

Improvement and Stabilization of Spatial Accuracy of Entire Processing Area Using Three-Dimensional Spatial Error Correction System for Double-Column Milling Machines



Large precision machine MVR30Fx

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The improvement of machining precision for double-column milling machines is in increasing demand, especially for such as automobile die and mold machining. While conventionally the priority lies in the precision attainable within a limited machining area and the relative error compared to the adjoining machined areas, demand in recent years calls for improving overall machining precision. In double-column milling machines, the error caused by changes in the level of the machine foundations over time, etc., is not insignificant. This report describes the “three-dimensional spatial error correction system,” which can maintain spatial accuracy throughout the machine’s entire stroke range over a long period of time, successfully ensuring the required machining precision in a stable manner.

1. Introduction

In machine tools, spatial error can occur as a result of fluctuating temperatures in the factory environment or changes in the level of the foundations on which the machine is installed. Spatial error here denotes the error in positioning the tip of the spindle in a space defined by the three coordinate axes of X, Y and Z, and involves three position errors and three orientation errors. Generally speaking, error due to temperature fluctuations is compensated for using technology to correct thermal displacements of the machine. Mitsubishi Heavy Industries Machine Tool Co., Ltd. has further reduced the spatial error caused by environmental temperature change by employing the internal spindle cooling system to prevent the occurrence of error and the thermo-stabilizer column to minimize displacement due to temperature changes. On the other hand, in the case of a change in the level of the machine foundations, the resulting spatial error can be minimized by enhancing the structural rigidity of the machine body for smaller machines. However, when it comes to facilities for large parts exceeding 2 m in size, such as dies/molds and semiconductor production equipment, the effect of such changes is not insignificant and compromises machining precision, leading to part quality issues such as defective accuracy or requiring returning to a previous processing stage for adjustment or modification.

2. Three-dimensional spatial error correction system

Changes in the factory environment or the level of the machine foundations over time can result in errors in positioning the tip of the spindle in the X, Y, Z-coordinate space. The three-dimensional spatial error correction system as shown in **Figure 1** was developed to make it possible for the machine itself to automatically correct such geometric deviations.

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2.1 Measurement system

Automatic measurement units (touch probes) are used to measure true spheres on the standard gauges installed along the X, Y and Z axes around the table as shown in **Figure 2**. The detection and correction of spatial error of the machine results in greater form accuracy (for example, in terms of straightness and squareness) and better dimensional accuracy, thereby realizing high-precision machining. Being made of a special material free from thermal deformation, the standard gauges are mounted on the table using a floating support structure and therefore are completely unaffected by external factors such as changes in temperature or the machine foundations. Moreover, as protection against cutting chip and fluid coming from the machine tool, the standard gauges are normally kept inside a protective cover that automatically opens at the time of measurement to allow access to the gauges.

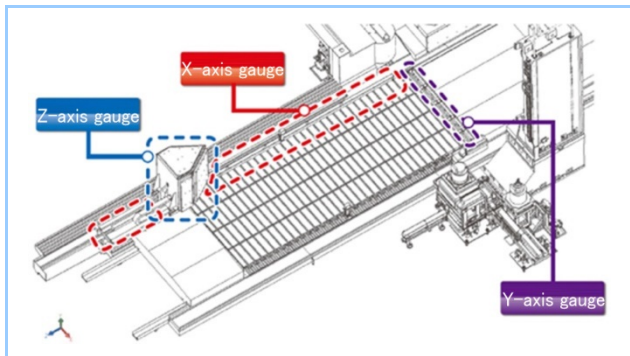


Figure 1 Spatial error correction system



Figure 2 Measurement using master gauge

2.2 Correction system

The correction system as shown in **Figure 3** is comprised of the arithmetic logic unit to compute how much correction is necessary and the three-dimensional spatial error correction unit that can reflect the computation results in the computerized numerical control (CNC) unit's instructions for positioning. Based on the spatial error detected by the measurement system, the arithmetic logic unit for correction computation calculates the deviation of position using reference grid points in the three-dimensional coordinate system that is constructed in such a way as to cover the machine's entire stroke range for the X, Y and Z axes as shown in **Figure 4**. The three-dimensional spatial error correction unit then proportions the amount of correction between grid points based on the positioning error of the grid points, before reflecting this in the CNC unit's positioning instructions.

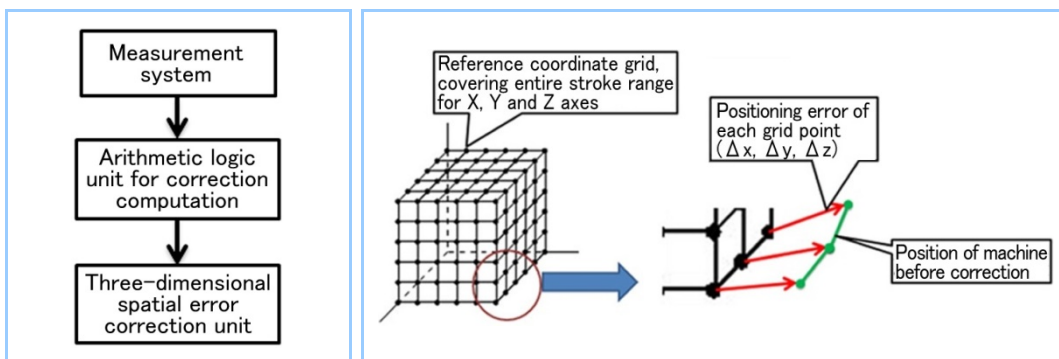


Figure 3 Correction system **Figure 4** Positioning error of grid points

2.3 Results

With the three-dimensional spatial error correction system, it has become possible to correct the machine precision (e.g., straightness and squareness), which is adversely affected by changes in the level of the machine foundations. One example of this includes a straightness of 18-25 μm before correction, being improved to 3-5 μm after correction. Regularly using this system makes it possible to maintain the machine's milling precision over a long period of time as shown in **Figure 5**.

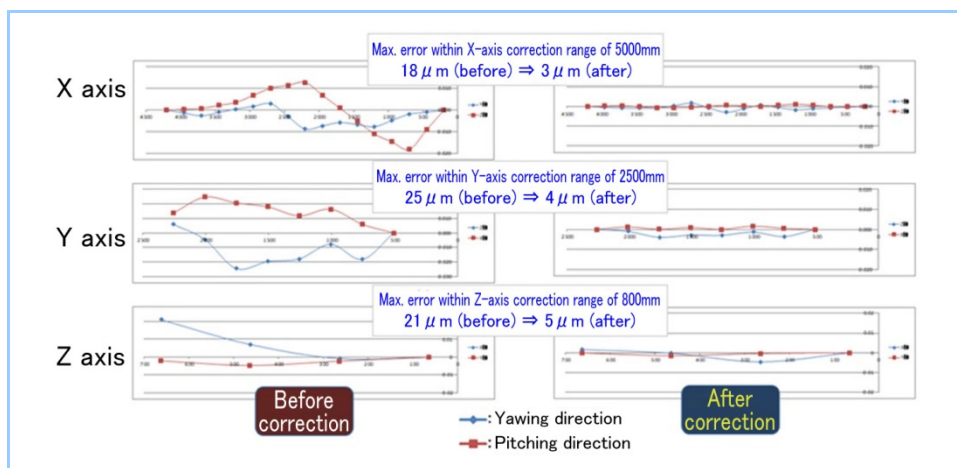


Figure 5 Example results of correction for changes in level of machine foundations

3. Effectiveness

Here we present an application case of a customer who manufactures dies and molds. The three-dimensional spatial error correction system was installed on a large precision machine MVR30Fx. Over the three years since its introduction in 2017, the required machining precision in terms of spatial accuracy has been maintained in a stable manner throughout the machine's entire stroke range. In a practical sense, the need for upper/lower die clearance adjustment, which was conventionally an indispensable modification process, has been eliminated as shown in **Figure 6**. Consequently, when manufacturing dies that are 2.5 m long, 40 hours per die have been saved. Moreover, the problem of compromised form accuracy of the finished product after the modification process has also been resolved.

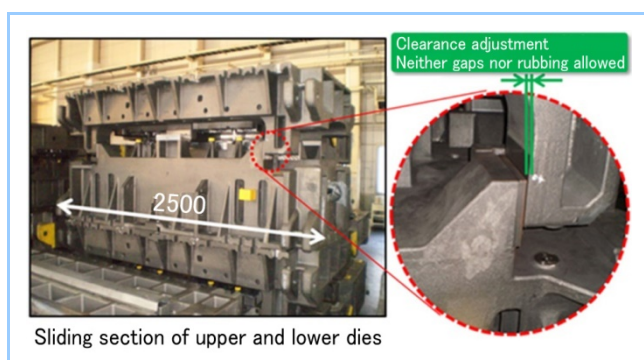


Figure 6 Images showing sliding section for upper/lower die clearance adjustment

4. Conclusion

The aforementioned application example pertains to the newly introduction of a fully-automatic correction system that can be embedded in the machine. The outcome has been outstanding for the customer, who required high-precision performance. To enable easy application to existing machines, we are also developing a portable system that can be carried by the operator him/herself, and we are planning to make it available in our maintenance services. By offering this technology to customers looking to improve the level and stability of required machining precision, we will continue to help solve the problems arising at manufacturing sites.