Data processing method for geometrical forms with form deviations in coordinate metrology

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Abstract
In coordinate metrology, extracted features (Gaussian substitute features) are normally calculated from measured data sets of CMM (Coordinate Measuring Machine). Then, the extracted features are compared with the nominal features which are indicated on the drawings. The extracted features are calculated using a least squares method and expressed without form deviations. The novel data processing method for geometrical forms with form deviations has been developed. In the method, every geometrical form can be processed with its form deviation which is calculated from the measured data set using the Gaussian (least squares) method as a standard variations $\sigma$. Using the method, we can calculate the form deviations of 2-D geometrical features. This directly implies that these values and these calculations can be used for the evaluations of measurement uncertainties and a computational tolerancing.

Keywords
Coordinate metrology, coordinate measuring machine, geometrical form, form deviation, Gaussian substitute feature, extracted feature

1 INTRODUCTION

In coordinate metrology, extracted features (Gaussian substitute features) are normally calculated from measured data sets of CMM (Coordinate Measuring Machine) (ISO TR 10360-1, 1995). Then, the extracted features are compared with the nominal features which are indicated on the drawings (see Figure 1) (ISO 10360-2, 1994). We should note
that the extracted features are calculated using a least squares method and expressed without form deviations. This is mainly because the accuracy of CMM is too low to measure the form deviations. However, the accuracy of CMM is increasing rapidly and the data accusing time of CMM is decreasing (Takamasu, 1985). Therefore, we can process form deviations, such as flatness, cylindricity, straightness and so on, positional deviation, and surface roughness in coordinate metrology (Furutani, 1988).

Thus, a novel data processing method for geometrical form with form deviations has been developed. In the method, every geometrical form can be processed with its form deviation which is calculated from the measured data set using the Gaussian (least squares) method as standard variations $\sigma$.

Generally, machine parts have three dimensional surfaces such as flat planes, cylindrical planes, conical planes, spherical planes and toroidal planes which can be measured directly by CMM. However, 2-D intersections of the 3-D surfaces such as an intersection line, an intersection point, an ellipse and a circle can not be measured directly by CMM (Takamasu, 1984). Therefore, these 2-D geometrical features are calculated from the 3-D substitute features. In these calculations, we proposed a novel data processing method based on statistical calculations using the relationship between the form deviations of 3-D geometrical features and these of 2-D geometrical features. Using the method, we can obtain the form deviations of 2-D geometrical features (Henzold, 1994 and Wädele, 1995). This directly implies that these values and these calculations can be used for the evaluations of measurement uncertainties and a computational tolerancing.

\section{EXTRACTED FEATURE}

Least squares features are normally used as the extracted features without form deviations. We should emphasized that some other types of data structures can be considered to use as the extracted features (ISO 1101, 1983, ISO 5459, 1981). Let us show four data structures in Figures 2 (a), (b), (c) and (d). Figure 2 (a) shows a least squares plane without a form deviation, and Figure 2 (b) shows that with a form deviation $\sigma$ which indicates the geometrical form. This data type is the simplest way of using form deviations in