor Control Systems by Patrick and Fardo

and

Electromechanics: Principles, Concepts, and Devices by Harter

Actuators

- Motor or valve that converts power into robot movement.
- Types of Actuators
  - ➔ Pneumatic - investigate in lab
  - ➔ Hydraulic - investigate in lab
  - ➔ Electric
    - » DC Motors
    - » AC Motors
    - » Special Purpose Motors

Background Information

- **The Electromagnetic Circuit**
  - ➔ **Formed when a closed ferromagnetic pathway (core) is wrapped with a coil of insulated wire through which electric current is passed resulting in a magnetomotive force (mmf).**
  - ➔ **The magnetic field resulting from the mmf is conducted through the core in the form of magnetic flux.**
  - ➔ **See diagram on handout. (Fig. 10.1)**

Magnetomotive Force (mmf)

- **Result of electric current circulating in the coil wrapped around the core.**
- **Must be applied to produce magnetic flux in the core.**
- ***mmf* = *NI***
  - ➔ ***mmf* = magnetomotive force in A (amp-turns)**
  - ➔ ***N* = number of turns traveled by the current in the coil**
  - ➔ ***I* = electric current in the coil in A**

Magnetic Flux, f

- Circulates in the core of the magnetic circuit when electric current passes through the coil.
- Use left-hand rule where fingers are in direction of electron flow and thumb points in direction of flux.
- Measured in units of webers (Wb).

Magnetic Flux Density, *B*

- **Amount of flux per unit cross-sectional area.**
- **Used as an indicator of the force of the magnetic flux.**
- $B = \phi / A$
  - ➔ **B = flux density, in Wb/m^2 or T (teslas)**
  - ➔ **ϕ = flux in the core, in Wb**
  - ➔ **A = area, in m^2**

Magnetic Field Strength, *H*

- **Takes in to consideration the pathlength taken by the magnetic flux as it circulates in the core.**
- **Shorter path leads to stronger field.**
- $H = (NI)/l = mmf\ /\ l$
  - ➔ ***H* = magnetic field strength in A/m**
  - ➔ ***l* = average length of the magnetic path in m**

Permeability, μ

- **Indication of a material's ability to carry magnetic flux when acted on by a *mmf*.**
- ***B*** **=** m***H*** **where** m **is the permeability of the core material in Wb/A-m**
- **The magnetization curve depicts the nonlinear relationship between flux density and field strength.**

DC Motors

- **Used in industrial applications where control of speed and torque is important.**
- **Motor Parts**
  - ➔ **Armature (rotor) - a laminated core with parallel slots in it to receive current-carrying conductors**
  - ➔ **Stator - stationary components providing field poles**
  - ➔ **Commutator Assembly and Brushes - allows the armature field to be commutated (periodically reversed)**
- **See handout. (Fig. 15.1)**

General DC Motor Operation

- **The conductors of the armature are connected to the segments of the commutator that are energized by the carbon brushes riding on the commutator.**
- **The current supplied by the brushes creates a magnetic field in the armature windings.**
- **This magnetic field interacts with the magnetic field created by the field windings in the stator thus producing a torque that causes the armature to rotate.**

General DC Motor Operation (cont.)

- **As the commutator (attached to the shaft) rotates, it continually reverses the armature current assuring the shaft continues to rotate.**
- **To ensure smooth operation, motors generally have four or more poles and the armature is wound with many conductors.**
- **The torque produced by the motor is $t = kI_A f$ where I_A is armature current and k is a proportionality constant dependent on the number of poles and armature conductors.**

DC Motor Characteristics

- **Counterelectromotive Force (CEMF)**
  - ➔ **An induced voltage, produced by any coil with an applied voltage, which acts to oppose any change in the winding current.**
  - ➔ **V = L *di/dt***
- **When initially energized, the armature current (I_A) can be very high but once acceleration of the armature starts, the generated CEMF opposes I_A.**
  - ➔ **Large values of armature current are accompanied by large values of torque which can damage the motor.**
  - ➔ **A dc motor starter is employed to restrict the starting current.**

DC Motor Characteristics (cont.)

- **Brushes are located in the planes where the applied voltage and the CEMF cancel.**
  - ➔ **With minimal voltage present when the commutator segments are shorted together by the brushes, minimal arcing is produced thus extending the life of the brushes and allowing operation at cooler temperatures.**
- **The neutral planes twist (move) as the motor speed increases. Interpoles are added to compensate for the shift in the neutral plane.**

DC Motor Characteristics (cont.)

- **Speed Regulation**
  - ➔**Indication of the response of a dc motor's speed to a change in load.**
  - ➔**Dependent on the type of motor.**
  - ➔***Speed regulation = $(S_{NL} - S_{FL})/S_{FL}$ X 100%***
    - » **S_{NL} and S_{FL} are the no-load and full-load speeds (in rpm or rad/s), respectively.**
- **Runaway - can occur at no load conditions without the proper precautions and causes high torque that damages the motor.**

DC Motor Characteristics (cont.)

- **Horsepower rating of motors**
  - ➔ **Based on the amount of torque produced at the rated full-load values.**
  - ➔ $hp = (2\pi NT)/33{,}000 = NT/5252$
    - » ***hp*** **= horsepower rating**
    - » ***N*** **= speed of the motor in rpm**
    - » ***T*** **= torque developed by motor in ft-lb**

DC Motor Losses

- **Winding Losses**
  - ➔**Caused by the electrical resistance of the motor windings and are equal to I^2R.**
- **Brush Contact Losses**
  - ➔**Caused by the resistance of the brushes and are equal to I^2R. Increases with heat.**
- **Friction Losses**
  - ➔**Caused by brush friction, bearing friction, and resistance. Heat is generated adding to loss.**

DC Motor Losses (cont.)

- **Iron Losses**
  - ➔**Eddy current losses**
    - » **Eddy currents are induced in a changing magnetic field adding to the loss and heat.**
    - » **Reduced by making the core of thin insulated stacked laminations.**
  - ➔**Hysteresis loss**
    - » **Produced by the resistance of the core to constant changes in magnetic field.**

DC Motor Losses (cont.)

- **Short Circuit Losses**
  - ➔**When the brush is in contact with two commutator segments, the brush shorts out the coil connected to those segments.**
  - ➔**This develops a torque opposing the main torque and introduces heat to the motor.**

Types of Motors

- **DC Motors are classified by the method used to produce the field flux.**
- **Types of Motors:**
  - ➔ **Permanent Magnet**
  - ➔ **Shunt-wound**
  - ➔ **Series-wound**
  - ➔ **Compound-wound**

Permanent-Magnet (PM) Motor

- Uses permanent magnets for its field poles.
- Since f is fixed by the magnet, starting torque is directly proportional to I_A.
- Speed is varied by varying the armature's terminal voltage.
- Good efficiency since power is not needed to create the stator field.
- See handout. (Fig. 15.6)

Shunt-Wound Motor

- **Uses field windings wrapped around field poles connected in parallel (shunt) with the armature thus providing the stator's magnetic field.**
- **Field flux is constant unless a rheostat (variable resistor) is placed in series with the field winding to control the current.**
  - ➔ **Increased resistance reduces current which in turn reduces torque**
- **See handout (Fig. 15.7)**

Series-Wound Motor

- **Field winding is in series with armature winding.**
- **A change in load affects the speed.**
  - ➔**Decrease in load results in decreased flux density reducing the CEMF and increasing shaft speed.**
- **Works extremely well in applications requiring high torque and low speed for starting and high speed and low torque for running (winch).**
- **See handout (Fig. 15.8)**

Compound-Wound Motor

- **Has both a shunt field winding and a series field winding.**
- **The speed can be decreased by varying the armature terminal voltage or increased by adding resistance to the shunt field circuit.**
- **Finds application in machines that require some speed regulation when sudden loads are applied to the running motor (punch press).**

The End

- **Activity**
  - ➔**Lab on mechanical principles**
- **Homework**
  - ➔**Read Chapters 9, 10, and 11**
  - ➔**Chapter 9: Review Questions 6, 7, 9, 10 Additional Problems 5, 6**