ROBOTS IN TECHNOLOGICAL PROCESS OF PAINTING

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Abstract: *In paper the new constructions of robots, modern technologies of painting and newest methods of paint robots programming were presented. Fanuc P-250iA robot using to painting was characterized. The general characteristic of robot with controller R-30iA was demonstrated. The technology and the paint equipment applied to paint frames and load-carrying boxes was showed. The possibilities of simulation software Roboguide were presented exactly, which is a tool for robot environment simulation on a computer PC. Roboguide system application can reduce the programming time of robots and necessary programs optimization conducting before implementation to production.*

Key words: *robot, painting process, roboguide system, programming, optimization*

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1. Introduction

Contemporary painting robots used in manufacturing processes allow for taking the operators away from the hazardous environments, limitation in working time, saving paint and energy consumption, reduction in the number of failures, enhanced quality of products and ensuring their repeatability. When employing the robots for the processes of deposition of coatings, the robots are required to move the painting gun similarly to the way it was done by experienced employees, i.e. to mimic human movements. Motion of the painting gun during painting is very complex. It does not simply draw complicated lines in the space, but it also changes its angular position in relation to the painted part. The robot's software allows for controlling the process of painting and communication with other equipment. It also controls changing colors, rotating the table or a transport line. If a robot is used for controlling other equipment, it should be provided with a suitable number of inputs/outputs. The current industrial painting robots are used for painting car bodies in the automotive industry, painting furniture, coating with a porcelain layers, smoothing of external surface of the rockets or propellers in wind power plants (Honczarenko, 2004; Zdanowicz, 2001).

2. Characteristics of Fanuc P-250*i*A Robot

Fig. 1. Painting robot Fanuc P-250*i*A (***, 2009)

The robot P-250*i*A is one of the products offered from a wide range of industrial robots manufactured by Fanuc (Fig. 1). The robot is a typical painting robot dedicated to painting and deposition of the coatings. These robots demonstrate high flexibility and accuracy of painting of a variety of components, such as plastics, metals, wood etc. P-250*i*A has been developed to ensure the effective integration with such functionalities as optional operation of two engines of gear pumps, whereas the external arm was designed for easy integration with the equipment used of painting. The robot features an option of ‘reflection’ of the axis 2 and 3, which extends the working space and ensures high flexibility during painting. The design of the arm ensures almost perfect opportunities for reaching a variety of places. Small amount of place ensures that the robot can be situated in small painting chambers. P-250*i*A can paint at the speed of 545 degrees/s. This speed is ensured in each place of the working space. The functional load of the robot amounts to 15 kg at the radius of 50 mm and axial displacement of 300 mm. The static repeatability with this load amounts to ± 0,2 mm.

The robot’s structure is made of aluminum. Lower weight allows for reduction in the power of servomotors, which finally translates into reduction of the costs of power consumption. The aluminum structure ensures minimal risk of spark generation in the case of collision. Smooth external surface, which minimizes the contamination, allows keeping the robot clean. The hollow-body structure ensures maximal flexibility of laying the user’s cables and reduces the risk of their damage. The cables and pipes which supply the paint or air are placed at the external side of the arm J3 or J2. The cables are kept at a certain distance from the robot’s wrist, which ensures the cleanliness of the painted components.

The robot can be mounted on the floor, wall or ceiling, without any limitations. The invert-mounted robots ensure easier access to the painted components.

The robot is equipped in a special *PaintTool* software which provides a number of opportunities. *PaintTool* is dedicated software used for painting and deposition of the coatings. The package of user’s software integrated with the robot and Fanuc control systems enables users to meet the demands of industrial painting.

3. Control System Fanuc R-30*i*A

Fig. 2. Control system Fanuc R-30*i*A (***, 2009)

The control system R-30*i*A in the robot Fanuc uses the advanced technology and open architecture which opens up opportunities for improvement in kinematic parameters of the robot and optimization of the performed applications (Fig. 2).

The controller features a variety of advanced communication options, such as:

- easy transfer and installation of programs,
- in-build Ethernet,
- Fanuc I/O Link (Master) interface,
- e-mail functionality,
- industrial networks,
- profibus.

The control system is supported by Fanuc operating system, which brings some advantages:

- resistance to viruses,
- high level of data security in the case of power failure,
- short time of start-up of a basic software,
- it is easy-to-use.

The controller offers different opportunities for programming:

- TPE (editor available from programming panel), being a standard method of programming,
- advanced options of off-line programming (Roboguide),
- integrated PMC controller
- Karel language.

The control system is equipped with a special module for robot cleaning. The module uses the method of a monitored blowing the fumes and gases which threaten its proper operation out of the robot's inside. The PCU (Purge Control Unit) additionally controls the pressure inside the robot. If, for any reason, the module detects the drop in the pressure inside the robot, the controller's power supply is switched off.

4. Technological Process of Painting

Protecting load-carrying boxes and the truck frames with paint occurs using a standard technology. The painted surface, before the deposition of the anti-corrosion layer, is previously subjected to the process of blast cleaning. Blast cleaning is a process which allows for cleaning the surface out of any type of contamination i.e. rust, casting remains and other contamination undesirable during the process of painting. Using the specialized equipment, the material in the form of the shot is supplied with a high pressure through special nozzles directly on the steel surface.

The technological line used for painting the frames and load-carrying boxes is equipped in two painting chambers. In the process of painting, 4 robots Fanuc P-250*i*A are used, i.e. two robots in each chamber. The prepared products, after blast-cleaning, are transported to the chamber used for the deposition of the anti-corrosion layer. Then, the product reaches a drying chamber where, at the temperature of 80^0C, the sub layer is dried. The dry component is then moved to the second chamber, where the protective/decorative layer is deposited. The component, covered with the second layer, is also moved to the drying chamber.

In order to protect the frames and the boxes from corrosion, the two-component paints are used i.e. the paints which are composed of the basic material and the hardener. The anticorrosion layer is made of the paints based on epoxy-resin, whereas the second layer is protected with polyurethane varnishes.

5. Methods of Deposition of Paints and Varnishes

The deposition of the anticorrosion layer and the protective/decorative layer is carried out by means of hydrodynamic spaying. The hydrodynamic spraying consists in supplying the paint through a very small nozzle at a very high pressure. The type of the jet depends entirely on the nozzle parameters such as the diameter and the angle which determines the width of the jet. This solution is characterized by high efficiency. This method allows for spraying paints on the materials which are poorly solved, with high viscosity or very thick, which ensures very low splashing of the paint. The disadvantages of this process include poor quality of the spaying, particularly with thin-layer, light materials, such as e.g. stains and varnishes. Therefore, in order to obtain a suitable quality of the varnish layer, the guns installed in the robots are operated in the Airmix system (with air support). An assumption for the hydrodynamic spraying with air support is to combine the advantages of air and hydrodynamic spraying. In order to ensure these characteristics, a mean pressure is used, supported indirectly by the air (at low pressure), which stabilizes the paint jet. This causes the pressure directly in the nozzle, where the paint is supplied, which allows for controlling the paint jet. The dedicated gun is equipped in an additional air nozzle (Air cap), which enables the supply of two types of air to the paint jet: atomizing air and forming air. The atomizing air is shot in the jet in order to fragment the paint, whereas the forming air is used for control of the angle of the paint jet. A general principle of the hydrodynamic spraying is presented in Fig. 3. In the case of the gun mounted on the robot, all the air and pressure parameters of the paint are adjusted by an operator in the programming panel.

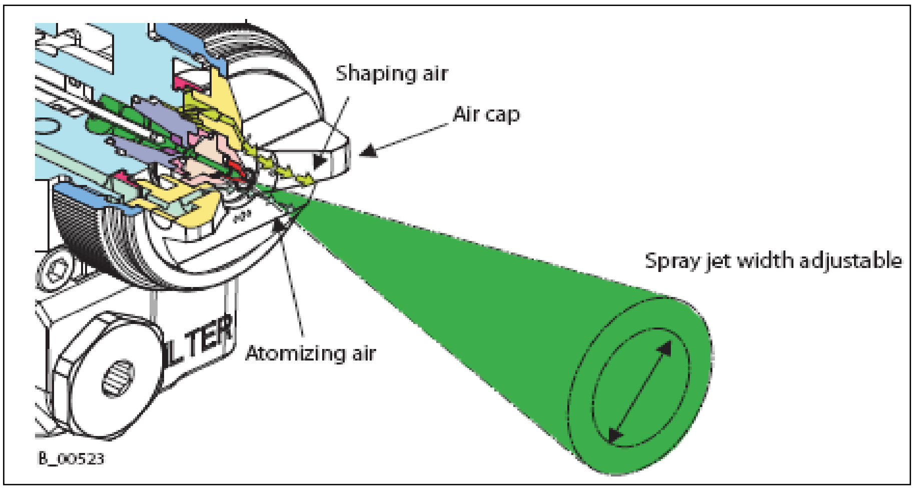

Fig. 3. The principle of hydrodynamic spraying (***, 2010)

6. Roboguide V 6.40

Roboguide is a tool for simulation of work environment of the robot on the PC (Fig. 4). It is used both in the offices by the system designers and in the production process. It is capable of checking interference between the robot and other objects and control different operations by means of simulations and monitor current status of the robot. The software generates suitable programs automatically in order to calibrate simulation with actual robot. Roboguide features a system for detection of collisions, which is very useful in using the robots for complicated operations.

Roboguide permits advanced programming through an intuitive and easy-to-use interface. It allows for:

- planning the order of the painted elements and off-line testing of programs,
- determination of actual cycle times and ranges,
- use of different models of robots,
- use of a virtual programming panel,
- optimization of the generated programs.

Fig. 4. Simulation in Roboguide system (***, 2010)

7. Example of Use of Roboguide System for Programming of Painting Robots

A Roboguide V6.40 system was used for programming the painting robots. The first step in the process of programming was to determine the working environment for the robots, which was the painting chamber. The programmed item was load-carrying box used in the tipper trucks. The robots were equipped in additional seventh axis in order to increase the working space. This allowed for painting the items with large dimensions (Kinas, 2010).

The next step was to select the model of the robot. Roboguide software has a list of all the robots offered by Fanuc in its database. The P-250*i*A robots were used for painting load-carrying boxes and truck frames.

Another step was to determine the robot ranges, i.e. the area where the robot is able to move. The programming utilized a special function of *Line-tracking*. The function allows robots to perform their tasks when the painted product is moving. The robot controller is connected with the encoder, which is installed in a kinematic chain of the transporter line. The encoder incessantly sends information such as current element position in the chamber. Mean speed of transporter line during painting process amounts to ca. 0.5m/min. This speed is also controlled by the robot controller. The solution ensures smooth production. The robots perform their tasks continuously, which results in painting a box in a time of ca. 30 minutes.

Another phase of program preparation was choosing the right tool from the list of tools available for a particular robot.

An example program was generated for an actual design of the load-carrying box used in tipper trucks for transporting loose materials. The box design is composed of profiles and steel sheet metal. The programming was limited to external surfaces of the box, i.e. side walls, front wall, cover and box floor.

Fig. 5 presents the view of the load-carrying box for tipper (Kinas, 2010).

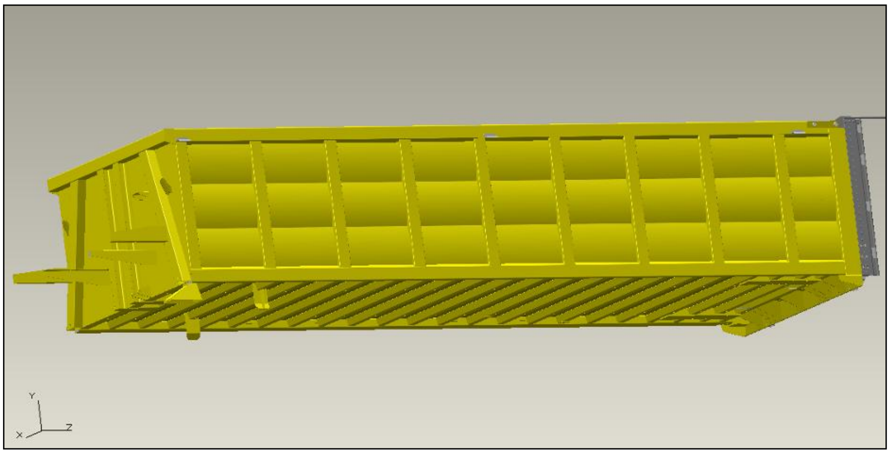

Fig. 5. Load-carrying box

Another step in programming was importing the drawing of the box. The Roboguide software reads the drawings prepared by means of CAD programs.

Figure 6 presents box orientation in the line for transporting the components in the painting chamber.

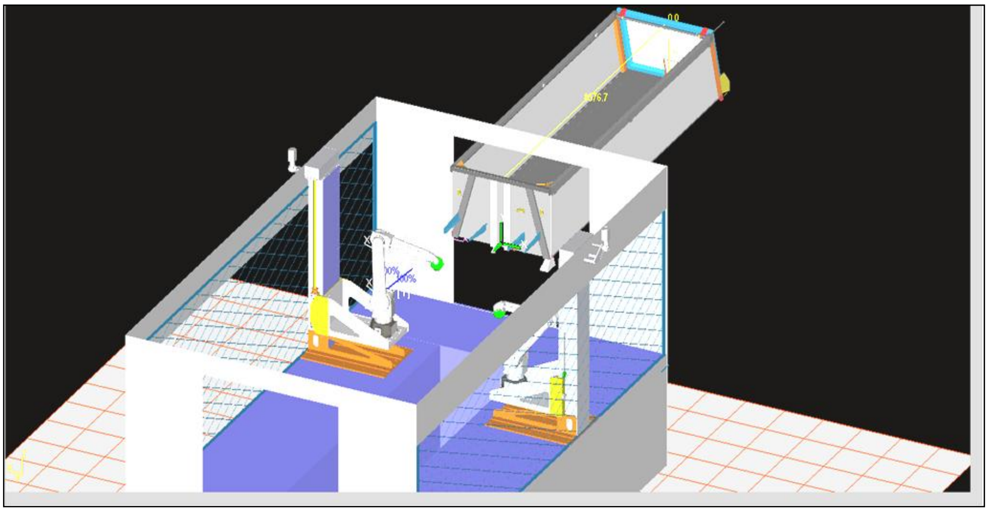

Fig. 6. View of load-carrying box situated in the painting chamber

The software allows for accurate determination of the painting grid. This ensures that the painted surface will meet the required uniform paint layer thickness.

Roboguide system features a programming panel identical to the actual workstation. Figure 7 presents the method of program creation by means of the programming panel.

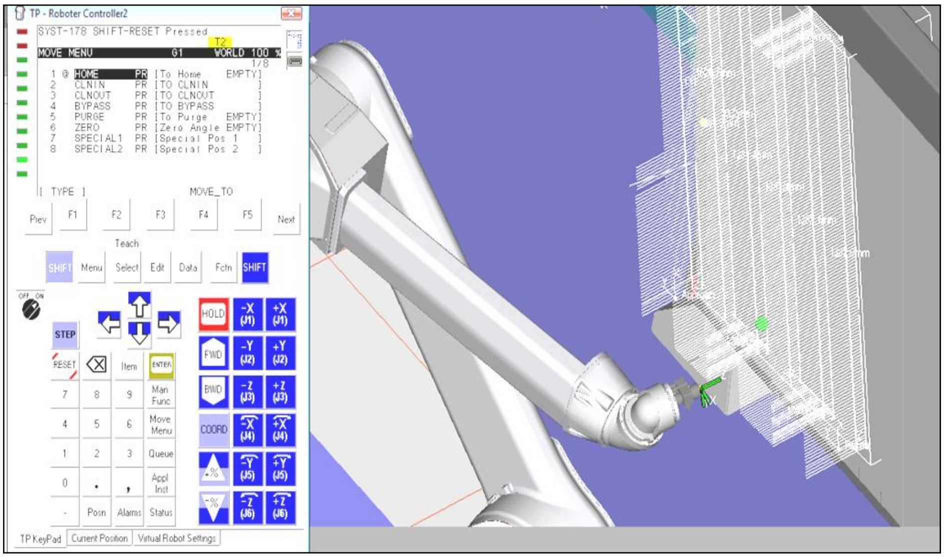

Fig. 7. Programming panel

Roboguide allows for using typical functions for painting process dedicated to *PaintTool.* They can be quickly used in order to program painting of the components with complex shape.

The software provides the graphical representation of the areas of the robot working range. It is particularly useful during programming of the robots, where the programmed item is moved. Seeing the working range for the robot, a secure work of robots, synchronized with the speed of the transporter system, can be ensured. It is especially useful during the design of inaccessible components or those which are situated at the border of the robot's working range .

Figure 8 illustrates the robot's working ranges.

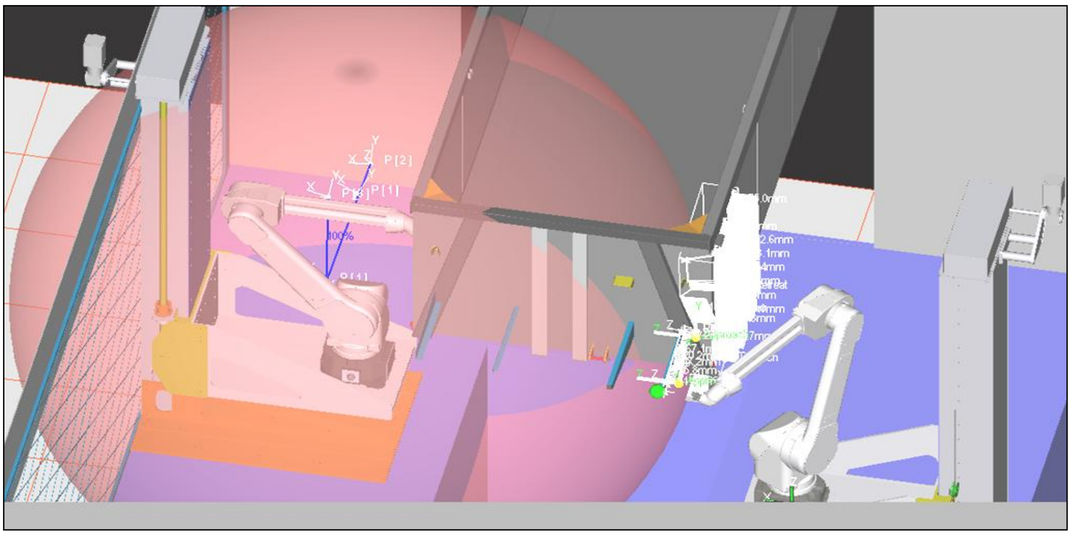

Fig. 8. Area of robot's working ranges

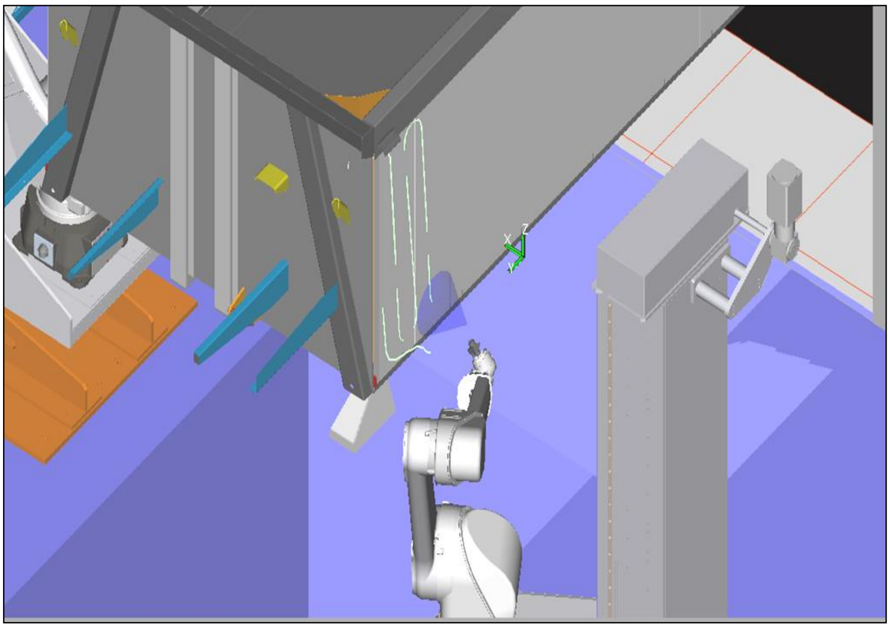

Fig. 9. Simulation of painting of side wall

Roboguide is equipped in an intuitive simulator. The simulator allows for performing of a number of tests before the program is implemented in the production line. It supports the programmers in checking and optimization of the whole program. It allows for elimination of collisions of the robot and protecting the expensive painting equipment mounted on the robot from damage. The simulator provides opportunities of elimination of other types of errors, such as limitations of robot axes and synchronization of the speed of transporter system with the time of the work performed by the robots. It is particularly useful during creation of the programs when the item is moving. Figure 9 presents an example of simulation of painting of side wall in a load-carrying box.

8. Program Optimization

The present study attempted to optimize the automatically generated programs. The programs were optimized in a variety of ways e.g. through changes in the speed of the transporter line, changes in the speed of the robot, changes in the material nozzle and the determination of the proper ranges so that the robots could operate smoothly and continuously.

After testing of the automatically generated program, the time of operation of 35 minutes was obtained.

As results from the assumptions of the technological line, the time of the program cannot exceed the half-hour time. The production cycle for each painted component amounts to 30 minutes maximally.

Several necessary modifications were added in the program. Application of the nozzle with greater diameter allowed for increasing the robot speed. This allowed for changing the speed of the transporter line. The adjustments of the robots' working ranges were also changed, which caused that the robots performed the painting process continually.

The optimization process involved the three variables:

1) The first variable was the standard robot painting speed. The output value of 900 mm/sec was increased to 1100 mm/sec. The percentage change amounted to 22%.
2) Another variable was the slow robot feed rate used during painting of complex shapes. The value of 600 mm/sec was replaced with 750 mm/sec (25%).
3) The third variable was the transporter line speed. Initial transporting speed amounted to 500 mm/min. This speed was changed to 600 mm/min (20%).

After the final testing of the optimized programmed, the following results were obtained: the time of performing the program after the assumed modifications: 29 min. In percentage terms, the time of program performing was shorter by 18%. The optimization of the program allowed for maintaining the production cycle of 30 minutes (Kinas, 2010).

9. Conclusion

In the paper presents the use of robots in the processes of painting and varnishing. The use of painting robot Fanuc P-250iA in the process of painting the load-carrying box for tipper trucks was discussed. The robot's design and its controller were also presented. The Roboguide system was used for the description of the method of programming of painting robots. This programming is one of the most modern methods, which ensures that programming of this type of robots is much faster and allows for optimization of automatically generated programs.

The study attempted to optimize the generated operating programs. The changes in three production variables resulted in shortening of the painting process by 18% for the example of the load-carrying box used in tipper trucks.

It was confirmed the usefulness of Roboguide system for programming, testing and optimization of industrial painting robots.

10. References

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