A New Combined LS and PSO Statistics Methods for Estimating Surface Characteristics.

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Abstract

In This work, combination of the least-square LS and particle swarm-optimization PSO statistics methods are applied using advanced coordinate measuring machine CMM measurement system, repetitive acquisition of data points were performed along a straight line in a flat slab in different directions. The least-square method gave rise to smaller straightness 7.22 µm with larger error ±0.20 µm as compared with the particle-swarm-optimization PSO method 9.08±0.13 µm. The combined average 8.15±0.11 µm of the results obtained by the two methods thus pertains to the better straightness from the LS method as well as the better accuracy from the PSO method.

1- Introduction

Straightness, flatness, and parallelism are important interrelated parameters indicate the highly smooth surfaces industrially used with different degrees of geometrical standards. Since a surface includes an infinite number of points, in practice, it is necessary to assess the shape using a set of representative sampling points of the surface. The min-max algorithm in which the maximum value of surface topography deviation (d_i) is minimized to the ideal shape based on many advanced techniques. In this work, each data point generates a constraint by means of list of equations below (1-4); in accordance the min-max average deviation zone limits should be investigated. Both formulations, of course, non-linear and both solutions are equivalent to a minimum surface area of the tested surfaces[1]. According to characteristics of form tolerances evaluation of standard slab surfaces, an adaptive LS and PSO optimization algorithm is proposed to implement the minimum-zone evaluation of spatial straightness errors. Least squares, the sum of the squared deviations from the ideal minimized function, do not have a minimum area result and often overestimated the tolerance range. In this paper, a new proposed linear approximation technique is introduced for use in evaluating the forms of straightness which is the most guided parameter in calibration of geometrical engineering standards.

Straightness geometric tolerance zone is specified to include all of the deviation sources such as waviness or other surface imperfections. Our proposed straightness measurement strategy depends on PSO code in addition to modeled least-square equations[2, 3]. Using MATLAB, we obtained the most logical straightness measurement results using different techniques.

2-Measurement and Calculation method

In an acceptable industrial straightness measurement range using CMM, I have found that a combination. Between LS and PSO is a better strategy to implement a minimum zone error. The calculated straightness using the least-square (LS) and particle-swarm-optimization (PSO) methods using 16 CMM measurement data along straight-line on a flat slab have been processed in highly controlled ambient conditions. As shown in figure 1, the Repetition axis indicates the number of repetitions of the measurement and calculation.

Auto repeated measurement at least 30 measurements for each 16 points on a straight line 150 mm with interval 1 cm. As graphically demonstrated in figure 1, a practical method makes scanning straightness measurement with PRISMO with repeated measurement 30 times for each 16 points of the same line; the total number of measurements 480 tests. The repeatability of the measurement probe has been tested and is better than 3 nm. The environment temperature is well controlled in a range of ±0.2 ◦C [2, 4].

In order to reduce the uncertainty caused by the geometrical errors further, especially relevant for the straightness deviations. a virtual CMM model with LS and PSO computerized simulation used for the task-specific uncertainty calculation will include the residual deviations as a function of the machine coordinates and will be able to precisely correct for them. A much lower uncertainty, especially for longer ranges will then be realized[5, 6].

In the least squares method, a least squares line is fit to the data to minimize the sum of the squared deviations of data points from the line. Let (x_i, y_i) be the coordinates of a sample point. The least squares line is of the form:

$$y = ax + c \qquad (1)$$

where,

$$a = (N \sum x_i \, y_i - \sum x_i \sum y_i) \; / \; N \sum x_i^2 - (\sum x_i)^2 \qquad (2)$$

$$c = \sum y_i - a \sum x_i / N$$

N is the number of resultant data points.

The orthogonal distance of a particular sample point from the least squares line is given by

$$d_i = \frac{y_i - (ax_i + c)}{\sqrt{1+a^2}} \quad (3)$$

The least squares straightness tolerance:

$$(d_i)_{max} - (d_i)_{min} \quad (4)$$

At the test area that reflects the straightness error, it is defined as the minimum distance entre two parallel lines which all the data items. The minimum surface area (tolerance zone) to calculate linear straightness error is assumed parallel to the x-axis. The maximum value of the deviation (d_i) from the ideal form is minimized. Minimum average deviation is also examined in this work[7].

These datasets for straightness were also evaluated using the Proposed particle Swarn-Optimization PSO by applying the Sequential Monte-Carlo SMC method introduced by Salah Ali et al [2]. Its minimum straightness error zone values based on similar results by using the mentioned technique are reported as:

Calculated average straightness = 2.28 µm

Standard uncertainty = 0.12 µm

Figure 3 represents the computed obtained values. The experimental data is utilized to verify this algorithm, together with a comparison with some typical optimization algorithms. This methodology could be applied generically to all CMM measurements on industrial pieces with rough surface (even for low surface roughness, R_a = 0.35 µm in our study), in order to increase CMM reliability and thereby minimize error measurements.

3. Results and discussion

An experiment results evaluated by using different methods such as the least square LS and particle swarm-optimization PSO indicate that the proposed method does provide better accuracy on straightness error evaluation as described in figure 2. The least-square method gave rise to smaller straightness 7.22 µm with larger error of ±0.20 µm as compared with the particle swarm-optimization PSO method (9.08±0.13 µm). The average of the results obtained by the combined two methods 8.15±0.11 µm has thus produced better straightness from the LS method alone as well as the better accuracy from the PSO method.

The datasets and results given for the least squares method as well as the optimization technique zone match the minimum zone result when tolerances are practical.

4. Conclusion

Set of precise measurements of straightness in controlled same conditions and by applying a designed PSO and LS interrelated programs, ideal minimum values of straightness form tolerances have proved its effectiveness in solving non-linear optimization problems. Compared with conventional optimization techniques, the LS and PSO -based method can easily with high precision experimental measurements to approximately implement the aimed true value. It is also well suited for various forms of error evaluation such as flatness, roundness, and cylindricity. It has the advantages of simple algorithm, robustness, and high accuracy.

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References

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Figures:

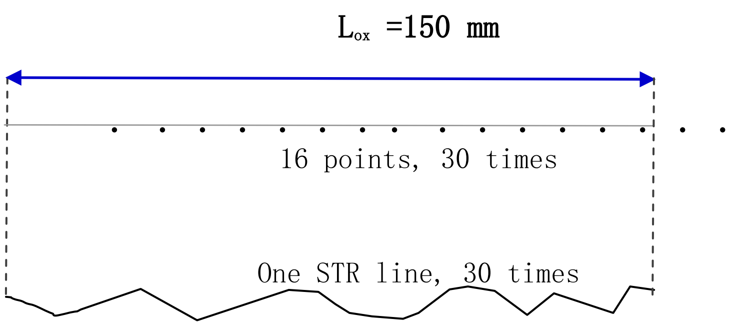


Fig.1

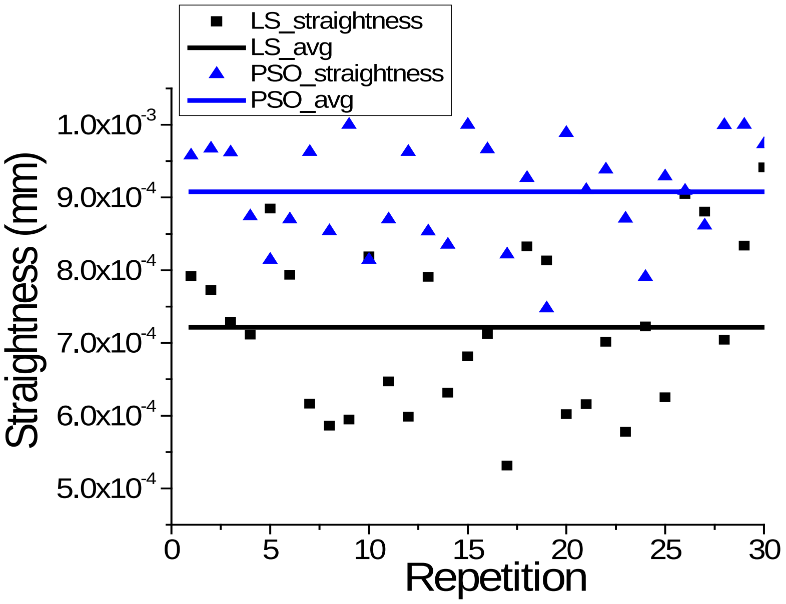
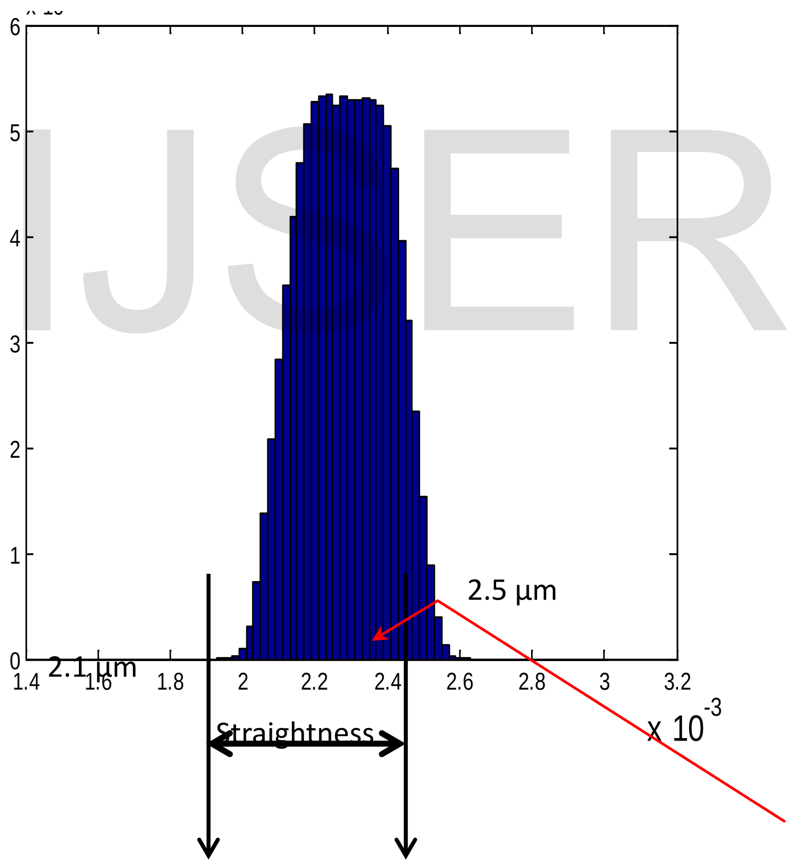


Fig.2



95% coverage interval =
0.4259 µm

Fig.3

Figure caption:

Figure 1 A graphical representation of the experimental protocol of CMM measurements.

Figure 2 The calculated straightness using the least-square (LS, black squares) and particle-swarm-optimization (PSO, blue triangles) methods, using 16 CMM measurement data along straight-line on a flat slab. The Repetition axis indicates the number of repetitions of the measurement and calculation. The solid blue and black lines are the average straightness from the corresponding PSO and LS methods.

Figure 3 Demonstrations of the practical obtained data by applying Mont-Carlo method.

Tables:

Table 1

X (mm)	Y (mm)
-137.702	-0.0013
-127.702	-0.0011
-117.702	-1.00E-03
-107.702	-9.00E-04
-97.7019	-0.0013
-87.7016	-0.0011
-77.7015	-0.0016
-67.7015	-0.0016
-57.7015	-0.0016
-47.7015	-0.0021
-37.7013	-0.0021
-27.7015	-0.0017
-17.7014	-0.002
-7.701	-0.0016
3.699	-0.0018

13.6991	-0.0019

Table 2

Computation tech.	Straightness (μm)
LS	7.22±0.20
PSO	9.08±0.13
LS+PSO	8.15±0.11

Table caption:

Table 1

The experimental xy data obtained using CMM system.

Table 2

The estimated straightness and the accompanied errors using PSO and LS methods as applied to CMM measurements.