Digital Switchable Magnet as a Power-Efficient Alternative for Sorting Colored Ferromagnetic Coins

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Abstract

The goal of this research is to investigate the efficiency of a digital switchable magnet (DSM), in place of an electromagnet, to pick up one-inch diameter ferromagnetic coins for a color coin sorting robot.

In the past, electromagnets have been used to achieve magnetic flux control desired for this application; however, electromagnets come with one significant limitation: continuous power consumption. Switchable magnets present a more efficient alternative for robotic applications specifically on a mobile system.

The switchable magnet’s housing is fitted with a digital servo motor to rotate the top dynamic magnet 180° using pulse width modulation (PWM) signals. The switchable magnet will be used in place of the electromagnet and tested for its power efficiency. Here, we present our ongoing work and accomplishments.

Introduction

Single permanent magnets have limited applications because there is no control over their magnetism; permanent magnets are always magnetic. The common solution for controlled magnetism is an electromagnet which has been in use since the last century. An electromagnet is a device that generates a magnetic field around itself as long as current is provided. When power is on, an electromagnet has magnetism. When power is off, an electromagnet has no magnetism. The issue with electromagnets surfaces when powered on for long periods of time. The longer the electromagnet is turned on, the more current is drawn from its power source.

In the case of mobile robotic systems, the power source is typically limited by its supply of Amp-hours. If at any point in time the battery is out of charge during operation, the electromagnet will turn off and lose the desired magnetic force. It is very important for a coin sorting robot to not lose any of its coins, and if power is cut to the electromagnet during the pick-up process, then the coin will slip away and may become impossible to find again. To insure reliability and power efficiency, a digital switchable magnet is tested under the same conditions, and compared to the electromagnet equivalent. An H-type switchable magnet is tested for the purpose of this research. The basic principle of switchable magnets relies on the ability of rotating one dynamic magnet 180° over a permanent magnet, thus changing the orientation of the magnetic flux to either inside or outside its housing.

Engineering Principles

The following equations were used to calculate the resulting data:

\[ P = V I \]
where \( P \) = Power (W), \( V \) = voltage (V), and \( I \) = current (A)

\[ \text{Energy Equation: } \text{Wh} = P \times t \]
where \( \text{Wh} = \) Watt-hours, and \( t = \) time(s)

\( \text{Wh conversion to Ah: } mAh = 1000 \times \text{Wh} \times V \)

Table of Values

Table 1. Comparison of DSM and Electromagnet

<table>
<thead>
<tr>
<th>Holding Force (N)</th>
<th>DSM</th>
<th>Electromagnet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage (V)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power (W)</td>
<td>2.73</td>
<td>5.047</td>
</tr>
<tr>
<td>milliWatt-hours (mWh)</td>
<td>1.138</td>
<td>28.039</td>
</tr>
<tr>
<td>milliAmp-hours (mAh)</td>
<td>0.163</td>
<td>4.006</td>
</tr>
</tbody>
</table>

** Considering the electromagnet is powered for 20 s

Results

The Digital Switchable Magnet is assembled with the output shaft of the motor to the shaft of the Magjig 60, which controls the top dynamic magnet via hub connections. The servo motor is operational at 7V with a max current of 300mA and changes the state of the magnet in a tested 1.5 s. The electromagnet is driven by a power of 1 W transmitted through a constant voltage of 5V at a max current of 1A.

In our case study, the coin sorting process takes 20 seconds per coin to complete. This time interval incudes picking up a coin off the floor, analyzing its color, and moving the robot to the correct colored square, whose distance varies depending on location. The electromagnet is required to be powered on for at least 20 seconds to complete this task. The DSM will only need to be powered on for its two instances of switching the state of the magnet.

Discussion

The comparison in Table 1 shows the advantage of using a DSM over an electromagnet. Despite the DSM operating at higher voltage levels, the DSM actually uses less power. Furthermore, because of the DSM’s unique power feature, it consumes much less energy than the electromagnet because it can be powered off while maintaining its current state. The other parameters of Table 1 can be taken into account when considering which type of magnet to use. In addition, A DSM can lift 5 times more weight and uses 60% less battery power than its electromagnet equivalent.

Conclusions

A digital switchable magnet is a power-efficient alternative that uses 60% less battery power than its electromagnet equivalent. This is due to its unique power feature that allows it to be turned off while maintaining its current state of magnetism. When using the DSM in the case of sorting ferromagnetic coins (where the device must be turned on for 20 seconds) power consumption is reduced by a factor of 200, resulting in an equivalent electromagnet. The DSM is most favorable in situations where ferromagnetic objects must be attracted for periods of time lasting longer than 1.5 seconds. Time spent after the magnet is turned on is not spent on wasting battery power to maintain its magnetized state. This parameter is desirable in mobile robotic systems, where a conservation of battery is critical for the success of the mission.

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References

