Electromagnetic Bodybuilder

ECE 445 | Spring 2016

Mock Design Review

Group 50
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Block Diagram

Schematic
Solenoid Circuit
Calculation

Equation Derivation

1) Calculate Inductance of Solenoid
\[ L = \mu_0 n^2 A / l \]

\( \mu_0 \) - Magnetic Permeability Constant

\( n \) - number of turns

\( A \) - Area of solenoid hole

\( l \) - Length of Solenoid

2) Calculate Energy of Solenoid
\[ E = \frac{1}{2} LI^2 \]

\( L \) - Inductance

\( I \) - Current

2.5) Equations 1 and 2 can be combined to make
\[ E = \frac{\mu_0 n^2 A I^2}{2l} \]

3) Calculate Force
\[ F_0 = \frac{E}{x} \]

\( E \) - Energy in Solenoid

\( x \) - Distance Moved

4) Combining equations 3 and 2.5, we get
\[ F = \frac{\mu_0 n^2 A I^2}{2lx} \]

This equation yields
\[ I = \sqrt{\frac{F2lx}{\mu_0 n^2 A}} \]

Parameters

Since we are using 4 Solenoids, our total force will actually be 4\( F_0 \). One weight we would like to replicate is 150lbs. Based on the products we researched, the bar itself is expected to weigh 25lbs, so subtracting the weight of the bar, we need to replicate 125 lbs.

We also used the average upper arm length for \( x \) which is 14.25in or 0.362m.

The bar we are using will be ferritic stainless steel with magnetic permeability of \( 2.26 \times 10^{-3} \) (N/A²)

Also, we one want to change the current since the number of turns, length, and area are not things that would convenient for the user to change.

The radius of our solenoid is 1 inch which is 0.0508m

Therefore the area of the solenoid is 0.0081073m²
$125 \text{lbs} \times 0.4536 (\text{kg/lbs}) = 56.7 \text{kg}$

$F = m \times a$

$F = 56.7 \text{kg} \times 9.81 (\text{m/s}^2) = 556.23$  

$F_0 = \frac{F}{4} = 139.06 \text{N}$

$A = 0.002027 \text{m}^2$

$l = 6 \text{in} = 0.1524 \text{m}$

$n = 100 \text{ turns}$

$\mu_0 = 2.26 \times 10^{-3} (\text{N/A}^2)$

$x = 0.362 \text{m}$

$I = \sqrt{\frac{2F_olx}{\mu_0 n^2 A}}$

$I = \sqrt{\frac{2(139.06 \text{N})(0.1524 \text{m})(0.362 \text{m})}{(2.26 \times 10^{-3} \text{N/A}^2)(100^2)(0.0081073 \text{m}^2)}}$

$I = 9.1511 \text{A}$

From this, after plugging the number into the equation found above for current, the required current will be $9.1511 \text{A}$ in order to replicate 150lbs.

Plot
Block Description

Solenoids (4): The solenoids are the meat of the system, as they are components that produce the magnetic fields. The solenoids must be able to produce forces that can replicate up to 150lbs of force. Our solenoids will use 18AWG copper magnet wire wound 100 times around PVC piping. With this number of windings, the solenoid must be able to withstand up to 12 V ± 2 V and 10 A ± 1 A in order to simulate up to 150lbs.

Requirements and Verification

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<th>Requirement</th>
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<tr>
<td>Solenoids (4)</td>
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<tr>
<td>1. Wire functions for $I_{\text{max}} \leq 10$ A</td>
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<td>2. Temperature of wire ≤ 70°C at 10 A</td>
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<td>Solenoids (4)</td>
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<td>1. Verification process for item 1:</td>
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<td>a. Set dc power supply to 12 V, 1 A, do not output yet. This will be a dc load.</td>
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<tr>
<td>b. Connect positive terminal of dc power supply to positive terminal of 12 V battery using a small strip of 18AWG copper</td>
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magnet wire. Repeat for negative terminals.
c. Output 12 V from dc power supply. Using multimeter, ensure no voltage drop across wire.
d. Slowly increase current of dc power supply to 10 A by increments of 0.5 A and ensure current flows at 10 A.

2. Verification process for item 2:
a. Continuing from verification process for item 1, attach temperature probe to one of the 18AWG copper magnet wires.
b. Wait 5 minutes for temperature to rise and ensure temperature of wire does not exceed 70°C.

Safety
Because our project utilizes high voltage power, we have considered different ways to keep the user safe. Also, because it is intended to be able to eliminate the need for a spotter, it must also protect the user from enduring dangerous activities.

Since the copper wiring will sustain actively flowing current of up to 10A, we must conceal the solenoids in a box so that the user is not in danger of accident touching them. We also will need to conceal other circuitry as well for the same reason.

In order to protect the user from sustaining injuries from the physical activity, a cut off switch in the form of a foot pedal is available to mitigate the current in the solenoids so that electromagnetic force will dissipate as soon as possible.

While we are building the design, we will test of the different sections, highlighted orange in the block diagram, separately. These difference sections are expected to operate with 120V, 12V, and 5V respectively. Since each of these sections operate at different voltages, we do not want the components of each to be exposed to voltages outside of their limits. Also we will perform and comply to the lab safety guidelines to make sure we work safely and react to potential hazards correctly.
Citations


