Latest Technologies of MVR-Eχ 5-face Machining Center for Realizing High-precision Cutting

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The challenge in the high-precision cutting of large workpieces is the reduction of heat deflection on machine tools caused by external and internal temperature changes. There is now a need for a new high-precision cutting technology, as existing heat deflection correction technology for dealing with the heat generation of the spindle no longer meets the need for higher precision. Mitsubishi Heavy Industries, Ltd. (MHI) developed the "MVR-Eχ" double column machining center. The MVR-Eχ realizes high-precision cutting with easier operation thanks to the internal spindle cooling system and thermally stabilized columns, which were installed as standard on a domestic product for the first time. As well as developing an operator assist system and adding a preventive maintenance system, we addressed improvements in the exterior design and made the machine take on a look that gives the impression of high precision.

1. Introduction

As are typified by the automotive and electric appliance industries, more large die mold workpieces are being produced overseas. There is also a move, however, to return production to Japan, and therefore there is an increased need for stable, high-quality die mold manufacturing. In addition, the demand for machine tools that can attain the machined surface quality level that requires no polishing has also been increasing, as has the need for improvement in the accuracy and quality of the machined surface, such as the reduction of stepping caused by thermal displacement, etc. Against this backdrop, MHI released the MVR-Eχ large double column machining center, which is equipped with the high-precision technology adopted for the recently released LH250 high-precision machining center. This paper presents the technological features of the MVR-Eχ, which realizes high-precision machining, and also details a cutting case example.

2. Latest technology for high-precision cutting

2.1 Purpose

In the manufacturing of large die molds that last up to several dozen hours, the thermal elongation of the spindle caused by heat generation from its rotation and the heat deflection of the machine peripherals due to temperature changes result in the stepping of the machined surface. This hinders the elimination of manual finishing. Although a thermally symmetrical structure or heat deflection correction technology is typically adopted for large machine tools, no correction technology can correct the inclination of the machine or the tool. As a result, technology improvement that does not overly depend on heat deflection correction is required.

2.2 Internal spindle cooling

The MVR-Eχ series uses internal spindle cooling technology and lubrication optimizing technology that have been cultivated with the LH250 high-precision double column machining center to suppress the thermal elongation of the spindle in high-speed rotation and the heat generation of the bearings to establish a structure that allows high-precision cutting without heat deflection correction. In addition, it uses efficient spindle cooling technology to increase the preload of the spindle bearing in low-speed rotation for the establishment of a structure that withstands rough cutting. In this way, the high-precision spindle achieves both low-speed heavy

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cutting and high-speed, high-precision finishing.

2.3 Thermally stabilized column

The MVR-Eχ series is equipped with a thermally stabilized column as standard equipment for high-precision cutting without the need for heat deflection correction. The column suppresses the heat deflection due to changes in the outside temperature, and even reduces heat deflection such as the inclination and shrinkage of the column that cannot be corrected by thermal correction. For example, changes in perpendicularity between the x axis and the z axis are suppressed to the maximum limit of 6 μm per 500 mm to attain a structure that is not subject to environmental temperature changes in the machine installation location. Meanwhile, the rigidity of the main structural components such as the saddle and the cross rail is enhanced to realize high-power and stable cutting even with the ram fed at 800 mm.

2.4 High-speed cutting contour control (FM control)

For cutting high-precision die molds, it is not enough to just reduce mechanical errors, and the correction of errors resulting from time lags of the controls is required. MHI uses unique high-speed cutting contour control (FM control) to attain high-speed and high-precision contour control. It is generally thought that an NC control machine tool such as an NC milling machine traces the exact path directed by a program, but actual operation has errors in the path caused by the servo characteristics of the feeding shaft. These errors increase when the curvature of the path is larger or the speed is faster. For the positioning or linear processing of milling, this causes no problems, but for die mold processing containing curved processing, however, it results in the dilemma of increased cutting speed worsening the accuracy of the product shape, thereby necessitating a decrease in the cutting speed for an accurate cutting shape. The FM system is based on the design concept of not decreasing, but rather eliminating completely the shape error, and solves this problem by using a method in which no cutting shape errors occur even when the cutting speed is increased.

3. Development of Two-stage Electric Turbocharging System

3.1 Features of operation screen

Together with the performance, the operability is enhanced through the introduction of cutting support functions for the entire cutting process including machine operation, reflecting customer needs. The operation screen is a large 15-inch monitor, and touch screen operation is made possible in addition to the conventional hardware switch operation. The multi-screen allows the simultaneous display of different pieces of information including positional information and tool information. This reduces the number of screen changes and touches, reducing the burden on operators. Operators can select and set what information is to be displayed on the multi-screen, enabling them to check necessary information according to the use conditions on a single monitor (**Figure 1**).

3.2 Preventive maintenance function

The majority of inquiries about machines from customers are regarding recovery methods and how to deal with alarms. In response to this, a maintenance screen is provided in order to allow customers to solve problems by themselves. For the recovery of existing machines, the customer needs to perform recovery work while following the manual. On the other hand, the MVR-Eχ highlights the relevant points using 3D drawings and allows the operator to perform recovery just by making simple selections on a screen and operating dedicated hardware switches (**Figure 2**).

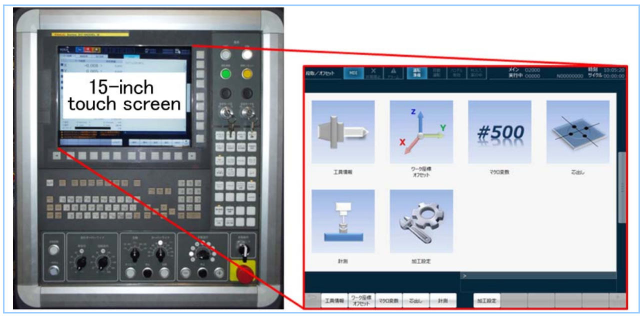

Figure 1 Screen with improved operability

Figure 2 Visually understandable recovery screen

In addition to alarm display, the MVR-Eχ indicates causes and countermeasures. Furthermore, the locations of the components that cause an alarm are indicated visually using 3D drawings. Accordingly, the clarification of alarms and fast maintenance and recovery are made possible.

4. Cutting case example

This chapter shows the result of the machining of an A5052 test piece. This test cutting was aimed at verifying the effects of the heat deflection suppression structure of the MVR-Eχ using the high-precision spindle and the thermally stabilized column. The test cutting was performed without any electrical correction of heat deflection such as spindle thermal elongation correction, while changing the spindle speed from 1000 min^{-1} to 8000 min^{-1} in order to intentionally generate spindle thermal elongation. To confirm the stabilization of spindle thermal elongation in a short time, the cutting was performed within 30 minutes of changing the spindle speed. Typically, a relative large heat deflection occurs in a change from low speed to high speed or from high speed to low speed, but the test resulted in a high-precision machined surface with a small amount of stepping up to 1 μm even under the conditions of the test environment where spindle thermal elongation tended to occur (**Figure 3**).

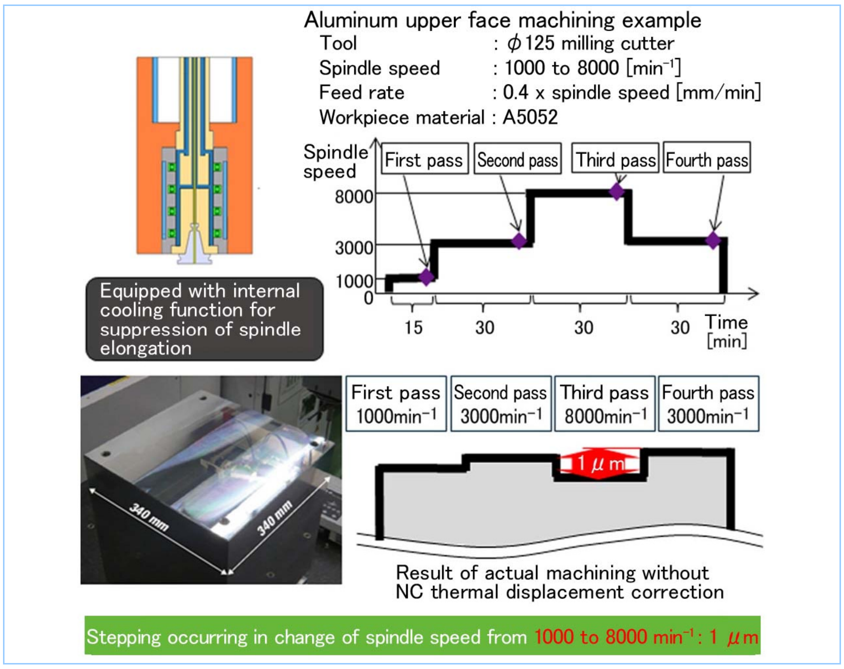

Figure 3 Case example of high-precision cutting (vertical shaft cutting)

In addition, for the confirmation of the reduction in heat deflection (in particular the stepping of the machined surface caused by column inclination) resulting from changes in machine peripheral temperature, side face cutting of an aluminum test piece was performed with a right head (horizontal spindle) attached. This resulted in a small amount of stepping of 8 μm between two machined surfaces of machining passes that were performed with an interval of several hours even when the outside air temperature of the machine peripherals changed by 5.5°C over 18 hours. Accordingly, the structure of the machine with which heat deflection and stepping of the machined surface caused by changes in outside temperature are much less likely to occur was verified (**Figure 4**).

In addition, the virtual lack of change in perpendicularity allows stable high-precision cutting, and even perpendicularity and accurate hole pitch in the five-face machining of a general workpiece cutting can be attained. In fact, the effects of the high-precision spindle and thermally stabilized column were verified in the cutting of a die mold model sample that lasted more than 40 hours. This die mold model sample cutting resulted in a small amount of stepping between surfaces machined with multiple tools having various diameters, suppressed the stepping of the connection between finished surfaces (where stepping tends to occur) to 1.5 μm at most and realized the elimination of manual finishing due to a high-quality machined surface that had no disorder of die mold dimensional accuracy and surface-machined shape (**Figure 5**).

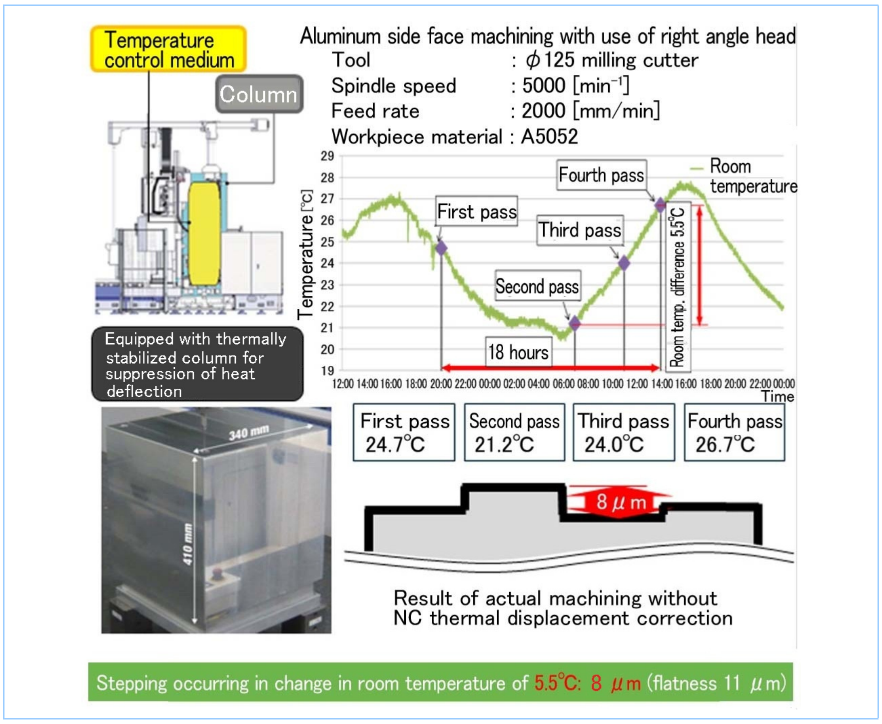

Figure 4 Case example of high-precision cutting (horizontal shaft cutting)

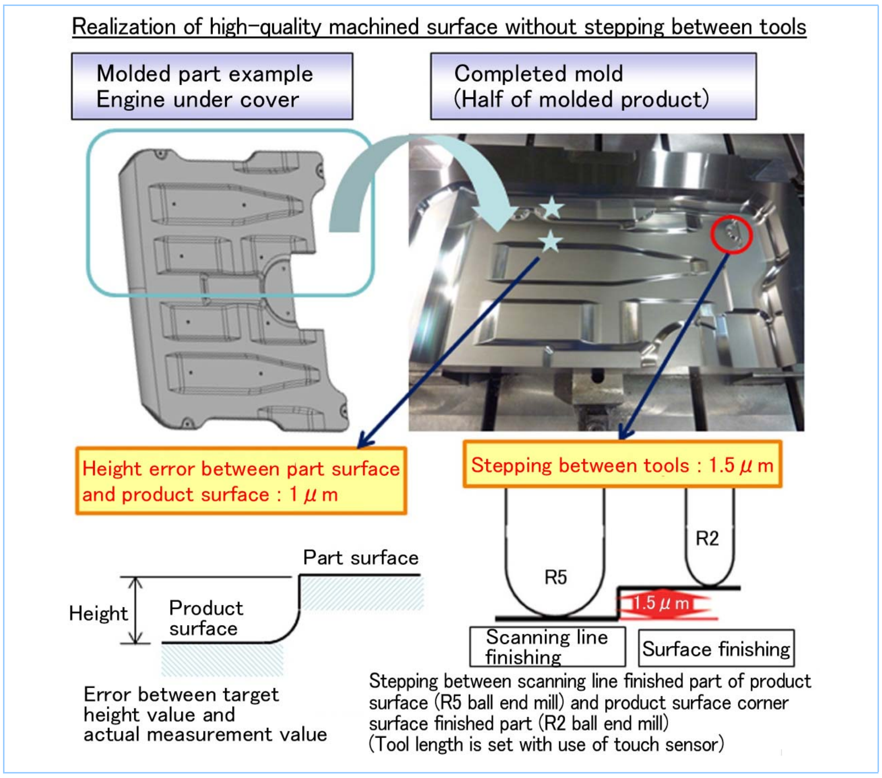

Figure 5 Effects of high-precision spindle and thermally stabilized column

5. Conclusion

This paper presented the features, performance, and a cutting case example of the MVR-Eχ double column machining center, which realizes high-precision die mold manufacturing. High-precision cutting is attained by suppressing the stepping of the machined surface through the significant reduction in heat deflection of the spindle and the mechanical components. This will help eliminate manual finishing. By understanding the need for the accurate machining of large, integrated die molds in the automotive and electric appliance industries, we will enhance the application and lineup of the machine, and meet the needs of users aiming at the advancement of their facilities. By doing so, the MVR-Eχ and the previously-released LH250 high-precision double column machining centers will contribute to social progress.