

# Methodological Aspects of Modelling and Simulation of Robotized Workstations

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**Abstract** – From the point of view of development of application and program products, key directions that need to be respected in computer support for project activities are quite clearly specified. User interfaces with a high degree of graphical interactive convenience, two-dimensional and three-dimensional computer graphics contribute greatly to streamlining project methodologies and procedures in particular. This is mainly due to the fact that a high number of solved tasks is clearly graphic in the modern design of robotic systems. Automation of graphical character tasks is therefore a significant development direction for the subject area. The authors present results of their research in the area of automation and computer-aided design of robotized systems. A new methodical approach to modelling robotic workstations, consisting of ten steps incorporated into the four phases of the logistics process of creating and implementing a robotic workplace, is presented. The emphasis is placed on the modelling and simulation phase with verification of elaborated methodologies on specific projects or elements of the robotized welding plant in automotive production.

**Keywords** – robotized workstation, computer-aided design, implementation model, simulation, welding workstation, testing of collision zones.

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## 1. Introduction

JIT, CAD/CAM, CIM, HIM can be defined as a new impetus for the integration of the philosophical, technical, economic and social concepts of project theories, methodologies and their tools for the developed market. New manufacturing technologies currently based on CNC manufacturing machines, industrial robots, flexible transport and storage facilities, controlling computer technology, and other resources bring problems of integration. Their solution requires a new industrial structure. The knowledge base that are based on scientific knowledge, methods and tools - that sufficiently develop analytical and synthetic culture of engineering activities - are important for its preparation. A significant innovation trend in this area is computer support for designing. According to scientific forecasts, use of computer support will be a basic method used in engineering activities of a different nature. The development trends of computer support all affect the area of technical preparation of production and production itself.

Problems of graphical character can be solved by computer graphics. By virtue of the fact that computer graphics penetrate most of leading disciplines, it also becomes an effective tool for computer support. Technical objects and tasks can be implemented in two-dimensional or three-dimensional spaces with a high level of clarity. Interactive methods and techniques can enable an effective communication way of solution or also support a creative invention of users.

The demanding work of modelling a workstation does not necessarily always have to be beneficial. Before investing in mostly costly software and demanding engineering modelling work or information support, it is necessary to consider the economic efficiency of this approach, to compare the modelling and simulation costs with the expected benefits it can bring. They include savings in time and money, portability and affordability, cost elimination due to errors, graphical interface, PC programming, elimination of costly systems,

increased accuracy, sophisticated calibration, support for concurrent engineering (simulative engineering), support for feasibility, reduction of non-subsidies and reworking of the program in robotized workstations.

## 2. Methodological aspects of modelling a robotized Workstation

The proposed method, Fig. 1, represents a succession of ten steps that are logistically linked to each other from formal perspective. The individual steps are integrated into the three development phases of the design and implementation of the robotized workstation.

The first two steps are a part of preparatory (input) phase. It specifies what is to be modelled and by what. The designer's request for the robotized workstation (output from the technical workstation

project) will be taken over at this phase, the other relevant requirements will be defined and completed, the necessary input data and the appropriate software for the virtual work will be selected [1].

The further six steps can be described as the phase of modelling and simulation itself. Modelling is a complex work involving not only the geometry of the design but also the non-geometric and functional (program) sides, usually by simulation techniques. The model is always closely bound up with the simulation and with procedures that specify it (the first phase) and transfer it to reality (the third phase). The realization (output) phase includes the steps by which the created and simulated model is safely transferred to the real world of robotized workstations.

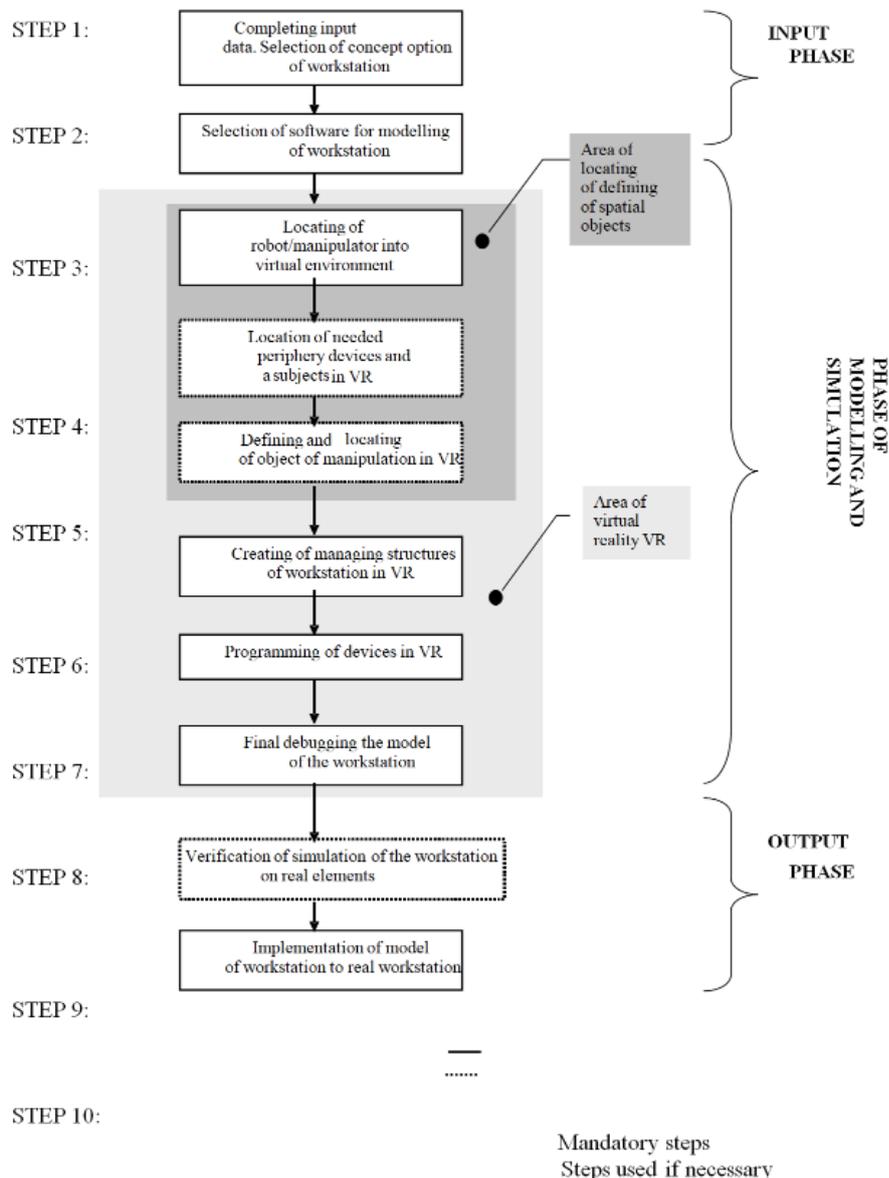


Figure 1. Implementation model of robotized workstations

At the beginning, there is a decision mechanism that will either use a step load function, or it will jump. The other steps proposed in the methodological procedure are mandatory [3,4].

The first step is designed and illustrated in the algorithm in Fig. 2, it has an analytic-selection character. Its task is to specify what to model and why. Appropriate inputs for this step are options of robotized workstations, or at least their rough concepts. An ideal input is a 3D workstation project in digital or printed form, or a standard 2D spatial layout. In the end, there is a clear concept in the mind of the designer - who then becomes a consultant for this step. The more accurate and the more specific input data for the workstation, the better the idea of the next step. It is necessary to complete and systematize as much data as possible about the various possible workstation options for this reason.

It is necessary to ask questions: How particularly should the workstation look like, what are its meaning and function, what to include, how and where to place, what are the geometric dimensions of the workstation and the individual elements, which geometric dimensions are fixed and so on. A documentation block is used to save as many answers as possible to the questions. Whenever one option is documented, it is good to ask if there is another solution to the workstation. If it exists, it is necessary to repeat the documentation process.

The difficulty of managing the first stage is closely related to the quality of the processed input documentation (the layout of the workstation). Subsequently, the selection of the optimal workstation option from the set of all documented workstations is implemented. The selection can be managed by functionality, cost, and simplicity requirements.

The ending procedure of this step is that it needs to be verified if the selected option is appropriately selected for modelling purposes. This will create a clearly specified workstation option that will be modelled and then simulated.

An object is labelled 1A in the algorithm in Fig. 2. This connector serves to return from the other steps of the methodological procedure where there is a similar connector with the address label 1A to that location, if necessary. The connector indicates that a situation may arise from where to return and to select

another solution in the later steps of the methodology.

After specification and obtaining all the necessary information for designing and its functions, including modelling objectives, the second phase can be launched to determine an appropriate platform for modelling. The platform is software that is capable of creating a virtual reality environment where it is supposed to embed the model of the workstation successfully and to achieve its objectives, Fig. 2. The first question is if this workstation has been previously modelled in some software. If it has been and this software is available, it is important to verify if the software meets the simulation requirements. If this software suits and is future-proof, so far it does not count for changes that would require other software. The situation is complicated if the answer to the first or second question in the algorithm is negative. It is necessary to select appropriate software for solution of the modelling and its objectives in this case.

Software selection begins with a market survey and product listing in the area. It is convenient to consult software vendors or search manuals or case studies here.

Subsequently, a selection is made from the list of products. It is necessary to select only those that meet the simulation requirements functionally. Functional requirements for software include, for example, compatibility with the programming language of the device being modelled, or a limitation of the number of devices, objects, so on. This creates a narrowed list. However, if the requirements of a specific simulation do not suit any software, it is necessary to make a change to the model or workstation modelling objectives which mean returning to the first step of the methodology through a connector outside the A1 side.

If the result of the narrowed list of software products after a functional selection has left one product, this product will be selected. If there more products having been left, there has been an option to select a product based on non-functional requirements. These include, for example, availability, product price, support for libraries and models, devices, quality of the VR environment, way of control, compatibility, future use options, etc. After considering these factors, the final product will be selected - the modelling software [2].

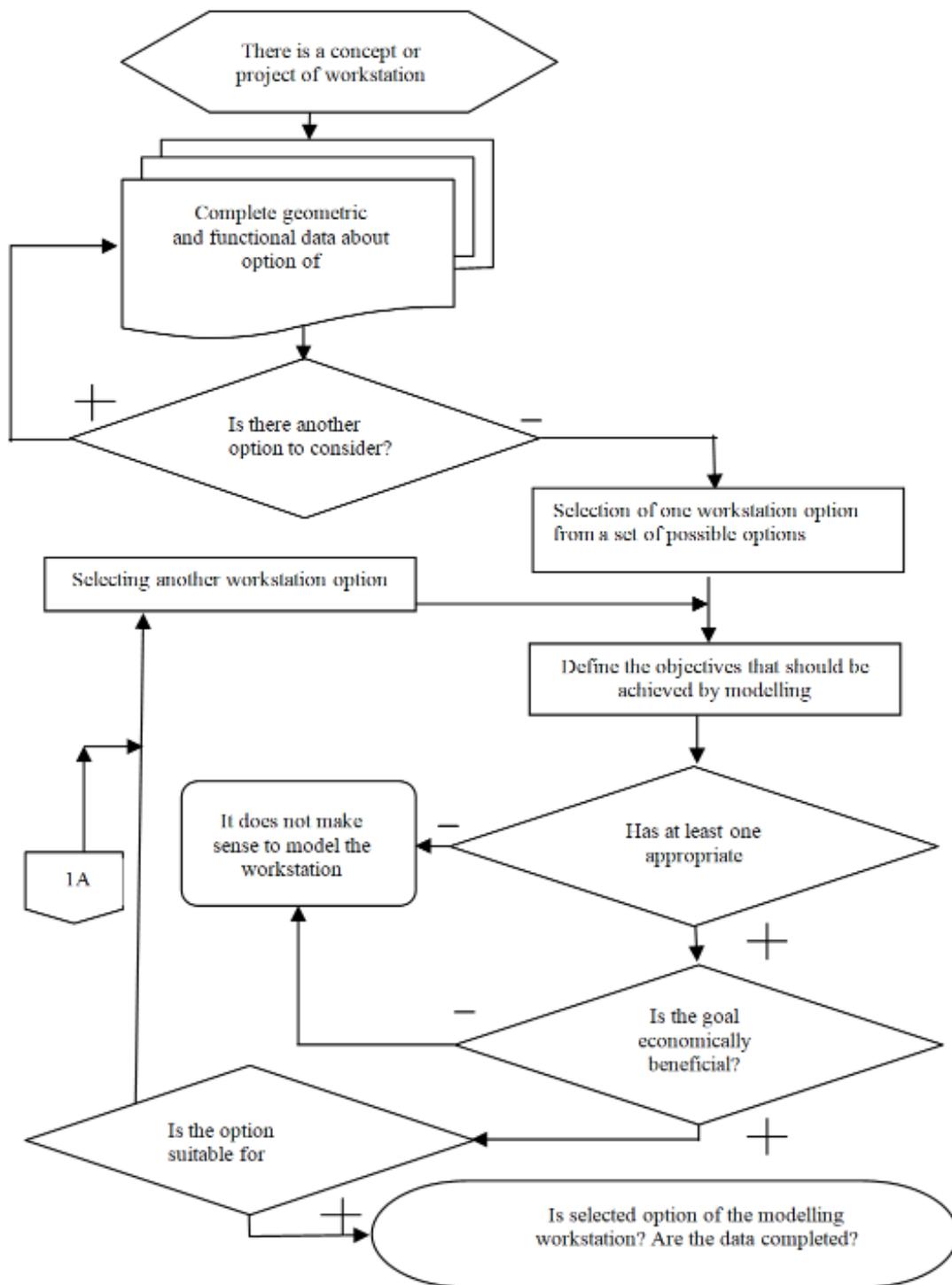


Figure 2. Selection of workstation option for modelling and completing input data

### 3. Verification and dimensioning of the methodology when designing a Kuka robot

The pilot workstation equipped with a Kuka VKR 125 robot that has fitted Nimak's "X" scissors, is shown in Fig. 3. The entire welding process is carried out using an RS PHASE welding unit. The

workstation is also equipped with a welding tool that contains parts for creation interior rear fenders of Porsche Cayenne. These are both right and left fenders. We have used the mirror layout of the individual elements of the product to create a mirror product [1,5].

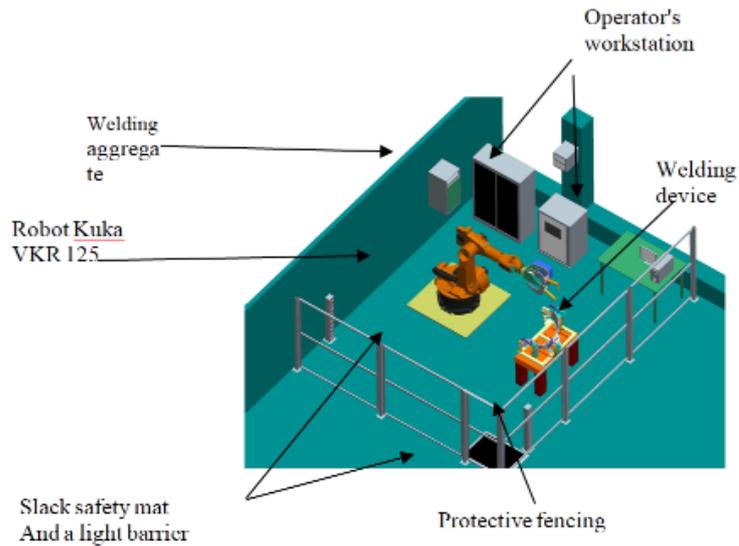


Figure 3. Pilot workstation with robot Kuka

In the case of robotized pointing pliers mounted on an industrial robot, the welding process is divided into three phases. The whole 5-piece welding process is divided into three preparations as the production cycle gives us a value of 104 seconds which we have to adhere. The total number of points for welding is 39.

When welding by welding pointing pliers, it takes one point to weld (feed pliers, pointing, pushing pliers) for about 5 seconds. It is necessary to use more agents for this reason. The use of multiple agents also forces poor accessibility to individual

welding points as well as the need to secure the flanges (parts of the welded sheets) against the displacement of the pliers (ensuring the correct geometry of the individual parts).

Three parts (the base part 7L6 809 412Do.Z., the pot shape part 7L6 810 884 and the rear part 7L6 809 678A) are going to be connected whilst 6 points are connected to the connection of the rear part with the base part as well as to close 8 points between the base pot and the pot shape part in the first phase (Fig. 4).

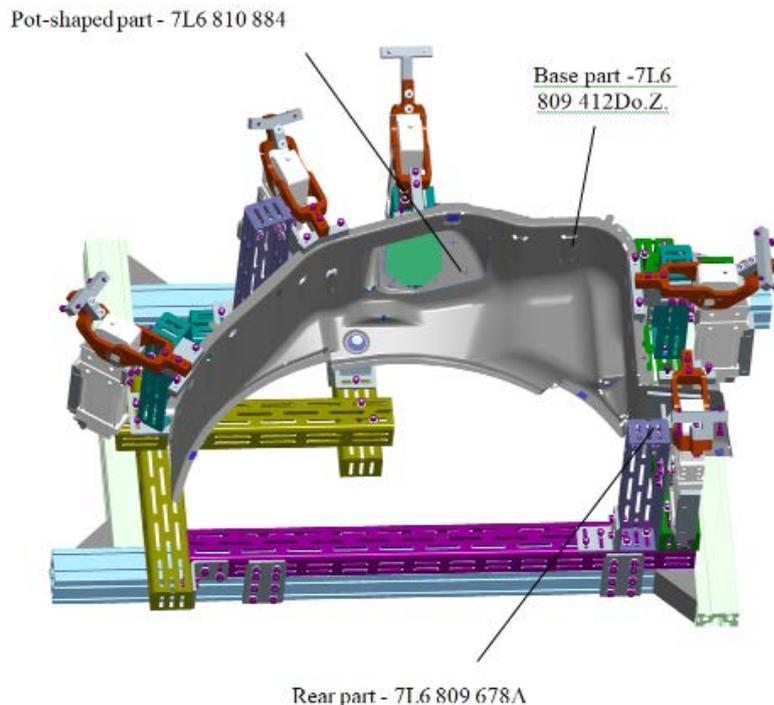


Figure 4. 3D model of the welding tool for robotized pointing welding - phase 1

#### 4. Simulation of collision relations pliers - clamps - welded parts

When designing a welding agent, it is important to achieve the best possible access to the welded points [7]. To find out about this accessibility, we are

simulating the reach of the pliers in which we can control the conditions that will be present in real-world applications on sufficiently realistic models. We shall achieve the optimal properties of the proposed welding agents using these simulations.

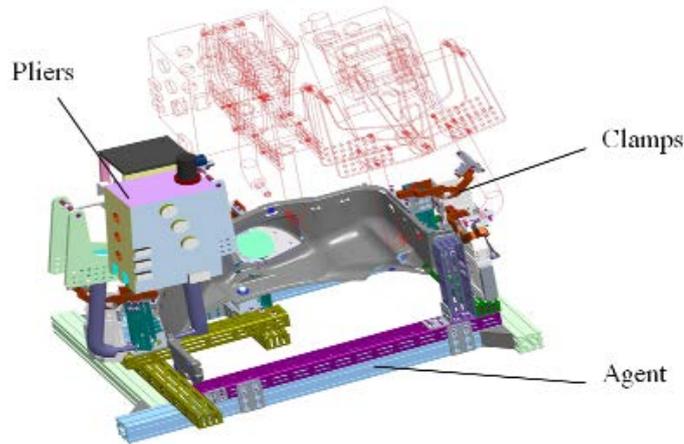


Figure 5. Reach of the pliers simulation

A welding agent in the ProEngineer Wildfire 2.0 3D application designed for welding an in-car interior fender, equipped with pneumatic clamps V50 T01 A10 of the German company Tuenkers is shown in Fig. 5. Welding is accomplished using robotic "X" pointing pliers. The figure illustrates the accessibility of pointing pliers to the welding points in pointing welding of three smaller parts to the base part of the fender. It is possible to control the accessibility of welding pliers to the welded parts as well as to

prevent collisions in CAD applications but the possibility of generating compatible code that the robot would be able to accept is problematic. Therefore it is appropriate to use programs capable of generating the necessary data appropriately for each type of robot. Simulation programs are mostly made up by larger robot makers, Robot Studio from ABB, RobCAD was created by Kuka but their mutual compatibility is problematic [6].

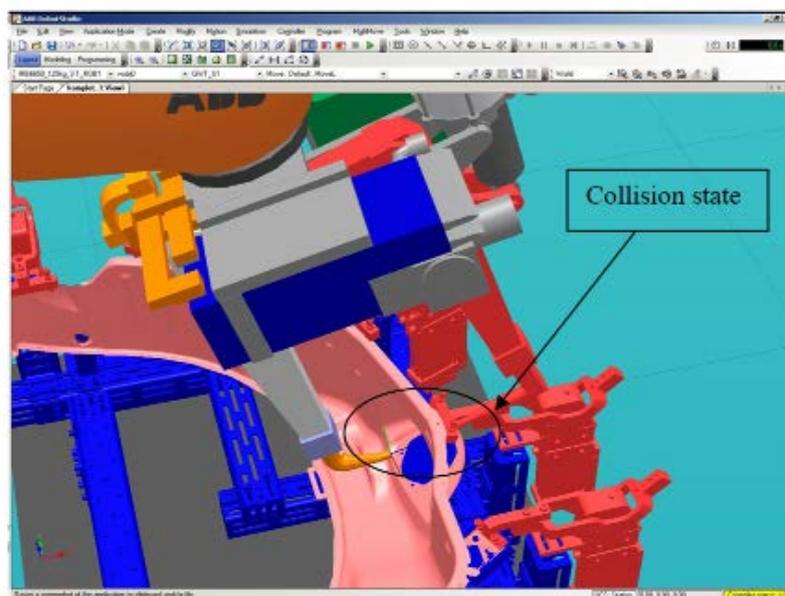


Figure 6. Simulation of pinch-to-weld alignment - collision state

It is necessary to use the possibilities of simulation programs for efficient use of off-line programming. Simulations of collisions can be performed under Robot Studio, Fig. 6, where they pinch the pliers into the clamping elements

Fig. 7 shows the overall view of a robotized workstation equipped with an ABB-IRB6650\_125kg\_320 industrial robot, pointing pliers ABB-GWT\_S1 and the welding agent fitted with a fender assembly.

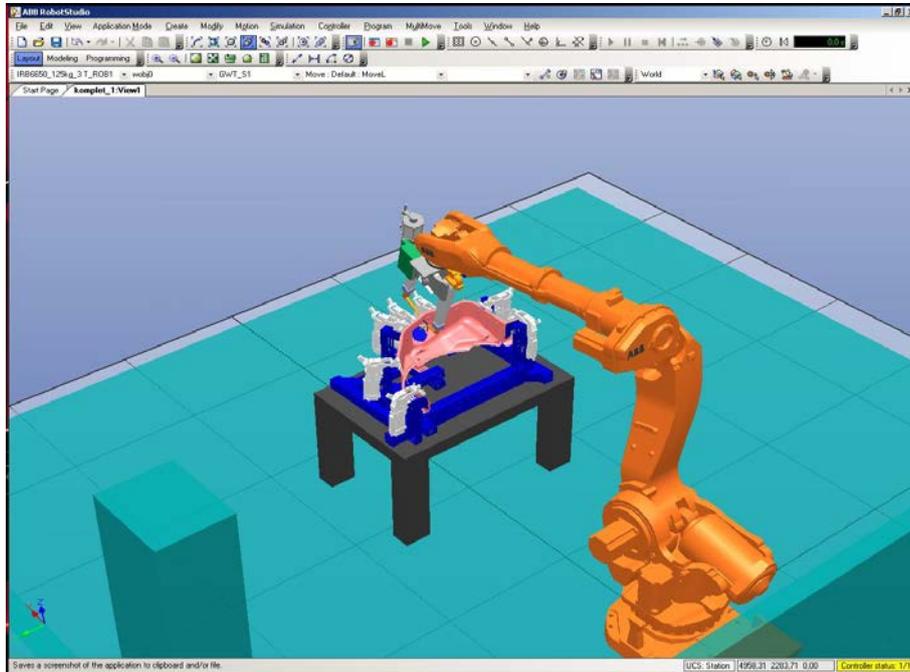


Figure 7. The overall view of the welding workstation equipped with the ABB robot

We can create a program using the Robot Studio simulation program that can be uploaded to the robot's control system. It is possible to transfer the program using portable media or via TCP/IP protocol.

##### 5. Testing accessibility of pliers - robot to welding points, optimizing the program

One of the advantages of off-line robots programming and the simultaneous use of simulation programs is an ability to control each point of the program in real time. In case of poor accessibility of end effectors - welding pliers, burners, etc., it is possible to change the program, to add or to remove problematic points in the program. It is possible to change the shape of individual parts of the product, to optimize it, or to change the type of welding electrodes, all in a simulation environment independent on real production, there is no downtime. Another advantage is an ability to exploit

a potential of the robot, its overall workstation, a possibility of avoiding dead zones. If there is a need to use two or more robots when welding in a common workstation, it is possible to create programs that will contain crash paths for each robot. It is possible to assign priorities of movements of each robot as well as to determine positions of the robots at any time of the working cycle. The biggest advantage is possibility of constantly optimizing the movements of the individual robots which greatly contributes to reducing the robot's working time and thereby increasing the productivity [3,8].

Testing the accessibility of the pliers to the welded parts is possible by setting the collision states function where it is possible to specify the minimum distance between the individual elements which enable us to identify the locations of collision states. As an example, Fig. 8 provides accessibility detection where the distance of the pliers from the pneumatic clamp is sufficient on 10 mm.

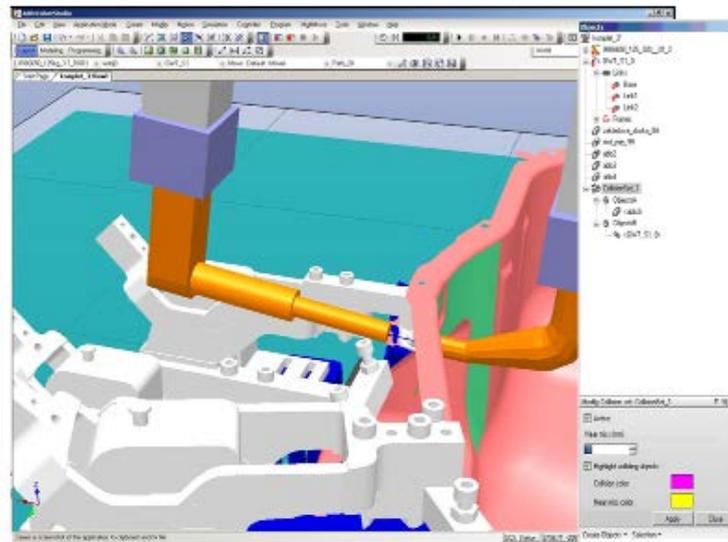


Figure 8. The tested accessibility is within the required range

## 6. Conclusion

In line with developmental trends in manufacturing culture (transition from industry to knowledge society, shortening and rationalization of pre-production phases of the product cycle through the introduction of global CAx technologies), the solution to topological problems of robotic systems is also a multidimensional and widely discussed problem. They have their specific optimization problems related to the production area.

Using our proposed solutions in the area of methodological aspects of modelling and simulation of robotized workstations brings benefits in the form of:

- Reducing redundancies in the design process (catalogue search, building dummy design, drawing plotting documentation, automatic calculation of some of the features of the proposed cluster, etc.).
- Increasing design intensity.
- Higher quality of projects in terms of handling logistics.
- A considerable increase in design speed, i.e. a possibility to create and assess multiple options of the robotic system solution at the same time.

Based on these facts, the quality of the final solution improve the economic efficiency of the proposed manufacturing process at the appropriate design phase and operating conditions.

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