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RAPID MACHINING WITH INDUSTRIAL ROBOT

Abstract: Industrial robots are used for many tasks, mainly for material handling and welding. Robots can be also equipped with other tools and used for machining. Nowadays small numbers of robots are used mainly for machining of soft materials, such as plastic, wood, foam and aluminium. This technique is used mainly for rapid prototyping. In this article an example of computer modelling of robotic cell for machining is shown. Some problems related with robot programming, accuracy, repeatability and calibration are discussed. An example of machining in polystyrene is presented.

1. Introduction

Industrial robots are now becoming wider use. It is estimated that around the world is already over one million industrial robots and a systematic increase in their numbers is observed. Most applications of robots include manipulation of cargoes and welding services. In such tasks, industrial robots have proven themselves very well. But robots are characterized by their high versatility and can be also equipped with cutting and grinding tools and used for some machining tasks. Because industrial robots are built similar to human arm and shows a high flexibility of movement, they are predestined to the tasks associated with manual work, such as e.g.: deburring and chamfering of sharp edges or grinding and polishing the surfaces [6].

Due to the low stiffness of robot arm and cutting forces arising during operation, previous application of robots is limited primarily to machining of relatively soft materials such as wood, plastics, aluminum alloys and non-ferrous metals. At work [2], a model of a load of the robot arm during machining is presented and predicted value of cutting force for different materials were compared. In the case of hard materials such as steels and cast iron, it is followed by a significant increase in cutting forces that result in unfavourable load of robot arm. Machining of soft materials can be classified as rapid prototyping techniques [3]. The resulting prototypes can serve as models for the implementation of the molds or as a temporary enclosure and insulation [4].

2. Robot programming

Robots can be programmed on-line directly at the workcell (teaching by operator) or off-line using a dedicated computer systems. Directly teaching by operator in the case of common handling task is relatively easy. However, in the case of machining tasks, there are some complications, because of a collision trajectory of the robot. Because the tool delves into the material and must move after specific trajectories associated with the geometry of the part.

This causes complications while programming, which is why the off-line programming with dedicated programs, such as, DELMIA, RobotMaster, RoboGuide and others, are used. These are the advanced CAD/CAM systems, which enables to build three-dimensional virtual model of the robot and workcell. Virtual robot can be controlled with virtual teach pendant similar to real robot. Generation and simulation of robot program is possible, which allows testing the robot work before implementation. Robot motion path can be generated based on the geometry of the workpiece (CAD to PATH). Then developed programs can be sent to the robot control system and executed. Developed model of robotic workcell for machining is shown in figure 1.

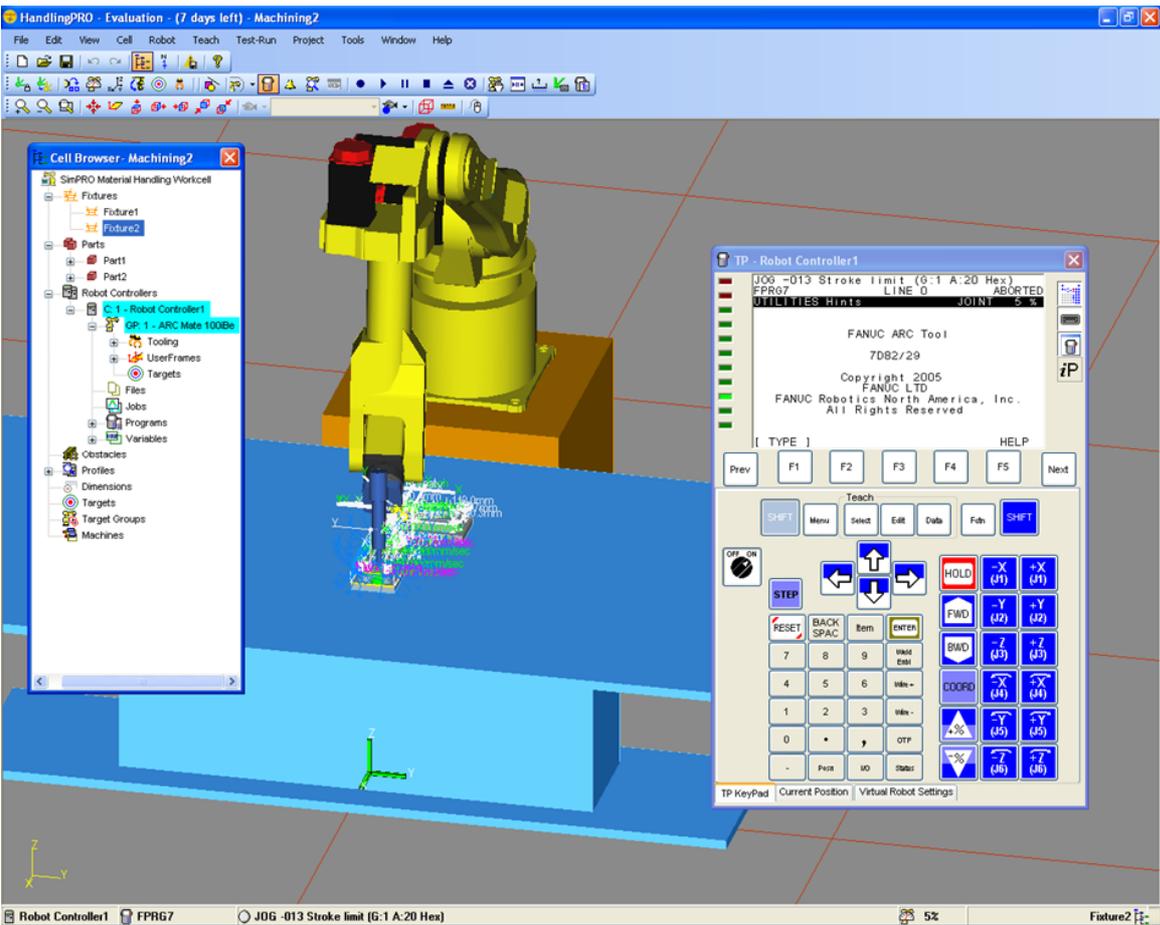


Fig. 1. Virtual model of robotic workcell for machining in RoboGuide

3. Robot accuracy, repeatability and calibration

Robot manufacturers, as an industry standard, publish the accuracy and repeatability of each machine. These specifications are determined in accordance with ISO standards 9283 [9]. Typical robots achieve the accuracy of positions and repeatability about ± 0.1 mm. High precision robots are possible to obtain accuracy about $\pm 0,01-0,05$ mm [6]. For high positioning precision a calibration of robot is needed. Calibration is the process of determining the actual values of kinematic and dynamic parameters of an industrial robot and is usually done by manufacturers.

In the case of computer-generated programs prior to running the robot a cell calibration is also required, i.e. determination of reference points between the computer model and position of elements in the real world. This is related, inter alia, with the dimensional inaccuracy between the computer model and the real workcell.

The robot's control system uses several coordinate systems (Fig. 2) that can be assigned to the various elements of the workcell and can be modified if necessary. The control system automatically recalculates coordinates expressed in different frames and adjusts the motion path. In typical applications the robot movement is done by non-collision trajectories and position accuracy is required only in certain positions. However, in the case of machining tasks there are some collision trajectories and precision robot movement is required. Each deviation has a direct reflection of the workpiece surface.

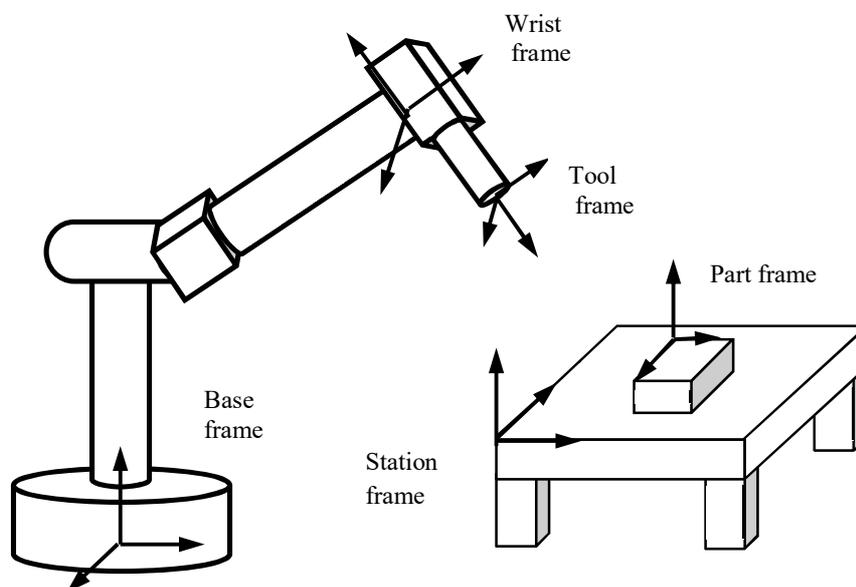


Fig. 2. Robotic workcell coordinate system

Positioning accuracy of robot is determined by a number of errors related to deviation in representation of the robot structure and kinematics and the dynamic influence [1]. It depends upon many different factors that include: friction, temperature, loading, manufacturing tolerances etc.

Robot positioning errors to a large degree are dependent on the arm configuration settings. At a constant setting of arm some tools errors ($+\delta-\delta$) are compensated, while at the opposite arm configuration the tool error is doubled (-2δ). (Fig. 3).

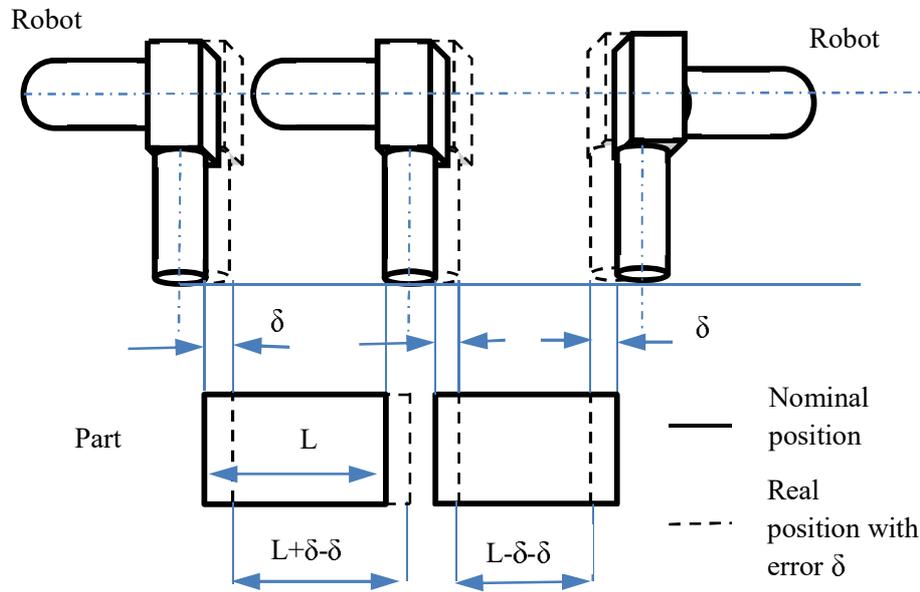


Fig. 3. Robot tool error δ and part accuracy

In the case of machining operation the uncertainty of robot motion is reflected in the uncertainty of the workpiece, therefore by measuring inaccuracies of the workpiece, it can be determined whether the robot was well calibrated. The most accurate method of robot calibration is the use of special laser trackers [7].

4. Robot machining

There are some examples of machining with robots described in bibliography [6] and presented in Internet [8]. The figure 4 shows the machining example of polystyrene cover. Robot program has been generated on the basis of the 3D model shown in Figure 1. The operation was carried out using a robot Fanuc ArcMate 100iB equipped with pneumatic spindle 2000 rpm with a mill cutter from HSS with diameter 12 mm. The treatment was successful and the desired accuracy $\pm 0,5$ mm has been achieved. Obtained part can be used as insulation cover. The processing was very fast, therefore it can be denominated as rapid machining.

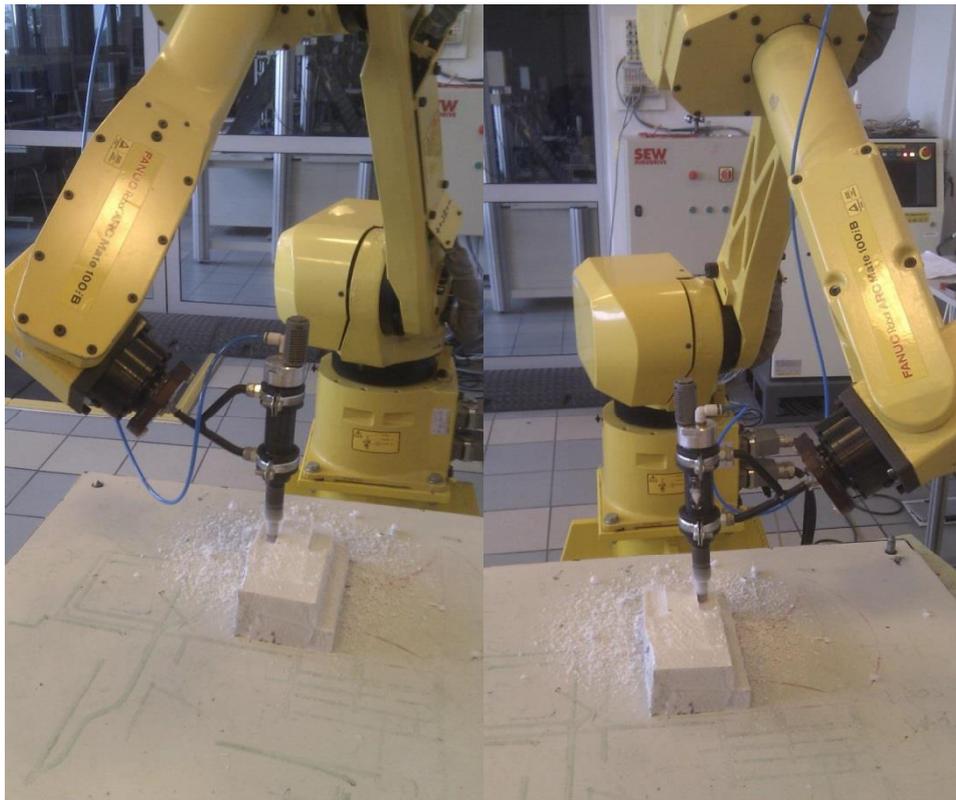


Fig. 4. Example of machining of workpiece from polystyrene

5. Conclusion

The use of industrial robot for the machining shows a number of advantages. Industrial robot can replace a worker while performing the tasks associated with manual processing and some machinery tasks. Compared to the classic machine tools, industrial robots have a much smaller mass and a lower stiffness. According to the work [5] rigidity of heavy-duty robots falls within the scope of about 200-700 N/mm. These values are about ten times lower than the typical rigidity of machine tools. As a result, positioning accuracy obtained by robots is much lower than the accuracy of the machine tools. However, for many of the machining tasks the accuracy is sufficient. Robots advantages are large workspace and faster speed of movement. The use of additional axes controlled as positioners or contact tracks allows enlarging the working space and handling of bulky workpieces. There are potentially large possibilities of use of robots in machining tasks, however, it is related with high cost of investment in robotization.

References

1. Conrad, K. L., Shiakolas, P. S., & Yih, T. C. (2000, July). Robotic calibration issues: Accuracy, repeatability and calibration. In Proceedings of the 8th Mediterranean Conference on Control and Automation (MED2000), Rio, Patras, Greece. p. 6
2. Gołda G., Kampa A.: Modelling of Cutting Force and Robot Load During Machining. Advanced Materials Research Vol. 1036 (2014) pp 715-720

3. Gołda G., Kampa A.: The use of industrial robots in rapid prototyping processes. *Postępy robotyki T. 2*, pod red. K. Tchoń, C. Zieliński. Oficyna Wydawnicza Politechniki Warszawskiej, Warszawa 2014, s.579-586. (in polish)
4. Kampa A.: Impact of rapid prototyping techniques for the manufacturing of new products. *SELECTED ENGINEERING PROBLEMS No 3*, Gliwice, 2012, p. 93-96
5. Lehmann Ch., Halbauer M., Euhus D., Overbeck D. (2012). Milling with industrial robots: Strategies to reduce and compensate process force induced accuracy influences. http://www.cometproject.eu/publications/etfa2012_a34.pdf
6. Yonghua Ch., Fenghua D.: Robot machining: recent development and future reaserch issues. *The International Journal of Advanced Manufacturing Technology*, June 2013, Volume 66, Issue 9-12, pp 1489-1497.
7. FARO – <http://www.faro.com/en-us/solutions/applications/robot-calibration> (access 7.10.2014)
8. Kuka Milling : <http://www.kuka-robotics.com/usa/en/products/systems/milling/start.htm> (access 7.10.2014)
9. ISO 9283 Manipulating Industrial Robots – Performance criteria and Related Test Methods”. International Standards Organization, 2003.