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SOFTWARE ALGORITHM FOR THE AUTOMATIC TOOL READJUSTMENT FUNCTION AT THE TMA 550 AL FLEXIBLE MANUFACTURING CELL

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***Abstract*—**The paper will present a software algorithm for generating tool lists necessary for the implementation of the automatic tool readjustment function (ATR) within the TMA 550 AL flexible manufacturing cell. The implementation of the algorithm will also be presented in the paper.

***Keywords*—**algorithms, flexible manufacturing, tool management.

I. INTRODUCTION

THE TMA 550 AL manufacturing cell was developed at the University of Oradea, Faculty of Managerial and Technological Engineering. The development of the flexible manufacturing cell was realized trough retrofitting activities of the existing components.

There were several areas which needed a significant upgrade in order to realize a functional flexible manufacturing cell. The mechanical structure of all the components needed either an upgrade or realization of new components or structure. The electrical systems of the involved components needed an upgrade tom ensure the interoperability between the components and also to be able to fully automated. The most significant system that needed an upgrade was the software subsystem. The main activities for the upgrade of the flexible manufacturing cell where the software upgrade for existing components and the realization and implementation of specific functions needed to achieve the flexible cell structure for the flexible TMA 550 AL manufacturing cell.

The main components of the flexible manufacturing cell are:

1) *The TMA 55 AL machining centre,*
2) *The 2 ABB IRB 1600 industrial robots,*
3) *One modular conveyor,*
4) *One storage system.*

The TMA 55 AL machining centre is a five axis machining centre realize by retrofitting of a three axis machining centre equipped with an older model of SIEMENS CNC. The entire CNC including the drive motors was changed with five axis CNC equipment realized by FANUC, model 310i.

The 310i model is part of the 31i-Type A CNC equipment and can control up to 20 axes and 6 spindles [1]. In Fig. 1 the main panel of the CNC equipment is presented.

Fig. 1. Control panel of the FANUC CNC system.

In order to realize a fully functional five axis machining centre two new axes where realized and integrated on the existing machine. In Fig. 2 is presented the TMA 55 AL manufacturing center.

Fig. 2. The TMA 55 AL machining center.

The storage unit is realized using standardized of aluminum profiles. The storage capacity is 8 units. Each unit may hold a tool, work piece or finished product [2]. The structure of the storage unit is presented in Fig. 3.

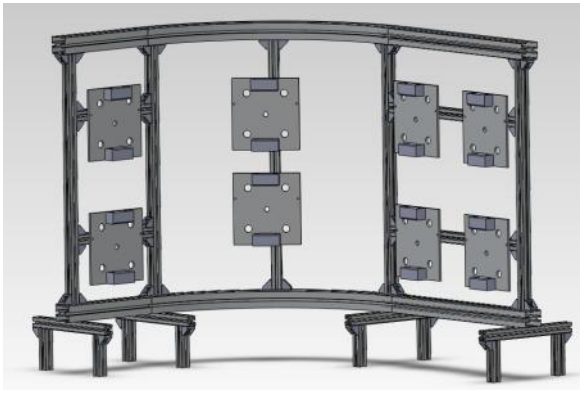


Fig. 3. Structure of the storage unit [2].

The two robots used in the flexible manufacturing cell are produced by ABB, model IRB 1600/1.2. The load that the robots can handle is 6kg [3].

The conveyor is realized by Flex Link. The control of the conveyor is realized through the PLC of the robots controller having the possibility of starting/stopping the conveyor according the inputs/outputs from sensors or from other triggers in the programs of the ABB robots.

The main feature of the conveyor is the two track structure selectable trough a pneumatic barrier (Fig. 4)[2].

Fig. 4. Structure of the pneumatic barrier for track selection, a- transfer from track 1 to track 2, b-transfer from track 2 to track 1 [2].

In Fig. 5 the layout of the TMA 550 flexible manufacturing cell is presented where:

1. *Machining centre,*
2. *ABB IRB 1600*
3. *Flex Link conveyor,*
4. *Storage unit.*

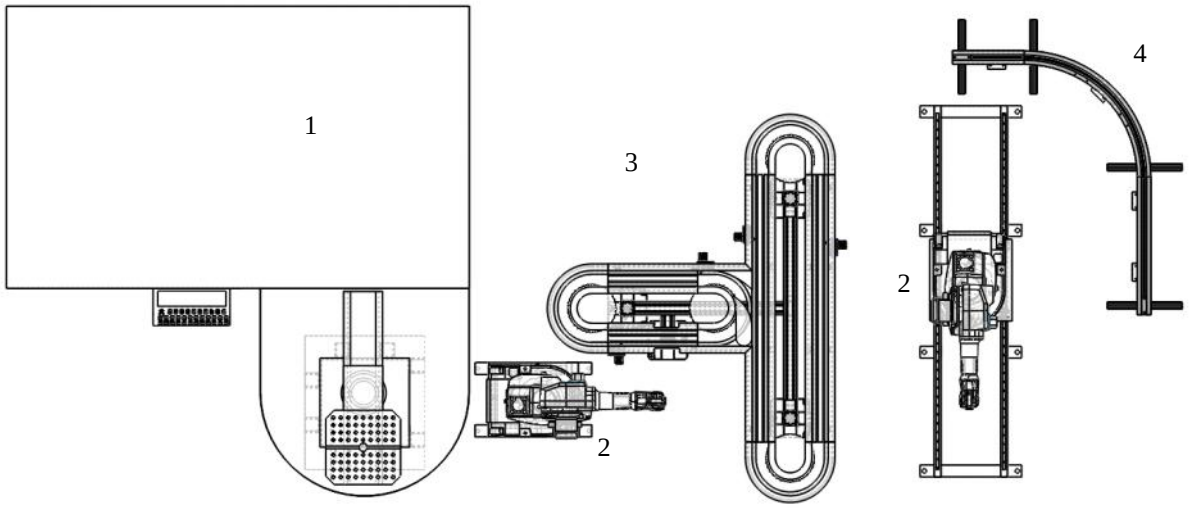


Fig. 5 The layout of the TMA 550 flexible manufacturing cell [2].

II. AUTOMATIC TOOL READJUSTMENT FUNCTION

The automatic tool readjustment function is a function specific to manufacturing systems from the flexible manufacturing cells upwards [4].

The ATR function realizes the preparation of a new set of tools in the machine ATC magazine. The new set of tools is prepared for the new piece to be realized. Some other factors can be included in the ATR function such as the replacement of tools that presents significant ware. Generally the ATR function aims to reduce the auxiliary times in flexible manufacturing cell.

There are several methods of realizing the ATR function. For the TMA 550AL flexible manufacturing cell the ATR function is realized using the tombstone device placed on the machining center. The tombstone device can be used for tools and materials being able to store 8 items [5].

The tools are stored in the storage unit and using the robots, the conveyor and the tombstone device the tools can reach the work space of the machine spindle and using the spindle the tools are transferred to the machine's ATC magazine.

III. ALGORITHM FOR THE AUTOMATIC TOOL READJUSTMENT FUNCTION

In order to realize the ATR function a several lists have to be generated according to criteria's that will define the tools present in the generated list. The main list that have to be generated for the ATR function are the list of tools necessary to be transferred to the manufacturing centre (MC) and the list of tools to be transferred to the storage (S).The first list is called input list and the second output list.

In Fig. 6 is presented the main diagram for the algorithm.

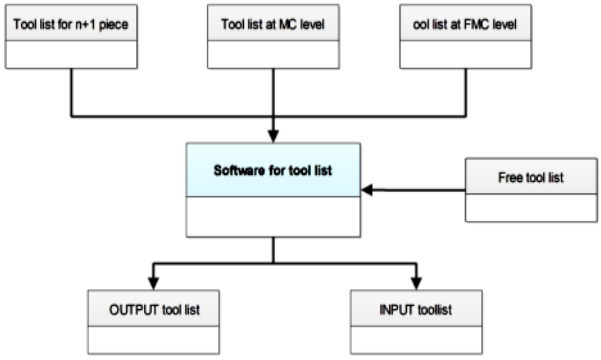


Fig. 6. General diagram for generating the tool lists for the ATR function [2].

In the diagram presented in Fig. 6 it can be seen that the algorithm uses an input data the tool list necessary for the next piece to be manufactured, the list of tools present at the MC level (tools present in the ATC magazine), the tools present in the FMC (tools fount in the storage unit) and as secondary input a free tool list. The free tools list is generated taking in account the tool list for the n+1 and n+2 pieces to be manufacturing and is an optimization of the basic algorithm. The goal of the free tool list is to avoid removing a tool form the MC that is not used for n+1 but will be used for n+2 [2].

In Fig. 7 is presented the algorithm for generating the list of tools to be transferred to the manufacturing center.

The algorithm uses as input the tool list for n+1 piece, a list with k elements and the list of tools at the MC level and those present at the FMC level. Element by element from i to k from the list of tools forn+1 piece are compared to the list of tools in the machine. If a tool needed for the n+1 piece are found, the next element is checked, if is not found in the list of tools present at MC level is verified in the list present at FMC level. If the tool is found at FMC level is written in the list of tools to be transferred and if the tool in not fount an error is generated [2].

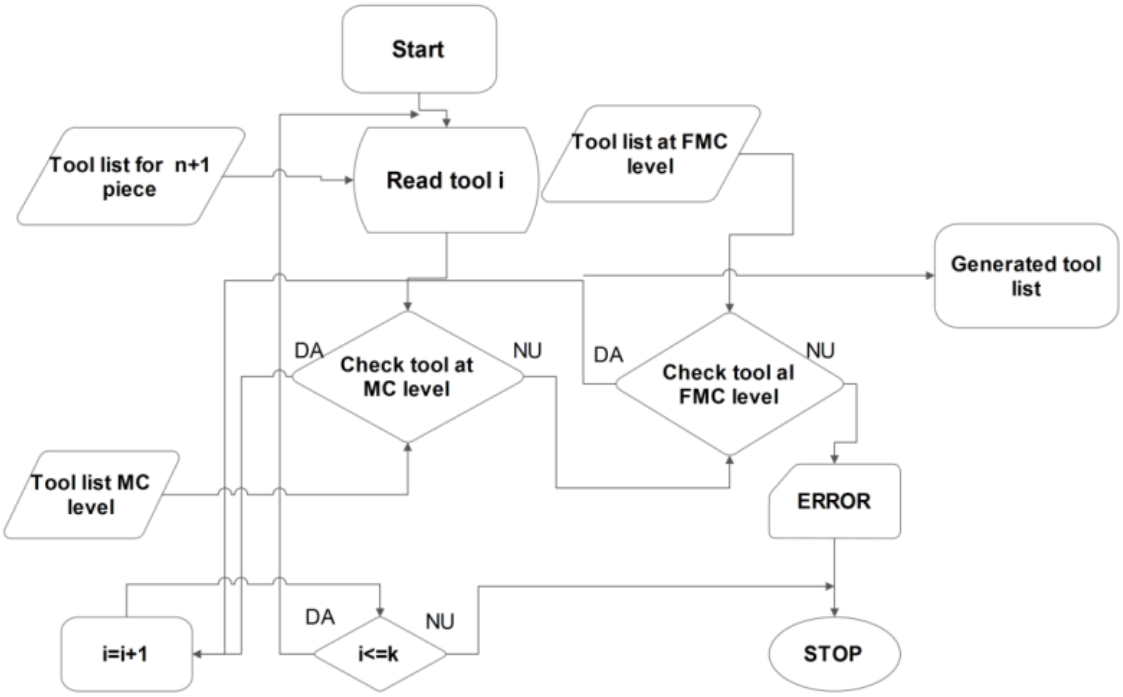


Fig. 7 Algorithm for generating the list of tools to be transferred to the manufacturing center [2].

IV. IMPLEMENTATION OF THE ALGORITHM FOR GENERATING TOOL LISTS

The algorithm has been implemented using data bases. The lists of tools for n +1, n +2 pieces, the list of existing tools in the machining center and the list of tools in the flexible cell are realized using MySQL database server [2].

System for generating lists of tools includes the following tables:

1) *Storage - contains the list of tools at the central warehouse of the flexible cell;*
2) *Tool - contains a general list of tools;*
3) *Tool_machine - contains the list of tools to level the processing center;*
4) *Part-list the parts that are scheduled to be manufactured;*
5) *Tool_part-containing lists of tools for each part of the planned manufacturing;*

In TABLE I are presented the structure of the tables.

TABLE I
STRUCTURE OF THE STORAGE TABLE [2]

Column	Type	Null	Default
storage_id	smallint(5)	No	
storage_part_id	tinyint(2)	No	
storage_tool_id	tinyint(2)	No	
storage_type	tinyint(2)	No	
storage_text	varchar(255)	No	

TABLE II
STRUCTURE OF THE TOOL TABLE [2]

Column	Type	Null	Default
tool_id	tinyint(2)	No	
tool_type	tinyint(2)	No	
tool_cutter_radius_1	double(10,4)	No	
tool_tool_length_3	double(10,4)	No	
tool_imaginary_tool_nose_7	double(10,4)	No	
tool_corner_r_11	double(10,4)	No	
tool_rfid	varchar(18)	No	

TABLE III
STRUCTURE OF THE TOOL_MACHINE TABLE [2]

Column	Type	Null	Default
tool_machine_id	tinyint(2)	No	
tool_machine_tool_id	tinyint(2)	No	

TABLE IV
STRUCTURE OF THE PART TABLE [2]

Column	Type	Null	Default
part_id	tinyint(2)	No	
part_name	varchar(255)	No	
part_rfid	varchar(18)	No	

TABLE V
STRUCTURE OF THE TOOL_PART TABLE [2]

Column	Type	Null	Default
tool_part_id	tinyint(2)	No	
tool_part_part_id	tinyint(2)	No	
tool_part_tool_id	tinyint(2)	No	

In order to run the software is required the use of a virtual server containing the tables. To run the program for generating lists of tools needed for the ATR function WampServer is used. This is a Windows web development environment that allows the creation of web applications using Apache2, PHP and MySQL database. PhpMyAdmin MySQl administration tool allows easy management of databases [6].

In Fig. 9 the main window of phpMyAdmin is presented. In Fig. 8 the tables loaded in the application are presented.

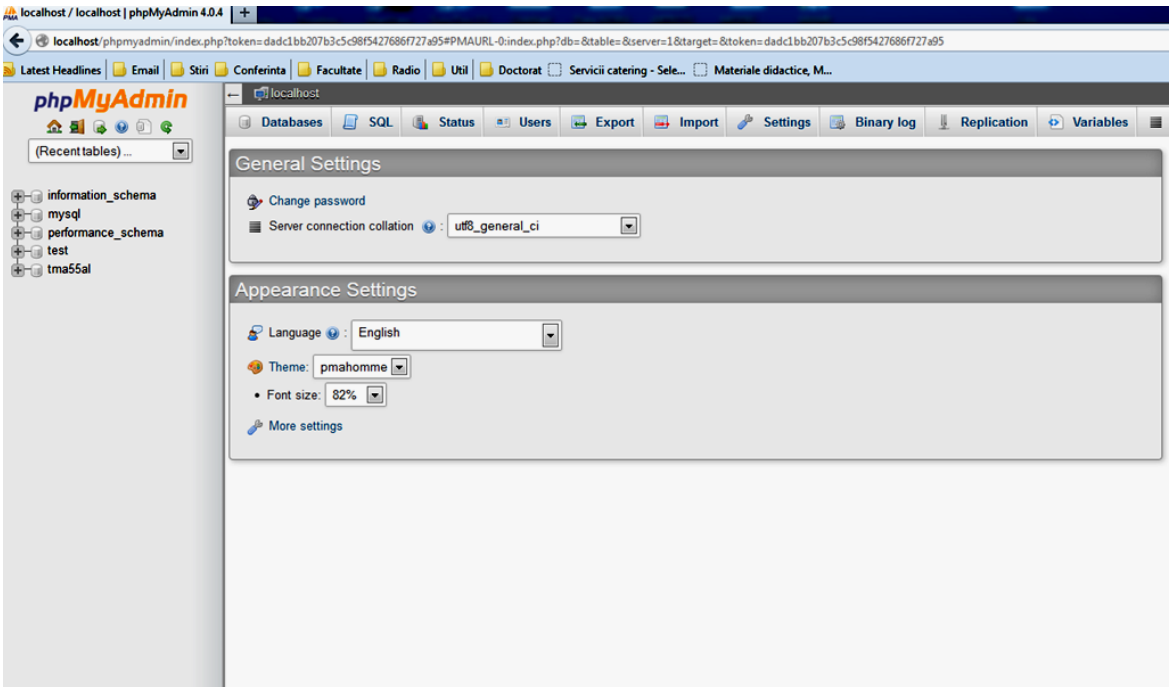


Fig. 8 phpMyAdmin administration panel.

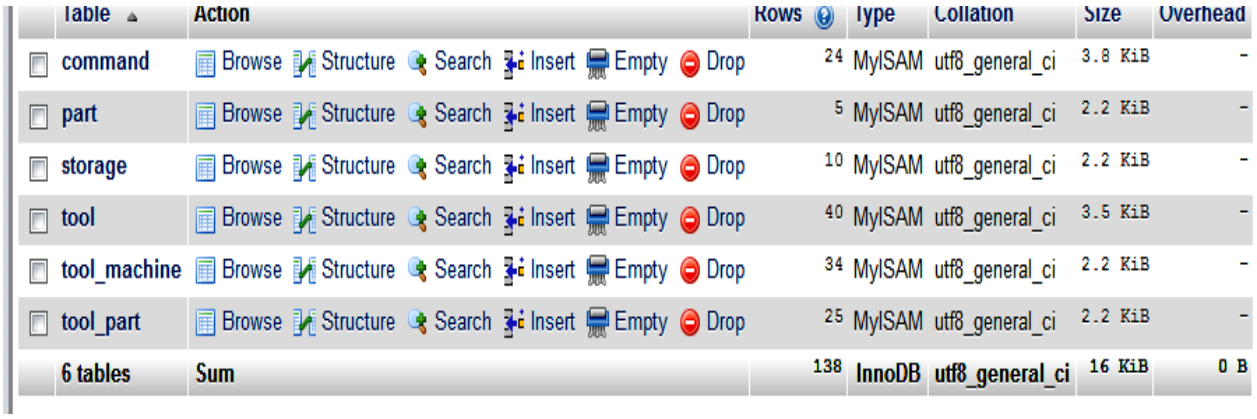


Table	Action	Rows	Type	Collation	Size	Overhead
command	Browse Structure Search Insert Empty Drop	24	MyISAM	utf8_general_ci	3.8 KiB	-
part	Browse Structure Search Insert Empty Drop	5	MyISAM	utf8_general_ci	2.2 KiB	-
storage	Browse Structure Search Insert Empty Drop	10	MyISAM	utf8_general_ci	2.2 KiB	-
tool	Browse Structure Search Insert Empty Drop	40	MyISAM	utf8_general_ci	3.5 KiB	-
tool_machine	Browse Structure Search Insert Empty Drop	34	MyISAM	utf8_general_ci	2.2 KiB	-
tool_part	Browse Structure Search Insert Empty Drop	25	MyISAM	utf8_general_ci	2.2 KiB	-
6 tables	Sum	138	InnoDB	utf8_general_ci	16 KiB	0 B

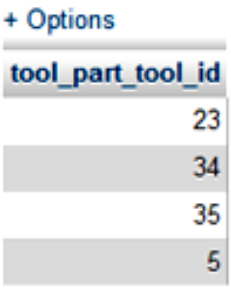
Fig. 9. Loaded tables for the tool generating application [2].

After having loaded all the data bases the program it can be used to generate the required tool lists. Generating the tool lists is done by using cod script.

In order to generate list of tools for ATR function the following code is used:

```
SELECT tool_part.tool_part_tool_id
FROM tool_part
LEFT JOIN tool_machine ON
tool_part.tool_part_tool_id =
tool_machine.tool_machine_tool_id
WHERE
tool_machine.tool_machine_tool_id IS
NULL
AND (
tool_part.tool_part_part_id =2
OR tool_part.tool_part_part_id =3
)
LIMIT 0 , 30
```

The system will use the data base and will generate a list of tools needed for the n +1 piece to be manufactured that are included in flexible cell but not in warehouse processing center (Fig. 10)



+ Options

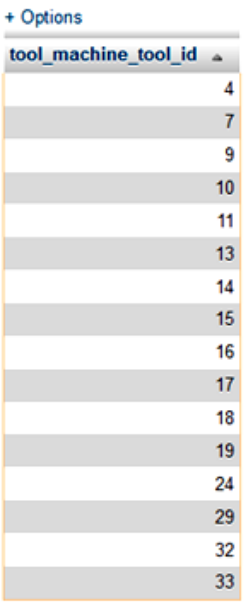
tool_part_tool_id
23
34
35
5

Fig. 10 .List of tools for the n+1 part, that need to be transferred using ATR function in the ATC magazine [2].

To generate the list of tools that can be removed from warehouse processing center without affecting the realization of the n +1 and n +2 piece (obtaining the list of free tools), the following code is used:

```
SELECT DISTINCT (
tool_machine_tool_id
) AS tool_machine_tool_id
FROM tool_machine
WHERE tool_machine_tool_id NOT
IN (
SELECT DISTINCT (
tool_part_tool_id
) AS tools_needed
FROM tool_part
WHERE tool_part_part_id =2
OR tool_part_part_id =3
)
AND tool_machine_tool_id <>0
ORDER BY tool_machine_tool_id ASC
LIMIT 0 , 30
```

The result is presented in Fig.11.



+ Options

tool_machine_tool_id
4
7
9
10
11
13
14
15
16
17
18
19
24
29
32
33

Fig. 11 List of tools for that can be removed from the ATC magazine [2].

As seen in the presented examples the software will generate lists based in tool identifiers. In order to be able to operate with this identifications the system must have an unique identification for each tool, even for identical

tools the identification must be different. This is necessary for the possibility of tool ware management function at the flexible cell level.

At system level an RFID tag system is implemented for monitoring with unique identifications of all materials (including tools) [7].

V. Conclusion

The presented algorithm and its implementation where realized for the as part of the activities related to realizing the TMA 550 AL flexible manufacturing cell.

As the ATR function is a characteristic of the flexible manufacturing cell it was necessary to implement this function. Due to limitations regarding the architecture of the individual components the applied solution for the ATR was the use of the machining center table to transfer the tools in the work area of the spindle, and transfer the tools in the magazine of the ATC.

Implementation of ATR function significantly reduces operating costs of flexible systems (by reducing waiting times in the machine tools and reducing the need for duplicate tools. Such flexible system can have duplicates central tool in the tool storage in a smaller amount than would be required if each tool would have a double, which is transferred to the machine tool wear monitoring indicates the possibility of exceeding the level of admitted wear[8].

In the case of the TMA 550 Al flexible manufacturing cell, tools are located either in the magazine of the machining center (ATC magazine) or in the storage system of the flexible cell. Having tools stored in two locations creates the need of a centralized management system of tools. The algorithm for generating the list of tools for the ATR takes in account the possibility of a tool to be located in one of the two storage places. In the informational system of the manufacturing cell there are individual tables for tools located in the ATC magazine or in the storage system. The algorithm uses both tables in order to obtain the list of tools to be transferred to the machining center or those to be transferred to the storage system.

As an improvement to a basic system, the described algorithm takes in account not only the list of needed tools for the next piece (n+1) but also those needed for the n+2 piece in order to optimize the management of tools. An implementation of the algorithm to also use the list for n+3 is possible but is limited by the storage capacity of the ATC magazine.

Improvements to the algorithm could be realized by introducing a new table of tools that present a significant degree of ware. In this case tools hath night be needed for the piece n+1 or n+2 could be introduced in the list of tool to be removed and at the same time in the list of tools to be introduced to the system, basically realizing a replacement of tool. The presented implementation of the algorithm is able to realize this function because each tool is identified by a unique id and not by type, length etc.

In order to achieve the possibility to change the tools based on the ware, a system capable to monitor the ware either during the manufacturing or when the tool is placed from the main spindle to the ATC magazine is needed. The system must be able to identify each tool, determine the ware of each tool and generate a list of tools with significant ware, table that can be used as an input for the algorithm.

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