Small size precision stage based on dual restrictive layer porous aerostatic bearing

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Abstract

In this research, a compact precision aerostatic stage with a moving platform of 100x100mm size is developed based on a dual restrictive layer porous aerostatic bearing to improve the performance of small-size air bearing. The performance experiment results show that the stiffness was improved to 2.37 times, compared with traditional porous air bearing and the load capacity was also increased to 449.8N with dual restrictive layer design within the actual aerostatic bearing active area 90x23mm.

1. Introduction

For the demand of miniature module in micro/meso machining systems, precision aerostatic stage has become an important technology to achieve the sub-micron accuracy performance which is required in the development of micro/meso machining systems. Such as the micro factory [1] at AIST in Japan, the micro/meso machine tools (mMTs) at UIUC, NWU in USA [2], and the reconfigurable micro/meso machining system at MIRDC in Taiwan [3]. However, the miniaturization of components within the small precision stages often deteriorates the performance of air bearing, such as load capacity, stiffness and stability. Porous type air bearing with high load capacity, good stiffness and stability characteristics were suitable for miniature the air bearing component of precision aerostatic stage, but it was difficult to obtain ideal performance with the variation of porous material's pore size, porosity, and permeability.

The main issue is to improve the design and prevent the application limitation and failure of small-size air bearing to overcome the deterioration of the bearing performance. In this research, a compact precision aerostatic stage with a moving

platform of 100x100mm size is developed based on dual restrictive layer porous aerostatic bearing, which has been examined in earlier research of MIRDC [4].

2. Compact small-size precision stage

2.1 Configuration of the small size precision stage

The compact precision aerostatic stage was designed as shown in figure 1, the construction were developed based on a 90 degree V-guide with two dual restrictive layer porous air bearing pads to achieve lower stage height design. The basic specifications of a moving platform of 100x100mm size, stage height 36mm and length 200mm. are shown in table 1.

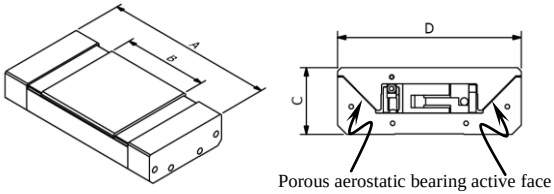


Figure 1: Configuration of the design for small size precision stage

Table1: Specification of the small size precision stage

Geometric dimension /mm				Angle of V-guide	Storke /mm
A	B	C	D		
200	100	36	100	90	40

2.2 The dual restrictive layer porous air bearing applied within stage

The dual restrictive layer porous air bearing is designed with two layers, as show in figure 2, including a restrictive layer on the porous material with micro holes array made by picosecond laser on the surface. The micro holes array mechanism could solve the inconsistency problem of porous material characteristics, and provides a possibility to design the porous type air bearing's performance by adjusting the height of air layer and micro holes density that could further to control the property of permeability and surface flow. The bearing's specifications are show in table 2. Permeability will be changed as a result of those design parameters. The main purpose was to get the best stiffness, loading capacity and stability by modifying the design of restrictive layer. The micro-holes on the bearings are also shown in table 2.

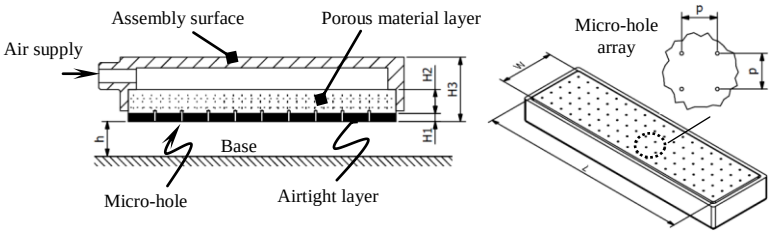
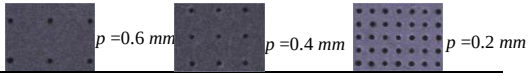


Figure 2: Configuration of the dual restrictive layer porous aerostatic bearing

Table 2: Specification of the dual restrictive layer porous aerostatic bearing

Geometric parameters of air bearing	(1) L : 90 mm (2) W: 23 mm (3) H2 : 3.5 mm (4) H3 : 10 mm
Geometric parameters of micro-hole array layer	(1) H1 : 50 μm (2) Diameter of Micro-hole : 50 μm (3)Pitch of Micro-hole array: *p*=0.6/0.4/0.2 mm  *p* =0.6 *mm* *p* =0.4 *mm* *p* =0.2 *mm*
Porous material	Carbon

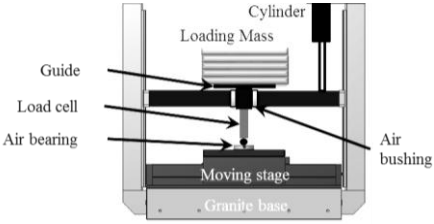


Figure 3: The performance experiment system setup

3. Bearing performance experiment results

Permeability refers to the ratio of fluid penetrates material under certain pressure difference, and determines the basic performance limitation of porous air bearing. The permeability of the bearing could be controlled within 10^{-14} to 10^{-16} m^2 which leads to different performance property. The bearing's performances are tested by a load cell mounted on the guide bar which supported by air bushing, as the experiment system shown in Figure 3. Figure 4 shows the experiment results that the load capacity and stiffness of porous air bearing can be enhanced by dual restrictive layer design, especially for air gap height lower than 5μm. Under the condition of pressure 0.55 MPa, gap height 5μm, the stiffness of new porous air bearing was increased

from 43.4N/μm to 103N/μm that was 2.37 times compared to traditional type, and the load capacity was also increased from 203.8N to 449.8N. The load capacity efficiency holds about 39.5% within the actual aerostatic bearing active area.

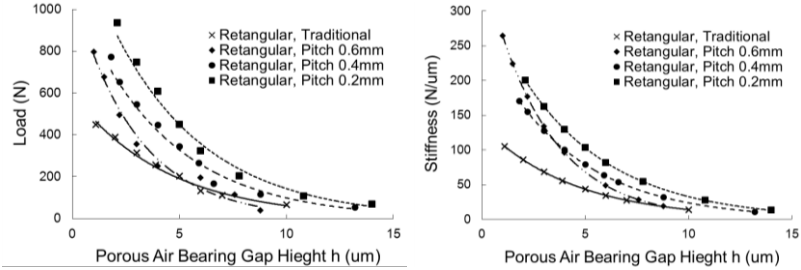


Figure 4: The bearings' load capacity and stiffness tendency are compared at air pressure 0.55 MPa.

4. Conclusion

Experiment results show that dual restrictive layer porous air bearing mechanism could enhance the performance effectively. For the application on compact size motion stage, the bearing's stiffness and load capacity offer excellent properties with the dual restrictive layer porous air bearing of pitch 0.2mm, which means the bearing and stage size could be smaller with great performance.

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