SOLENOID

Topics Covered

- Magnetic fields of coiled conductors.
- Implementation of electromagnetic field theory for use in a solenoid.

Prerequisites

- The QNET Mechatronic Actuators has been setup and tested. See the QNET Mechatronic Actuators Quick Start Guide for details.
- You have access to the QNET Mechatronic Actuators User Manual.
- You are familiar with the basics of LabVIEW™.
- You are familiar with the basics of electromagnetism.

1 Background

A solenoid is a type of electromagnet that produces a uniform magnetic field in a volume of space when an electric current flows through a conductor that is tightly wound into a helix shape. In electromechanical applications, the coil is wound around a movable steel or iron rod called the armature. Typically, solenoids are only used for fast, but very limited, linear movements of the armature, such as on/off position switches, dot matrix printers or fuel injectors. Its function is based on the principle that current flowing through a conductor will induce a magnetic field that is perpendicular to the conductor.

1.1 Right Hand Rule

Electrons moving through a conductor generate a magnetic field that is centered at the conductor. In particular, the *right hand rule* can be used to determine the direction of the resulting magnetic field. For a straight conductor, imagine your right thumb pointing in the direction of the current flow through the conductor. The curl of the remaining fingers of your hand indicate the direction of the magnetic field. Vice versa, if the direction of magnetic field is known, it is possible to determine the direction in which the current is flowing.

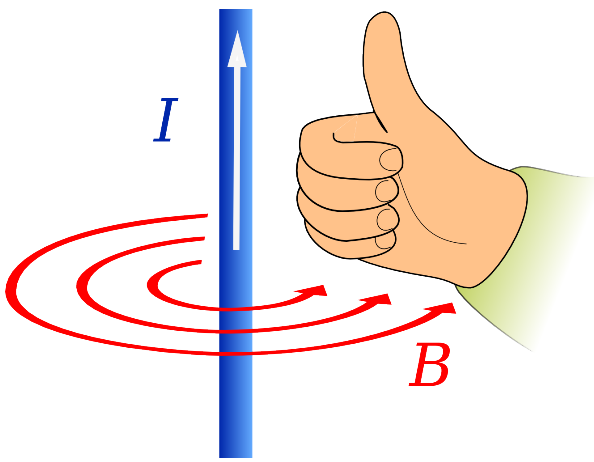


Figure 1.1: Conductor right hand rule [1]

This idea can be extended to coiled conductors such as helices or solenoids. Imagine your right hand curls in the direction of the electron flow of the coil. Your right thumb then indicates the direction of the magnetic field by pointing to the north pole of the coil. Vice versa, if the direction of the magnetic field is known, it is possible to determine the direction of the current flow in the coil.

1.2 Choosing a Solenoid

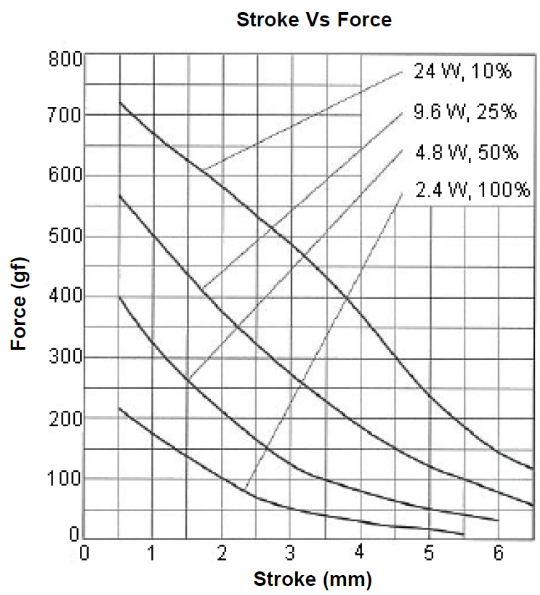
To choose the right solenoid for your project, you first need to specify your requirements, notably the holding force, desired stroke and duty cycle. The holding force of a solenoid is dependent on the length of the solenoid and the number of coil turns, the material of the armature, and the applied current.

Depending on the application, solenoids may be used for short pulses or continuous use. The relationship between active (*ON*) and inactive (*OFF*) times of the solenoid is captured in the duty cycle

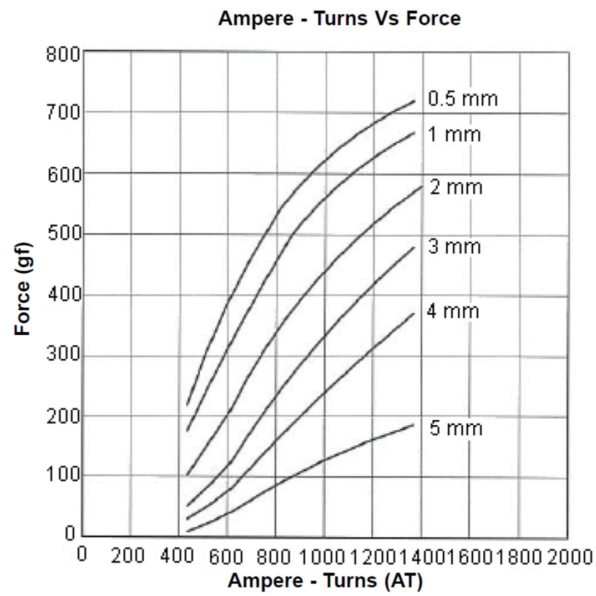
$$\text{Duty Cycle} = \frac{ON}{ON + OFF} \times 100\ \%. \tag{1.1}$$

[1] José Fernando - Universidad de Granada

2 In-Lab Exercise



(a) Stroke vs. Force



(b) amp-vs-force

Coil Data

Duty Cycle (%) = $\frac{\text{"ON" Time}}{\text{"ON" Time + "OFF" Time}} \times 100\%$	Continuous (100%)	Or Less (50%)	Or Less (25%)	Or Less (10%)
Maximum "on" time seconds	∞	55	19	3
Watts at 20°C	2.4	4.8	9.6	24
Ampere - turns at 20°C	432	615	864	1,368

Specification Table

Description	Resistance (20°C) Ω ±10%	Number Turns	Volts DC				Part Number
Solenoid, Open Frame, Push, 6 V	15	1,080	6	8.5	12	19	MCSMO-0630S06STD
Solenoid, Open Frame, Push, 12 V	60	2,160	12	17	24	38	MCSMO-0630S12STD
Solenoid, Open Frame, Push, 24 V	240	4,320	24	34	48	76	MCSMO-0630S24STD

(c) Coil Data and Specifications

Figure 2.1: Parts of the data sheet of a solenoid

1. Open `QNET Actuators - DC Motors and Solendoid.vi` . **Make sure the correct Device is chosen.**
2. Run the VI.
3. You can activate the solenoid by pressing and depressing the Power Solenoid button. Activate the solenoid and touch it with your fingers. Characterize the temperature of the solenoid qualitatively.
4. Leave the VI running in the background with the solenoid activated.
5. Figure 2.1 shows parts of a typical datasheet of a solenoid. In particular, we are interested in the solenoid with the part number MCSMO – 0630S12STD in Figure 2.1c. This solenoid is designed such that it can run continuously at 12 V, but may be run at higher voltages for shorter duty cycles. With the data given in Figure 2.1c, determine the current that runs through the solenoid for the specified voltages that relate to a 100 %, 50 %, 25 % and 10 % duty cycle using Ohm's Law.

6. Explain why the maximum time the solenoid is active is decreasing with a lower duty cycle.
7. Explain why you would want to run a solenoid at a higher voltage.
8. Using Figure 2.1b, explain why the holding force is lower if the armature is travelling further.
9. Recall the temperature test from the beginning of the laboratory experiment. Note the hot surface warning symbol on the board, shown in Figure 2.2. Repeat the test by briefly and ***cautiously*** touching the solenoid with your fingers. Characterize the temperature of the solenoid qualitatively. Explain your observations.

Figure 2.2: Hot Surface Warning Symbol

10. Click on the Stop button to stop the VI.

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