History and Current Situation of Multi-Tasking Machine Tools

Akimitsu Nagae[1],Toshiyuki Muraki[1],Hiromasa Yamamoto[1]

[1]Yamazaki Mazak Corporation, Japan

[Received November 16, 2012; Accepted October 09, 2012]

Abstract

Manufacturing industries are in intense global competition, and stricter demands for reduction in cost and total in-process time increase year after year. As a result, a production system that can produce a wide variety of components in small lot sizes in response to fluctuations in demand with small floor space requirements is strongly demanded. Our company has been responding to this challenge by process integration and high-efficiency machining methods using multi-tasking machine tools. In this article, we describe the development and history of such multi-tasking machines as well as examples of workpieces processed by this type of machine tool and examples of recently developed new functions.

Keywords: Multi-tasking Machine Tool, High productivity, Done-in-One

1 INTRODUCTION

Manufacturing industries are in intense global competition, and stricter demands for reduction in cost and total in-process time increase year after year. As a result, a production system that can produce a wide variety of components in small lot sizes in response to fluctuations in demand with small floor space requirements is strongly demanded. Our company has been responding to this challenge by process integration and high-efficiency machining methods using multi-tasking machine tools.

Since multi-tasking machine tools have both functions of turning (the same as turning centers) and machining (the same as 5-axis simultaneously controlled machining centers which perform milling, end milling, boring, tapping, etc.), machining processes requiring multiple turning centers and/or machining centers can be integrated and run on a single multi-tasking machine.

This article will presents the development and history of such multi-tasking machines as well as examples of workpieces processed by this type of machine tool and examples of recently developed new functions.

2 HISTORY OF MULTI-TASKING MACHINE TOOLS

Multi-tasking machine tools have been developed originally from lathes. That is, normal lathes → CNC lathes → Multi-tasking lathes → Multi-tasking machine tools (lathe-based) → Multi-tasking machine tools (machining center-based). (See Figure 1.) The principal difference between multi-tasking lathes and multi-tasking machine tools (lathe-based) lies in their milling capacity. During the development of multi-tasking lathes, the diameter of the milling spindle was small, it was thought that multi-tasking capacity limited to small-diameter drilling and tapping was adequate for multi-tasking lathes. But for multi-tasking machine tools (lathe-based), a spindle of 70mm or larger in diameter with sufficient milling capability to perform milling and also end milling was required. Unless multi-tasking machine tools have this milling capacity, machining by a machining center in a following process would be necessary. As a result, process integration was not sufficiently realized in many cases.

On the other hand, multi-tasking machine tools (machining center-based) have recently appeared on the market. These machines allow milling and turning of extremely-large-diameter workpieces which used to be transferred to a machining center for milling after completion of turning. Performing all processes on a single machine results in a significant reduction of in-process time.

3 MULTI-TASKING MACHINE TOOL STRUCTURE AND APPLICABLE PARTS

The typical structure of multi-tasking machine tools (lathe-based) is shown in Figure 2. It consists basically of 5 axes: 3 linear axes (X,Y and Z), a rotary C axis of the turning spindle, and a rotary B-axis around the Y-axis. In addition, if the machine has a second turning spindle, it

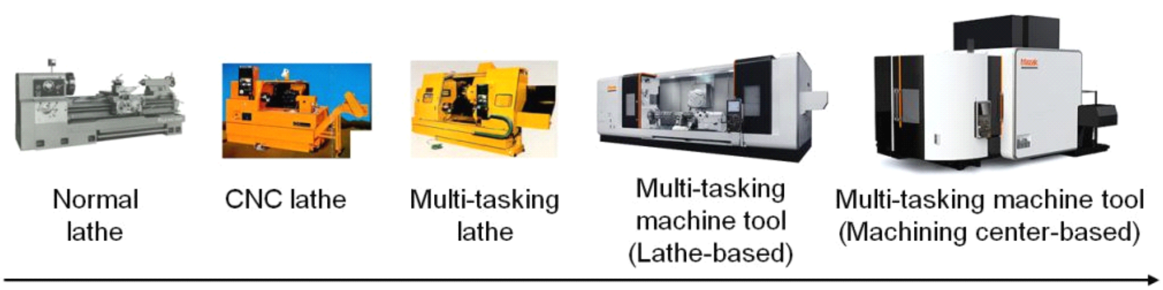

Figure 1: History of multi-tasking machine tools

consists of three rotary axes, and the Z-axis of the spindle which moves in the Z direction is added. Moreover, if the machine has a second turret, Z- and X-axis movements of the turret are added. A representative example of machining by a multi-tasking machine tool with such a structure is shown in Figure 3.

A typical structure of multi-tasking machine tools (Machining center-based) is shown in Figure 4. This is a machine with a horizontal machining center table whose rotational speed is increased to about 600rpm. Various machining processes such as turning can be performed by various tools mounted in the milling spindle which can swing in the B-axis direction. Having a ram spindle which corresponds to the second turret of multi-tasking machine tools (lathe-based) allows workpiece I.D. machining. A representative example of a workpiece machined by a multi-tasking machine tool with such a structure is shown in Figure 5.

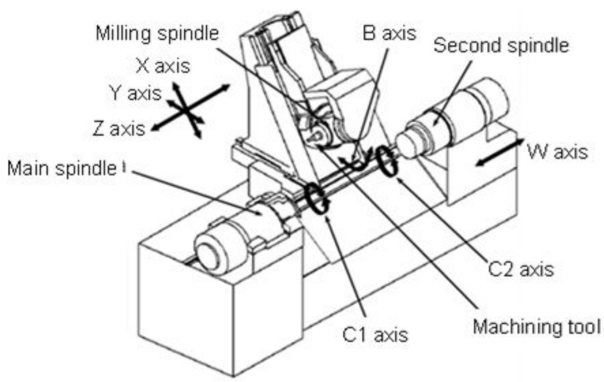

Figure 2: Structure of multi-tasking machine tool (Lathe-based).

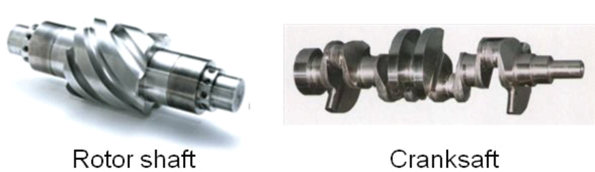

Figure 3: Parts shaped by machining by multi-tasking machine tool (lathe-based).

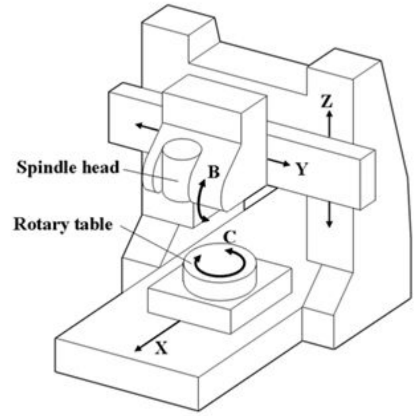

Figure 4: Structure of multi-tasking machine tool (Machining center-based).

Figure 5: Examples of machining by multi-tasking machine tool (Machining center-based).

4 ADDITION OF NEW FUNCTION

Multi-tasking machine tools have been developed to integrate lathe and machining center processes. With the recent development of machines having advanced functions, multi-tasking machines are now capable of special machining which was previously considered as processes that were difficult to integrate. (See Figure 6). On the other hand, workpieces of difficult to machine materials increased, and there has been a challenge to

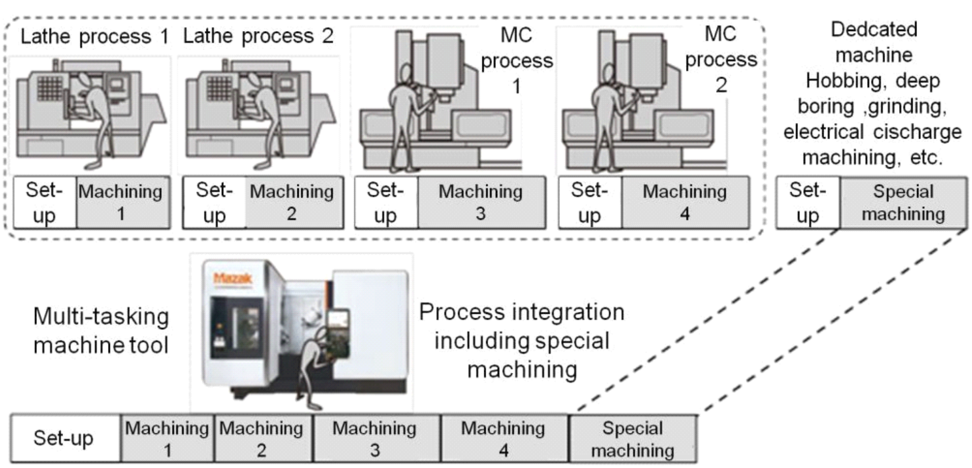

Figure 6: Process integration by multi-tasking machine tool including special machining

reduce their machining time. Examples of process integration and highly-efficient machining methods in which the advantages of multi-tasking machine tools with advanced functions are utilized are shown below:

4.1 Deep Boring by Long Boring Bar

For aircraft landing gear (landing wheel struts) components, deep boring is required. For many deep boring applications, dedicated machines have previously been used because it is difficult to machine them by general-purpose machines.

A long boring bar system for such deep boring processes for multi-tasking machine tools is introduced here. This long boring bar is hydraulically clamped to the Y-axis lower saddle with a construction that ensures sufficient rigidity. (Figure 7). Three long boring bars that can bore a 1000mm deep can be stored in a dedicated stocker. The inserts of some boring bars can be automatically replaced.

Figure 7: Deep-hole boring by long boring bar

4.2 Deep-hole Milling with Special High-rigidity Tool Holder

Keyway milling in deep-bores is difficult to be performed by a normal angle tool. For such deep-hole milling, a special high-rigidity tool holder for process integration by multi-tasking machine tools was developed (Figure 8.). This special high-rigidity tool holder is clamped at four locations on the tool spindle surface and has a high-rigidity structure to withstand deep-hole milling. This special high-rigidity tool holder is stored in a dedicated stocker and automatically loaded/unloaded to/from the tool spindle.

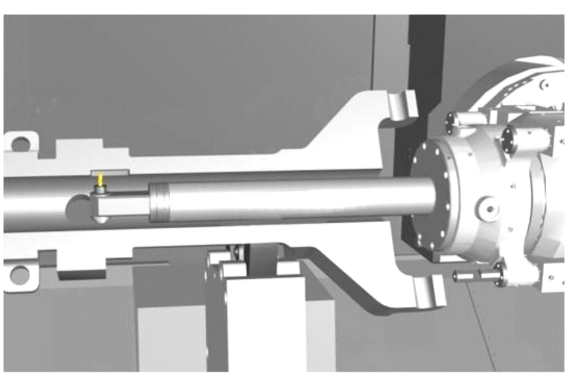

Figure 8: Deep-hole milling with high-rigidity special tool holder

4.3 Taper Boring by U-axis Tool

In tapered bore (conically shaped hole) machining of valve-related components, a fine finished surface is normally required for the purpose of high sealing property. Normally, tapered-hole boring cannot be performed by the milling spindle; however, it can be performed using a special U-axis tool. The U-axis tool has a control axis (U axis) in the radial direction of the tool spindle, and the tip of the tool can be controlled in the radial direction while the milling spindle is rotating (Figure 9). Complex inner taper or curved surfaces can be finished with high accuracy by the U-axis tool.

Figure 9: Boring by U-axis tool (D’andrea TA-C160)

4.4 Hobbing

Components found in many industries – such as jet engines, energy, construction machinery and others, have gears integrated on shafts. Gear teeth are normally machined by dedicated machine tools such as gear hobbing machines. Gear hobbing can be performed by multi-tasking machines by synchronizing the spindle rotation with that of the milling spindle (Figure.10).

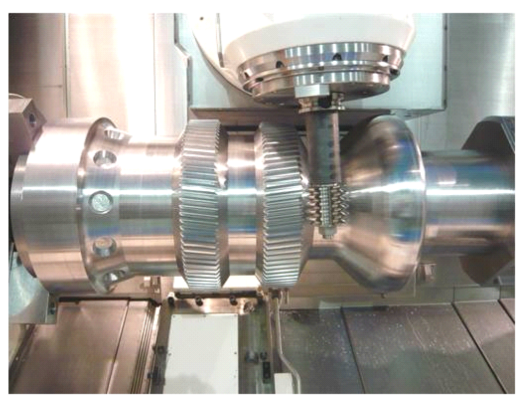

Figure 10: Hobbing in turning spindle-tool spindle simultaneous control

4.5 Grinding of Turbine Blades

Up to thousands of turbine blades are required for one jet engine or gas turbine. For this reason, higher productivity and automation are strongly demanded for these components.

5-axis simultaneous machining by multi-tasking machine tools has been widely applied in machining of materials to produce turbine blades. In the future, by performing not only cutting but also grinding by multi-tasking machine tools, it is expected that automated grinding and other processes can be integrated into a multi-tasking machine tool (Figure.11). In addition, by integrating all processes into a single machine, changes in blade shapes and production lot sizes can be handled with much flexibility.

In addition, supplying grinding lubricant through the grinding wheel would minimize grinding burns and material clogging the grinding wheel to realize improved grinding accuracy.

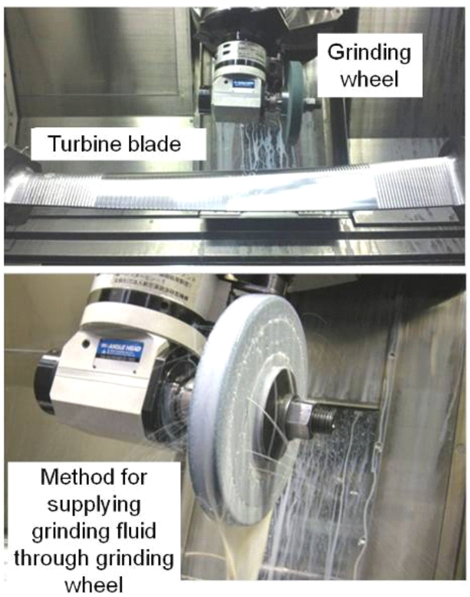

Figure 11: Grinding of turbine blade

(Photo provided by: Tokyo University of Agriculture and Technology, NASADA Co. Ltd.)

4.6 Electric Discharge Machining of Turbine Disks

In addition to turning and boring operations, turbine disks require the broaching of a complex shape (Christmas tree) on the outer diameter where the turbine blades are mounted. This broaching requires a large dedicated machine tool and a dedicated broach.

Figure 12 shows a multi-tasking machine tool with the capacity for both cutting and electric discharge machining to integrate all these processes required for the machining of turbine disks. A tank and an electric discharge unit having wire guide unit, etc. are installed in this multi-tasking machine tool. Turning and boring are performed on a workpiece and in the same setup, electric discharge machining is performed on the disk outer diameter to cut the complex shape. Research is underway regarding finish machining of this complex shape by endmilling. This would allow after rough machining is performed by electrical discharge machining, the disc could be indexed for finish machining by the multi-tasking machine milling spindle. By performing electric discharge machining and cutting at the same time, it is anticipated that a single machine can produce 2 disks a day while performing continuous unmanned machining.

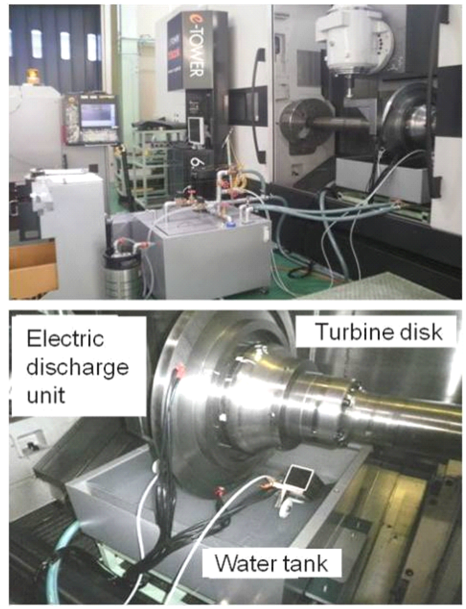

Figure 12: Electric discharge machining of turbine disk

(Photo provided by: Tokyo University of Agriculture and Technology, Chiyoda Kinzoku)

4.7 Turning Tools with Round Inserts

By performing turning operations with round inserts on multi-tasking machine tools, the B-axis can be used to change the tool rake angle during each cutting pass. By doing so, heat generated by cutting is better dissipated and tool life is extended. By applying minute quantities of oil-mist to the tool tip, tool wear and built-up edge are minimized. It is anticipated that this will allow cutting of heat-resistant Inconel alloy 718 (HRC45) up to 10 times faster than conventional processing (Figure 13).

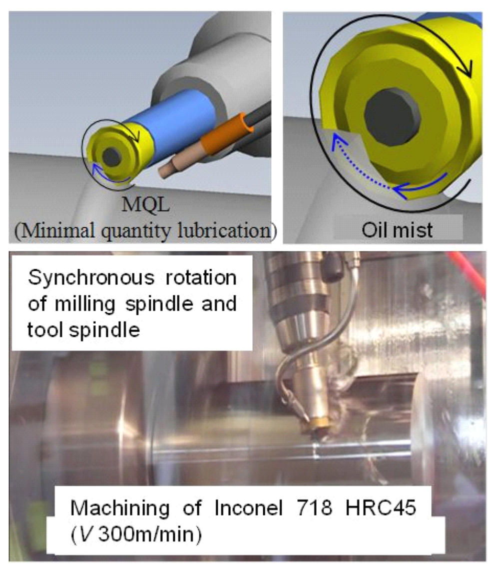

Figure 13: Rotary cutting

4.8 Mill-Turning

Mill-Turning is performed by using a rotating milling cutter instead of a normal turning tool (Figure 14). The cutter rotates during cutting, then as with rotary cutting, the tool tip can be cooled while air cutting as well as reducing tool wear. High-efficiency machining can be realized by rotating the tool at high speed even if the workpiece is not rotated at a high speed, which is extremely beneficial for heavy-duty cutting of unbalanced workpieces as well as intermittent cutting. Additionally, this ensures the breaking of the machined chip for difficult to machine materials.

More research is required to determine the optimum cutting conditions for these two machining process.

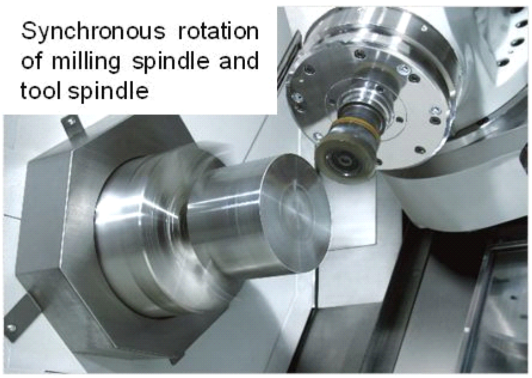

Figure 14: Mill-Turning

5 CLOSING

In this article, the history and structure of multi-tasking machine tools and how they are used recently have been introduced. A review of the history shows that a reduction of the total production lead time – from supply of raw material to the finished product, has been realized. Therefore, as long as there continues to be strong customer demands for higher efficiency, the evolution of multi-tasking machines will continue in the future resulting in further improvements in productivity.

REFERENCES

[1] Report on results of support project of advancement of strategic basic technology in fiscal 2011 “Study of advancement of machining technology of difficult-to-machine components in complex shape of gas turbine engine” (in Japanese)

[2] Report on results of support project of advancement of strategic basic technology in fiscal 2011 “Development of hybrid machining technology of jet-engine turbine disks without machining strain (in Japanese)

[3] YAMAMOTO Hiromasa, SATAKE Kentaro, SAHARA Hiroyuki, NARITA Toru, TSUTSUMI Masaomi, & MURAKI Toshiyuki. Effectiveness of MQL on high-efficient machining of difficult-to-machine materials by rotary cutting: Journal of The Japan Society for Precision Engineering, 77, 3 (2011),316-321 (in Japanese)

[4] OKUDA Toshihito, MURAKI Toshiyuki, NAKAYAMA Tatsuomi, & OTA Minoru: Development of dry turn-milling with multi-blade cutter for alloy steels (Advanced machine tool), Proceedings of LEM 21 (2005) 433-438