Design of a New Type Multi Degree of Freedom Spherical Actuator

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INTRODUCTION
Recently, the study of single unit spherical actuators that can perform multi degree of freedom movements has increased. The spherical actuator is an electric machine that is able to tilt its shaft on multiple degrees of freedom using electromagnetic force. Various types of spherical motors have been developed. Lee et al.[1-4] devised variable reluctance spherical actuators. They researched the design, sensing, and control of the spherical actuator. Yan et al.[5,6] developed a spherical actuator similar to Lee’s; their drive principles are actually synchronous. Tomoaki et al.[7-9] have been studying and developing a wide range of multi degree of freedom drive systems.

In the previous research, spherical actuators have complexity and difficulty in control to accomplish high precision because, to control and drive the actuators, the calculations of the flux density of each driving part according to rotational angle are required. Therefore, an accurate analytic model of flux density is needed. In addition, it has low tilt torque for size.

We propose and design a new type of spherical actuator. The designed actuator has a large tilt angle of ±40º, high tilt torque, and uniform and decoupled torque constant by each coil within a compact diameter of 100 mm.

CONCEPTUAL DESIGN AND PRINCIPLE

Concept of the VCM spherical motor
Figure 1 shows the conceptual design of the proposed new type of spherical voice coil actuator. It is composed of a stator and a moving coil type rotor. The stator of the actuator has eight permanent magnets and steel yoke for high uniform magnetic flux density. The rotor is composed of a 2-DOF (degree of freedom) gimbal guide mechanism and four coils to drive the tilt motions.

FIGURE 1. Concept of the spherical actuator

FIGURE 2. Stator part of the proposed spherical actuator

FIGURE 3. Schematic diagram of the magnet and the yoke of the stator

The stator part is fixed to the base frame. As shown in figure 2, the stator is composed of a four permanent magnet pairs (eight permanent magnets), an outer steel yoke, an inner steel yoke, and the fixed shaft. The red colored magnets are polarized along the radially-outward direction, and the blue colored magnets...
are polarized along the radially-inward direction. The blue-colored arrows represent the flow of the magnetic flux of the stator. High and uniform magnetic flux density is formed at the air gap between the permanent magnets and the outer steel yoke. There is internal empty space to insert the gimbal guide mechanism for two degree of freedom tilt motion and a one degree of freedom rotational motor.

**CONCLUSION**

In this study, a new type multi degree of freedom spherical actuator is proposed and designed. It generate high tilt torque and Outer diameter of the stator of the system is only 100 mm. Future work includes design of a guide mechanism and assembly of the system.

**REFERENCES**


