Questionnaire Survey on Ultra-precision Positioning

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Abstract

Questionnaire surveys on the ultra-precision positioning have been held seven times every four years since 1986. This paper presents the results of the surveys. According to the questionnaires, the following results were obtained. Averaged recognition levels of "precision" and "ultra-precision" are approximately 1 µm and 10 nm, respectively. Although the positioning accuracy is currently at the limit of development, the accuracy of less than 1 nm is expected in the future. Because the demand for higher speed and acceleration, as well as a longer stroke is increasing year by year, the linear motor drive is getting more popular. Performance of displacement sensors has been considerably improved. In particular, a linear scale unit is most often adopted for practical reasons. Because a concern has recently arisen regarding environmental issues, the replacement of hydraulic actuators with electromagnetic actuators, sparing the use of lubricating oil, is becoming more common.

1 Introduction

Ultra-precision positioning technology is one of the base technologies to support some high value-added technologies for which the semiconductor manufacturing industry is assumed to be a pinnacle. Besides, the positioning technology is an integration of broad mechanical and electronics technologies, including sensor devices, mechanical elements, and control systems. Questionnaire surveys regarding ultra-precision positioning have been administered seven times every four years since 1985 by the technical committee of ultra-precision positioning, belonging to the

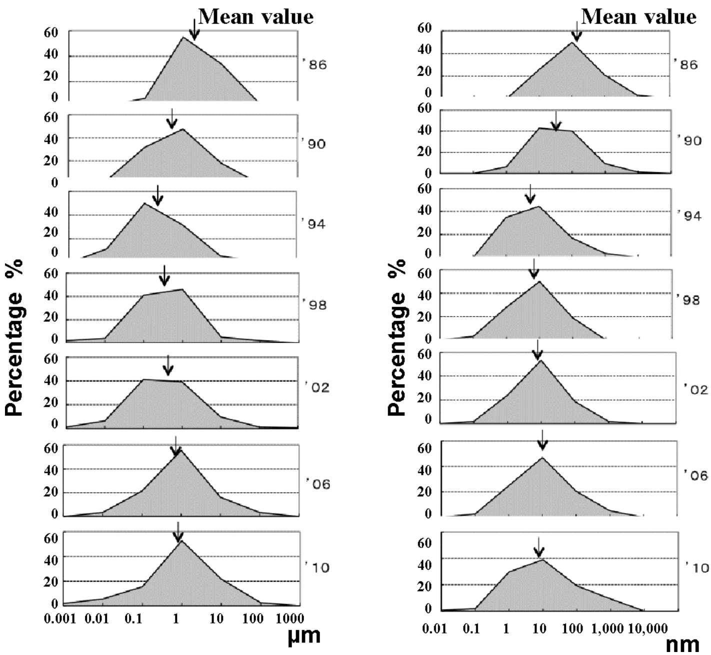
Japan Society for Precision Engineering (JSPE)[1][2]. The questionnaire aims to investigate the transition and current trends in ultra-precision technology in Japan. In addition, actual problems and prediction regarding the future have been surveyed every four years. This report describes only a few results of the surveys because of space limitations though the questionnaire has tons of questions.

2 The sample

Members of our committee and the JSPE were invited to take part in questionnaires asking their opinions regarding ultra-precision positioning. In 2010, 161 people replied, 16% of the invitees. The professional affiliations of the respondents were 79% companies, 15% universities, and 4% public research organizations.

3 Awareness of Precision Positioning

The first question asked the respondents about their level of awareness regarding “ultra-precision positioning” and “precision positioning”. Figure 1 shows the results



(a) “Precision Positioning” (b) “Ultra-precision Positioning"

Fig. 1 Change in awareness of ultra-precision and precision positioning since 1986. Many people were confused in their answers because the question was ill-defined and nonspecific. However, we can see distinct peaks in each survey. Over the first decade, the recognition level of both ultra-precision and precision positioning improved by one order of magnitude. During recent years, most of the respondents believed 10 nm and 1 μm to be the levels of the ultra-precision and precision positioning, respectively.

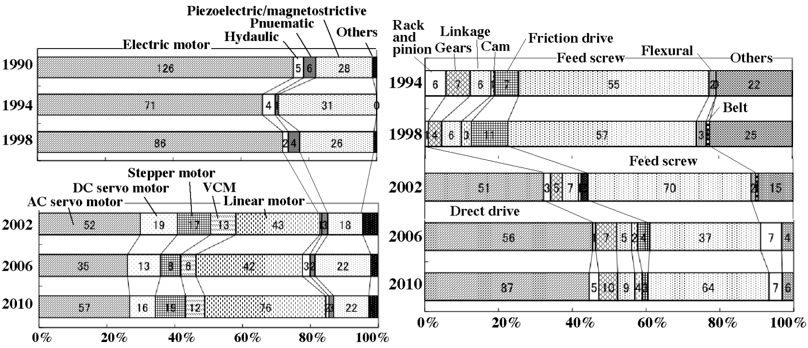
The second question asked about the limiting values of ultra-precision positioning both in the present and the future. Many people expected the present limitation to be 10 nm. However, they have predicted that the limitation in the future will be improved to 1 nm.

4 Positioning accuracy of positioning devices

Next, the respondents were asked to describe the specifications of the ultra-precision or precision positioning device that they are interested in. Figure 2 shows the classifications of actuators and transmission elements. Fig. 2(a) shows that electrical actuators including piezoelectric and magnetostrictive actuators account for 94.8% of the total. The linear motors increased from 25% to 35.7% in eight years.

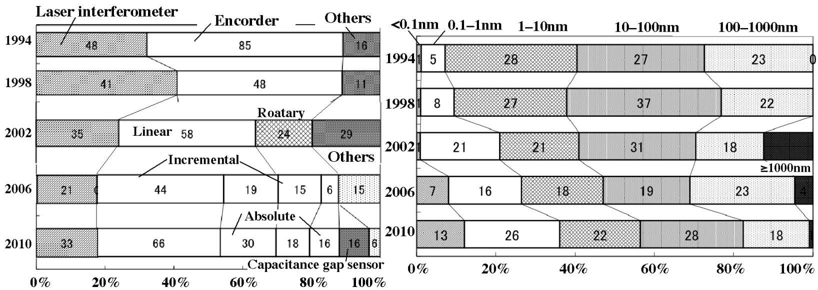
The distribution of the guide ways does not show remarkable change. However, the percentage of rolling-element guideway gradually increased to 43.5%, while sliding contact and hydrostatic bearing have decreased in the last decade. It is expected that this change is due to many respondents being concerned about environmental contamination and pollution. Forty two percent of the devices equipped with a linear motor employed the rolling-element bearings. The devices equipped with the servomotors and the ball screws tend to use rolling-contact bearings rather than aerostatic bearings.

Figure 3 shows the results of the positioning sensors. In 2006, the linear and rotary encoders were subdivided into incremental and absolute encoders. Until 1998, the laser interferometer approximately increased to the same proportion (42%) as the encoders (41%). However, in the 2006 and 2010 surveys, adoption of the encoders increased to more than 70%, although the use of laser interferometers decreased to 18%. This result indicates that the linear scale unit is becoming popular because of its enhanced performance, practicality, and stability against disturbance.



(a) Actuator for positioning (b) Power transmission element

Fig. 2 Mechanical elements used in positioning device



(a) Principle (b) Resolution

Fig. 3 Displacement sensor

Moreover, the resolution of the positioning sensor system has been improving year by year. Figure 3(b) shows that the proportion of sensors with resolution less than 1 nm has reached 36% in 2010.

References:

[1] Takaaki Oiwa and Masahide Katsuki: Survey of Questionnaire on Ultra-precision Positioning, Journal of Japan Society for Precision Engineering, 69(8), pp. 1077-1082 (2003) [in Japanese].

[2] Takaaki Oiwa and Masahide Katsuki: Survey of Questionnaire on Ultra-precision Positioning, Journal of Japan Society for Precision Engineering, 74(10), pp. 1027-1032 (2008) [in Japanese].