Coordinate Measuring Machine (CMM) Tutorial

AtomSolve
元析科技

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Introduction

A Coordinate Measuring Machine (CMM) is a high-precision metrological device used to measure the physical geometrical characteristics of an object. Utilizing a mechanical probe system that determines the exact coordinates of points on a workpiece's surface in three dimensions. These measurements are critical in ensuring dimensional accuracy and quality control in manufacturing processes, especially in industries such as aerospace, automotive, and precision engineering.

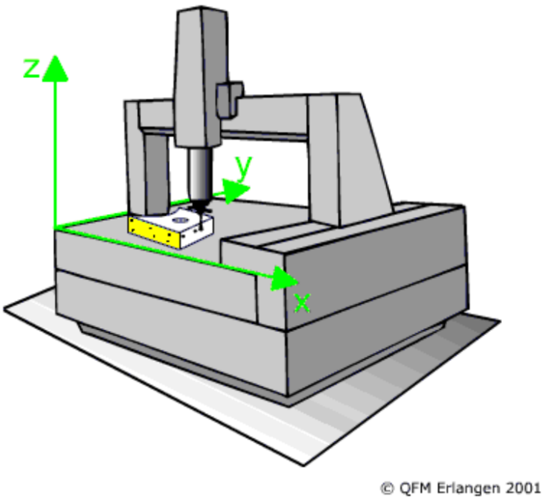

Figure 1: Schematic of CMM tool on obtaining the coordinate[1].

Mathmatical concepts

1. Standard deviation

The standard deviation is a statistical measure of the dispersion or variability in a set of values. It provides a quantified assessment of how much individual data points differ from the mean of the dataset. A larger standard deviation indicates greater variability, while a smaller standard deviation suggests less variability. The standard deviation (σ) is calculated as the square root of the average of the squared differences between each data point (x_i) and the mean (μ) of the dataset with N numbers:

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \mu)^2}$$

2. Flatness deviation in CMM tool

The flatness is defined in ISO 1101 [2] as a distance between two parallel planes, confining the surface, oriented in such manner that the distance between the planes is a minimum possible value [3]:

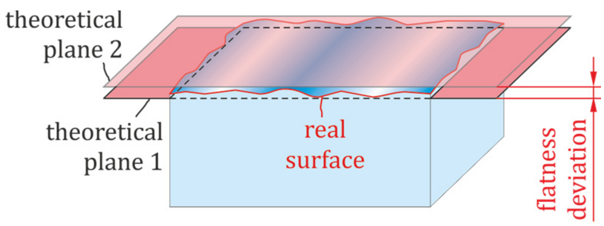

Figure 2: The definition of flatness deviation (the so-called "flatness") [3].

Results

1) 3D scatter plot

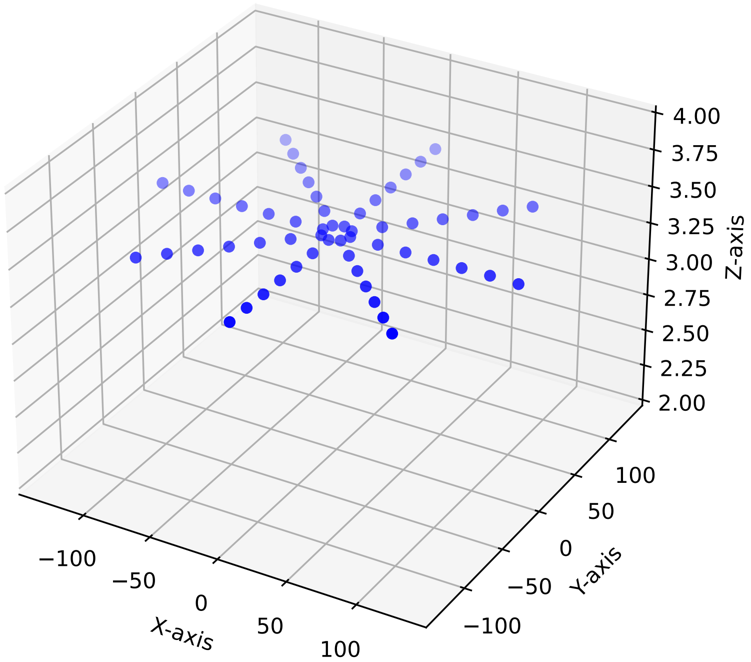

Figure 3: 3D scatter plot of the 56 points from .xyz data

2) Best-fit plane

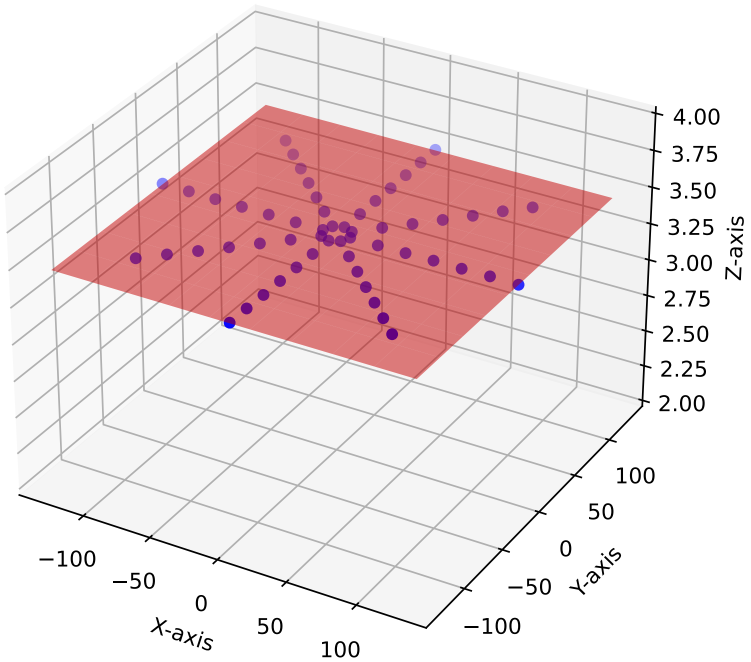

Figure 4: Find the best-fit plane by linear-regression

3) Distance from point to the plane

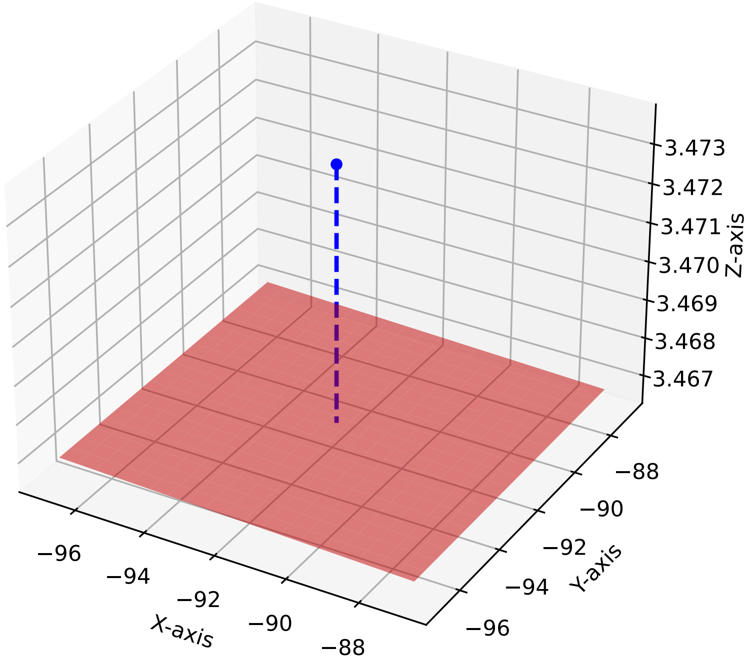

Figure 5: Distance from a point (upper) to the plane

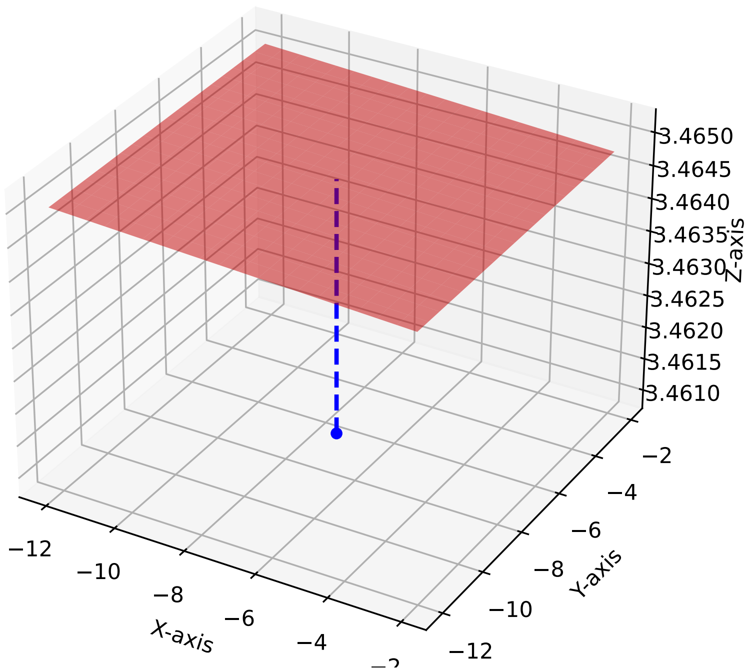

Figure 6: Distance from a point (lower) to the plane

4) Standard deviation and flatness deviation

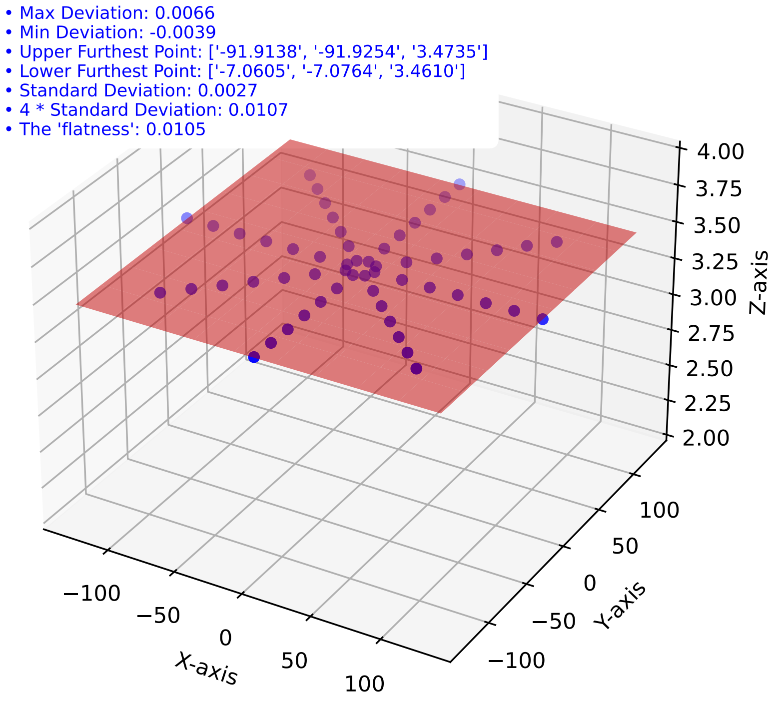

Figure 7: The upmost and lowest points are noted, 4σ and flatness deviations are noted.

5)* Surface interpolation

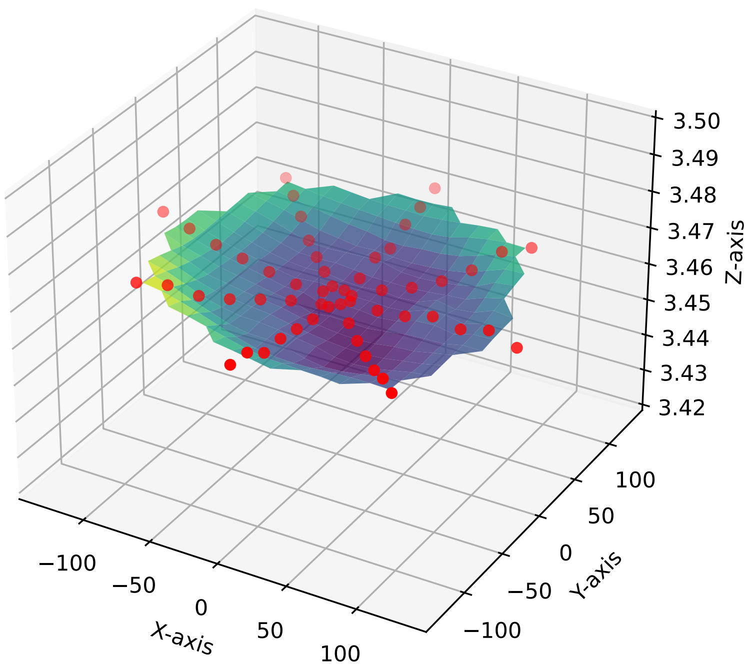

Figure 8: 3D surface plot with the meshgrid interpolation

Cubic interpolation involves fitting a cubic polynomial to each set of four adjacent points in the input data, estimating values at points within the convex hull. The cubic polynomial is chosen because it balances smoothness and accuracy. Though we run it in Python environment, we suppose the method is similar to that in MATLAB [4].

6)* Line profiles

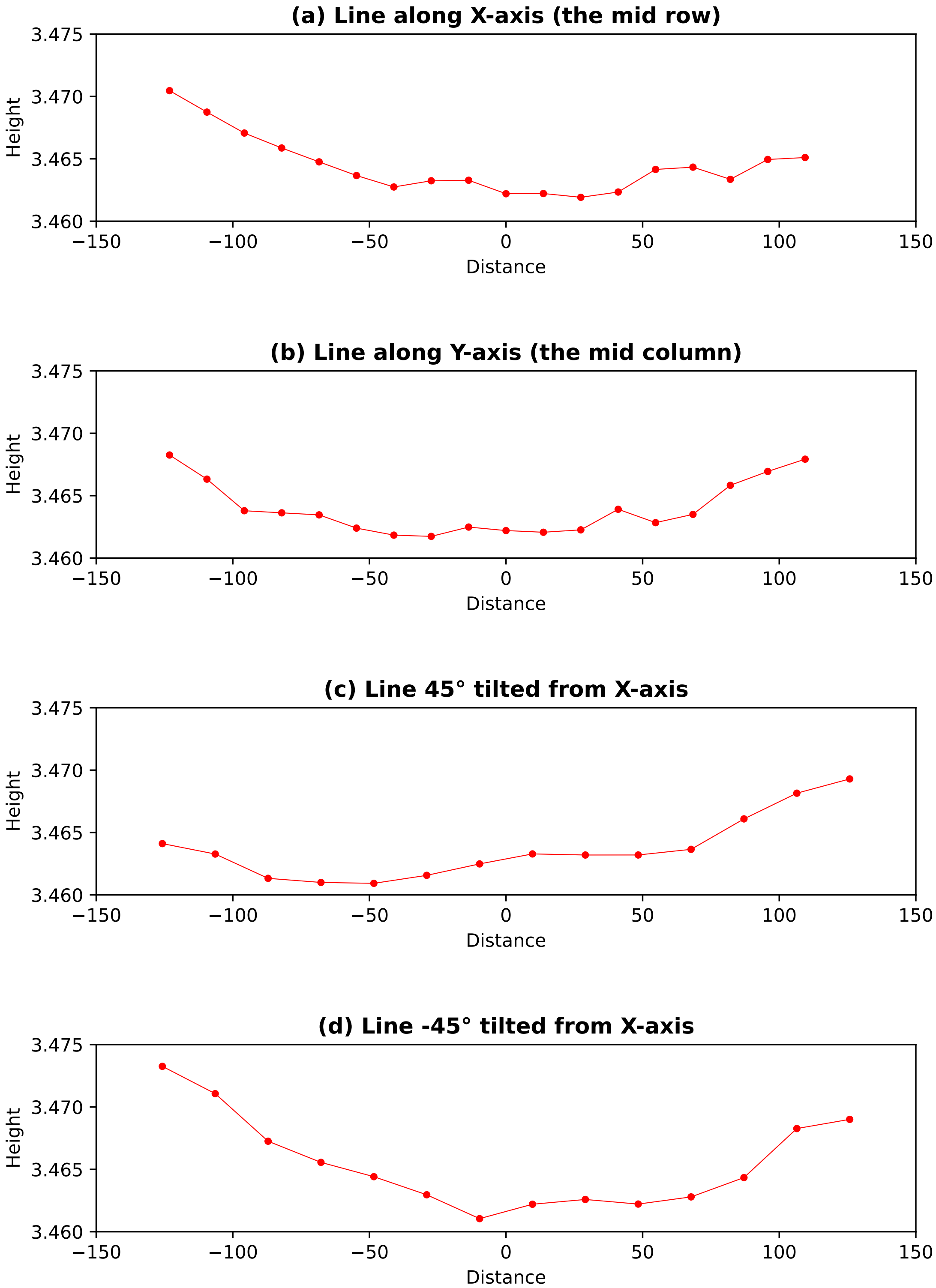

Figure 9: Line profiles at different directions: (a) 0, (b) 90, (c) 45 and (d) -45 degrees tilted from X-axis. The data are from the grid data used for surface plot shown in Fig.8.

***NOTE:** The result shown in Figure 8 and Figure 9 are obtained through data interpolation.

Conclusion

- Max (highest) Deviation: 0.0039
- Min (lowest) Deviation: -0.0066
- Upper Furthest Point: [-7.0605, -7.0764, 3.461]
- Lower Furthest Point: [-91.9138, -91.9254, 3.4735]
- Standard Deviation: 0.0027
- $4\times$ Standard Deviation: 0.0107
- The '**flatness**' (actually, flatness deviation): 0.0105
- Unit: μm

References

[1] *CMM*. Oct. 2008.

[2] *Geometrical product specifications (GPS) — Geometrical tolerancing — Tolerances of form, orientation, location and run-out*. Standard. International Organization for Standardization (ISO), 2017.

[3] Nermina Zaimovic-Uzunovic et al. "Flatness measurement on a coordinate measuring machine". In: *New Technologies, Development and Application II 5*. Springer. 2020, pp. 165–172.

[4] *Interpolate 2-D or 3-D scattered data - MATLAB griddata*. `https://www.mathworks.com/help/matlab/ref/griddata.html`.

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