

A cylindrical capacitive sensor (CCS) for both radial and axial motion measurements

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Abstract

Conventional cylindrical capacitive sensors (CCS) are used only to measure the radial error motion of rotating machinery. However, axial error motion is also very important in rotating machines and it is very difficult to measure the axial motion due to the limited space. This paper presents a new CCS for both radial and axial motion measurements. The idea behind the new sensor is that the unused axial area of the CCS is exposed to measure the axial motion of a target. A theoretical model of the proposed CCS was derived. Based on the derived theoretical model, compensation methods to decouple the radial and axial motion measurements were proposed. In addition, an error analysis of the CCS was performed and a design rule was developed to guarantee the same accuracy in measuring both radial and axial motion measurements. Finally, a test rig and electronics for the proposed CCS were built and the effectiveness of the proposed CCS was verified through experiments and simulations. The developed CCS is expected not only to reduce the system complexity but also to afford a good balance between the radial and axial motion measurement accuracies.

Keywords: capacitive sensor, displacement measurement, rotating machinery

(Some figures in this article are in colour only in the electronic version)

1. Introduction

Smart sensor systems, particularly position measurement systems, are expected to play a significant role in the high-precision intelligent manufacturing system. For example, a feedback control is inevitable to ensure sufficient repeatability for the high-resolution positioning of semiconductor manufacturing systems [1]. In addition, usage of active bearings like active magnetic bearings is being increased to achieve higher precision and productivity [2]. In these systems, the position measurement systems not only affect the system performance, but also the system size and complexity.

Probe-type displacement sensors are highly sensitive to the surface quality of a target and these sensors require an additional algorithm to detect and compensate for the unnecessary signal induced by geometric errors [3, 4]. To

analyse an air-bearing spindle error motion, a cylindrical capacitive sensor (CCS) was introduced by Chapman as an alternative to the probe-type sensors [5]. It was verified that the CCS showed much better performance in rejecting the geometric errors of a rotor than probe-type sensors [6], and it can minimize the effects of geometric errors by adjusting the sensor angular size [7]. Also, an extended analysis of a multi-segment CCS was performed [8] and a CCS was applied to the rotor motion measurement of a small air conditioning compressor [9].

The CCS is used only for measuring the radial error motion of rotating machinery. However, axial error motion is also very important in rotating machines such as hard disc and machine tools and it is very difficult to measure the axial motion due to the limited space. Moreover, it is very hard to balance the accuracies of both the radial and axial error motion measurements.

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A decorative graphic element consisting of a light blue horizontal bar with a rounded right end, and a red-to-white gradient semi-circle overlapping the right side of the bar.

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