Large Precision Machine MVR-Fx Achieves High-Precision and High-Quality Machining

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Weight reduction and increased design complexity for products such as automobiles have been advancing. Along with this situation, demand for high machining accuracy of die-mold machines and high machined surface quality has been growing. If satisfactory quality cannot be obtained on a machined die, time is taken for redoing the machining or a workman repairs the machined die by hand. Considering the improvement of productivity and the shortage of skilled laborers, satisfactory quality should be achieved in the first machining, but it is difficult for a general purpose 5-face machining center to fully satisfy this need. We conducted a drastic review of the machine body structure and the control method so that high-accuracy and high-quality die mold machining can be realized, and the large precision machine MVR-Fx, in which our proprietary technologies were incorporated, was commercialized. With the concept "Target set to ZERO," the MVR-Fx has gone through evolutions in various machining cases to achieve ZERO steps, ZERO form errors and ZERO hand finishing. The high-precision 5-axis index head (universal head) and the Visionplus Tool optical image tool measurement system were newly developed and multilateral approaches to machining have been realized, which are introduced here.

1. Features

(1) Machine body structure

The MVR-Fx is a large machine tool with which automotive dies/molds can be machined and which is structured so as to achieve the machining accuracy of 0.01 mm or less. The feed device has a unique structure in which the motors are directly connected to both ends of the ball screws, allowing the feed device to accurately track as directed. Of particular note, dies/molds weighing more than 10 tons are placed on the table section, and therefore, as one technological feature, two ball screws are driven by four motors. Compared to the conventional device in which one ball screw and one motor are used with a reduction gear in-between, mechanical backlash and torsion of the ball screw are reduced and high-response driving is achieved. To prevent vibration due to driving acceleration and deceleration, a column which is 1.8 times as wide as the conventional one and a cross rail double-column structure without an overhang are adopted. The table has a 3-row guide structure to prevent deflection when a die/mold is put in place. Thus, the MVR-Fx has substantially increased rigidity. Thermal displacement caused by heat generated in the machine itself by driving and changes in the temperature of the environment where the machine is set lead to the deterioration of machining accuracy. Therefore, countermeasures to deal with thermal displacement have been thoroughly implemented. In the feed device, all heat generating parts such as ball screws, bearings and motor mounting faces are cooled by oil to prevent temperature increases caused by driving. In the column, a special liquid is enclosed as a temperature control medium. Thus, the machine body has a structure that is not affected by temperature changes (**Figure 1**). Furthermore, to ensure stable accuracy with high reproducibility, electrical thermal displacement correction is not conducted.

(2) Control method

Our proprietary HGP3 control method is adopted to realize high-accuracy control. Four motors that drive the table provide multi-synchronous control for high gain setting. Even if the

load is high, stable driving with good response is possible. In the parts where the driving direction is inversed, intelligent friction correction is adopted to automatically change the correction amount, thereby achieving high machining surface quality. Furthermore, vibration control through a combination of feedforward control and feedback control provides both the improvement of machining surface quality and increased speed.

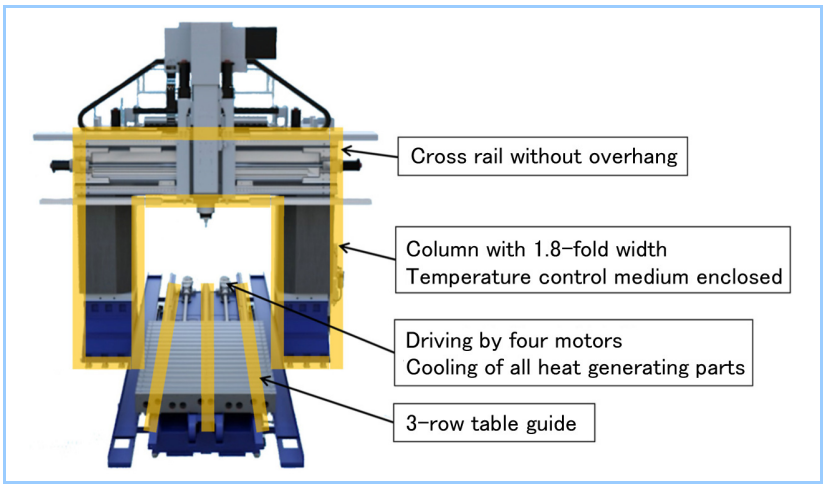

Figure 1 Features of the machine body

(3) 5-axis index head

The standard spindle head of the MVR-Fx is a tool angle fixing type. In some cases, for the improvement of the machining condition, a change of the tool angle is required. Therefore, the 5-axis index head was newly developed and commercialized. The standard spindle head can be automatically replaced with the 5-axis index head, which has a maximum spindle speed of 20,000 rpm and is the same as that of the standard spindle. The 5-axis index head has a complicated structure, and there is the problem of ununiform heat generation occurring during the rotation of the spindle, easily causing accuracy errors and increased vibration. For the spindle of this machine, a unique internal and external spindle cooling technology and a special jet lubrication technology were adopted to solve this problem, achieving highly-stable quality while reducing heat generation and vibration during low-speed to high-speed rotation (**Figure 2**).

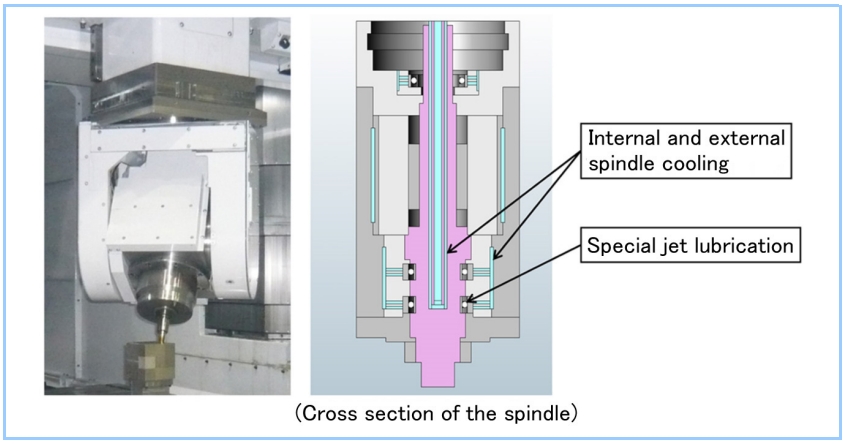

Figure 2 Features of the 5-axis index head

(4) Optical image tool measurement system

The Visionplus Tool using a high-precision camera was also developed to allow the measurement of a tool angled by the 5-axis index head. In addition to the measurement of general dimensions such as tool length and diameter, it allows three-dimensional and continuous measurement of the angle actually used and the position of the cutting edge of a tool being rotating. It only has one camera, but a mechanism for horizontally rotating the tool itself is provided, allowing the capture of images from two directions and three-dimensional measurement of the position of the cutting edge (**Figure 3**). In addition, through continuous

measurement, whether the position of the cutting edge is stable can be checked, and a stable state of thermal displacement can be automatically determined. Thus, the Visionplus Tool can automatically conduct high-accuracy machining without depending on the machine operator's experience or intuition.

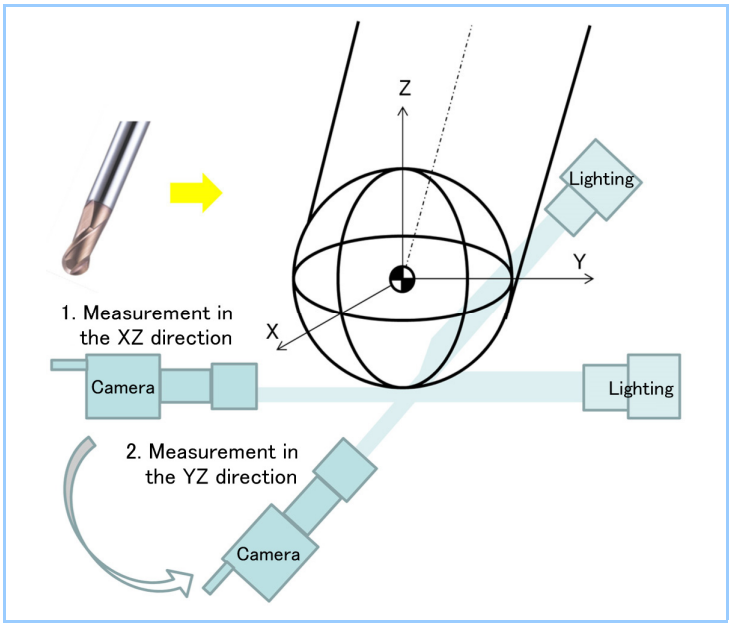

Figure 3 Image of measurement of tool

2. Example of high-accuracy machining

Using the newly-developed 5-axis index head and the Visionplus Tool optical image tool measurement system, a resin mold for automobile bumpers was machined (**Figure 4**). Such molds are large in size and have complicated shapes, and the required quality is very high. In the machining of such molds, different kinds of tools are used and frequent tool replacement is required, and the tool angle is also changed many times. It takes several hundred hours to finish the machining. Therefore, the machining is easily affected by changes in the environmental temperature, and there is a high degree of difficulty in achieving both high-accuracy and high-quality machining. In particular, steps are easily created between machining surfaces with different conditions. In die-mold machining basically using a general-purpose 5-face machining center, steps of 0.03 mm or more are often created even if the machine operator adjusts the tool height, conducts warming-up, etc. In machining using the MVR-Fx, which is an automatic operation, the steps observed on the surfaces were 0.01 mm or less. In addition, a good-quality surface with a shine was obtained. This proved the high performance of the machine.

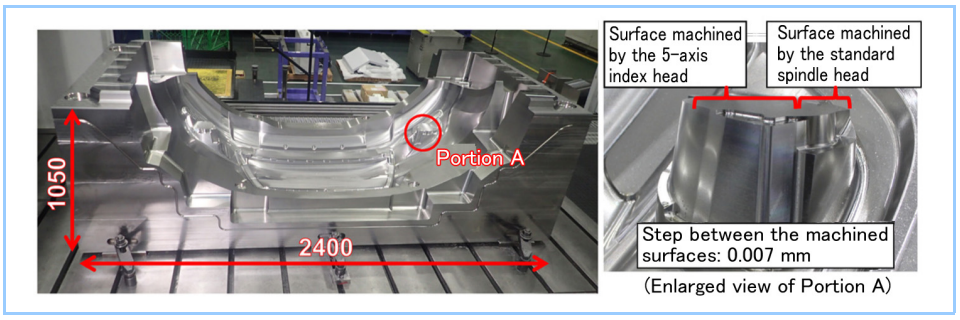

Figure 4 Example of machining of resin mold for automobile bumpers

3. Future development

We will continue the "Target set to ZERO," which is the concept of the MVR-Fx, make efforts for the further improvement of the performance of the machine and increase the track record of its actual use. We will also promote development in response to customer needs including the development of peripheral application technologies such as work measurement.