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ARC WELDING ROBOTIC FLEXIBLE CELL SIMULATION USING ROBOGUIDE SOFTWARE

Dragos-Lucian Baboi [1]

Julian Andreoiu [1]

Gabriela Bucur [1]

[1] Petroleum-Gas University of Ploiesti, Romania
e-mail:gbucur@upg-ploiesti.ro

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ABSTRACT

The objective of the work is the design and simulation of a flexible manufacturing structure with two robots, integrated in a welding application, using the Roboguide software. FANUC ROBOGUIDE is a robot simulator that simulates both the movement of the robots and the commands from the designed application, significantly reducing the time needed to create new motion configurations.The possibility to import the CAD models of the components, of the fixing devices and of the final effectors of the robots integrated into the designed application, allows the creation and evaluation of various structures. Automatic program generation simplifies manual programming operations. ROBOGUIDE allows pre-programming of robots before they are installed in a cell, as well as visualization and confirmation of robot trajectories before downloading the programs to the real robot.

***Keywords*:** flexible cell, welding robot, offline programming, Roboguide

INTRODUCTION

The last two centuries were marked by a series of scientific discoveries that left their mark on human society and laid the foundations for further technological development. The emergence of robots, welding processes and their improvement have decisively contributed to the current technological level and represent a fundamental component for future progress.[2-14]

The welded joint represents the non-removable metal connection between two or more metal elements, made by a welding process and showing mechanical strength and operational safety. [1]

For high productivity, welding robots must be distinguished by short acceleration and braking times, high travel speed and high repeatability [3-7]. Among the specific applications of welding are the automotive industry, the aeronautical industry, the manufacture of electronic and medical equipment, the manufacturing industry, civil construction, capital repairs and maintenance, and last but not least, the oil and gas equipment industry.

Automatic welding with industrial robots is a technological process in which the necessary operations (advance of the electrode wire, movement of the welding head, bringing/evacuating the components to be welded) are performed by bringing/evacuating installations and industrial welding and handling robots. Among the advantages of automatic welding with robots are the increase of the melting capacity by achieving higher current densities, the improvement of the welding quality by the elimination of discontinuities, the increase of work productivity by the reduction of auxiliary times, the ease of the work of the human operator, the reduction of production times, the efficiency of the technological flow [7].

DESIGN OF FLEXIBLE MANUFACTURING STRUCTURE WITH TWO INTEGRATED ROBOTS

Roboguide 9.0 software is used for the design and simulation of the flexible manufacturing cell with two robots integrated in a welding application. For reducing the impact on production, all configuration on flexible cell can be designed, verified and modified completely offline. So, all the component models can be imported in CAD data format. The purpose of the application in this paper is the serial welding, on one side, of a metal box [15].

The stages of designing a flexible welding structure with robots, with the Roboguide software, are presented in Figure 1.

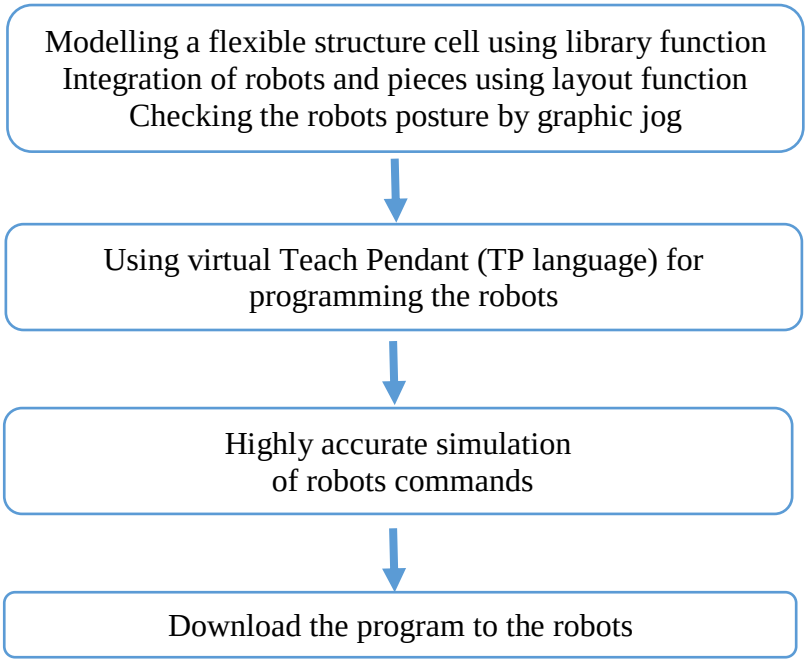

Figure 1. *Design and simulation stages* [1]

The components of the flexible manufacturing cell are as follows: the ARC mate 100iD/8L robot (6 axes); two rotary tables for positioning the parts; the R30iB Plus controller; welding source Kemppi A7; Pistol (Torch Gun) Binzel Abirob 500W; slave robot Manipulator M710iC/50H [15].

The ARC Mate 100iD/8L robot is intended for electric arc welding, being ideal for integration into compact robotic cells. It occupies a small footprint (343 x 343 mm). The robot benefits from a fully integrated cable management system. Cables for the sensor or camera and the pneumatic pipes are drawn through the special pipes in the body of the robot. Figure 2 shows the image of the robot made with the Roboguide software.

The ARC Mate 100iD/8L welding robot features easy steering during welding, featuring cables with weld monitoring sensors. All the additional utilities (weld bead monitoring sensor cables, viewing cables and air ducts) are guided through the arm and its ball joint, allowing it to fully articulate the arm to fit into tight spaces.

The robot has the largest ball joint in its class – 57 mm. Its structure allows the design of more compact welding cells with less interference with peripheral equipment [15].

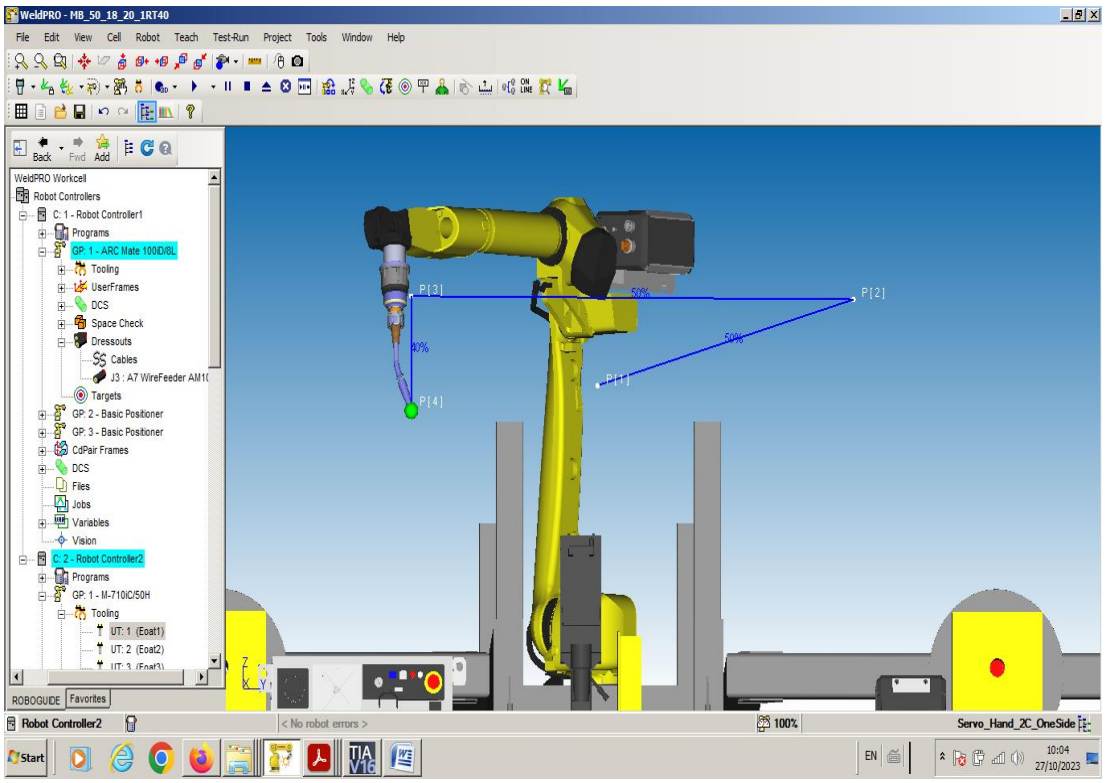

Figure 2. *Robot ARC Mate 100iD/8L*

The R30iB Plus controller (Figure 3) offer a very high performance in terms of cycle time, speed, accuracy and safety and full connectivity via an Ethernet network, allowing easy connection with other robots, remote computers or other hardware.

Intuitive and simple to use, the iPendant (interface touch) facilitates the use of the R20iB Plus controller for all personnel involved in the production cycle. With a flexible layout, the user interface – iHMi – benefits from increased screen resolution and powerful processing power. The interface displays setup and programming guides as well as tutorials on the main home page, allowing for easier use of the bots. Figure 4 shows the model of the controller imported from the Roboguide software.

Figure 3. *R30iB Plus Controller* [15]

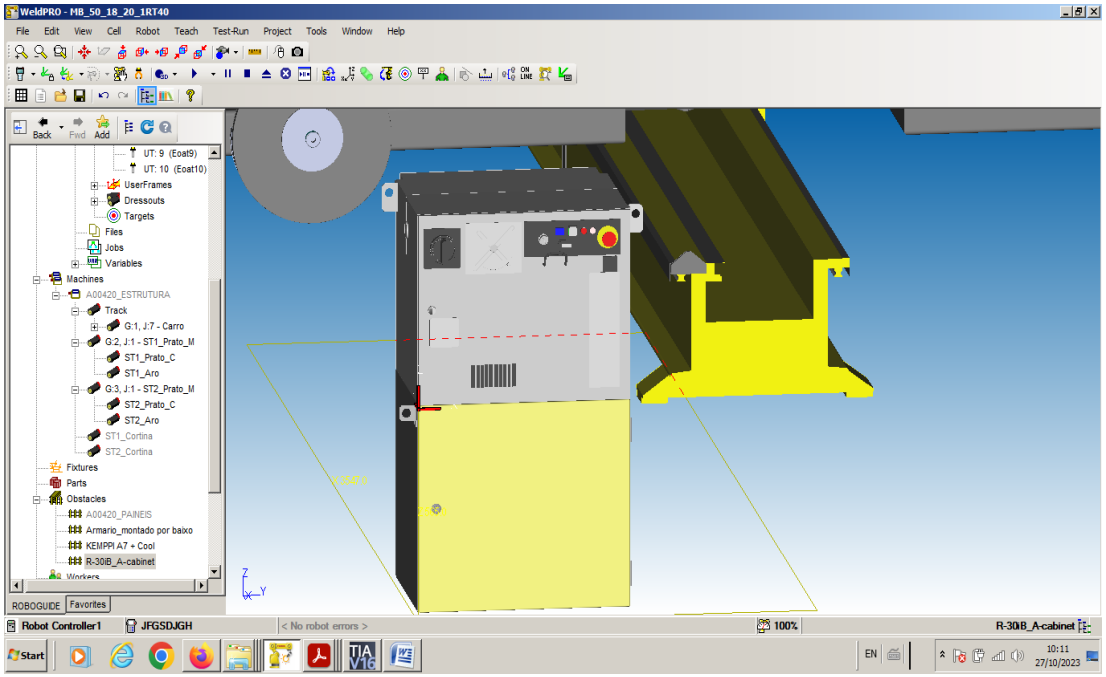

Figure 4. *R30iB Plus controller*

The integrated PMC (Integrated Programmable Machine Control) unit has access to the entire I/O system of the robot, offering the possibility of separate or asynchronous control of peripheral devices without negatively impacting the performance of the robot. The Unlike controllers that use Windows, the R30iB Plus controller uses Fanuc's own software, providing increased protection against viruses and cyber attacks. This type of controller benefits from intelligent functions such as visual detection, interference and force visualization.

Welding source KEMPPI A7 (Figure 5) it is compatible with a wide range of welding robots. No additional programs are required. Allows quick and easy configuration of parameters, leading to time savings. The equipment can be used for a wide variety of welding tasks and applications, integrating effectively within flexible automated manufacturing cells.

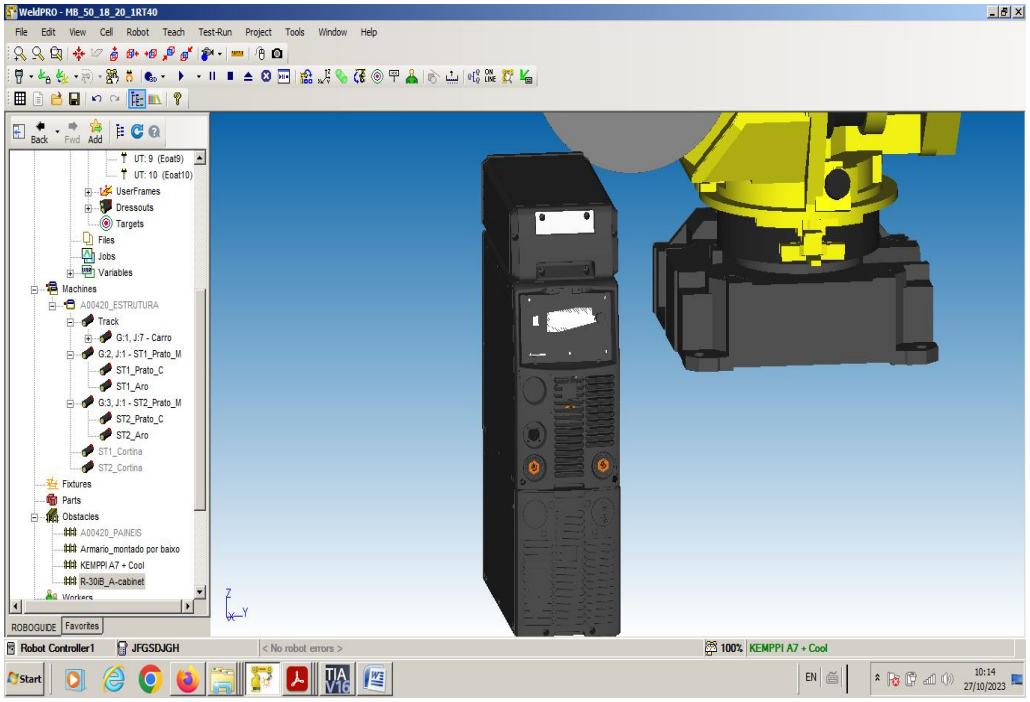

Figure 5. *Kemppi A7 welding source – screenshot taken from Roboguide software*

Binzel Abirob 500W gun allows welding currents up to 600 A, is equipped with a coolant hose package and a high-tech interface. (Figure 6).

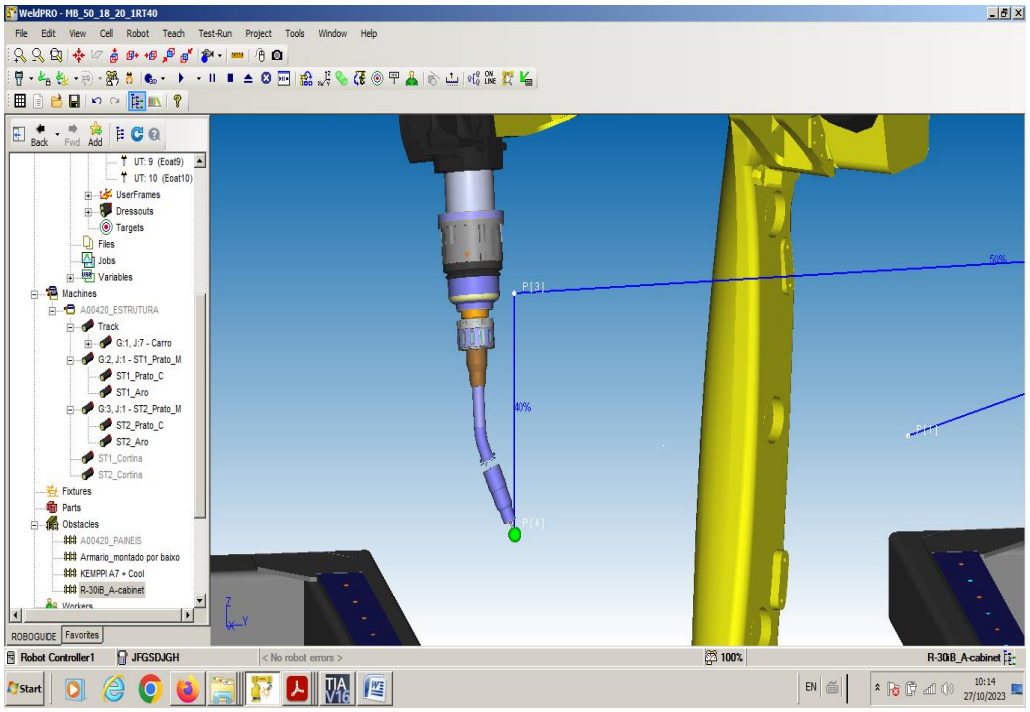

Figure 6. *Gun Binzel Abirob 500 W [11]and screenshot taken from Roboguide software*

Robot Manipulator M710iC/50H it has a low weight and has a compact joint with a rigid arm and a small installation area. High axis speeds allow for fast movement and the 5-axis design gives it robustness and precision. The robot complies with the IP67 protection standard for the joint being sealed against the ingress of water and dust. Number of axles: 5; Reach: 2003 mm; Load capacity: 50 kg.; Footprint: 535 x 550 mm; Controller: R-30iB Plus (Figure 7).

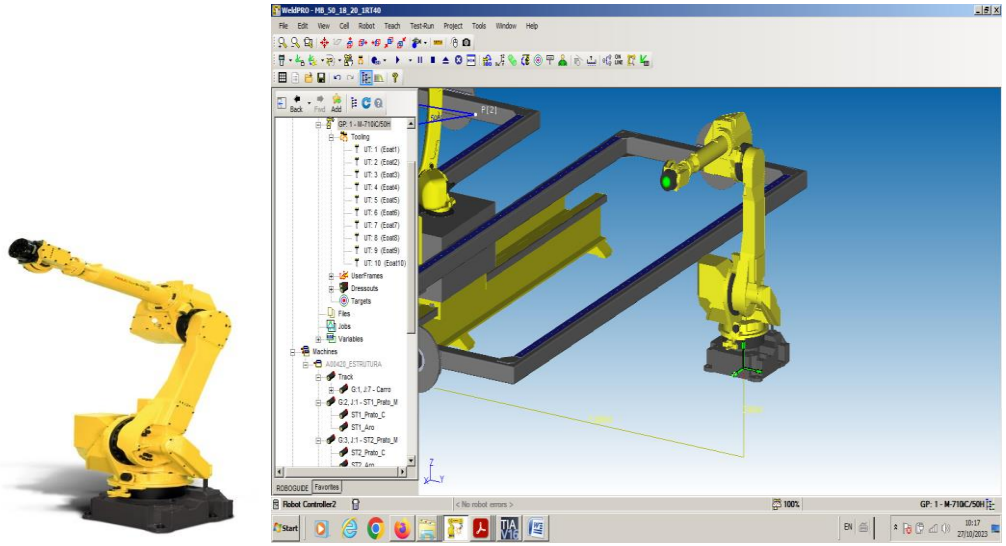

Figure 7. *Robot M 710iC/50H* [15]

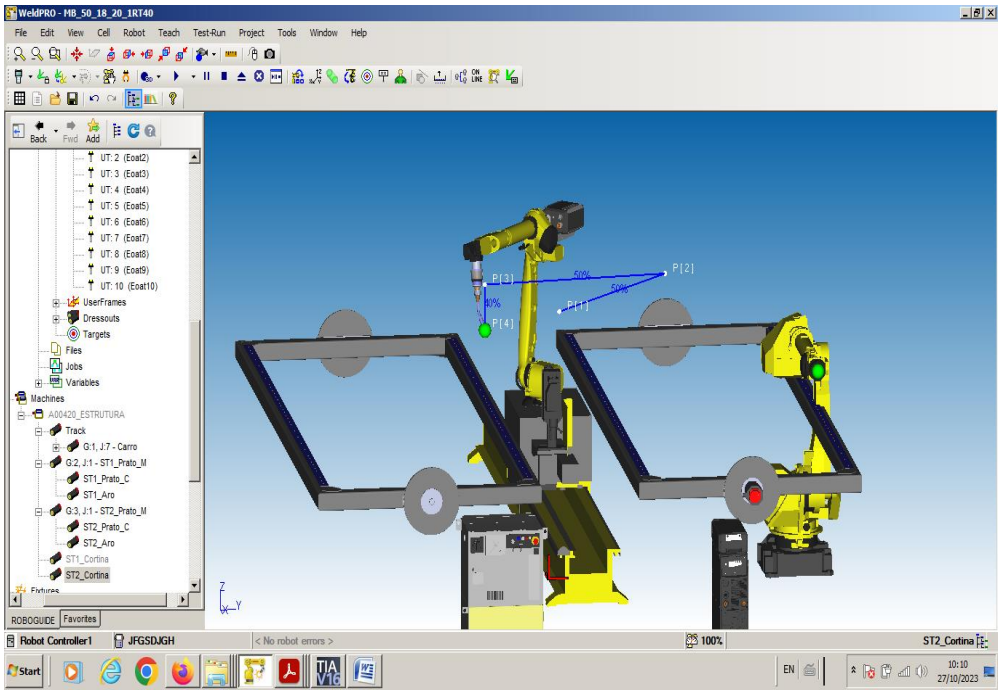

Figure 8. *Rotary tables – 1 axis – capture taken from Roboguide software*

The overall structure of the designed cell is shown in figure 9.

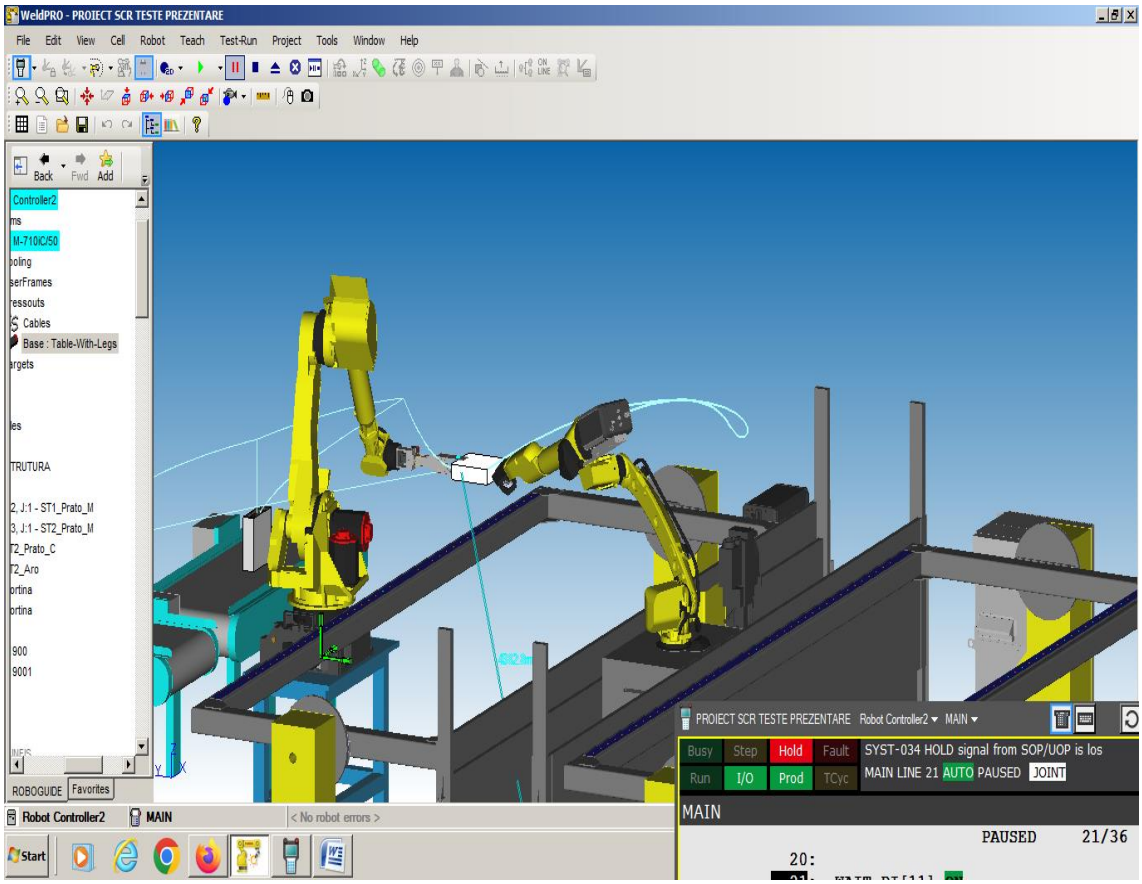

Figure 9. *Location plan*

SOFTWARE IMPLEMENTATION

The Roboguide version 9.0 software, through the application dedicated to the WeldPRO welding processes, allows pre-programming the robots before they are installed in a cell, as well as viewing and confirming the trajectories of the robots, before downloading the programs to the real robot. Both robot movements and application commands can be simulated.

The extensive library in the simulation software enables users to select and modify components and dimensions according to their needs. Access to the multiple fixtures, conveyor tables and grippers at the end of the robot arm offers the possibility of fast and optimal design of the desired applications. Additional 3-D shapes are provided in the form of modeling tools for the purpose of creating custom fixtures and fixtures. The software offers the possibility to build and save your own CAD library.

The robot movement planning algorithm within the designed structure is presented in figure 10.

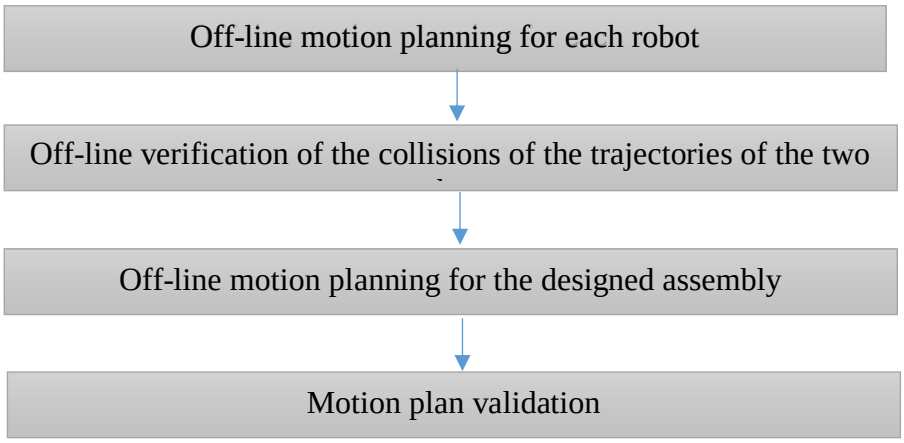

Figure 10. *The motion planning algorithm*

The sequence of operations in the designed flexible welding cell is the following:

1. The manipulator robot has the gripper open and, after the Start command, moves above the conveyor and fixes the part in the gripper. This robot also has the role of supporting the part in the welding position.

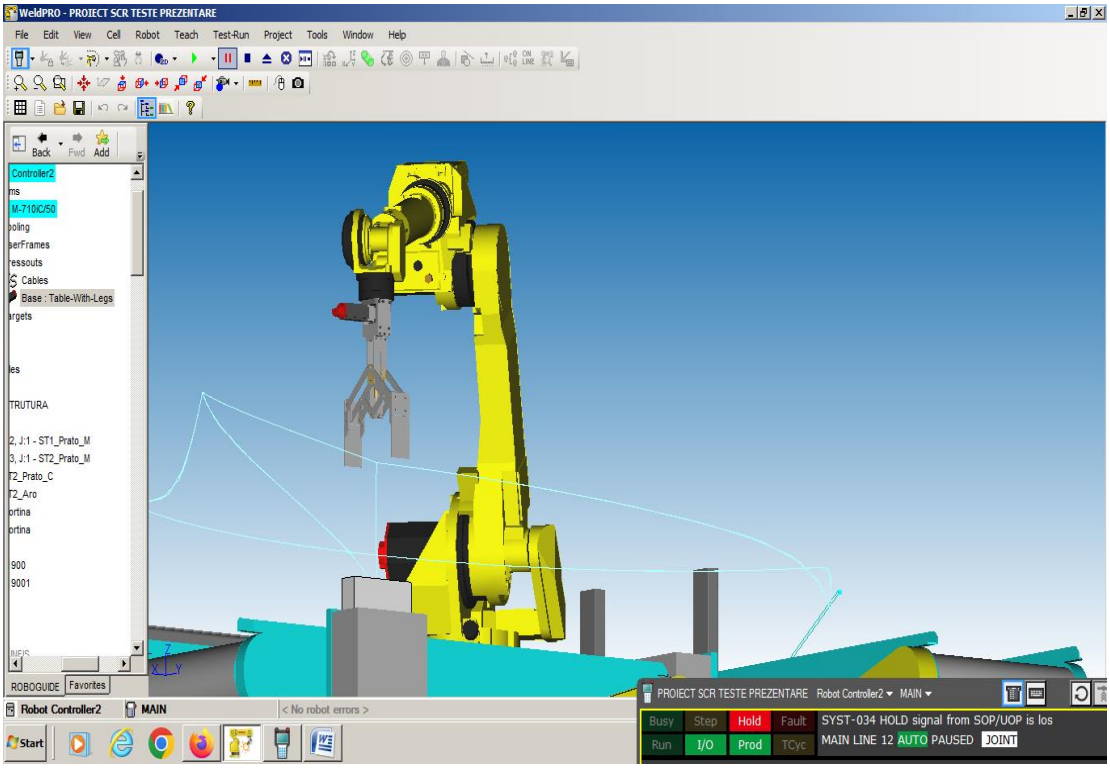

Figure 11. *Grab the piece*

2. After fixing the part in the gripper, the manipulator moves to the Weld Position area and confirms to the robot that performs the welding that it is Ready to WELD. The welding robot executes the welding program.

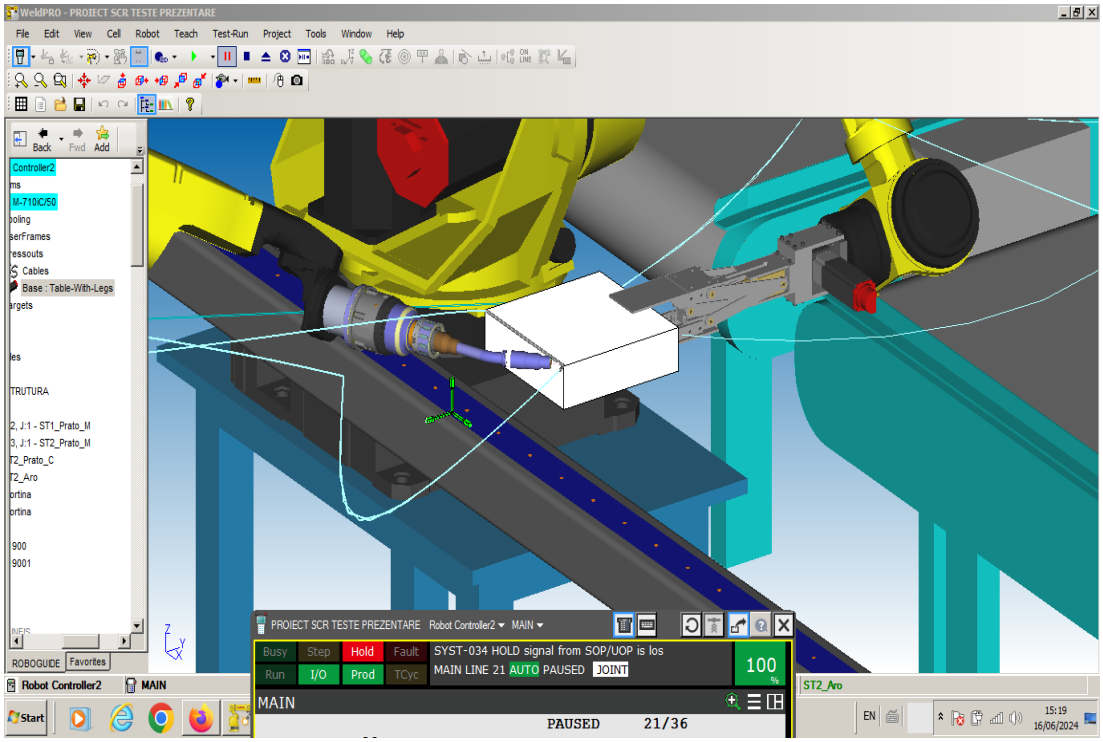

Figure 12. *Welding the piece*

3. After completing the welding program, the robot returns to the Home position and the manipulator robot, also passing through the Home position, goes to the part release area.

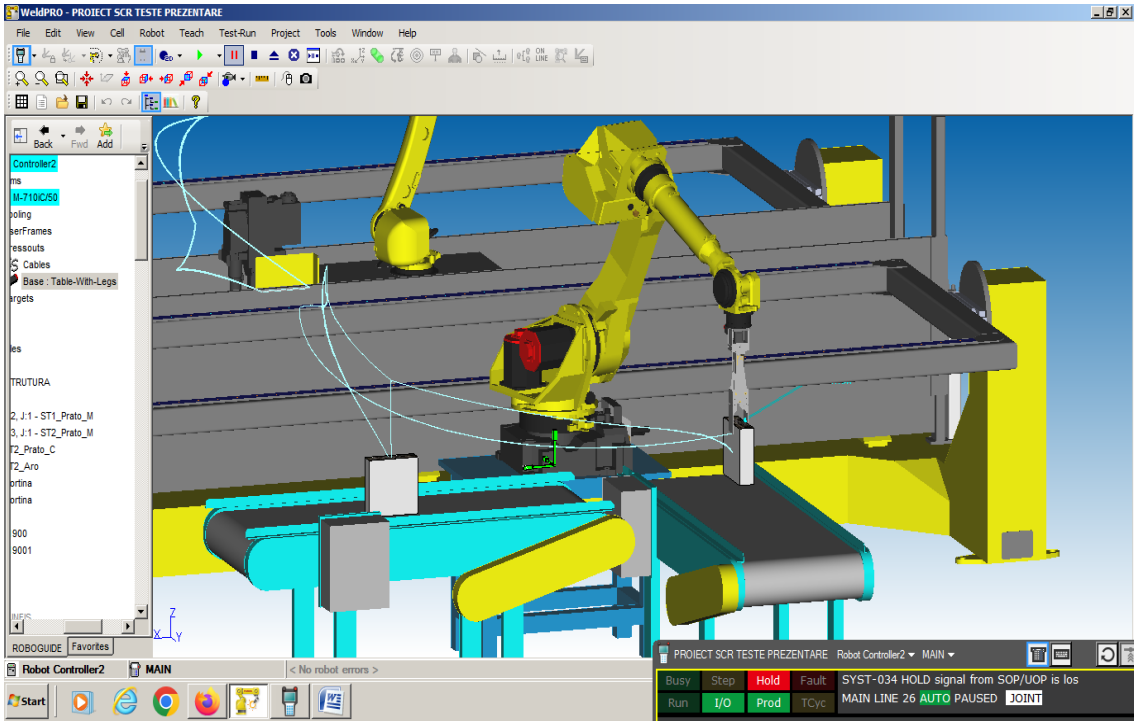

Figure 13. *Release the track*

The robots are individually programmed and communicate interactively through directly activated signals, depending on the position at the time or the imposed condition. Figure 14 shows some intercommunication instructions.

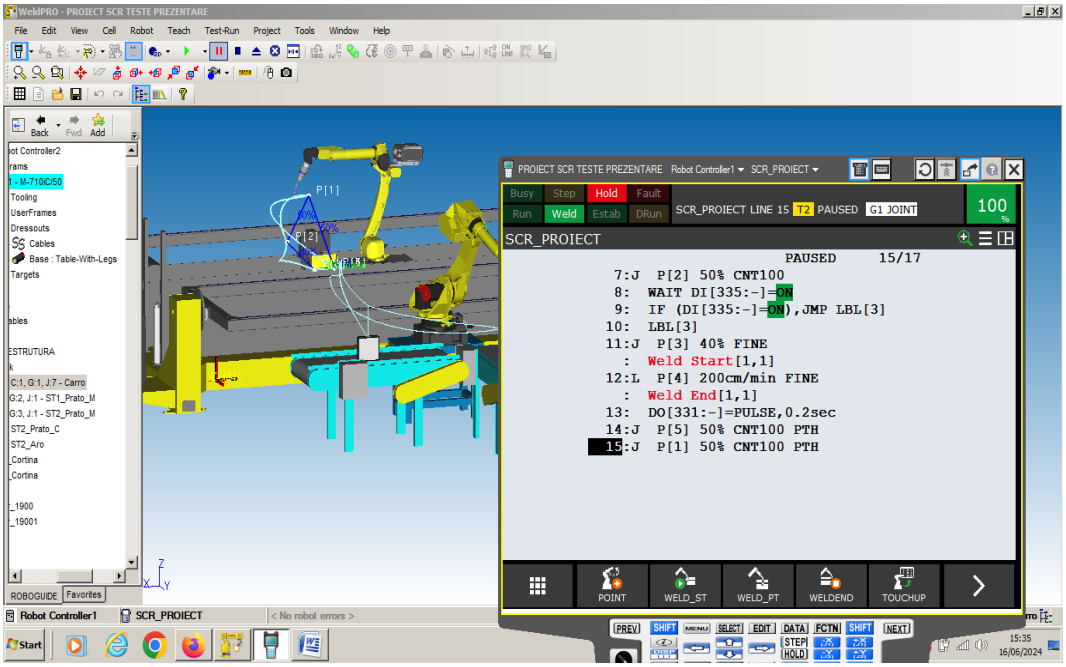

Figure 14. *Intercom sequence*

With the support of an internal virtual controller, operating cycle times can be calculated and validated quickly and accurately. Thus, the actual time in which the designed industrial operation is carried out, i.e. welding one side of the metal box, is 15.66 sec / piece (Figure 15).

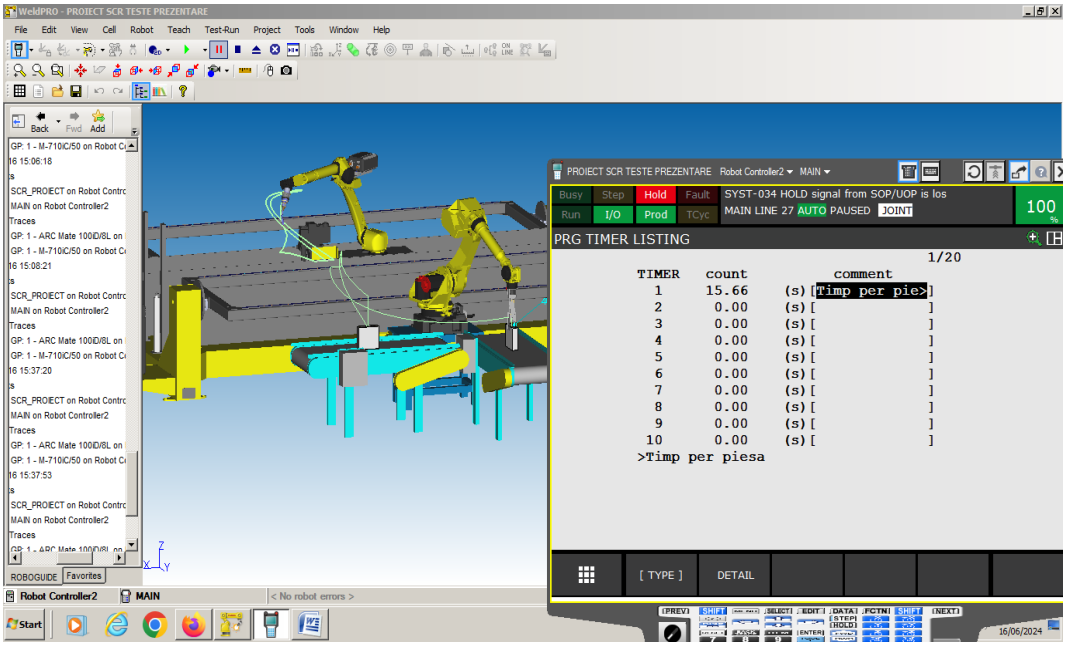

Figure 15. *The calculated duration of the projected operation*

Just like all other robot manufacturers, FANUC has its own text programming language. The TP language is the code that can be seen on the teach pendant and must be used on every robot application. The TP language is a textual language that has many similarities to common structured text. During initial tests before final runtime, the TP code can be stepped through one line at a time. There is no WHILE loop so jumps to labels are the only option to jump over different sections of code that you don't want to execute, or to return to a previous line. In this way, the jumps and labels form the program flow that is normally performed by a WHILE loop [17].

Most robot applications require the program flow to be interrupted because of an event that has occurred in the physical world. In the FANUC world, these interruptions are called "Skip". When a skip is called during a movement, and the skip condition is satisfied, the program jumps to another section of code. This is similar to a jump to label command, except that the skip command can occur during a move command. Interrupts are an important feature of any robot program because they allow for the program to stop what it's doing and do something else in the event of a physical signal [17].

The FANUC code is a drastic deviation from the structured text style. There are two main types of registers; data (numeric) and position registers. Standard data registers have the structure of R[x], and store normal integers for counting loop repetitions and storing sizing information for various payloads, among other uses. Position registers PR[x] store xyz positional information accessible across every program, useful for robot Home and Safe positions which should not change between programs [17].

For the welding sequence, the WeldPRO software option is used, which allows the automatic creation of the TP program for making the seam according to the shape of the piece. A sequence from The Welding Robot schedule is shown below.

```
1: LBL[5] ;
2:JP[1] 50% CNT100 ; movement in JOINT mode
3: IF (DI[330:-]=ON), JMP LBL[2] ;
4: LBL[2] ;
5: ;
6:
7:JP[2] 50% CNT100 ;
8: WAIT DI[335:-]=ON ;
9: IF (DI[335:-]=ON), JMP LBL[3] ;
10: LBL[3] ;
11:JP[3] 40% FINE
: WeldStart[1,1] ;
12:LP[4] 200cm/min FINE ; moving in LINEAR mode
: WeldEnd[1,1] ;
```

13: DO[331:-]=PULSE,0.2sec ;

14:JP[5] 50% CNT100 PTH ;

15:JP[1] 50% CNT100 PTH ;

16: JMP LBL[5] ;

The robot manipulator program is made using the iRPickPRO software option, which allows easy and quick simulation by just selecting the number of conveyors. A sequence from this program is presented below.

1: //LBL[*5] ;

2: DO[12]=PULSE,0.2sec ;

3:JP[1] 100% FINE ;

4: ;

5: LBL[5] ;

6: //PAUSES ;

7: TIMER[1]=RESET ;

8: TIMER[1]=START ;

9: ;

10: ;

11: ;

12:J PR[2:P1] 100% FINE ;

13:JP[2] 100% CNT100 Tool_Offset,PR[6:TOOL OFFSET] ;

14:LP[3] 100mm/sec FINE ;

15: CALL CLAMP1 ; calling subroutines

16:JP[4] 100% CNT100 Tool_Offset,PR[6:TOOL OFFSET] ;

17:J PR[1:HOME] 100% FINE ;

18:J PR[4:weldpos] 100% FINE ;

19: DO[10]=PULSE,0.2sec ;

20: ;

21: WAIT DI[11]=ON ;

22: IF DI[11]=ON, JMP LBL[2] ;

23: LBL[2] ;

24:

```
25:
26:JP[7] 50% CNT10 ;
27:JP[6] 50% FINE ;
28: CALL DROP ;
29:
30:JP[8] 100% CNT100 ;
31:JP[9] 100% CNT100 ;
32:
33: TIMER[1]=STOP ;
34: //J PR[1:HOME] 100% CNT100 ;
35: JMP LBL[5] ;
```

CONCLUSIONS

Automation of manufacturing technologies with industrial robots is one of the ways to increase production quality and productivity. Industrial robots as flexible automatically working machines are able to adapt themselves to the changes in the product production very fast by the flexible reprogramming way. Utilization of computer aid, namely of simulation offline programs for robots programming does not cause a downtime in production by programming and shorts starting of new product production.

The article presents the possibilities of the Roboguide software, WeldPRO and iRPickPRO, utilization for the solution of partial tasks of automation of manufacturing technologies with robots on the real examples. With an intuitive and very easy-to-use concept, the software templates can be modified so that the configuration operations of auxiliary axes, positioners and multi-group machines are considerably simplified. They can then be tested using verification tools, including motion, execution, cycle times and collision detection. Automatic program generation replaces manual programming operations contributing to time savings and efficient management of desired applications.

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