

# Automatic Die/Mold Manufacturing System "UH-SUPPORT SYSTEM"

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*This report introduces an automatic die/mold manufacturing system, "UH-SUPPORT SYSTEM," a super high speed machining center developed to machine small to medium size die/mold, "UH55," and a customer's automatic die/mold manufacturing line as an introductory example of the above system and machine.*

**Key Words:** automatic die/mold manufacturing line, high speed machining, reduction of lead time

## 1. Introduction

Recently, in accordance with the push towards shortening development lead-time and achieving cost reduction in automobile or electric appliance makers, demands for shortened lead-time and high precision in the production of dies and molds have increased.

In an effort to satisfy these demands, JTEKT has been making efforts to improve machines' functions, as well as working on developing high-speed direct technology for the machining of dies and molds. However, without automation, improved processing accuracy, and enhanced efficiency in various processes, it is impossible to realize high-speed machining of dies and molds. Therefore, we have been advocating "UH-SUPPORT SYSTEM" since October 2002. This system has supported all tasks from process designing to machining in manufacturing of dies and molds.

This paper introduces the UH55 Super High-speed Die/Mold Machining Center and "UH-SUPPORT SYSTEM" as well as an example of automatic die/mold manufacturing line delivered to a customer.

## 2. UH55 Super High-Speed Die/Mold Machining Center<sup>1)</sup>

This machine's outstanding features include a high-speed & high-acceleration feed mechanism and high-speed & high-stiffness spindle. High-speed machining allows this machine to drastically reduce die/mold manufacturing lead-time.

**Figure 1** shows an outer view of the machine, and **Table 1** shows the main specifications.



**Fig. 1** UH55 super high-speed die/mold machining center

**Table 1** UH55 machine specifications

Items	UH55
X-axis stroke, mm	600
Y-axis stroke, mm	600
Z-axis stroke, mm	600
B-axis movement, degrees	360
Pallet dimensions, mm	□450
Pallet maximum load, kg	400
Turning feed speed, m/min.	60
Turning feed acceleration, m/s <sup>2</sup>	9.8
Spindle rotational speed, min <sup>-1</sup>	500~50 000
Spindle end taper	Special HSK-A40

### 2. 1 High-Speed & High-Acceleration Feed Mechanism

Linear guide slides are provided on both sides of each moving body, so that the moving body of each shaft can be very rigidly supported like a two-way supported beam. Also, the moving body on the feed shaft is made of special iron casting designed to have high stiffness despite having a thin wall and its' lightweight according to FEM analysis.

The feed mechanism is comprised of a double-start, high-lead screw and a low inertia feed servomotor. This structure and driving in the vicinity of the center of gravity combines to enable high-speed and rapid acceleration feed of 60 m/min, 9.8 m/s<sup>2</sup>. In addition, taking account of heat generation, the locating accuracy is insured by cooling ball screws.

### 2. 2 High-Speed & High-Stiffness Spindles

The spindle, which is supported by ceramic bearings, has performance of maximum rotational speed of 50 000 min<sup>-1</sup> for 50mm spindle diameter. Its dn value, 2 500 000, is one of the highest in the world. As a spindle end shape, a two-face-clamping chuck (HSK-A40) has been adopted. This is because its' tool clamping stiffness is high and its' fluctuation while rotating at high-speed is small.

To ensure locating accuracy at high speed, the axial expansion of the spindle is directly measured by a sensor and corrected by sending locating directions.

## 3. UH-SUPPORT SYSTEM

The "UH-SUPPORT SYSTEM" is a computer system to support the automatic die/mold manufacturing process. It provides comprehensive assistance for a wide range of processes from process designing for high-speed machining of a die or mold to accuracy correction on the products.

The system, in which skilled engineers' know-how and the characteristics of the machine are contained, enables even a beginner to perform machining comparable to a skilled engineer.

The "UH-SUPPORT SYSTEM" is comprised of subsystems ① through ⑥ as shown in Fig. 2.

- ① Process design support system for die/mold manufacturing "Mill-Plan/UH"
- ② Super high-speed & high-precision control function "UHPC-I/UHPC-II"
- ③ DNC system for die/mold manufacturing "TIPROS DM-10/DM20"
- ④ On-machine measurement and correction system "UHCS"
- ⑤ Composite sensing and correction function
- ⑥ Spindle thermal displacement correction function

Description of the above subsystems ① through ④ is given below.

## 4. Functions and Features of Each System<sup>2),3)</sup>

### 4. 1 Process Design Support System for Die/Mold Manufacturing "Mill-Plan/UH"

In preparing an NC program for machining a die or mold, it is necessary to determine the type of process, the tools to be used, and the processing conditions, etc., based on the model data designed with a 3D CAD system as shown in Fig. 3. However, as this work requires both technical expertise and skills, it has been handled by skilled engineers who take into consideration the type of machine used, the material to be cut, the shape of a die or mold and the required accuracy. Consequently, the design time, processing time and accuracy vary depending on who makes the NC program.

Therefore, in order to solve this problem, the "Mill-Plan/UH" has been developed.

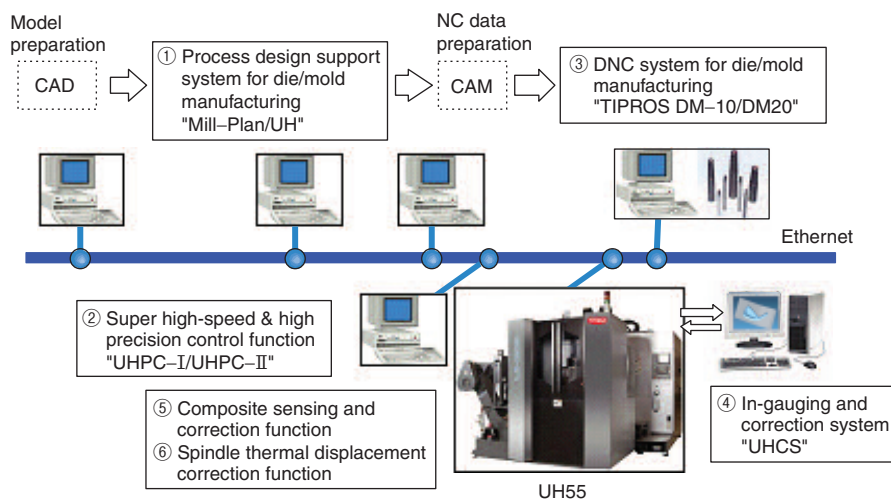


Fig. 2 Composition of UH-SUPPORT SYSTEM

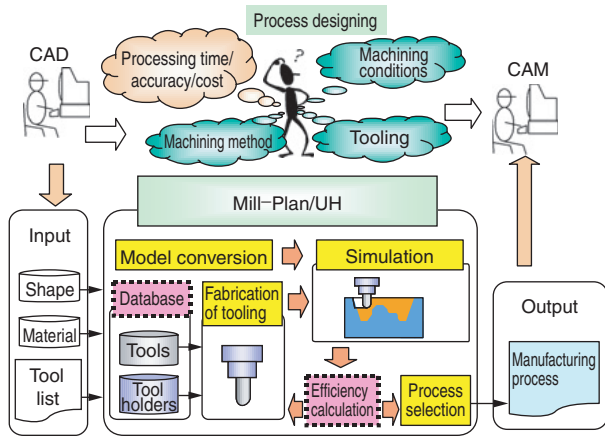


Fig. 3 Composition of Mill-Plan/UH

#### 4. 1. 1 Features of Function

As shown in Fig. 3, "Mill-Plan/UH" requires an operator only to input the 3D model data of the material to be used and the product to be made. From this information, the program will automatically determine the machining process, the tools to be used, and the process conditions. Here, as the system is provided with machine property information and high-speed cutting know-how that are available only to a machine tool manufacturer, it can decide on the optimum machining process for die/mold manufacturing.

#### 4. 2 Super High-Speed & High-Precision Control Function "UHPC-II"

In die and mold manufacturing, one of the most important requirements is the feed control technology that should meet the accuracy and surface quality that the customer wants, while enabling the product to be manufactured efficiently. Conventionally, one processing mode out of several options (like high-efficiency mode or high precision mode, etc.) has been selected at the discretion of the customer. However, as each mode has its favorable and unfavorable configurations to cut in, it has been difficult to provide optimum feed for all tool paths of a given work. For example, using the high efficiency mode to cut on a bumpy surface or a corner can cause problems such as defects or die wear. On the other hand, the use of high precision mode on a smooth curved surface would unnecessarily slow down the speed resulting in extended machining time. To solve these problems, "UHPC-II" based on our unique control logic has been developed.

##### 4. 2. 1 Features of Function

Figure 4 shows the composition of "UHPC-II" which outputs optimum NC data based on the NC data generated by CAM and processed by the optimum speed control.

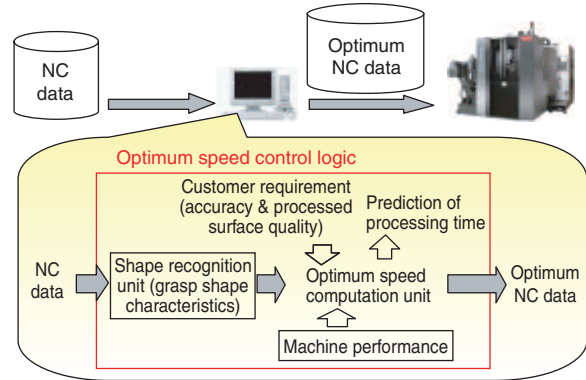


Fig. 4 Composition of UHPC-II

In the shape recognition unit, the NC data are read to recognize the shape and to compute the characteristic values. The optimum speed computation unit combines the shape characteristic values obtained from the shape recognition unit with the previously quantified machine performance information. This is then used to compute the feed speed best suited to the accuracy requirements of the customer, based on which the optimum NC data is produced. In addition, the required machining time is predicted precisely by utilizing the results of the optimum speed computation.

#### 4. 3 DNC System for Data Server "TIPROS DM10/DM20/MG30"

This is a simple DNC (Direct Numerical Control) system which is capable of express transfer of high volume of data required for die/mold machining and is compatible with the FANUC data server. This system does not only facilitate the preparation of process program without mistakes, but also monitors the machining progress on a real time basis.

The process programs used for die/mold machining are normally prepared separately by CAD/CAM. Then, they are taken in the data server one by one. Also, they require a main program to call out one of the plural process programs stored in the server. This system has been developed to replace these troublesome operations with simple personal computer operation.

#### 4. 4 In-gauging and Correction System "UHCS"

The conventional approach to correction of errors in the die and mold accuracy has been first to measure the die or mold on a coordinate measuring machine. If the errors are too large, the piece is then returned to the process for correction. This approach requires a great deal of time for unloading and reloading as well as material handling until completion. Furthermore, there still remains the problem of difficulty in correction machining due to centering errors encountered in the reloading of the die or mold.

4. 4. 1 Features of Function

As shown in Fig. 5, the developed correction system is composed of inboard touch sensors to measure the workpiece in the machine. Additionally, it includes CAD/CAM (Unigraphics NX), which is used to formulate the program for measurement, to analyze data and to prepare NC data for corrective machining. The features combine to form the die/mold manufacturing system.



Fig. 5 Composition of UHCS

First, the measurement program is formulated by CAD/CAM, followed by inboard measurement of the die/mold using the touch sensors. Then, the measured data is transferred to CAD/CAM where this data is analyzed to identify surfaces including any errors, for which the NC data is formulated. Finally, the machine works out any necessary correction processes using the formulated NC data.

Since the use of such systems as the aforementioned "Mill-Plan/UH" and "UHPC" allows output of optimum process conditions and optimum machine control, the

process errors can be reduced. However, taking into account the possibility of tool wear, tool inclination and thermal deformation of the die or mold, it is necessary to check quality of the finally processed die or mold.

5. Example of Delivered System

An example of this system delivered to a customer is introduced below. This example is an automated mold manufacturing line consisting of two UH55 super high-speed die/mold machining centers, a robot "UH-SUPPORT SYSTEM," an outsourced robot and an electric discharge machine. This integrated line is intended to provide the customer with everything needed from idea to the finished molds for resin parts of automobiles from process designing to machining and electric discharge processes (see Fig. 6).

First of all, as the production preparation system, the "Mill-Plan/UH" and "UHPC" are used for automatic development of process flow chart and NC data, while the DNC system "MG30" keeps data and the like under control. Next, the robots are used to load the workpiece onto the machine and UH55 performs high-speed & high-precision machining. In doing so, the UH55 also measures the workpiece's shape inboard and performs corrective machining to ensure the quality standards of the workpiece are met.

Finally, the workpiece is transferred by the robot to an electric discharge machine wherein the workpiece is finished up.

This automatic die/mold manufacturing line is capable of working out a die or a mold by extremely simple operation without requiring difficult techniques or the know-how of skilled workers.

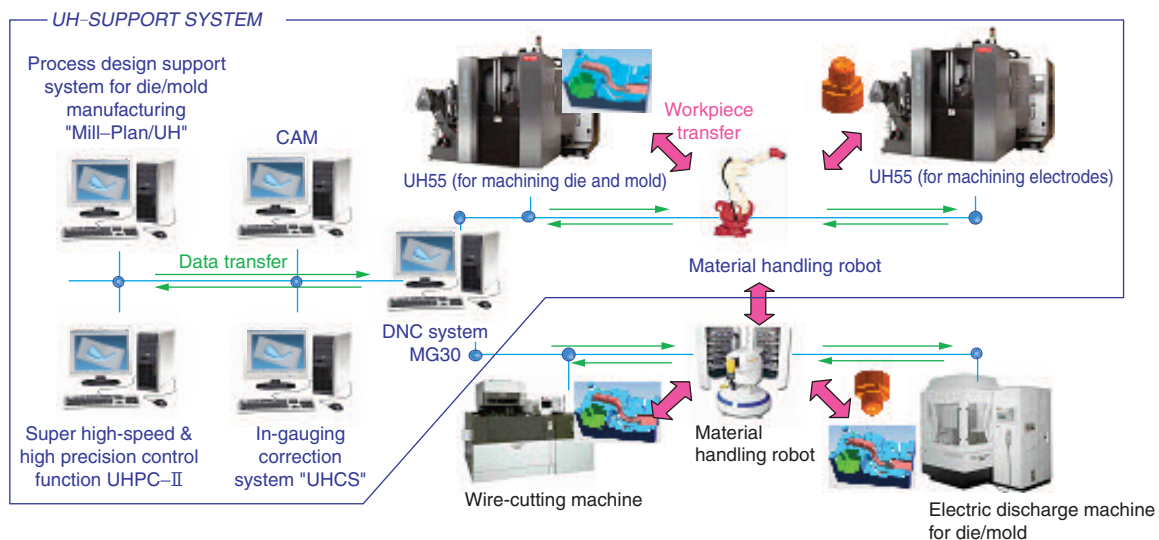


Fig. 6 Automatic die/mold manufacturing line

### 5.1 Sample Workpiece Processing

Figure 7 shows a photograph of a die for switch lever actually processed in the above automatic manufacturing line. The material of this die is SKD61 (HRC48±3) directly cut from a block of 200 × 100 × 100mm.



Fig. 7 Switch lever die mold

The result of processing was excellent as represented by surface roughness 2.8 μm Rz, and profile accuracy of 20 μm or less.

The total lead-time from process design to machining completion was only 33 hours, as shown in Fig. 8, which was a reduction by half compared to the 63 hours needed conventionally.

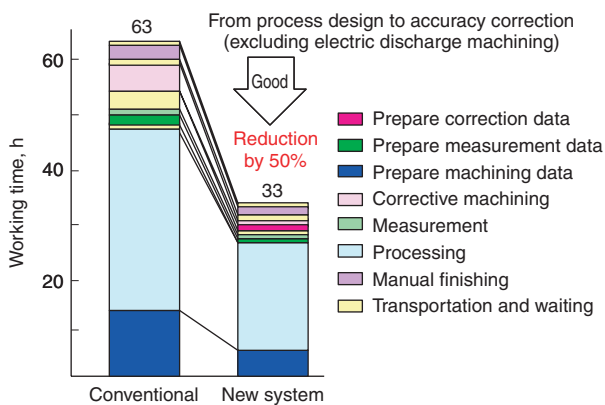


Fig. 8 Comparison at lead time

### 6. Conclusion

This report has presented a description of an automatic manufacturing line for small and medium size dies and molds, which can drastically reduce production lead-time. Also included was an example of one such line delivered to a customer.

Down the road, while the efforts to further functional improvement of the "UH-SUPPORT SYSTEM" will be continued, attempts will be made to extend this technology to large size dies and molds through incorporation of large size machines and 5-spindle machines.

### References

- 1) Y. Yamada, I. Kondo, T. Takada: *Kikai to Kohgu*, **45**, 6 (2001) 24.
- 2) S. Ohishi, T. Okita, S. Murakami, Y. Yamada, K. Tsujimura, H. Nakano, H. Ohtani, Y. Nishida: *Toyoda Kohki Giho*, **45**, 2 (2004) 27.
- 3) H. Nakano, A. Yamada, H. Ohtani, T. Senga: *Japanese Society of Die Mold Technology, Kouen Ronbunshu*, (2004) 68.



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