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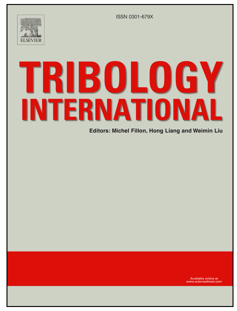

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Performance analysis of aerostatic journal micro-bearing and its application to high-speed precision micro-spindles

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Abstract: An aerostatic journal micro-bearing has advantages of simple structure, almost zero friction and increasable load capacity due to aerodynamic pressure effect, which makes it a possible choice for high-speed and precision micro-rotatory machines. This study comprehensively investigates the effects of restriction, structure and operation parameters on the performance of an aerostatic journal micro-bearing using numerical models. The numerical models are verified on a prototype aerostatic journal bearing. Considering both the performance requirement and current machining capacity, the restriction parameters of 8-12 μm in average bearing clearance and 0.08-0.14 mm in orifice diameter are recommended. Another focus of this study is the aerodynamic pressure effect on the performance of micro-bearing, which is thoroughly investigated from the aspects of restriction, structure and operation parameters. The aerodynamic pressure effect is outstanding only at ultra-high speeds and large eccentricities. Two prototypical high-speed precision micro-spindles are developed and their micro-tools with a diameter of 3.175 mm are directly supported by the micro-bearing. The aerodynamic pressure effect resulting from the ultra-high rotational speeds can improve the performance of micro-spindles under loading. However, the low rotational accuracy and balance quality compromise their performance.

Keywords: Micro-bearing; Aerostatic pressure; Aerodynamic pressure; load capacity; Micro-spindle

1. Introduction

In manufacturing precision and ultra-precision miniature parts, micro-cutting and micro-grinding with micro-machine tools provide significant advantages not only in machining quality, efficiency and machining ability of intricate 3D geometry, but also in cost, size and energy consumption, and thus draw more and more attention [1, 2]. The micro-spindle, as a key component of micro-machine tools, requires high rotational speed (more than 500,000 rpm), excellent rotational accuracy (better than 1 μm), sufficient load capacity and compact structure [3]. To meet the above requirements, bearing of the spindle is critical, which must be able to provide high rotational accuracy, sufficient load capacity, good stiffness and excellent dynamic performance. Besides, it should be millimeter-sized. Comparing the existing types of bearings, conventional rolling element bearings in most modern production equipment are reaching their limited accuracy of about 2 μm and usually generate much heat at high speeds. The liquid-lubricated bearing has a limited rotational speed due to heat generation at high speeds. The magnetic bearing has complicated structure and thus is difficult to use in micro-spindles. The gas-lubricated bearing, due to its low heat generation, high rotational accuracy and simple structure, is a good choice for high speed and precision micro-spindles.

The common gas-lubricated bearings are aerodynamic bearing, aerostatic bearing and