Research on the Micro Pattern forming of Spiral Grooves in a Dynamic Thrust Bearing

Sol-Kil Oh, Hye-Jin Lee#, Jung-Han Song, Kyoung-Tae Kim, Nak-Kyu Lee, and Jong-Ho Kim

Abstract**—**This paper deals with a novel technique for the fabrication of Spiral grooves in a dynamic thrust bearing. The main scheme proposed in this paper is to fabricate the microgrooves using desktop forming system. This process has advantages compared to the conventional electro-chemical machining in the viewpoint of a higher productivity. For this reason, a new testing apparatus is designed and built for press forming microgrooves on a surface of the thrust bearing. The material used in this study is sintered Cu-Fe alloy. The effects of the forming load on the performance of micro press forming are experimentally investigated. From the experimental results, formed depths are closed to the target ones with increasing the forming load.

Keywords**—**Desktop forming system, Fluid dynamic bearing, Thrust bearing, Microgroove.

I. Introduction

RECENTLY, fluid dynamic bearings(FDBs) have important applications in high speed, lightweight rotating machinery, such as those found in the computer information storage industry due to their improved stability characteristics when compared to conventional journal bearing [1]. Micro sized slanted groove causes the lubrication to be pumped inward causing an increase in pressure toward the center of the bearing. As now, the microgrooves in FDBs have been fabricated with electro-chemical machining (ECM). ECM is a method of creating metal shapes by removing metal using an electrochemical process. A direct current with high density and low voltage is passed between a workpiece (the anode) and a pre-shape tool (the cathode). At the anodic workpiece surface, metal is dissolved and thus the tool shape is copied into the workpiece. While ECM is a good and effective method in machining of complex shapes, it raise some problem such as manufacturing costs and time to fabricate the microgrooves in FDBs. Micro metal forming can be one of the alternative fabrication method to keep the product manufacturing time and

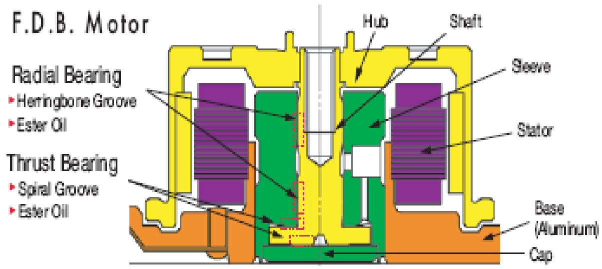

Fig. 1 Structure of the fluid dynamic bearing

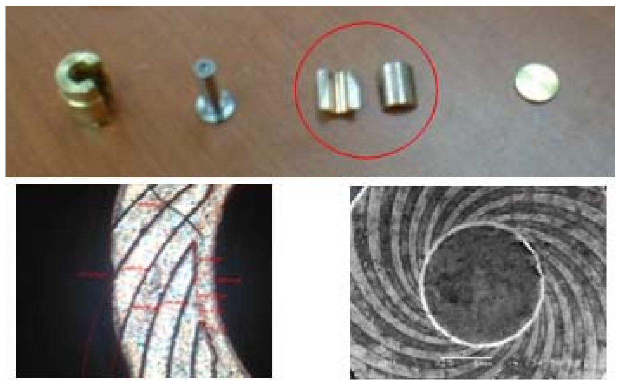

Fig. 2 Spiral patterns on the FDB used in 3.5 inch HDD

costs low [2-4]. Several studies on form rolling for the radial(axial) bearing grooves found in the literature. But, little work has been done on forming of the thrust bearing.

This paper presents a novel technique for the fabrication of the microgrooves in a dynamic thrust bearing by press forming system. It involves consideration on the possibility of the microgroove forming from the verification on the effects of the forming load in a variety of conditions.

II. Experimental Equipment and Tool Sets

In this paper, we proposed micro forming method using desktop press system for fabricating the spiral grooves in FDB. In the design of micro forming equipment, the size and load capacity of system must have a desktop size and to 2tonf as result that achieve investigation and research about optimal size and load capacity that equipment of commercialization concept must have as progressing research for press equipment's miniaturization to form micro component that use micro thin

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TABLE I
TARGET SPECIFICATION OF MICRO FORMING SYSTEM

Specification	Description
Size (mm)	260×340×655
Capacity (Kgf)	2,000
Max. speed (mm/s)	1.4
Disp. Precision (um)	0.1
Drive method	AC servo geared

foil material[5-6]. Forming system that has specification more than this is judged that it is suitable that classify to component's production equipment that have milli-size than micro. In this research, the micro press system planed to have target specification in Table I. Structure and design optimization are achieved according to the target specification in Table I. The picture of manufactured micro press system with this optimal design result is displayed in Fig. 3(b).

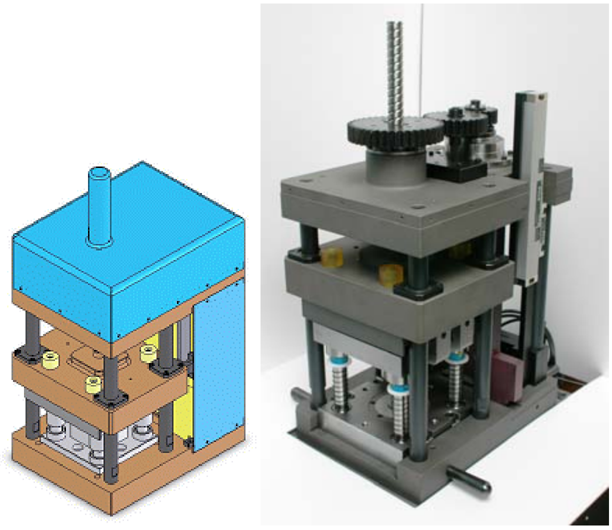
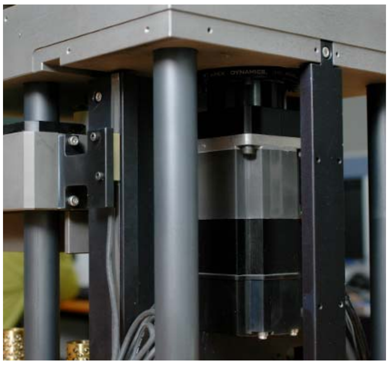


Fig. 3 Desktop forming system

The 10.1 inches industrial controller is used for control of this system. And the controller considers a commercialization of micro press system to basis control principle and applies PID control law. This manufactured micro press system planed a cross head part to be suitable to various micro components forming process, and did so that can use exclusive die set that can form the component between base part and cross head part of micro press system.

The micro press system was manufactured to operate using AC geared servo motor and high precision Ball Screw, and applied a pulley structure as additional so that can regulate a forming speed. Therefore, it is judged to embody optimal forming condition if control the ratio of pulley setting to the optimum forming condition of application parts. The pulley and servo motor structure's pictures applied to this system are shown in Fig. 4. This system did to apply an idler and regulate a tension of belt to minimize the error that can happen in the pulley structure.

(a) Pulley driven structure



(b) Attached AC servo motor to drive pully structure

Fig. 4 Pulley and AC servo motor structures to make a variable forming speed

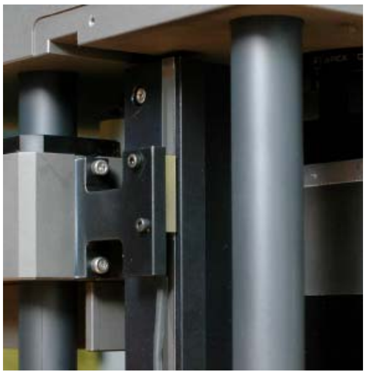


Fig. 5 The linear displacement sensor that have a resolution of 0.1um

The micro press system and die set to manufacture a micro component have a micron size accuracy, so the detailed displacement control fewer than sub-micro must be needed to prevent a damage by an over load of die set and system. The linear displacement sensor that have a resolution of 0.1um is applied to the system to solve these precision displacement control problem. And a precision displacement feedback control fewer than sub-micro can be achieved using this sensor. The linear displacement sensor's picture that have a resolution of 0.1um is shown in Fig. 5.

In order to fabricate the spiral micro patterns on the base of FDB using micro press system developed from this research, tool and die sets were designed as shown in Fig. 6. As shown in Fig. 6, spiral patterns are engraved on the die.

The compound type die set such as Fig. 7 is made by precision micro machining and assembly processes to manufacture a die set that can manufacture the micro thin foil valve in these space restriction. The clearance between a die and a punch establishes less than 20μm.

(a) construction of die for micro pattern forming

(b) closed view of spiral patterns

Fig. 6 Die for spiral pattern forming

Fig. 7 Die set and spring structure

III. EXPERIMENTAL RESULTS

Micro forming tests were conducted with the developed desktop system and die sets. The testing material is sinter-forged Cu and Fe alloy used in the actual FDB. Table II explains the powdery metallurgy configuration ratio of testing material. At first, testing samples are prepared as depicted in Fig. 8. The shape of the test sample is hollow cylinder with the outer and inner diameter of 7.89 mm and 3.96 mm, respectively. The height of the specimen is 10.52 mm.

With the sample specimen, forming tests were performed with various forming pressure to achieve the optimal forming conditions. The forming loads vary from 800 kgf to 1500 kg f as shown in Table III. At each forming load, we measured and compared the diameter (D, d) and size (H) of deformed specimen in order to inquire into an extensible change of material as shown in Fig. 9. Depth of micro patterns are also compared with various forming loads as depicted in Fig. 10. Above the forming load of 1300kgf, we can acquire the micro spiral pattern with the depth of 14um, which is acceptable in the application of actual FDB in hard disk drive. In order to evaluate the formability qualitatively, SEM image of fabricated

TABLE II
COMPOSITION OF SINTERING METAL

	Cu	Fe	Sn, etc.
Composition(%)	65	30	5

TABLE III
EXPERIMENT CONDITION

Forming load (Kgf)							
800	900	1000	1100	1200	1300	1400	1500

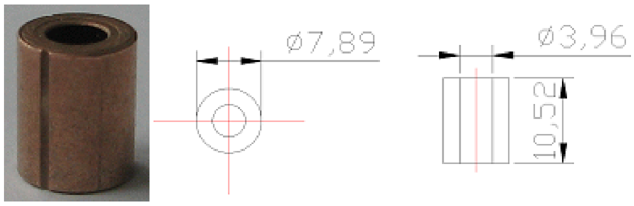


Fig. 8 Shape and dimension of the sample specimens used in the experiment

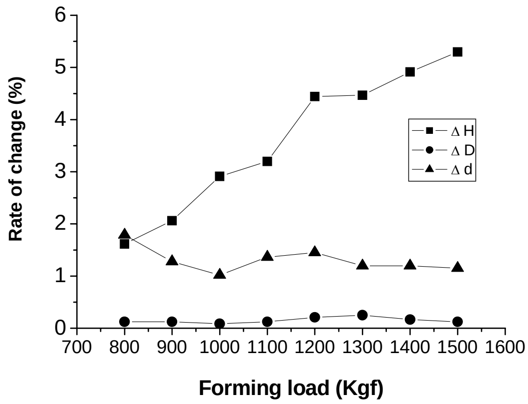


Fig. 9 Difference of dimension after the forming

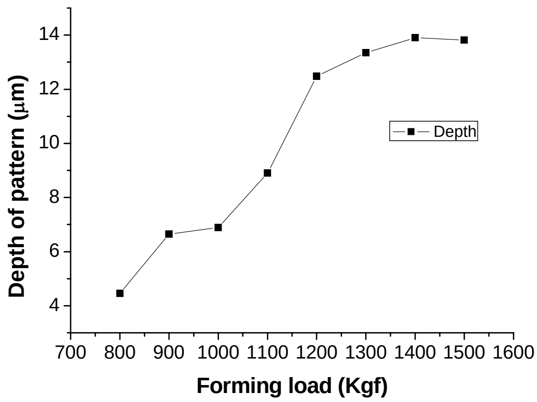


Fig. 10 Experiment result with various forming load

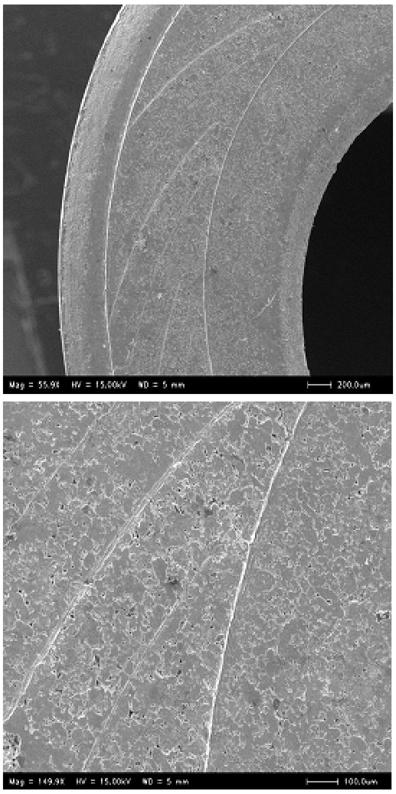


Fig. 11 Top-view SEM of FDB (forming load:1, 400Kgf)

patterns were observed as shown in Fig. 11. Experimental results demonstrate that herringbone grooves in FDB can be fabricated micro forming method using desktop press system to keep the product manufacturing time and costs low.

IV. Conclusion

This paper deals with a novel technique for the fabrication of spiral grooves in a dynamic thrust bearing. The main scheme proposed in this paper is to fabricate the microgrooves using desktop forming system. At first, a desktop press system was newly designed as shown in Fig. 1. The micro press system and die set to fabricate herringbone patterns should have a micron size accuracy, so the detailed displacement control fewer than sub-micro must be needed to prevent a damage by an overload of the die set and system. The linear displacement sensor that has a resolution of 0.1um is adopted to the system to guarantee the precise displacement control. Using this sensor, precise displacement feedback control fewer than sub-micro can be achieved. After that, die sets were also designed with the aid of finite element analysis. Tool dimension and shape of die sets shown in Fig. 2 were determined from the FE results. Finally, micro forming tests were conducted with the developed desktop system and die sets. The testing material is sinter-forged cupper used in the actual FDB. In order to evaluate the formability and forming accuracy, SEM image of fabricated herringbone patterns were observed after the test. Experimental results demonstrate that herringbone grooves in FDB can be fabricated micro forming method using desktop press system to keep the product manufacturing time and costs low.

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