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SIMULATION AND OFF-LINE PROGRAMMING OPTIMIZATION OF THE ROBOTIZED PRODUCTION CELL USING KAWASAKI K-ROSET SOFTWARE

Abstract: The article describes current researches realized during works on development of a new robotized production cell in Laboratory of Multimotion Control. Actual state of the station progress is shown. The study on optimization of off-line Kawasaki RS005L robot programming in AS-Language and virtual simulation with use of K-ROSET software are presented. At the end the further plans of the laboratory expansion and recommended researches are indicated.

1. Introduction

Modern solutions in automated and robotized, flexible manufacturing systems should give possibility of easy changes in manufacturing of products with different design and construction characteristics, but similar technology. This requires the use of computer simulation and off-line programming methods of every production equipment, like CNC technological machines, manipulation and transportation systems with robots and automated guided vehicles, even warehousing, because of fast reaction on the changes in future production (configuration, tools and programs for the cells, lines, departments, etc.) and quick response for a further, of course, clients orders [1]. In the newest Laboratory of Multimotion Control, the flexible, robotized cell with Kawasaki RS00L robot, is developed. During the expansion of the laboratory, a researches on off-line robot programming optimization, using different simulation techniques and software, are conducted [2,3,4]. The last study is connected with use of Kawasaki K-ROSET software included AS-Language programming interface [5,7].

2. Virtual simulation and off-line robot programming optimization

The effective robot and whole automated cell programming and its optimization require virtual simulation software, dedicated for real equipment. Only thus obtained, optimized operating parameters (robot trajectory without collisions, correct implemented logic and communications based on input/output signals, sequence and operation time of manipulation, production and other services) gives possibility to implement correct model in real production system and execution of planned tasks.

During the researches [3,5,6,7] on off-line programming optimization a virtual models of real robotized cells were created with use of the K-ROSET Lite 1.7.0 software. In a first step, the virtual models of robot tool adapter, gripper and other elements of created laboratory station (pallets, gravity conveyor, manipulation objects, stands and other constructions) were designed in CAD/CAE Siemens NX system and saved as a files with *.stl format, which is readable for the K-ROSET. After the choice of Kawasaki RS005L robot with correct control system E71, the import of CAD files (tools, work parts, equipments, obstacles) was necessary to map a real workstation environment. Identical (with reality) layout of objects, connection of robot gripper and configuration of virtual controller auxiliary data should be realized before off-line programming. The K-ROSET 3D simply model and expanded real station [5,7] are presented on Fig. 1.

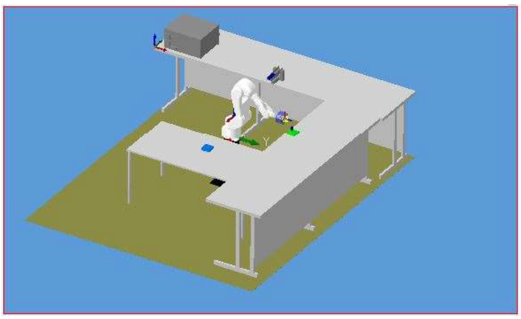

Fig. 1. The K-ROSET 3D simply model and expanded real laboratory station with Kawasaki RS005L robot

Next step was connected with creation of robot programs including block teaching (only for not complicated tasks and solutions - programs without optimization) and using AS-Language editor located inside virtual teach-pendant (programs to further optimization). First, it required the establishment of global and local program variables in K-ROSET (so-called "*real value*") concern with program loops, number of pallets, rows and columns etc., and position registers ("*joint value*" or "*trans value*"), which describe robot poses and transformations (e.g. robot or tool displacement in Joint, Base, Tool co-ordinate systems). All described data were entered to the system beyond the robot program, before and during programming.

Effective robot programming requires the use of large number of AS-Language instructions [8,9] relating to:

- definition of variables and calculation of robot's coordinates and positions - inside robot program:
  - "*variable / position instruction*": TOOL, BASE, HERE, POINT, DECOMPOSE, LLIMIT, ULIMIT,
- creation of collision-free trajectories:
  - "*motion instructions*": JMOVE, LMOVE, CMOVE, DRIVE, LAPRO, LDEPART, DRAW, SHIFT, TRANS, DELAY, HOME,
  - "*motion auxiliary instructions*": SPEED, ACCELERATION, DECELERATION, ACCURACY, PAUSE, TIMER, BREAK,
- connected with realization of other tasks and operations, not related with robot movement :

- "*input / output instructions*": OPEN, CLOSE, SIGNAL, PULSE, BITS, SWAIT, TWAIT, RESET,
- "*program control instructions*": CALL, GOTO, IF, THEN, ELSE, ON, FOR, END.

After robotized cell programming in AS-Language, the optimization of created solutions was conducted. The elimination of unnecessary points of robot or tool trajectory (minimization of unproductive kinematic chain movements while maintaining the collisions-free paths) and reduction of redundant program instructions (by the use of logic and program control instructions for creating robot macros for typical applications, instead of block teaching) were the main optimization criterions.

The method of off-line programming, sample program optimization and virtual visualization and simulation in K-ROSET software are presented on the Fig. 2.

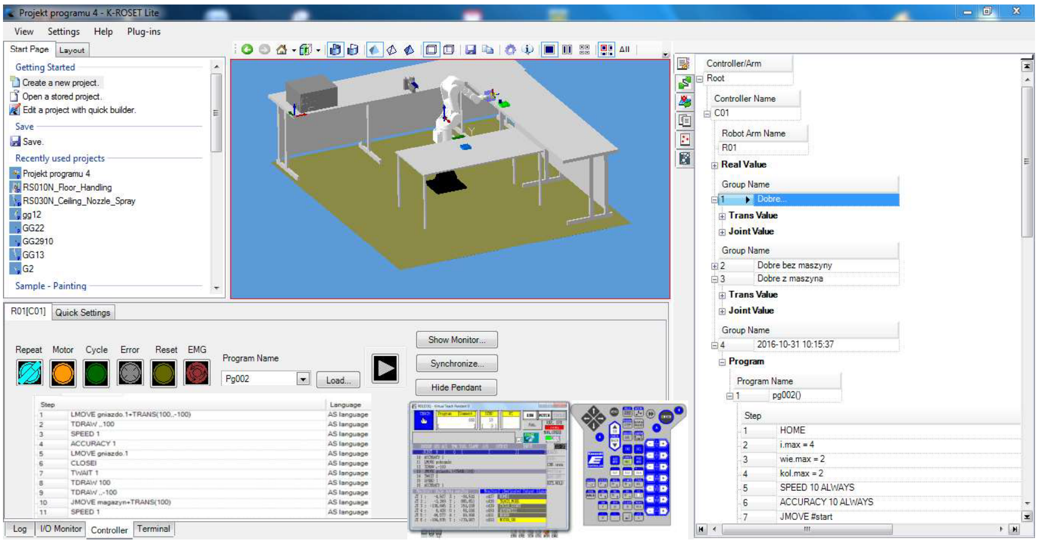

Fig. 2. Off-line programming, program optimization and virtual simulation of robotized cell using the K-ROSET Lite 1.7.0 software

The main aim of realized researches and off-line optimizations was improving the performance and productivity of robotized cell, and speed up process of Kawasaki robots off-line programming by creating user defined subprograms and macros for typical or untypical solutions (manipulation, palletizing, machining, rapid prototyping and other).

Parallel to the works and researches on off-line programming and optimization, the real components of robotized cell were fabricated. Some of them (gripper clamps, pallets) were produced using modern 3D printing rapid prototyping method. Other equipment was manufactured by classical machining methods. Some dimensional problems connected with precision of fabricated elements can occur. Therefore, the main problem with correct robot calibration, can be associated with the reference point of scene coordinate system.

Off-line created and optimized, in the terms of accepted criteria, programs were uploaded into robot control system and tested successfully, according with the safety principles, on the laboratory station.

3. Future works, researches and conclusion

Further works on the development of the laboratory station with Kawasaki RS005L robot require its expansion of other components like: robot tools (double gripper, vacuum surface gripper, automated tool's changer, spot welding and painting simulator, milling tool or 3D printer etc.), external equipment (external I/O and vision system, CNC machines and warehouses, safety system) and other robots. It is necessary to do future researches on programming and optimization of multi-robots cells for standard (e.g. spot welding, painting) and atypical (e.g. rapid prototyping and multi-tool machining) solutions.

Data obtained during Kawasaki robot off-line programming and K-ROSET modeling will be used in product lifecycle management class simulation software (PLM) and in software for production and logistic flow optimization (e.g. Enterprise Dynamics 8, Flexsim 7, etc.). It gives possibility of creation effective enterprise production and logistic system before its real implementation and later allows to optimize the performance of the structure and realized processes. This is consistent with progress towards digital manufacturing.

References

1. Shivanand H., Benal M., Koti V.: Flexible manufacturing system. ISBN: 978-81-224-1870-5, UVCE, Bangalore, Karnataka 2006.
2. Gołda G., Kampa A.: A micrologistics system analysis on example of robotized rapid prototyping cell. Selected Engineering Problems vol. 5, Gliwice 2014, pp. 37-40.
3. Gołda G., Kampa A., Paprocka I.: The application of virtual reality systems as a support of digital manufacturing and logistics. IOP Conference Series: Materials Science and Engineering. vol. 145-042017, doi:10.1088/1757-899X/145/4/042017, 2016, (http://iopscience.iop.org/article/10.1088/1757-899X/145/4/042017/pdf, access: 23.09.2016).
4. Sękala A., Gwiazda A., Foit K., Banaś W., Hryniewicz P., Kost G: Agent-based models in robotized manufacturing cells designing. IOP Conference Series: Materials Science and Engineering. vol. 95-012106, doi:10.1088/1757-899X/95/1/012106, 2015, (http://iopscience.iop.org/article/10.1088/1757-899X/95/1/012106/pdf, access: 10.01.2016).
5. Pawlaczyk T.: The development of laboratory and programming the Kawasaki robot in AS language. Master thesis (realized under the direction of supervisor: dr. eng. Grzegorz Gołda), Gliwice, 2016.
6. Kampa A., Gołda G.: Rapid machining with industrial robot. Selected Engineering Problems nr 5, Gliwice 2014, s. 57-62.
7. Students' Science Club of the Design and Exploitation of Robotized Systems - unpublished researches on the flexible manufacturing systems modeling, simulation and robots off-line programming (realized under the direction of supervisor: dr. eng. Grzegorz Gołda), Gliwice, 2016.
8. Kawasaki Robotics GmbH. K-ROSET – Technical documentation, tutorial and help of the software, 2015.
9. Astor Sp. z o.o.: Utility software: K-ROSET - product and software description, (https://www.astor.com.pl/produkty/robotyzacja/oprogramowanie-narzedziowe/k-roset.html, access: 20.02.2016).