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Off-line Programming of Welding Robots – Process and Economic Advantages

Abstract: The article presents the advantages of the off-line programming of robotic welding stations using the example of DTPS (Desk Top Programming and Simulation System) software by PANASONIC.

Keywords: welding robots, off-line programming, PANASONIC

The off-line programming of welding robots is becoming increasingly common by production companies manufacturing mainly unitary goods or small series of elements. An exemplary application for off-line programming is DTPS (Desk Top Programming and Simulation System) by PANASONIC. Presently, every producer of welding robots has their own "software"; therefore it is not possible to import the programme code from competitive software.

A great advantage of off-line programming is the lack of necessity for stopping a welding cycle in order to programme a computer with new robot movement trajectory or modify the existing one. Such a solution minimises production down-time, which can be very expensive, as programming very complicated elements on a real robot may last even an entire shift.

Additionally, off-line programming does not require moving the robot arm slowly in the designated welding area (as in the teach mode). It is only necessary to indicate a characteristic point with a cursor and the robot arm will be positioned there automatically. This accelerates the software developer's work several times and translates to occupational safety as the virtual environment is free from risks such as damaging corporate property or exposing operator to production-related hazards. All collisions or errors in software operation are signalled on the

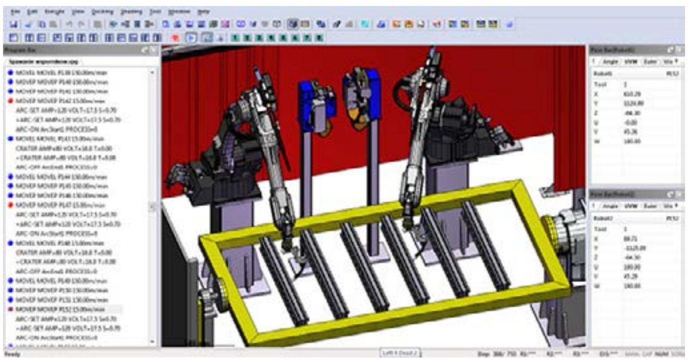

Fig. 1. Exemplary off-line programme. On the left - programme line preview window, in the middle – graphic presentation showing the positions of robots and elements, on the right – windows with coordinates of robot and manipulator positions

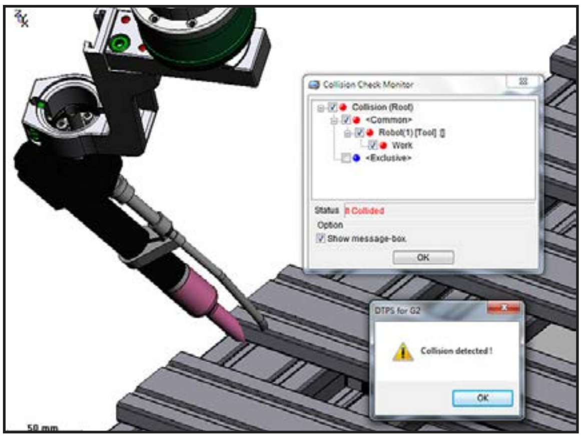

Fig. 2. Simulation indicated the collision of the welding torch with the workpiece. In the communication window colliding positions are marked red

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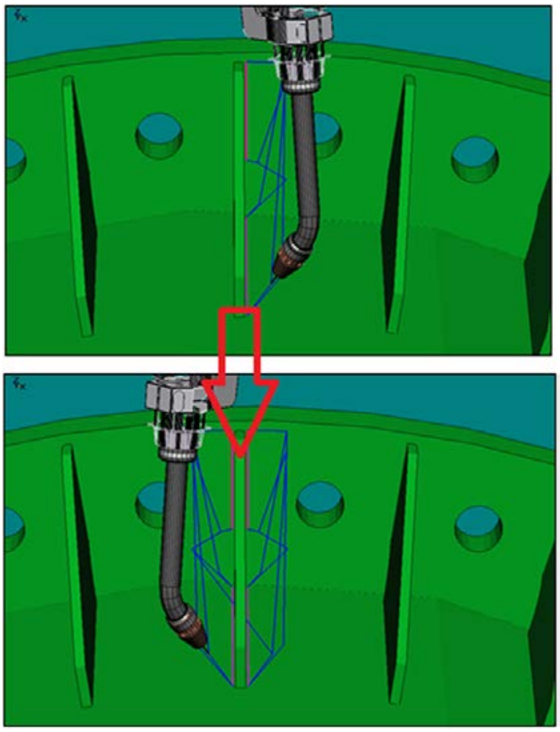

Fig. 3. Example of the mirror reflection function in the DTPS application

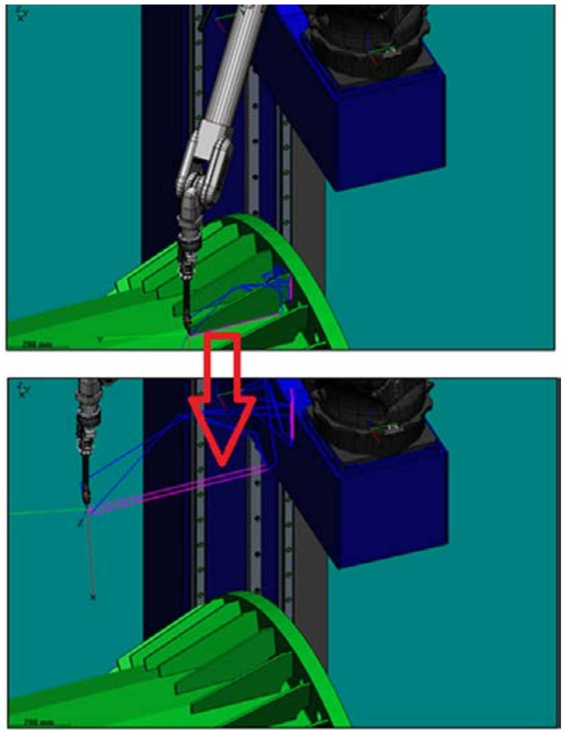

Fig. 4. Example of programme zooming-in function in the DTPS application

computer screen as related warning communications (Fig. 2). The robot collision function can be associated with its environment, e.g. workpiece, fixing devices, supporting structure elements or protective housing. The status of collision during programme simulation is illustrated in a graphic manner. The robot collision status is marked red, a distance from the workpiece shorter than 100 mm is marked yellow and the lack of collision is marked blue.

Computer-aided programme development also makes work more comfortable. It is not necessary to use ladders or platforms while programming large-sized elements or positioning the welding torch in poorly accessible places. The software developer does not even have to be present in the production hall and, as a result, is not exposed to process noise or welding fumes.

Another advantage related to the offline programming of robots is faster editing of existing programmes, e.g. quick changes of point location, welding parameters, logical or mathematical functions using the entire alphanumerical keyboard. Very useful are also keyboard shortcuts providing quick access to functions and commands. The programme algorithm itself is clearer on the computer screen and nesting windows additionally facilitates the preview of several parameters in one moment. Some programming functions like the mirror reflection or zooming (in or out) are available only on the computer as their implementation on the real robot would be difficult. Figure 3 presents the mirror reflection function application. A programme for welding the left workpiece side was generated automatically as the programme mirror reflection from the right workpiece side.

Such a solution will enable making identical welds on both workpiece sides and will shorten programme development time by half. Figure 4 presents an example of the fragment zooming-in function. As a result the lines of welding and those of idle movements are magnified two times.

Off-line programming also enables the graphic preview of robot trajectory. On the screen, the software developer sees lines and curves representing welding torch movements and idle movements. The tool enables the optimisation of the trajectory by maximally reducing it or by eliminating unnecessary movements.

However, software development is not free from some inconveniences. The programme is unable to simulate the movements of freely hanging conduits, e.g. behind the robot arm. Such conduits move in an uncontrollable manner, difficult to predict for various positions and torsions of the arm. The main issue is connected with the filler metal wire guide providing the wire from a reel or a barrel to the filler metal wire feeder mounted at the top of the robot arm. It is usually suspended on special balancers in order to be easily unrolled and, as a result, reduce wire feeding resistance. Panasonic has addressed this issue as well. In the new series of robots designated as TM the filler metal wire guide can (from the filler metal wire feeder) come directly into the centre of the first rotation axis of the robot in its base (Fig. 5).

Such a solution eliminates problems with setting conduits behind the robot arm, difficult to solve at the software development stage using a computer. During off-line programming it is also helpful to hide the conduits between the filler metal wire feeder and the welding torch inside the robot arm (Fig. 6). Such an approach eliminates the risk of hooking the conduit up against the workpiece, welding tooling or another robot during virtual programming.

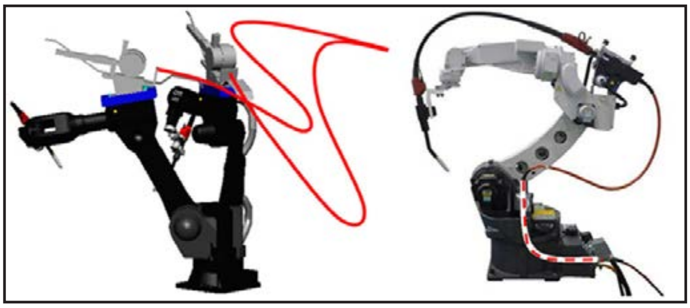

Fig. 5. Comparison of the standard filler metal wire guidance (on the left) with the innovative guidance through the first axis centre in TM robots

The use of off-line programing increases the process energy-saving as a typical computer operation needs only 60 W in comparison with approximately 20 kW needed by the welding robot. Saving energy translates to the reduction of production costs and environmental protection.

Using DTPS it is also possible to determine the optimum duration of a welding cycle and connect it with the assembly of new elements and dismantling of welded elements on another work field. Such processes must be synchronised with preceding or following production stages. This is a very important aspect while designing complete production lines.

The DTPS for off-line programming described in the article is fully compatible with all Panasonic robots. It enables not only the development of welding programmes but also the creation of the virtual environment precisely representing the real welding stand, along with all the peripheries. Below are presented two significantly different examples of welding stands created in the DTPS with complete welding cyclograms. The first system is intended for welding large-sized elements, i.e. components for lorry semitrailers. The second system is intended for welding small-sized elements, i.e. car front shock absorbers. In both cases it was necessary to use Panasonic's DTPS-based off-line programming

Fig. 6. TM robot with the conduits guided inside the arm

Fig. 7. Robotic welding system TAWERS by PANASONIC

both at the design and implementation stages. In real applications both stands were provided with innovative TAWERS welding systems (Fig. 7) featuring the power source integrated with the robot controller. These systems practically use the SP-MAG spatter-free welding method and enable the obtainment of a high welding rate of 1.2 m/min.

Stand for Welding Lorry Semitrailer Elements

At the request of the Purchaser who has bought this stand, some design and technological changes were introduced in the article in order not to reveal detailed information. The lengths and numbers of welds as well as the time of their manufacture differ slightly to the real ones

Due to large sizes of workpieces, this system has been equipped with a steplessly adjustable track of a 32 m long stroke for two moving column-booms with suspended robots (Fig. 8). Along the track, there are two welding fields featuring positioners having a lifting capacity of up to 2000 kg used for rotating workpieces in a horizontal axis. The right field is used for welding stringers for semitrailers, whereas the left field is used for welding semitrailer frames with stringers made previously on the right field. All welds made are single run welds and in most cases are conducted with oscillatory motion. Due to dimensional deviations of such big elements the robots had to be provided

Fig. 8. Stand for welding lorry semitrailer elements; the tight field for welding stringers

with sensors supporting the location of a proper welding line.

By touching the workpiece with a gas nozzle before welding, the sensor of touch localises the joint and next detects its presence and displacement (if any). In turn, during the welding process the arc sensor operates with oscillatory motion measuring current in two extreme torch deflections. If the values of deflections differ, the robot arm is moved accordingly to the left or right.

In addition, to increase the arm range, robots can move across on the column-booms within 2.5 m (Fig. 9).

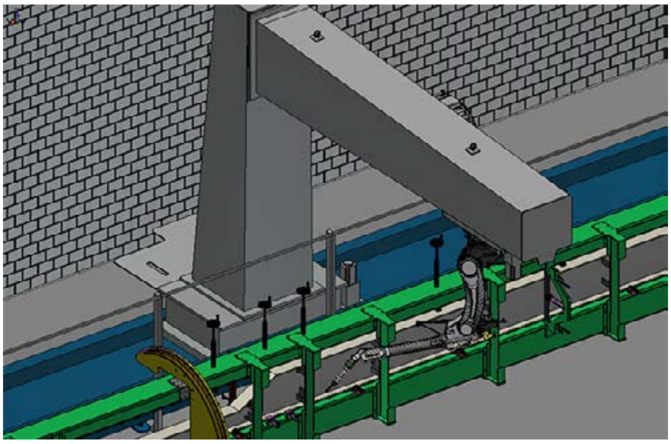

Fig. 9. Longitudinal movement of the whole column-boom and the crosswise movement along the robot arm support

The total number of elements to be programmably controlled on the stand included 18 axes, i.e. 12 robot axes and 6 external axes – 4 shifting and 2 rotating (one of the rotation axes moves in the +/- 360° range whilst the other axis moves in two positions only, i.e. 0° and 180°). In order to associate such a complex virtual system with the real system it was necessary to calibrate the positions of all the axes. Figures 10, 11 and 12 present the calibration process of all the stand axes.

First, only the robot arms underwent calibration. To this end it was necessary to feed two reference points saved on the real robot. These points determine the same location in two different positions of the support to which the robot is fixed (Fig. 10).

Afterwards, each of the shift axes in the system were calibrated, i.e. the longitudinal movement of the column-boom and the crosswise move of the support with the robot (Fig. 9). This task required the use of 3 reference points saved in the real system and determining two different support positions. Afterwards, these points were matched with corresponding virtual points (Fig. 11).

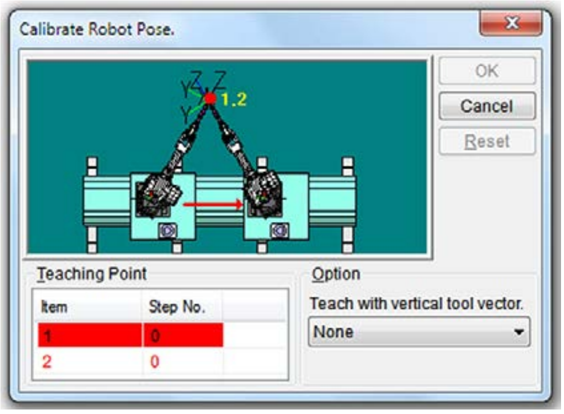

Fig. 10. Robot arm calibration process in DTPS

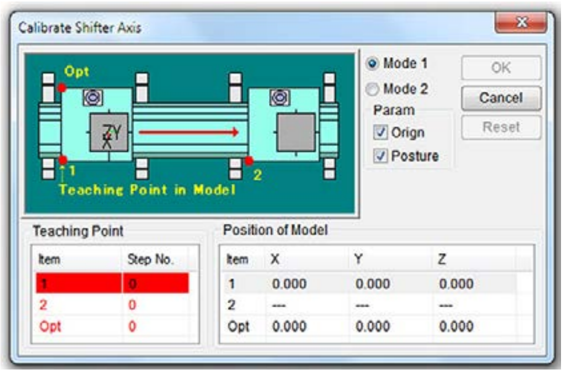

Fig. 11. Calibration of external shifting axes in DTPS

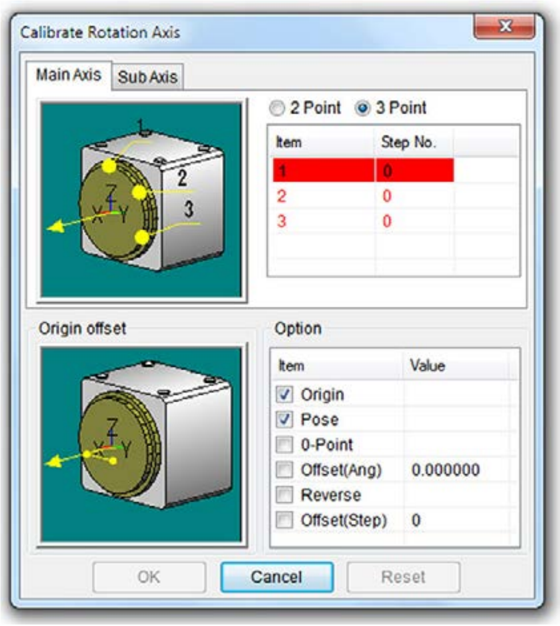

Fig. 12. Calibration of external rotation axes in DTPS

Also the rotation axes required calibration ensuring the proper rotation of a workpiece in the horizontal axis during welding. To this end it was necessary to feed three reference points from the real system. The points were located on the positioner disc and defined the rotation axis (Fig. 12).

The completed calibration allowed starting the virtual programming of the stand. The lack of calibration would result in the offset of all the external axes of the real stand. In consequence, after uploading the virtual programme to the real programme the operator would have to shift all the programme points.

The example below presents welding the stringer on the right field (Fig. 13). All the welds present are fillet welds made in a horizontal position (PB). The stringer is welded using the continuous method on one side and the intermittent method on the other side.

The DTPS programming functions for off-line programming of intermittent welds proved very useful. Among other things, these functions enable copying a selected fragment and pasting its

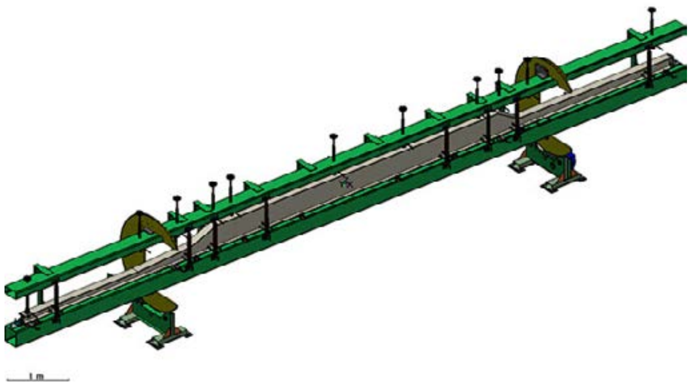

Fig. 13. Stringer in welding positioner

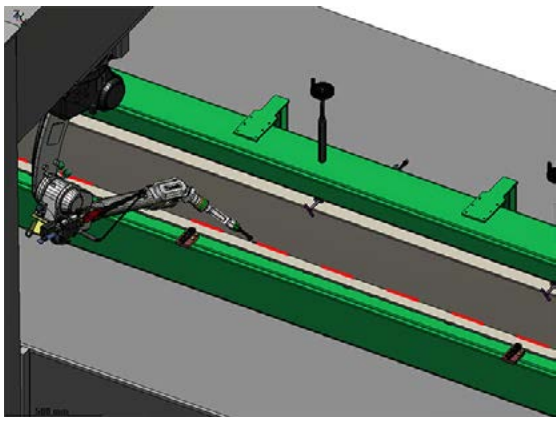

Fig. 14. Series of intermittent welds (marked red)

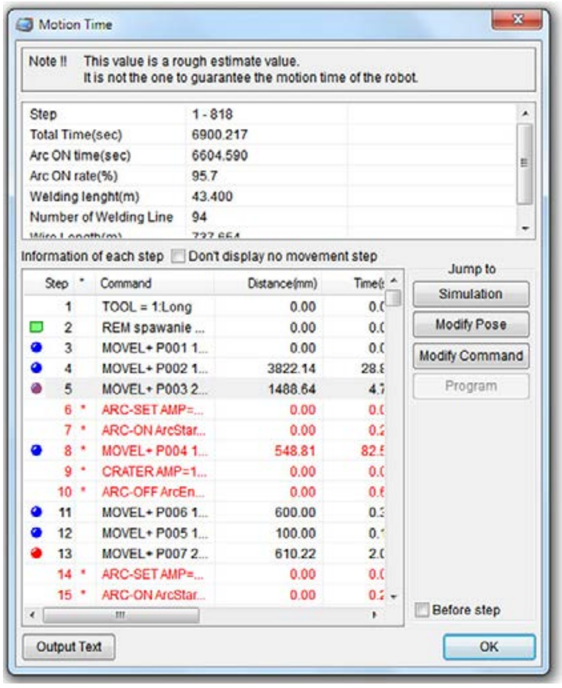

Fig. 15. Stringer welding cyclogram generated automatically in DTPS

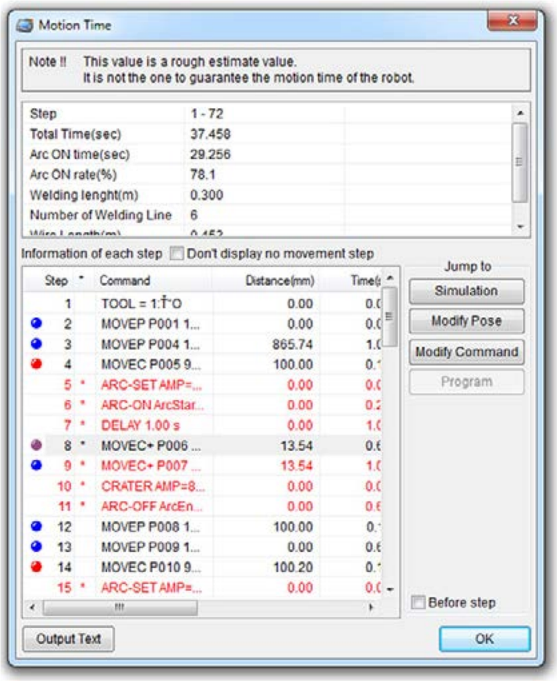

Fig. 17. Cyclogram for welding front shock absorbers generated automatically after developing the programme using the off-line method

multiplicity as the further part of the algorithm. This enables the automatic generation of a series of 200 mm long intermittent welds distant from one another by 200 mm (Fig. 14).

Dtps enabled developing a complete welding programme with pre-set welding parameters and enabled the estimation of the welding cycle duration (Fig. 15) presented below:

- total cycle time – 6900 seconds (115 minutes),
- welding time – 6604 seconds (110 minutes),
- percentage content of welding time in the entire cycle: 95.7% (arc on time); the rest: idle movements,

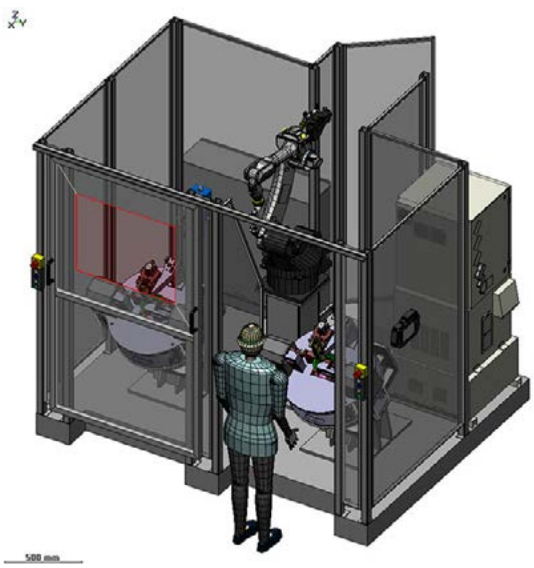

Fig. 16. Robotic stand for welding front shock absorbers

- total length of welds – 43.4 m,
- number of welds – 94.

Stand for Welding Car Front Shock Absorbers

The welding stand was designed in accordance with the requirements of the automotive industry, in the modular system and on the common supporting structure. If necessary, such a solution enables easy transport of the whole stand around the production hall by means of a forklift (Fig. 16). In order to obtain a convenient welding position, i.e. in this case flat, the stand was provided with positioners permanently inclined at an angle of 30o. Such a solution was tested virtually at the design stage in dtps. The off-line programming proved also very useful while constructing specialist welding devices.

It was necessary to use full automation along with element-detecting sensors and a fluid cooling system. Such a complex system had to be optimised as regards the angle of accessing welding places with a welding torch. To this end it was necessary to develop the whole front shock absorber welding cycle using the off-line method (Fig. 17):

- total cycle time – 37 s,

– welding time – 29 s,
– percentage content of welding time in the entire cycle: 78% (arc ON time); the rest: idle movements,
– total length of welds – 300 mm,
– number of welds – 6.

The entire time also includes the time of arc initiation and termination. The off-line method also enabled the process optimisation as regards operator's efficiency. The cycle time of 37 seconds was selected in order to make it possible for the operator to remove the welded element and place a new element to be welded; the situation when the robot has to wait for the operator should not take place.

Conclusions

Off-line robot programming offers numerous advantages, such as

- software development outside the robot – no production down time,
- usefulness for unitary production,
- shorter software development time,
- creation of welding cyclograms at the design stage,
- shorter software editing time,
- energy-saving process,
- support with software function not available in the real robotic system.