Inductive Sensing Based Accurate Rotation Angle Detection for Commercial Building Roller Blind

Joon Moon[1], JaeJeong Hwang[2]*
[1]JF Systems Ltd., Korea
[2]Kunsan National University, Korea

Abstract: In the commercial building such as huge enterprise building, more accurate operation of the center-controlled roller blind is necessary. We design, in this work, the target disc that its shape is nonlinearly changing and the sensor coils that are differentially arranged. The performance shows less than 1% accuracy when it is implemented in the roller blind.

Key-Words: *Inductive Sensing, Non-destructive Testing, Roller Blind, Rotation Angle Detection*

1. Introduction

When a metal on the target is placed in close proximity to the sensor coil, the induced current produces a counter field that reduces the effective inductance of the sensor coil, thus changing the resonant frequency and electric voltage [1]. Using the phenomena, we can measure distance between two conductors.

In the application of roller blind, moving up and down, distance between two conductors is fixed and induced eddy current does not change. Thus, we need to introduce variable shape of the target that is changed by rotation of the sensor coil. The amount of the coil-target overlap changes as the target rotates. Overlapped area can be used to measure rotational angle. To accomplish the task, we design the target disc and corresponding sensor coil.

2. Model for inductive sensor and target

The principle of inductive sensing is based on the variation of inductance when a conductive material, such as a metal object, is placed in a magnetic field of the sensor coil. Figure 1 shows an electrical model for inductive sensor and target material. The eddy current induced on the target is a function of distance, size, and composition of the conductor. The voltage across the sensor coil is represented by

$$V_P = L_{SS}\frac{dI_1}{dt} - M\frac{dI_2}{dt} \tag{1}$$

where L_{SS} and M denote inductance in the sensor coil and mutual inductance by interacting with the target. That is, inductance L_{SS} is affected by target inductance L_{ST}.

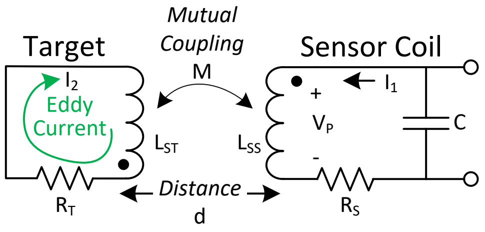

Figure 1 Electrical model for inductive sensor and target

3. Rotation angle detection for roller blind

Although the eddy current is a function of distance between sensor and target, we assume that the distance is fixed but area of conductor may change depending on the rotation angle, since the sensor is located on the roller blind bracket. Figure 2 depicts the target and sensor coil that are overlapped when rotating. Though the thickness between two circles is linearly variable on the rotation angle, the overlapped area is nonlinearly changing.

Received: 2016/12/5, Accepted: 2016/12/23
*Corresponding author: JaeJeong Hwang
Email: hwang@kunsan.ac.kr

Sensor coil sets A and B are placed 90 degrees from each other, enabling the set A referred to as in-phase cosine shape and the set B referred to as quadrature sine shape. Data from each set is derived by differential operation as

$$\begin{aligned} D_A &= D_{A+} - D_{A-} = \eta_A \cos(\theta) \\ D_B &= D_{B+} - D_{B-} = \eta_B \sin(\theta) \end{aligned} \qquad (2)$$

Note that at position 0 degree, D_A becomes maximum and D_B becomes minimum. The sensitivity factor η_x equals 1, if the condition is ideal.

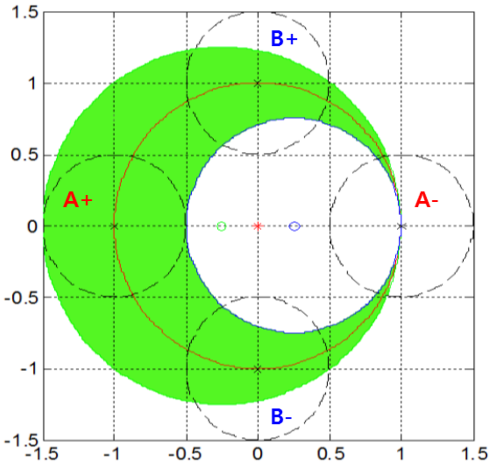

Figure 2 Design of target board and overlapping four sensor coils

D_A and D_B in Eq. (2) are used to calculate the rotation angle, which is given by

$$\theta = \begin{cases} \arctan\left(\dfrac{D_B}{D_A}\right), & \text{if } D_A \geq 0 \text{ and } D_B \geq 0 \\ \arctan\left(\dfrac{D_B}{D_A}\right) + 180^\circ, & \text{if } D_A < 0 \\ \arctan\left(\dfrac{D_B}{D_A}\right) + 360^\circ, & \text{if } D_A \geq 0 \text{ and } D_B < 0 \end{cases} \qquad (3)$$

However, due to various reasons such as the mechanical tolerance, coil inductance tolerance, surrounding metals, calibration is needed to reduce the initial errors.

We have implemented the target and sensor coils as shown in Figure 3, including sensor coil antenna, microcontroller unit, oscillator, USB connector, LED indicator, and processing chipset from TI [2].

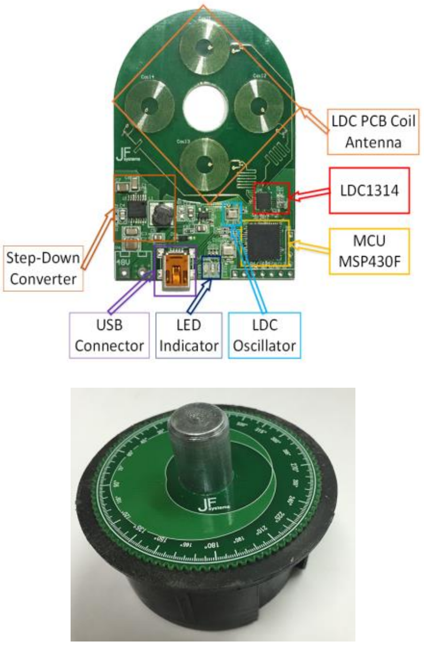

Figure 3 Assembled sensor coils (above) and target (below)

Table 1 Accuracy of the proposed roller blind system

Movement (cm)	Max. Error (cm)	Error rate (%)
25	0.146	0.584
30	0.24	0.8
35	0.197	0.563

Table 1 shows the result of accuracy of the roller blind set in terms of activation length and errors. When 30cm motion, maximum error of 2.4mm (around 0.8%) is resulted, that means highly accurate system.

4. Conclusion

We design the target disc that its shape is nonlinearly changing and the sensor coils that are differentially arranged. The performance shows less than 1% accuracy when it is implemented in the roller blind.

References:

[1] H. Ewald and H. Krueger, “Inductive sensors and their application in metal detection,” 1st Int. Conf. on Sensing Technol., Nov. 21-23, 2005.

[2] http://www.ti.com/lit/ug/tidu953/tidu953.pdf.