CHARACTERISTICS COMPARISON OF SELF-PROPELLED ROTARY ACTUATOR IN CONSIDERATION OF SHAPE AND ROLLING DIRECTION OF STEEL SHEETS

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Abstract. In this paper, in order to improve self-propelled rotary actuator, characteristics comparison of the actuator in consideration of shape and rolling direction of steel sheets used for the actuator is reported. A grain-oriented electrical steel sheet is used as the stator core of the actuator. The shape of steel sheets affects the characteristics of the actuator greatly. Moreover, the relation between a rolling direction of steel sheets and a direction of an exciting magnetic field is important for the starting torque and rotational stability of the actuator. Therefore, the relation between the shape and rolling direction of steel sheets in the stator of the actuator is investigated by finite element magnetic field analysis which introduced the complex E&S model which is one of a vector magnetic property utilization technique. Regarding the shape of steel sheets, a triangle and a rectangle are investigated. As a result, in order to improve the starting torque of the actuator, it is considered that a triangle is better than a rectangle as the shape of the stator core.

1. Introduction

In order to detect cracks and defects inside of a tube with complicated structure, it is necessary to develop an electromagnetic actuator self-propelled in a tube [1] [2]. An exciting magnetic field for moving an actuator is able to be easily supplied to the actuator in a tube from the outside of a tube by a solenoid coil which winded copper wire on the surface of a tube. In this case, the exciting magnetic field is induced in parallel to the axis direction of a tube by the coil. Therefore, the self-propelled rotary actuator whose rotational axis is parallel to the exciting magnetic field was fabricated as shown in Fig. 1 [3]. In this actuator, the pole pieces of the stator are made of a grain-oriented electrical steel sheet, and the rotor has permanent magnets. Moreover, as a feature of this actuator, the shape of steel sheets of the stator was not a rectangle, but a triangle as shown in Fig. 1. It was thought that a triangle steel sheet generates larger starting torque than a rectangle steel sheet, because magnetic flux distribution at the base of triangle steel sheet under an exciting magnetic field is asymmetrical to the rotational direction of the rotor as shown in Fig. 2 (a). However, as shown in Fig. 2 (b), by setting the rolling direction of a grain-oriented electrical steel sheet in the different direction from the exciting magnetic field direction, it was clarified that magnetic flux distribution at the end of the steel sheet becomes asymmetric even if the shape of stator is a rectangle [4] [5].

In this paper, the suitable setting direction of the rolling direction of triangle steel sheets is investigated by the magnetic field analysis. When carrying out magnetic field analysis in consideration of the rolling direction, it is effective to introduce the vector magnetic property utilization technique to the analysis. Therefore, the magnetic field analysis of self-propelled rotary actuator's stator is carried out by using the complex E&S model which is one of a vector magnetic property utilization technique.

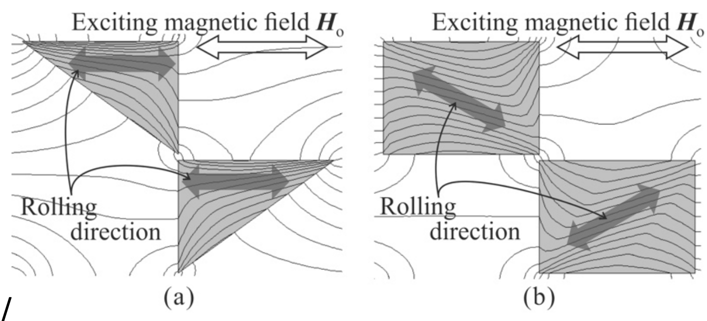

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Fig. 1 The self-propelled rotary actuator.

Fig. 2 Magnetic flux lines in steel sheets of the stator under the exciting magnetic field.

2. Analysis results of stator core in the actuator

When the exciting magnetic field $\boldsymbol{H}_o$ is not applied, the rotor is stationary at the position stabilized by the attractive force acting between the permanent magnets of the rotor and the steel sheets of the stator. As a result of experiment, the permanent magnets are stationary at the right-angle corner of the triangle steel sheets and are stationary in the middle of the rectangle steel sheets. The magnitude of starting torque of the actuator is dependent on the magnitude of *y*-axis direction of magnetic flux density over the magnet shown in Fig. 3 when the exciting magnetic field $\boldsymbol{H}_o$ is applied. Therefore, area-average of B_y (i.e., *y*-component of magnetic flux density) within the region of stationary position shown with the dashed line in Fig. 3 is calculated. The exciting magnetic field $\boldsymbol{H}_o$ is a sign waveform of the peak amplitude 500 Oe, and the frequency is 50 Hz. Fig. 4 shows the relation between the area-average of B_y within the region of stationary position and the inclination angle ϕ of the rolling direction in the triangle and rectangle steel sheets. The inclination angle ϕ of the rolling direction in the steel sheets is defined as shown in Fig. 3, and $\phi = 0°$ means the rolling direction of steel sheet is parallel to the direction of exciting magnetic field $\boldsymbol{H}_o$. In every inclination angle ϕ, the average of B_y of the triangle steel sheets is large than that of the rectangular steel sheets. The average of B_y in both the triangle and the rectangle steel sheets becomes large in accordance with increase of the inclination angle ϕ. The data enclosed with a circle in Fig. 4 denotes the maximum. The average of B_y of the rectangle steel sheets takes the maximum in $\phi = 30°$, however, that of the triangle steel sheets takes the maximum in $\phi = 35°$. The reason of this difference is effect of the shape of steel sheets. As shown in Fig. 2 (a), the magnetic flux lines bend at the end of the triangle steel sheets even if the rolling direction of the steel sheets is parallel to the direction of the exciting magnetic field $\boldsymbol{H}_o$. Furthermore, the maximum value of the average of B_y of the triangle steel sheets is about 1.7 times that of the rectangle steel sheets. These results indicate that a triangle steel sheet generates larger starting torque than a rectangle steel sheet.

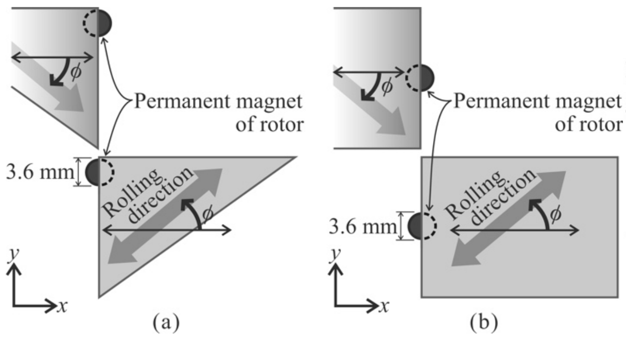

Fig. 3 The stationary position of the permanent magnet of the rotor when the exciting magnetic field $\boldsymbol{H}_o$ is not applied.

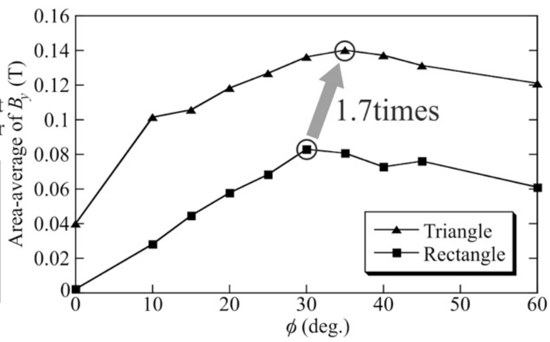

Fig. 4 The relation between the area-average of B_y within the region of stationary position and the inclination angle ϕ of the rolling direction

Conclusions

In this paper, the relation between shape and rolling direction of steel sheets in the stator of the self-propelled rotary actuator is investigated by finite element magnetic field analysis which introduced the complex E&S model. As a result, it is concluded that the starting torque of the actuator using a triangle steel sheet is larger than that of a rectangle steel sheet. It is important to optimize a shape of steel sheets in consideration of an inclination angle of rolling direction because an optimum inclination angle of a rolling direction changes with a shape of steel sheets.

References

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