ANNALS of the ORADEA UNIVERSITY.
Fascicle of Management and Technological Engineering, Volume IX (XIX), 2010, NR3

METHODS OF REALIZING THE ATR (AUTOMATIC TOOL READJUSTMENT) FUNCTION IN THE HORIZONTAL SPINDLE FMC

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Keywords: Flexible manufacturing, tool changers, ATR function.

Abstract: The aim of this paper is to present a general overview on the main types of tool changers and the methods of realizing the automatic tool readjustment function in the horizontal spindle flexible manufacturing cells. The automatic tool rearrangement is a key function for the advanced FMS which ensures low downtime for tool rearrangement by eliminating the need for an operator to intervene in the process making high cost efficiency possible. The ATR function in correlation with the APC and the AWPC which provide the functions necessary for pallet changing and work pallet changing the ATR function ensures the too readjustment function.

1. FLEXIBLE MANUFACTURING SYSTEMS.

Manufacturing is the industrial activity that changes the form of raw materials to create products. The derivation of the word manufacture reflects its original meaning: to make by hand. As the power of the hand tool is limited, manufacturing is done largely by machinery today [1]. In order to be able to achieve the standards required by the global market an important characteristic of any manufacturer is flexibility. Flexibility was introduced as the mean to obtain high quality products with minimal cost, but also for reducing the amount of time needed from changing from a product to another. The development of the flexible manufacturing systems is made possible by advances in machine tools and industrial robots.

Flexibility is defined as the capacity of the machine tool to adapt to the variations either in quantity or type, influenced by technological diversity with random variations, in conditions of imposed and constant standards of quality and optimal work load (2).

The goals regarding the quality and quantity of the products realized using a flexible cell manufacturing system and also maintaining a low operation cost which will transfer less operational cost to the product price can be achieved with a high autonomy of the system in reference to the operator. The autonomy to the operator is defined as the capacity of the machine to produce in condition of flexibility with the partial presence or lack of the operator (2). The autonomy of the machine in relation to the operator has a mathematical expression (1.1).

$$a = \frac{\sum t_{ai}}{t_{tot}} \qquad (1.1)$$

Where: t_{ai} = operation time without user intervention.
t_{tot} = total operation time.

In order to achieve a greater autonomy of machine tools and of flexible manufacturing systems a series of specialized functions have been implemented eater in on machine tools or on the entire manufacturing systems. Among this we mention the most important:

- Management function.
- Automatic tool change function (ATC).
- Automatic tool readjustment function (ATR).
- Automatic work pallet change (APC).

- Automatic pallet readjustment function (APR).
- Automatic work process monitoring function.
- Automatic Work piece changing (AWPR).
- Automatic determination of work piece and tool offset.
- Tool malfunction detection. [3]

2. AUTOMATIC TOOL CHANGE FUNCTION (ATC)

As presented above one of the functions, which is specific to high efficiency flexible manufacturing systems is the automatic tool readjustment function (ATR). Before presenting the main methods of realizing the ATR function in the horizontal spindle flexible manufacturing cells we must analyze another function specific to machine tools, the automatic tool changer (ATC).

ATC function implies the existence of the following parts on the machine tool:

- One or more tool storage systems (required).
- One or more tool changer devices attached.

This system is completed by hydro-pneumatic parts, electronics and software. From a construction point of view the tool changer system can have different shaped: disk, chain, drum, fixed rack, mobile rack [3].

A tool magazine is an indexable storage used on a machining center to store tools not in use. They are available as rotary drum and chain types. When the tool is called into use, the magazine indexes by the shortest route to bring the tool to a position where it is accessible to a mechanical handling device. At the end of use, the tool is returned to its slotted position in the magazine before calling the next tool. Rotary drums with 12–24 stations are available and 24–180 stations are available for the chain type [1].

Automatic tool changers have two main characteristics by which they are differentiated: by tool-to-tool time and the number of tools they can manage.

In figure 1 is presented the CTA 40 HS designed to equip vertical or horizontal tool machining centers, milling machines, transfer machines, lathes and special machines.

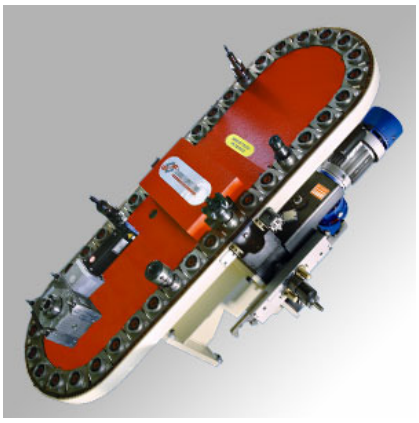

Fig. 1 CTA 40 HS Tool changer.

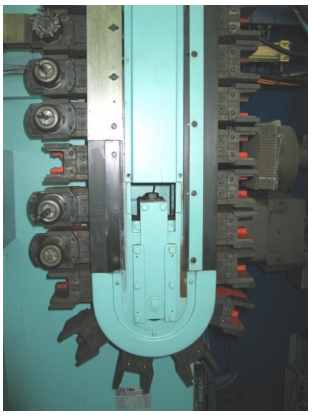

Fig. 2 TMA550 - tool magazine

The CTA 40 fits cones of the following types: ISO 30, ISO 40, BT 40, HSK 50, HSK 50, and HSK 63 for tools with a maximum weight of 10 kg [4].

In figure 2 is presented the tool magazine of the TMA 50 horizontal spindle machine tool. The TMA 550's tool magazine is served by a mechanized arm sown in figure nr. 3.

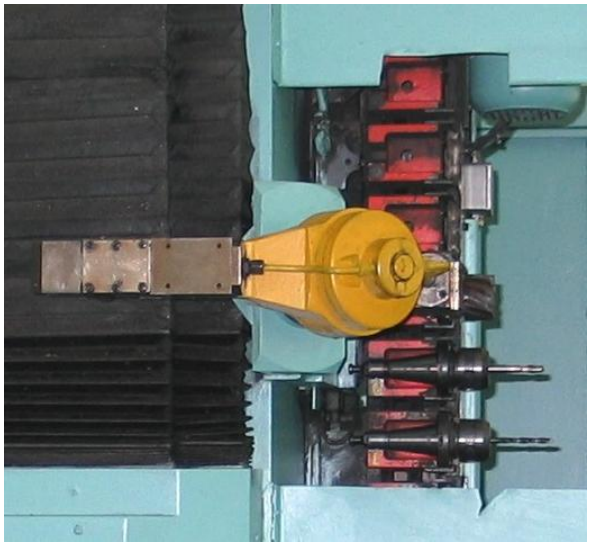

Fig. 3 – Mechanized arm of the TMA 550 machine tool.

3. THE AUTOMATIC TOOL READJUSTMENT (ATR) FUNCTION.

As factory automation has progressed, NC machine technology has also progressed to allow construction of Flexible Automation (FA) or Flexible Manufacturing Systems (FMS) by connecting machines with production equipment such as robots, Autonomous Guided Vehicles (AGV), automated warehouses and computers [1]. In this complex system the need for reducing and even eliminating the down time of the system for different tasks such as tool readjustment and pallet readjustment had appeared. This need haze arisen for several reasons, most importantly being the hazard of having the operator in the flexible manufacturing cell, work area at every product change and another reason being the need of a minimal downtime of the system.

The automatic tool readjustment function is specific to the FMC (Flexible Manufacturing Cell) and FMS (Flexible Manufacturing System) and consists of automatic setup of a new set of tools in “hidden” time necessary for the next work piece. The solutions vary depending on the type of ATC mounted on the main machine tool in the cell or system []2).

The main methods for realizing the ATR function are:

- Readjustment with high flexibility having a double tool magazine (active and passive) and an ATR manipulator.
- Readjustment with medium/large flexibility using a tool rack.
- Readjustment with limited flexibility using a monorail manipulator and the double subordination of the tool magazine management.
- Readjustment with medium flexibility using ATR robot behind the machine tools and an ATC tool magazine with double subordination.
- Readjustment with reduced flexibility using a tool rack type pallet that can be accessed by the ATC.

3.1. Readjustment with high flexibility having a double tool magazine (active and passive) and an ATR manipulator.

The method is based on the existence of two tool magazines both accessible to the manipulator, one of which is "active available to the CNC for the piece that is being worked and the 2nd is "passive" available to the ATR function PLC's (connected to the DNC) with a 2nd manipulator to update (ATR). It makes the automatic tool changing in the "passive" tool magazine by using the ATR manipulator, with tools from the reserve supply of tools on board a tool rack, brought the machine tool on by the ATR function control system.

3.2. Readjustment with medium/large flexibility using a tool rack.
The method is used for tool racks serviced by an ATC coordinated programmable manipulator and where the rack is fixed. The manipulator workspace is divided by removable sectors, which consist of tool racks, which can be replaced with others containing new set of tools for the next work piece. The method of replacing a portion of the tool magazine (average limited flexibility), not suitable to replace the complete set of tools related to the ability of the tool magazine (5.

3.3. Readjustment with limited flexibility using a monorail manipulator and the double subordination of the tool magazine management.
This type of tool readjustment method is based on a manipulator which moves on a monorail track above the flexible manufacturing cell, in order to rearrange "tool by tool" the tool magazine of the ATC system, in order to prepare the next set of tools for the next wok piece. This solution is used by Yasda and Csepel firms (2).
The monorail manipulator is moving over the tool magazine, which have there maximum point over the rail, and have the same tool direction as the tools form the PIDS, in this way the mechanic arm of the manipulator can grip all the tools from the system just as the ATC system [6].
A software problem that is specific to this variant of the ATR is "double subordination" of tool magazines: CNC for the ATC function and d DNC for the ATR function.

3.4. Readjustment with medium flexibility using ATR robot behind the machine tools and an ATC tool magazine with double subordination.
This type of readjustment with the robot behind the machine tool involves the machine tool's ATC double subordination: to the machine CNC for the priority ATC function and to the robot's CNC for the tool readjustment function. This is essentially similar in terms of the previous case (readjustment with limited flexibility using a monorail manipulator and the double subordination of the tool magazine management), with differences in the software driving of the robot. The differences is that the robot is headed by his own CNC subordinated to the machine DNC just as the machine's CNC, robot motion is done by CNC subprograms assembled after a graphic cycle representation having the sequenced composed of CNC subprograms inter-conditioned with initial conditions and final confirmations which enter in the assembler. The machine tool has a chain type tool magazine and an ATC manipulator which is subordinated to the machine CNC and during work time the ATR magazine is subordinated to the robot's CNC and after finalization of the readjustment operation the list with the changes is transmitted from the DNC to the machine CNC.

3.5. Readjustment with reduced flexibility using a tool rack type pallet that can be accessed by the ATC.
In this type of readjustment system stock pallet type tool rack, which is a technological pallet (ISO) accepted by the palletizing device (PCA) of the machine tool, but it contains a set of tools instead of the work piece. Tools are attached using pliers as type tool rack magazines, which catch the V-shaped flanged tool. Tools are located on 4 levels and are positioned in polar coordinates.
The work for updating the tool is:

Step 1- Discharge cycle of a machine tool from the tool magazine (this is done by the machine spindle, with the stop of the work piece processing);

- The old tool is selected and placed in the machine spindle using the machine's ATC
- A CNC subprogram is launched to place the tool from the machine tool spindle in the ATC's magazine.

Step 2- cycle for acquisition of a new tool.

- A CNC subprogram is launched to pick up a tool from the stock pallet according to its management system.
- The ATC function will place the new tool for the machine spindle in the ATC system tool magazine.
- The tool management list is updated with the new tool brought in the tool magazine.

This method is adequate for readjustment of a reduced number of tools and only when needed in order to not affect the flexible manufacturing cell's autonomy in regard of the operator.

4. CONCLUSION.

Since manufacturing has become an industrial phenomenon, the problem of adequately sizing plants has always been discussed. Capacity in general can be defined as the set of any kind of resources that can be used to create value for the customer and, in general, the cost of capacity is lower than the value the customer pays to acquire the product or the service provided [7].

The dimensions of manufacturing capacity are:

- Type.
- Amount
- Cost.

Cost is defined as the total economic value that is necessary to spend for acquiring, running, maintaining and dismissing a manufacturing system [7].

In the cost dimension of manufacturing a major role have the flexible manufacturing systems. This system can be cost effective only if they are used properly these meaning that the use of this systems must be done according the specifications provided by the supplier of the manufacturing cell. This means that all processes done on manufacturing cells ideally must be realized at maximum speeds with minimum use of resources and minimum tool ware. This problems are addressed by a highly computerized design systems meant to optimize the use of raw material when a new manufacturing program is developed for the CNC and by advanced system for process and tool monitoring, systems meant to monitories the work process in order to archive the high speeds of the process but continuously monitor the parameters of the tools in order to avoid unnecessary ware.

The second aspect related to the cost effectives of the flexible manufacturing systems is their ability to manufacture a large number of pieces with minimum percentage of defective products. The key word here is "large number". In order to achieve these large number of pieces produced per unit of time of coursed a major roll it haze the sped at which the machine operates. The speed although it haze seen considerable advances in the last decade is limited by mechanical parts. In this condition another way to increase the production capacity and trough it the cost efficiency of a flexible manufacturing cell is to have the additional operations required in the manufacturing cell, done automatically. Such functions are the automatic pallet changing and the automatic tool readjustment (ATR) function.

Analyzing the types of implementations of the ATR function in different systems, types described in this paper, we can see a correlation between cost, flexibility and efficiency.
Analyzing the method with a double tool magazine (active and passive) and an ATR manipulator we see a high degree of flexibility since the ATR function can be realized while a work piece is being processed. From an initial cost point of view this solution is expensive since is uses two tool magazines (one for ATC and one for the ATR) and a manipulator.
The last method presented is using a tool rack type pallet that can be accessed by the ATC. This method haze a reduced flexibility and a major disadvantage consisting in the fact that the ATR function can be realized only when the machine tool is not in used. From an initial cost point of view this is an optimal solution since it uses standard equipments and has a relatively low implementation cost. The long term cost or cost of use is rather high and may have negative influence on the production cost of the cell specially if the cell must change often the product it'd realizing. From a technical point of view this solution is easiest to implement but lack the efficiency the other methods presented in the paper.

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