Automatic Assembly System of Modular Tools*

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Modular tools have the potential to offer a more economical solution to the problem of designing FMS lines for machine shops. However, the coupling of a cutting tool edge and a cutting holder is achieved manually and takes 5 to 10 min. It is suggested that an automatic assembly device for modular tools would be very useful, especially for machine tools with many cutting tools. We designed a system and named it ATASS® (Automatic Tool Assembly and Supply System). This system consists of a magazine for the cutting edge, an assembly device, a supply device, and a controller. We also designed a new modular tool that is easy to assemble automatically, and in which coupling can be completed within 0.5 sec. The new modular tool has cutting performance equivalent to that of the conventional tools. By applying ATASS to machine tools, we can reduce the total cutting tool expense by 14~70% and cutting tool space by 20~75%. As practical examples, this paper describes 3 types of ATASS for turning center, lathe, and machining center.

Key Words: Cutting, Cutting Tool, Assembly, Modular Tool, Lathe, Machining Center, Turning Center, Tool Exchange Cost

1. Introduction

A small batch-size production system is an optimum alternative to a total production line. However, use of such a system introduces some new problems that must be resolved. For instance, in the case of a machining center process, operators must prepare a variety of cutting tools for many kinds of work and change them often, which means that tool cost becomes very expensive and much idle time is consumed in tool exchange. Hence, cutting tool management is a very important in the design of a small-batch size production system for a machine shop⁽¹⁾.

A modular tool system is available as a means of reducing total tool cost⁽²⁾⁽³⁾. A tool has two parts: a cutting tool edge part and a holding part. An operator picks up the cutting tool edge part and joins it to the holding part, which is used as common to all tools, i.e., he changes only the cutting edge part for other

cutting operations in the system. He can prepare cutting tools at low tool cost in a total tooling system, but tools are assembled manually, which takes 5 to 10 min per one modular tool.

We postulated that an automatic assembly device for modular tools would be very useful, especially for a machining center. We therefore designed a system of this type, which we call ATASS®.

From ATASS, we can expect a reduction in total cutting tool expense and space required for cutting tools.

2. Cutting Tools for ATASS

Cutting tools are essential to machining operations. When the shape of the workpiece is complex, many kinds of cutting tools are required, and when the lot size is small, the cutting tool must be changed often. This means a high tool cost and long tool exchanging time.

Tool cost is considered to be about 10~20% of machine tool cost, a substantial amount. A modular tool system is effective in reducing total tool cost. However, a conventional modular tool is not suited to automatic assembly.

* Received 26th June, 1991

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2.1 Conventional modular tools

Figure 1 is a photo of a conventional modular cutting tool which has a cutting edge part and a holding part. These two parts are joined together. This type of tool has a long history of development, and it is as reliable as a solid or one-piece-type cutting tool. Some modular tools consist of several extension parts between the cutting edge part and the holding part. These conventional modular tools are designed for manual assembly by means of a screw and a wrench, and this means that assembly time is long, even if a nut tightener is used. Block tools developed by Sandvik Corp. Sweden, are acceptable in the nonrotational cutting market⁽⁴⁾.

2.2 Newly developed modular tool for ATASS

It is very important to reduce the time required for automatic assembly of the two parts of a modular tool. Instead of the screw used in the conventional modular tool, we use a cam-link mechanism to assemble the edge part and the holding part of a modular tool. Figure 2 is a newly developed modular tool for

Fig. 1 Conventional modular tool

Fig. 2 Modular tool for ATASS

Fig. 3 Cross section of newly developed tool

ATASS. Figure 3 shows the cross section. One pair of rods in Figure 3 rotates a ring in the holding part, and contacts push a tapered ring to pull up the cutting part. The accuracy of the position is determined by the tapered coupling of the tool. Assembly of modular tools is achieved by simply pushing the rods, and takes less than 0.5 sec.

3. Automatic Assembly of Modular Tools

3.1 Rotational cutting tool

Figure 4 illustrates the principle of assembly of a modular tool in the case of a machining center. Only the cutting edge parts are installed in the magazine of a machine tool. The handling arm in the picture picks up a new cutting edge part from the magazine of a machine tool and the used cutting edge from the assembly pot simultaneously. After the insertion of the cutting edge into the holding part of a modular tool, rods push the cam-link, which works to hold the tool together. In this situation, a modular tool is ready for use at any time. When a cutting tool in a machining center is finished machining, it is picked up by ATC, as it would be in an ordinary machining center. The cutting edge part is disassembled from the holding part at the assembly pot. Then, a handling arm picks up the cutting edge part and puts it on the tool magazine.

3.2 Nonrotational cutting tool

There are many kinds of very effective nonrotational cutting tools especially used in turning operations. Sandvik has already produced and marketed a nonrotational cutting tool. The tool is named "block tool" and is acceptable in handling and tool performance. Figure 5 shows ATASS with block tools which are embedded on a magazine. A cutting head or a cutting edge part mounted in the magazine of a machine tool is picked up and inserted into the holding

Fig. 4 Rotational tool in ATASS

part by a robot. The holder works as a cutting holder itself; hence the system has a multi-cutting tool function as if it had a multiturret tool holder. In this case, assembly takes about 0.3 sec.

4. Example of ATASS

4.1 Turning center

Figure 6 shows the ATASS for a turning center. It has 78 tool pots on the main tool magazine and 16 tool pots on the sub-tool magazine for cutting edge parts, holding parts and tapered tool holders. The traverser has an assembly head which is used for assembling modular tools by means of a nut tightener. At the first stage of assembly, an assembly head picks up a tool holder or the holding part of a modular tool on the main tool magazine. Then the tool magazine rotates to select the exact position where the tool holder can connect with the cutting edge part. Then, an assembly head is lowered to this position and the cutting edge part is joined to the holding part. After the tool ID code is checked by a bar-code reader, an assembly head with a modular tool moves to the ATC of the turning center. The ATC puts a new tool onto the spindle of the turning center and the spindle part traverses to the machining point. The motion that follows acceptance of the tool is the same as that in an

Fig. 5 Nonrotational cutting tools in ATASS

Fig. 6 ATASS for a turning center

ordinary turning center. After machining, the used cutting tool is returned to the ATC. The assembly head takes a used tool and travels to a washer through a cutting tool failure detector and then proceeds to an empty pot in the magazine. Besides the main magazine, there is a subtool magazine where an operator removes the broken cutting tool and replaces it with a new tool. The dimensions of this ATASS are 4 500 mm × 1 900 mm × 3 450 mm. The total time required for tool exchange is 140 sec. The tool cost is 3 million yen for this turning center and it is 14% less than that in a conventional cutting tool system. Set-up time is decreased by 1.5 h/day. Twenty-four-hour nonstop operation of the machine tool is realized with a space reduction of 20% and increased safety.

4.2 Lathe

In the case of the lathe, it is very easy to create an assembly system for modular tools, because the cutting edge part is smaller and more simple than the rotational tools. Moreover, the lathe has a long history of performance improvement. Figure 7 is a typical example of an ATASS for a lathe. Around the disk magazine, there are 12 cutting edges. A hand on the device picks up a cutting edge from the magazine and puts it on a cutting holder which is mounted on the device. In the holder, there is a draw bar which works to connect the cutting edge part to the holding part. The device can easily be placed on the lathe table, which means that the ATASS has the capability of a 12 cutting turret lathe. Thus, it is very useful in the machining of a very hard material which requires many cutting edges because of the short tool life. The advantages of ATASS become even more apparent when it is used with larger machine tools. Figure 8 shows an ATASS for a vertical lathe. Here, an assembly head picks up a cutting tool mounted on the flat three-faced plate. In comparison with the conventional system, the following advantages are obtained.

- (1) Tool cost: 18 million yen → 5 million yen (70% reduction)
- (2) Tool magazine cost: 30 million yen → 15

Fig. 7 ATASS for a lathe

Fig. 8 ATASS for a vertical lathe

million yen (50% reduction)

- (3) magazine space: $8 \text{ m}^2 \rightarrow 2 \text{ m}^2$ (75% reduction)
- (4) available for nonstop operation

4.3 Machining center

In this case, rotational tools are used for the operation. Only cutting edges are mounted on the magazine, as in an ordinary magazine of a machining center in Figure 9. There is an assembly pot, from which the assembly arm fetches the cutting edge and places it on the holding part of a cutting tool. After a modular tool is completed, it is picked up by ATC, and machining proceeds along with the ordinary operation of the machining center. By using this system in a machining center, we were able to reduce both the cutting tool cost and the dimensions of the magazine by 1/3.

5. Conclusions

1. Modular cutting tools, designed for use with ATASS lend themselves to automatic assembly and show that tool performance is comparable to that of conventional cutting tools.
2. ATASS can assemble modular cutting tools within 0.5 sec. It is possible to obtain an assembled cutting tool from an ATC, similar to in the

Fig. 9 ATASS for a machining center

conventional system.

3. ATASS can accept two types of modular tools: rotational tools and nonrotational tools.
4. By installing ATASS in a machine tool, we can reduce cutting tool cost by 14~70% and magazine space by 20~75%.

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