Latest Technologies for High-Precision, High-Efficiency Gear Grinding Processing

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There is increasing demand for high-precision gears for the improvement of the fuel consumption, downsizing, and the reduction of the transmission error of gear devices such as automobile transmissions and reduction gears. In response to this, the need for gear grinding machines that can process high-precision gears efficiently and stably is rapidly expanding. This paper presents the technological features of the MHI ZE series generating-type gear grinding machine for the realization of high-precision and high-efficiency processing.

1. Introduction

Demand for improvement in the accuracy of gears installed in widely-used gear train devices such as automobile transmissions and reduction gears for the improvement of quietness, the enhancement of transmission efficiency, and the reduction of transmission errors has risen sharply in recent years. Market demand for a continuous generation grinding method using a thread-shaped grinding wheel is also showing a rapid increase among high-precision gear processing methods for mass production such as honing, carbide skiving hobbing, etc. Mitsubishi Heavy Industries, Inc. (MHI) has a product line that suits needs for mass production gear grinding consisting of the ZE series gear grinding machine for external gears and the ZI series gear grinding machine for internal gears. We have further improved the efficiency and accuracy of the ZE series gear grinding machine for mass production of external gears in response to the recent market demand described above.

2. Features of the ZE series

2.1 Realization of high-precision and high-efficiency dressing

A gear grinding process is a method to transfer the shape of a grinding wheel that is dressed by a dressing device. For the improvement of process accuracy, it is important to dress the grinding wheel accurately. However, the improvement of dressing accuracy cannot be attained just by the performance enhancement of a single dressing device. It has to go with the enhancement of the rigidity and accuracy of the whole machine.

For the realization of highly accurate tooth profiles, the ZE series performs on-machine dressing using a rotary dresser located in a position almost the same as that of the workpiece, so that the dressing of a grinding wheel can be performed in the same position and posture as the actual gear grinding. In addition, by increasing the maximum rotation speed of the rotary dresser from the conventional 3,260 min^{-1} to 6,000 min^{-1}, the rotation speed of the grinding wheel can be increased without changing the rotating speed ratio between the dresser and the grinding wheel. Together with high-speed and high-precision control of the grinding wheel shift axis, this results in the reduction of the dressing time.

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2.2 Tooth profile pressure angle correction function

To perform tooth profile pressure angle correction, in the case of competitor's gear grinding machines, the conventional two-rotary dresser specification needs manual fine adjustment of the dressing device mounting angle. The formed composite dresser specification cannot change the on-machine pressure angle and requires correction of the shape of composite dresser. **Figure 1** shows the conventional pressure angle correction method.

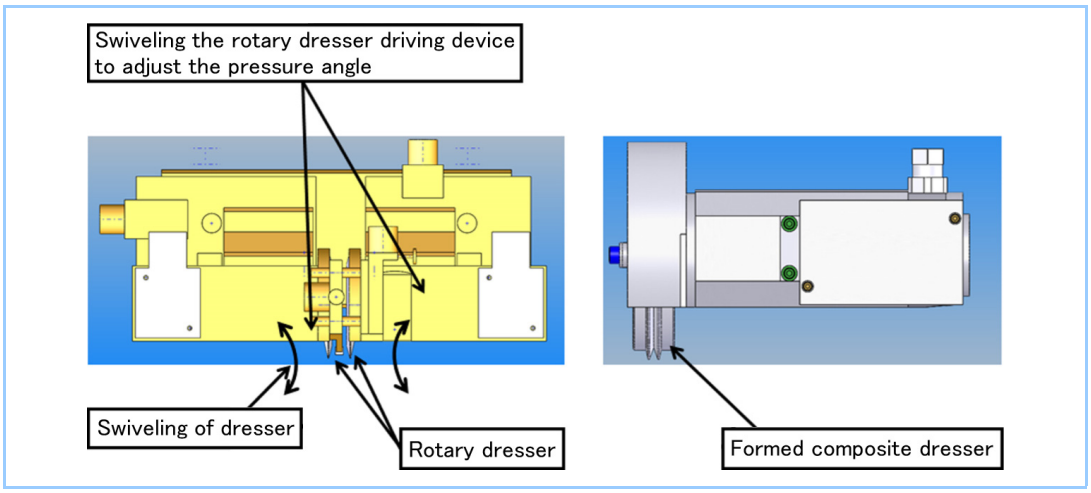

Figure 1 Conventional pressure angle correction
Pressure angle correction is performed by adjusting the dresser mounting angle manually or adjusting the pressure angle of dresser.

Our ZE series has a function to simultaneously dress both sides of the grinding wheel to correct the pressure angle by simply inputting correction data. Due to this function, even an unskilled operator can easily and accurately adjust the pressure angle. The tooth profile pressure angle correction changes the relative positional relation between the dresser and the grinding wheel in dressing. Conventionally, the grinder shape was corrected by fine adjustment of the dresser. For this machine, the dresser is fixed and the correcting function is realized by correcting each axis of the grinding wheel using the NC. **Figure 2** shows an example result of the correction performed by inputting the required pressure angle correction values of both grinding surfaces in the NC and performing the correction. As this figure indicates, the correction result is almost the same as the input values. This function is essential for production sites where the number of skilled workers is decreasing.

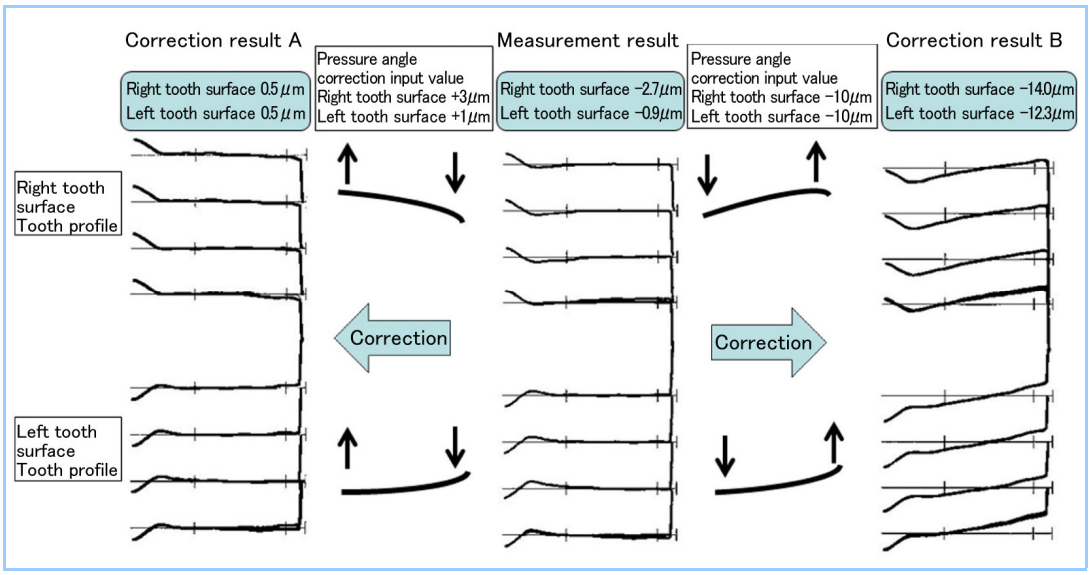

Figure 2 Example of correction of pressure angle
Correction amount is input based on gear measurement result

2.3 Quick setup change for similar workpieces

Today's production sites are shifting from traditional small-variety mass production to multi-variety variable production, thereby necessitating frequent setup changes. A generating-type gear grinding machine requires changes of tools including grinding wheels and dressers depending on restrictions such as workpiece specifications, target accuracy, etc., when the machined workpiece is changed to a similar workpiece such as one having a different number of teeth. When the machined workpiece is changed, dressing tooth meshing (meshing work between the grinding wheel and the rotary dresser) and processing tooth meshing (meshing work between the grinding wheel and the gear workpiece) are necessary. This machine adopts an AE (acoustic emission) sensor to realize automatic tooth meshing.

In addition, the ZE series is equipped with two sets of dressing devices with rotary dressers that have settings different from each other, which can reduce the number of dresser changes in response to the workpiece to be processed. **Figure 3** shows an example of this reduction. When the workpiece to be processed is changed to one for which the current mounting tools and grinding wheel are used commonly, the dressing device can be exchanged with the other one by a simple operation on the dialog screen, and setup changes can be made without opening the door of the machine. Furthermore, the meshing work can be omitted depending on the specifications of changing workpieces, resulting in the reduction of setup time by 10 minutes or more.

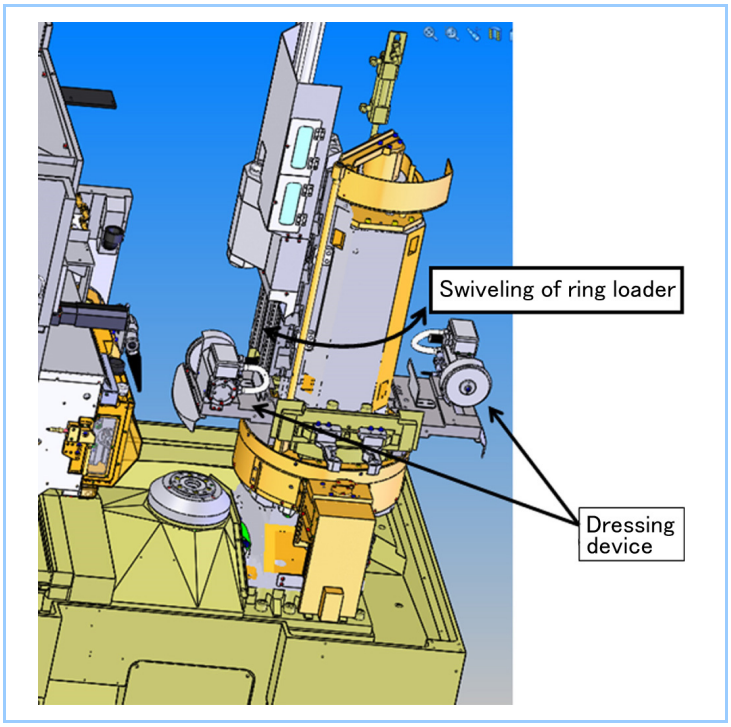

Figure 3 Specifications for two sets of dressing devices
The ZE series' two sets of dressing devices reduced the number of setup changes.

2.4 High-precision process

There are an increasing number of cases where even a non-involute gear that was formerly ground and formed using a single grinding wheel is generation-ground using a thread-shaped grinding wheel for high-efficiency finishing. With regard to non-involute gears, the tooth profile accuracy and the OPM (i.e., the distance between teeth bottoms) are considered to be important. **Figure 4** shows an example where a sizing device is added to the high-rigidity and high-heat rigidity machine in order to perform high-precision processing. In continuous processing of non-involute gear workpieces with an external diameter of 150 mm, module 4 in the middle of which the grinding wheel is dressed, this specification attained the OPM fluctuation of 10 μm or less, while that of a conventional machine was approximately 40 μm.

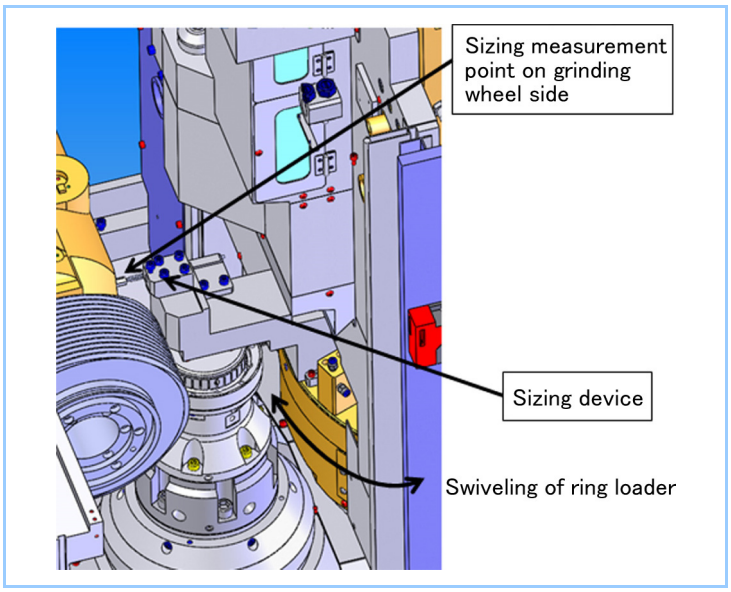

Figure 4 Mechanism of sizing device
A sizing device is added to the counter column side to correct the distance between axes

2.5 Gear grinding process with water soluble grinding liquid

Water soluble grinding liquid is used for many grinding processes due to its superior cooling property in comparison with grinding oil and with the aim to reduce environmental load in disposal and prevent fires caused by sparking during processing. It has not been used practically for generating-type gear grinding machines, however, because of problems with tooth surface burning and sludge. This time, MHI developed a grinding wheel specifically for water soluble liquid and water soluble grinding liquid itself and modified the machine specifications including the coolant tank in cooperation with Toyota Motor Hokkaido, Inc., Noritake Co., Ltd, and Yushiro Chemical Industry Co., Ltd. As such, a mass production gear grinding process with water soluble grinding liquid was brought into practical use.

3. Conclusion

There has been sharply increasing demand for higher-precision gears in recent years, and the market requires gear grinding machines that allow even unskilled operators to perform high-precision, high-efficiency processing and maintenance work. MHI planned to improve the accuracy and efficiency of processing with the ZE series in response to recent needs for the enhancement of productivity, and realized the reduction of machine down time and more accurate processing. We will henceforth seek even higher precision and shorter cycle times for processing, and aim to create production sites for our customers where environmental load and total costs are reduced by offering high-value-added gear grinding machines with superior operability and maintainability.

Reference

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