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음성 코일 구동장치의 설계와 해석을 위한 통합 설계 방법

Integrated Design Method for Design and Analysis of Voice Coil Actuators

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1. Introduction

Optical disk drives (ODD) are a popular type of storage devices that are generally used for digital video, audio, and data storage because the disks are removable and can be produced in bulk. The actuator for optical pickup is one of the key components in ODD, which makes the objective lens move to the desired position. Recently, as the demands of the information storage devices with large storage capacity such as HDTV are increased, the optical storage devices are also required to have high density and fast data transfer rate. In keeping with this trend, the actuators should satisfy the following requirements: first is high AC and DC driving sensitivities for satisfying fast data transfer rate, second is radial tilting function for compensating the coma aberration due to the leaning between the optical pickup and the disc, and third is high flexible mode frequencies for ensuring sufficient servo bandwidth.

Many actuators for optical pickup are voice coil actuators. The voice coil actuators use electromagnetic force, which is the force exerted on a charge moving in a magnetic field. They offer excellent control characteristics where linear actuation is required over short distance with electronic control systems. The voice coil actuator (VCA) is composed of electromagnetic (EM) part and structural part. EM part consists of coils, permanent magnets, and yokes. And structural part consists of bobbin, lens, and EM elements such as a coil and a magnet. Therefore, in design of voice coil actuator, EM circuit and structural part cannot be designed independently because they are coupled closely. The change of dimensions of EM circuit brings about structural changes. It means that characteristics of structural vibration such as flexible mode frequencies and mode shapes can vary according to EM circuit. Accordingly, a design method is required to design voice coil actuators effectively, considering EM part and structural part simultaneously.

In this paper, an integrated design method that enables multi-physics modeling and coupled-field analysis by connecting an electromagnetic field and a structural field is proposed. The proposed method can be utilized to design any device with electro-magnetic-mechanism. Particularly, we apply it to design voice coil actuators in ODD. It offers systematical design procedure and accurate analysis for predicting dynamic characteristics of the real system. Therefore, designing time and errors caused by incorrect simulations can be reduced. The effectiveness of the proposed method is verified experimentally using previously manufactured actuator with the error undiscovered in design procedure.

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2. Integrated Design Method

2.1 Integrated Design Method

The VCAs have multi-physics system with EM field and structural field. Generally, as the structural part and EM part of VCAs share EM elements such as a coil and a magnet, the structure of VCAs changes according to variations of EM circuit. The proposed integrated design method is an efficient and automatic method that can simultaneously perform modeling and FE analysis, by connecting MAXWELL FE tool for electromagnetic analysis and ANSYS FE tool for structural analysis, using MODEL CENTER as shown in Fig. 1. The MODEL CENTER is connected to both ANSYS and MAXWELL, through a script, which is a controller that can change design parameters for FE modeling and link the related parameters between EM field and structural field. And it is also used as an analysis server client that can run ANSYS and MAXWELL found on a same server. Therefore, the constructed design method enables multi-physics modeling and coupled-field analysis. Using this method, we can precisely analyze our target model without omitting data, because EM field and structural field are automatically connected by not a designer but a computer.

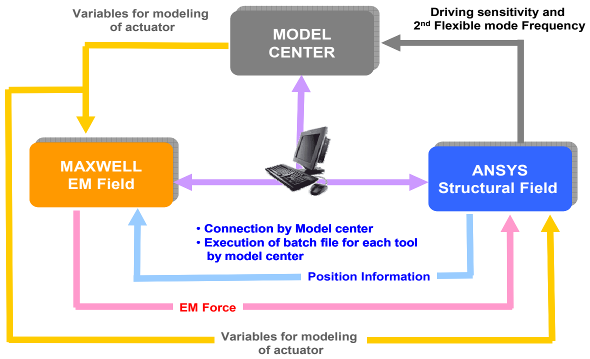


Fig. 1. Construction of integrated design method.

Therefore, the proposed design method reduces time required for designing and errors caused in design procedure. Also, the integrated design method can be applied to optimization process with multi-physics objective function, because the simulation results from EM and structural part can be obtained at the same time, according to change of the linked design variables. Therefore, the optimization process considering electromagnetic force and structural vibration simultaneously is constructed, using this method as shown in Fig. 2 .

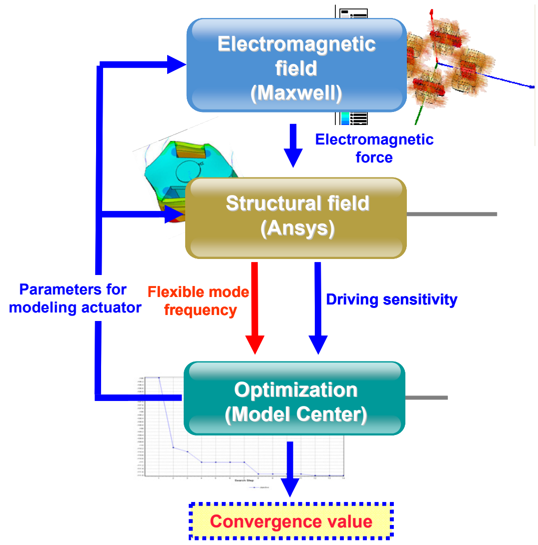
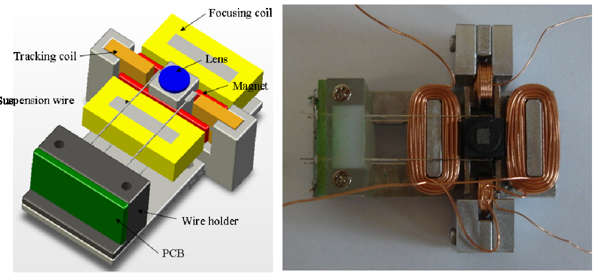


Fig. 2. Construction of optimization process.

2.2 Verification of Integrated Design Method Using Experiments

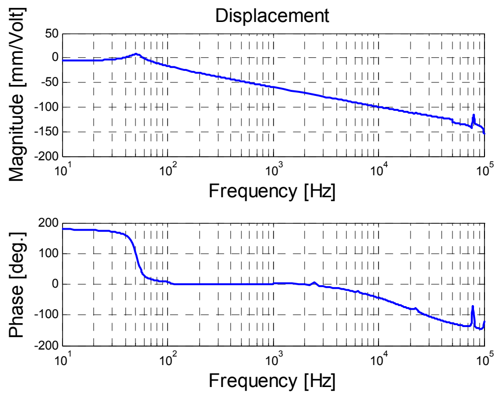
Kim et al. proposed the moving magnet type actuator with high flexible mode frequencies. It was designed and fabricated as shown in Fig.4.[2][4]. Figure 4(a) shows the frequency response of the actuator in the tracking direction by previous simulation. The 2nd flexible mode frequency is observed at 81 kHz. But the frequency response function (FRF) by experiments shows the peak at 20 kHz that does not exist in previous simulation as shown in Fig. 4(b).

As shown in Fig. 5(a), the mode shape at 20 kHz represents that the bobbin has a little movement in the tracking direction owing to the deformation of magnets. But the peak is not observed in previous simulation because the magnitude of the peak is very small as shown in Fig. 4(a). Therefore, it is anticipated that there are factors amplifying the magnitude of the peak in real system. Through the repeated experiments and simulations, it is verified that the factor is the force generated between the coil electromagnet and permanent magnet. When the current is applied to the tracking coils to move the actuator to the tracking direction, the tracking coils become the electromagnet by solenoid effect as shown in Fig. 5(b). The force generated by effect of the coil electromagnet amplifies the deformation of magnets existing at 20 kHz as shown in Fig. 5(c), which also enlarges the magnitude of the peak because it depends on the deformation of magnets.

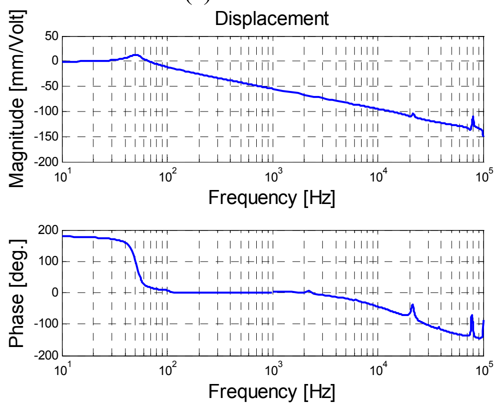


(a) Design of actuator (b) Fabrication of actuator

Fig. 3. 3D model of actuator.

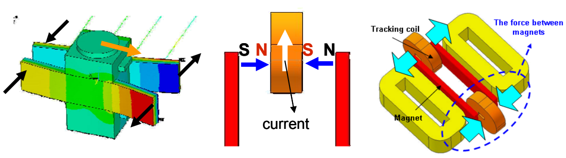


(a) Simulation



(b) Experiment

Fig. 4. FRF of Actuator.



(a) (b) (c)

Fig. 5. Resonance by the force between magnets: (a) mode shape, (b) coil electromagnet, and (c) the force between the coil electromagnet and the permanent magnet.

The fabricated actuator is designed to have high flexible mode frequency, but the force unrecognized in the design procedure makes the fabricated actuator to have unexpected peak in the low frequency region. Actually, it is difficult to apply all conditions to FE analysis by the designer and also conditions ignored or missed by the designer in the design procedure can cause the unexpected problems like this fabricated actuator. To validate the integrated design method, we carry out multi-physics modeling and coupled field analysis by construction of the integrated design method. As a result, the peak at 20 kHz occurs in the simulation using the integrated design method and the frequency response by the simulation almost coincides with that by experiments as shown in Fig. 6. It means that the proposed integrated design method is very accurate and useful. Generally, in FE simulation of ODD actuators, the effect by coil electromagnet is ignored by designer because its magnitude is much smaller than the driving force (EM force). But the integrated design method offers us more exact simulation results, because it can interchange information between EM field and structural field automatically by a computer, without omission of data such as the effect by coil electromagnet.

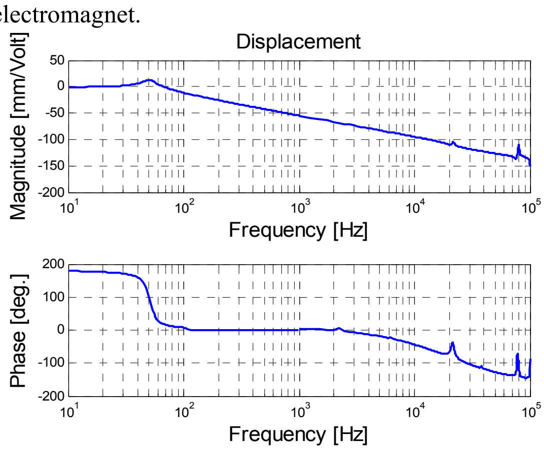


Fig. 6. FRF simulation using integrated design method.

3. Conclusions

The integrated design method is proposed to design voice coil actuators. It makes the design procedure systematical and enables accurate analysis, by connecting electromagnetic field and structural field automatically. The effectiveness of the proposed method is verified experimentally using previously manufactured actuator with the error undiscovered in design procedure.

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