Proceedings of the 16th International Conference on Manufacturing Systems – ICMaS
ISSN 1842-3183
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MAZAK - INTELLIGENT MACHINE TOOLS

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Abstract: *This paper tries to point the fact that Mazak, as the machine-tool industry's leader in Multi-Tasking technology, is releasing multi-tasking manufacturing equipment for an expanding range of parts applications in an equally wide range of manufacturing industries. "Mazak is constantly refining Multi-Tasking technologies to make them more workable, so more industries benefit and grow stronger from Done-in One machining that eliminates multiple machines and multiple fixtures and completes complex parts in a single setup." The Intelligent Functions come from a combination of machine design features and the processing power of the 6th-generation Mazatrol CNC, the Matrix. The result is the ability to look ahead and identify conditions before they become problems. Mazak Intelligent Machine functions include Active Vibration Control, Intelligent Safety Shield, Intelligent Thermal Shield, Intelligent Performance Spindle, Mazak Voice Adviser, Intelligent Maintenance Support, and Intelligent Balance Analyze* [1].

Keywords: *intelligent, functions, spindle, control, vibration, thermal, safety, performance.*

1. INTRODUCTION

As machine tools have become increasingly more complex, the number of highly skilled operators in machine shops continues to decrease. Additionally, unmanned operation or automated systems are increasingly used for higher productivity, resulting in the need for machine tools to have "Intelligence." The Mazak Intelligent Machine, i machine, with a variety of Intelligent Functions realizes optimum machining conditions without requiring highly skilled operators.

Mazak machine tools are being upgraded to Intelligent Machines. They are equipped with a "nervous system" and have the ability to detect and react to changes in their environment. The power of the synergy provided by these new functions will bring a considerable innovation to machine tool operation. Intelligent Machines are equipped with seven newly developed functions. [2]

2. ACTIVE VIBRATION CONTROL (AVG) – MINIMIZED VIBRATION

One of the intelligent functions, AVC, reduces vibration caused by axis movement acceleration/deceleration for both high speed and slow speed feedrates (Fig. 1).

Thanks to this function, higher quality surface finishes even with high speed feedrates are realized with both reduced machining time and higher machining accuracy.

Frequency characteristics of acceleration/deceleration filter (Fig. 3) can be set to counteract the natural frequency of machine. And furthermore high-frequency vibration will be lessened (Fig. 4).

To control machine vibration at axis movement, Mazak has developed new, acceleration/deceleration filter (Fig. 2).

Fig. 1. AVC icon.

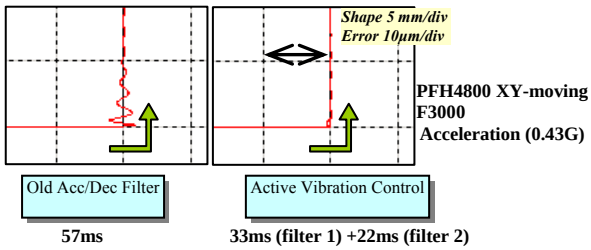

Fig. 2. Acceleration/deceleration filter.

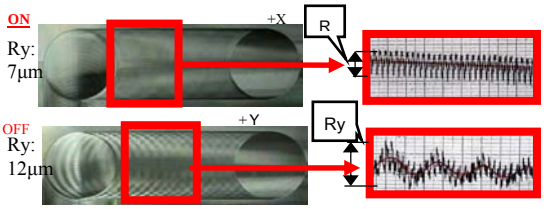

Fig. 3. Feedrate: 3000 mm/min.

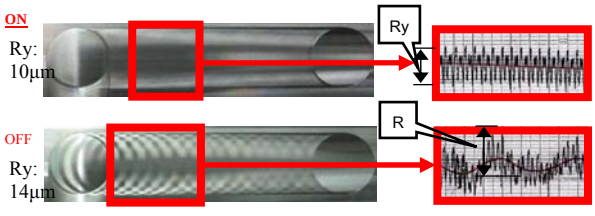

Fig. 4. Feedrate: 5000 mm/min.

The pictures show machining of aluminum with a cutting feedrate of 3000 mm/min and 5000 mm/min – first, machining is in the Y-axis direction and then changes 90 degrees to the X-axis direction. The picture shows surface finishes of both cutting feedrates with AVC ON/OFF.

When AVC is OFF, vibration resulting from axis movement acceleration/deceleration that occurs when the cutter passes through a corner results in cutter, marks on the workpiece surface. When AVC is ON, no vibration due to axis movement acceleration/deceleration is generated so that a higher quality surface finish is realized – the differences are apparent in the photographs to the right. Surface roughness is 12 µm with the function OFF and cutting feedrate of 3000 mm/min; surface roughness is 10 µm with the function ON and cutting feedrate of 5000 mm/min. [3]

3. INTELLIGENT THERMAL SHIELD (ITS) – HEAT DISPLACEMENT CONTROL

Machine heat displacement is a critical issue for manufacturers as it directly affects machining accuracy.

Accordingly, high machining accuracy is normally realized by customers performing tool compensation and/or installing machines in temperature controlled environments. Having received comments from customers regarding this subject, Mazak's engineers have worked hard to improve this situation.

For countermeasures to heat displacement, Mazak machines are designed with the units which generate heat arranged symmetrically so that if there is any heat displacement it will have minimum affect on machining accuracy. Additionally, spindle motors with less heat generation are used as well as advanced cooling systems for machine structures. We have also focused on the impact of changes in coolant temperature as well as room temperature change. As a result, using a room in which the temperature can be closely controlled, we have accumulated extensive data for machine displacement according to changes in the temperature.

To realize high accuracy machining to the µm-level, sophisticated heat displacement compensation is required to minimize heat displacement caused by high-speed machine operation or changes in the room temperature. To meet this requirement, MAZAK has developed the ITS, based on our experience and unique technology. This function makes it possible for a machine to detect changes in temperature and automatically compensate in order to ensure stability of the positional relationship between a workpiece and tool (Fig. 5).

The ITS was introduced more than a year ago and is standard equipment for all Mazak Intelligent Machines. Since then, good results have been realized in many customers' factories.

At the customer's factory, large doors are frequently fully opened to bring material in and out of the area and

Fig. 5. ITS icon.

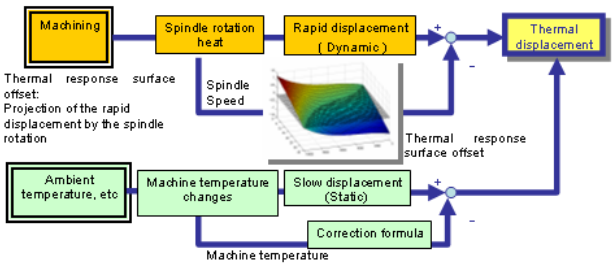

Fig. 6. Function of the new thermal displacement compensation.

the factory temperature may be less than 10°C in the morning and gradually rise until 2 o'clock in the afternoon. Data show results for the temperature controlled test room and an actual factory. Even in such an environment, machine displacement is minimized.

Through other similar experiments and observation, Mazak could confirm stable high machining accuracy can be achieved in various environments by optimum heat displacement compensation based on data collected from sensors (Fig. 6). The sensors are located on components that have strong collaboration with heat displacement. Mazak will continue to experiment and observe heat displacement and collect data to improve our heat displacement compensation technology to meet customers' requirements. [4].

4. INTELLIGENT SAFETY SHIELD (ISS) – INTERFERENCE PREVENTION

ISS (Fig. 7) works when an operator manually moves the machine axes for setup, tool measurement by the Tool Eye or changing inserts. Mazatrol shows a synchronized 3D model on the CNC display to check machine interference. If any machine interference is likely to occur, the machine motion immediately stops (Figs. 8 and 9)

With Virtual Machining, machine programs can be made with minimum errors and time required for test cuts thanks to realistic machine 3D simulation displays that can be used for convenient program confirmation and checking for any machine interference [5].

Corrections through the program before test cutting:

- reduced machine setup time;
- operation with reduced stress even for first workpiece;
- elimination of repeated machine setup/test cutting.

Fig. 7. ISS icon.

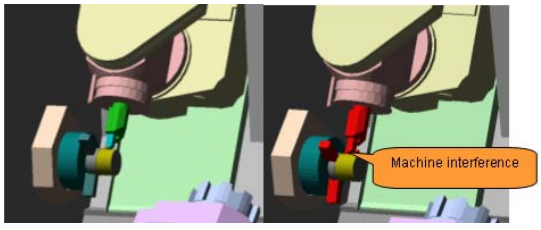

Fig. 8. Virtual machining.

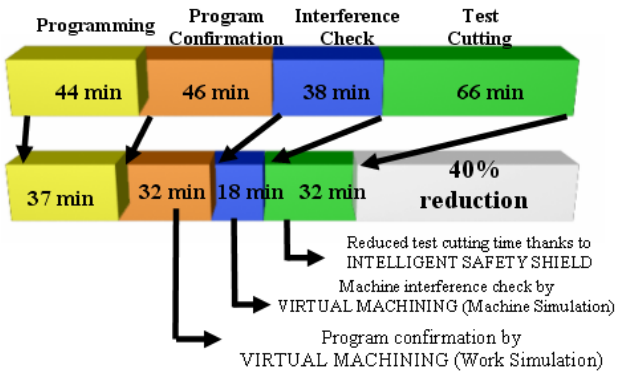

Fig. 9. Results obtained by using ISS.

Fig. 10. MVA icon.

Fig. 11. IPS icon.

5. MAZAK VOICE ADVISER (MVA) – VERBAL MESSAGE SYSTEM

The MAZATROL MATRIX verbally informs which switches have been selected and advises caution as necessary during manual machine operation (Fig. 10).

This function contributes to the considerable reduction of problems due to operator error. For example, when an operator selects the B-axis, the function advises, "B-axis has been selected. Please be careful about the machine interference," when lubricants have to be added, the function advises, "please refill the lubricants," and when tool life is about to the end, it advises "the tool life is over," for smooth operation [6].

6. INTELLIGENT PERFORMANCE SPINDLE (IPS) – COMPREHENSIVE SPINDLE MONITORING

The Intelligent Performance Spindle monitors a variety of proprieties with sensors housed in the spindle – including temperature, vibration and displacement – and provides useful information to the operator. Thanks to these data, machine problems due to the spindle can be prevented. Additionally, a considerable reduction of production loss due to machine down time can be realized (Figs. 11 and 12).

High productivity (high accuracy, high-efficiency machining thanks to monitoring-including temperature, vibration and displacement Data relating to spindle load, temperature and vibration is stored for 1 year on a rolling basis.

Maintenance (Preventative maintenance and diagnostics) avoid unexpected machining downtime thanks to accurate preventative maintenance and prediction.

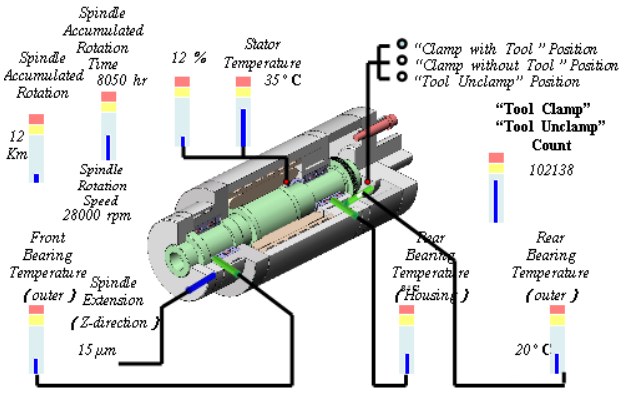

Fig. 12. Spindle status display.

Operator support (Safety and Monitoring) - improved operation safety thanks to monitoring of tool balance and tool clamp status.

7. INTELLIGENT MAINTENANCE SUPPORT (IMS) – PREVENTIVE MAINTENANCE

IMS (Fig.13) monitors the status of perishable items such as filters, cover wipers and the operation history of several machine units. Shops can use this information to determine a preventive maintenance program to avoid unexpected machine downtime. Additionally, when the replacement time is reached for an item such as a filter, a pop-up window notifies the operator to ensure the required maintenance is performed (Figs. 14 and 15).

Accumulated operational life is used to instigate preventative maintenance:

1) accumulated operation log – the log displays used life against target life time;

2) unit work log screen displays the accumulated usage for main units;

3) operator can check accumulated values. Information can be displayed as a graph or numerical data,

4) unit life data is clearly displayed in unit's applicable, distance, angular or actuation frequency;

5) operator friendly alarm generation.

Fig. 13. IMS icon.

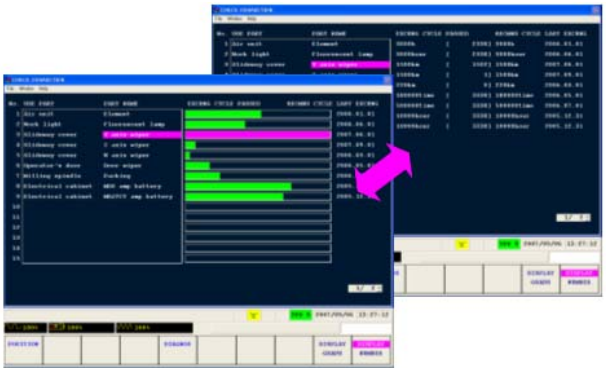

Fig. 14. Double display.

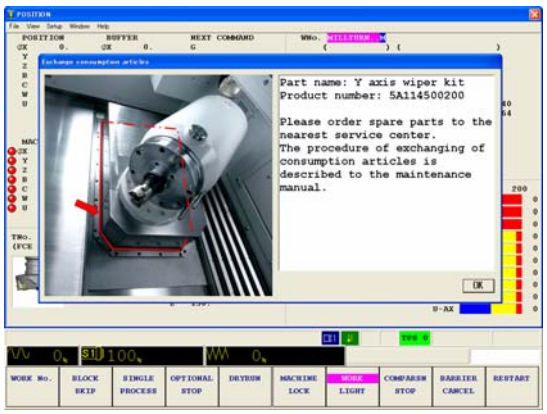

Fig. 15. Window display example.

8. INTELLIGENT BALANCE ANALYZER (IBA) – UNBALANCED TABLE DETECTION AND ANALYSIS

If fixtures and/or workpieces are loaded on the machine table in an unbalanced condition, a vibration occurs. This brings the possibility of work machining failure and machine component degradation, and risk of jumping-off of workpieces, etc.

In order to prevent these problems, unbalanced turning table detecting functions comprising two functions were developed.

Unbalance Alarm Function. Function to detect a vibration when the table rotates, and check if the table is in a hazardous situation or not. Before machining, executing the function at a speed of use is recommended.

Balance analyzer. Function to analyze a machine balance (Fig. 16).

The unbalance magnitude and direction are displayed on the NC screen and the positions of balance weights are indicated.

Before machining, check a balance at a speed of use.

Mechanism. When rotating a turning table, a vibration due to unbalance can be observed through a ball screw as X-axis servo droop. So the servo droop and turning spindle rotational angle data are analyzed, the unbalance magnitude and direction are evaluated and displayed on the screen.

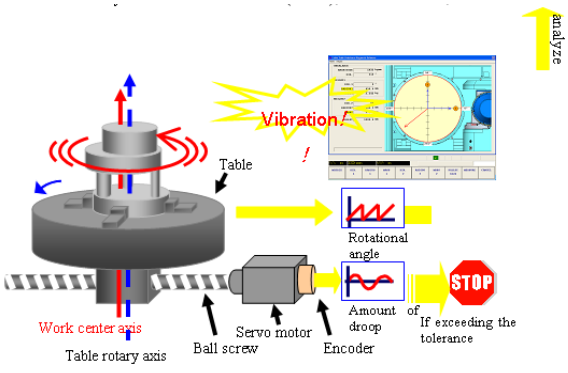

Fig. 16. Balance analyzer.

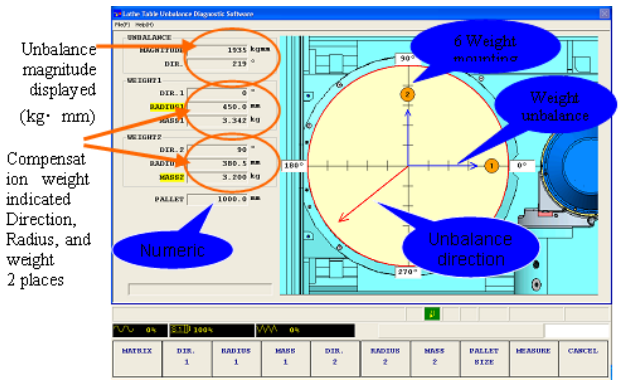

Fig. 17. Balance analyzer.

Balance Analyzer Screen. On the screen (Fig. 17), the unbalance magnitude and direction are measured, and the positions of balance weights are proposed.

The unbalance direction and magnitude, and the places where balance weights are mounted are visually displayed.

Thanks to its innovative monitoring functions, the system continuously monitors changes in spindle temperature, vibration, and heat displacement. It significantly contributes to high accuracy machining and provides comprehensive data for preventative spindle maintenance. Mazak provides innovative technology as your partner to increase your productivity and strengthen your competitiveness by focusing on "Versatility," "Evolution," and "Intelligence."

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