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A MICROLOGISTIC SYSTEM ANALYSIS ON EXAMPLE OF ROBOTIZED RAPID PROTOTYPING CELL

Abstract: The article presents a proposal of a robotized rapid prototyping cell configuration. This cell is treated as an elementary micrologistics system. The real example of existing system was described. The main aim of the researches is establishment and development of methodology for the analysis of complete, integrated logistics systems in a new product prototyping, production and assembly. Realization of the technology is developed for the purposes of the didactic processes and the research project, proposed by one of mechanical enterprise, in area of construction the prototyping cell with machining robots.

1. Introduction

According to current trends in the development of automated systems in product design and manufacturing use of industrial robot is growing. In addition to standard applications of industrial robots in typical production cells, like: fixing parts on the machines, part manipulation and handling, welding, painting, polishing, etc., a new proposals for the use of robot as a technological machine for rapid prototyping processes will appear, e.g.: milling, turning, 3D printing [1]. In conducted studies autors attempted to use a industrial robot (Fanuc ArcMate 100iB) in the processes of rapid prototyping a new parts and these production. The industrial robot is here both as a manipulation and technological machine. This should shorten the duration of the prototype manufacturing and reduce costs [2,3,4].

Proper planning of whole robotized system is essential to cope with the modern trends of shortening the time to produce the prototypes and striving minimize the manufacturing costs [3]. Therefore, robotized system is treated as an elementary micrologistics system forming part of larger, integrated system of material and information flow which is whole enterprise. So, we can use computer simulation tools for robots programming using off-line method (e.g. Roboguide software [5]) and application to analyse queueing systems and logistics (e.g. Enterprise Dynamics 8 software [6]). Results obtained during two-step simulation will be compared with actual measurements of the robotized rapid prototyping cell productivity to validate the correctness of the model. Then, we can start to use a properly functioning model to predict parameters of micrologistics system for prototyping or manufacturing, a new, different parts and products.

2. The robotized rapid prototyping system

The use of conventional machining technologies and incremental rapid prototyping techniques by robot as a technological machine is still on the margins of research. This is due to use in that process the classical and modern CNC machines or 3D printers [1,2,3,4]. Apply industrial robot only as a manipulation device in prototyping processes (treated as a job or single-batch production) by machining is too expensive. On the other hand, the working space limitations of typical 3D printers give possibility to make only small objects, besides that, the process is very long. Thus, the use of the industrial robot with six (or more) degrees of freedom, long-range arms, possibility of automatic tools and grippers change will allow for faster and cheaper production of individual prototypes. While trying to apply the robot for rapid prototyping we should remember about limitations like: stiffness of the kinematic chain, accuracy of robot positioning, payload depended on the manipulator size [2].

In the course of research the station with Fanuc ArcMate100iB robot (Fig. 1) was used (degrees of freedom - 6, maximum range of arm - 1373 mm, load capacity - 6 kg, position accuracy - 80 µm, semi-continuously regulated feed rate, the linear and circular interpolation). Due to parameters of the manipulator and pneumatic milling machine mounted in the robot wrist (nominal pressure - 6 bar, spindle speed - 2200 r/min, tool - end mill Φ 12 mm) the study was started from easy-machinable materials (styrodur - XPS, plastics, machinable wax).

Fig. 1. The rapid prototyping station with Fanuc ArcMate100iB industrial robot

The material was a XPS plate fixed on machining table. First, theoretical parameters of milling (cutting speed, feed rate, depth of cut layer, number of transitions, processing time) was calculated for different surfaces like: flat surfaces, fillets, chamfers, holes, keyways etc. Then experimentally the impact of processing parameters controlled by the robot was tested by changing their types and values. The range of changes was the following: type of interpolated movement (linear, circular in options: precise and with inaccurate),cutting speed: 20-80 m/min (dependent on the pressure, difficult for precise adjustment),feed rate of milling tool: 1-100 mm/s (the setpoint speed of the tool center point - TCP),depth of the cut layer: 0,5-5 mm.

During the tests the cutting parameters was chosen experimentally, so that surface accuracy is comparable with standard 3D printing. In view of the fact that XPS is easy to machining process, with its high compression resistance and low hardness, the cutting force influence on the machining accuracy is small (deflection of the kinematic chain and tool fixed in industrial robot wrist).

Considering the low cost of the material and short time of machining the application of industrial robot in the rapid prototyping process seems justified. In connection with the need to estimate the processing time of the any other prototype and minimize the time it was decided to treat the rapid prototyping station as a micrologistics system consisting of subsystems: production (robot and machining table), manipulation and transport (robot) and warehouses. For the analysis of the micrologistics system a creation of a simulation model was proposed. The productivity tests of the model are the next step.

3. The simulation of robotized rapid prototyping cell

Modelling of robotized rapid prototyping cell begins by choice of appropriate robot, creation of elements of robotized station and data acquisition on the shape and dimensions of the prototype (workshop drawing made in a CAD application, e.g. Siemens NX 8.5 [7] saved in the iges format). The next step is to prepare the off-line robot subprogram of the processing by defining the trajectory and motion parameters of TCP, relative to the starting raw material (machining operations) and subprogram with the trajectory of manipulation (transport, gripping and fixing of the workpiece on the station). In this case, it is necessary, to calibrate the robot and to define coordinate systems associated with the tool, workpiece, and other elements of the robotized station. As a computer simulation software the Roboguide (demo version - Fig. 2) was used [5]. Prepared off-line program, after optimization, was loaded into control system of the real Fanuc ArcMate 100iB and successfully executed [3].

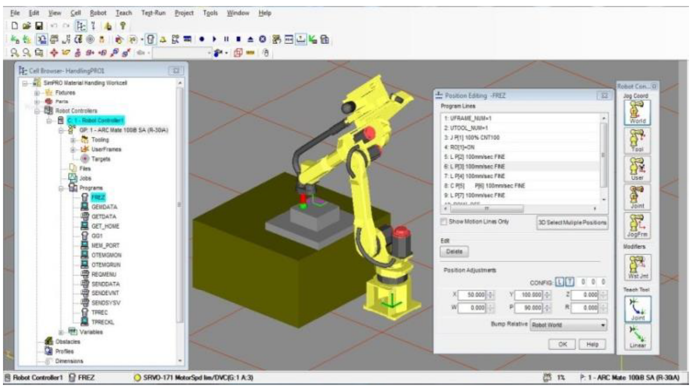

Fig. 2. Modelling of the rapid prototyping station in Roboguide software

During the simulation of rapid prototyping process, for different parts, in Roboguide software, the execution time of manipulation and machining was measured. Then the reconstruction of micrologistics system (robotized cell) was created in Enterprise Dynamics 8 - Logistics Suite (Fig. 3) [6]. A study of the system productivity was conducted. The main aim was a compare the results for two dedicated simulation systems to the next researches. A further target of these activities is the proper location of the prototyping station elements, selection the optimal material flow parameters (in storage, manipulation, transport and production operations) in order to minimize the total manufacturing time and the cost reduction of a new prototype.
The next stage will be to extend the existing micrologistics model of the rapid prototyping system to additional equipment, including more developed structures of the prototyping, manufacturing, assembly and logistics system.

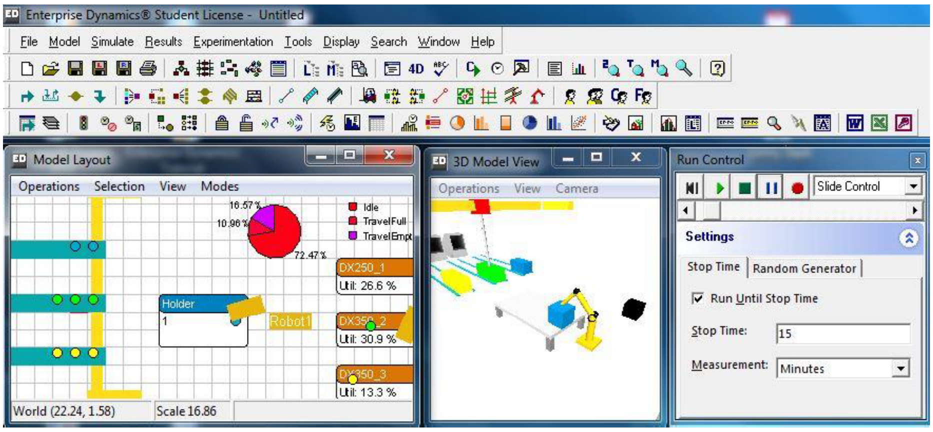

Fig. 3. The created model and productivity tests of micrologistics rapid prototyping system in Enterprise Dynamics 8-Logistics Suite software

This will estimate the time needed to produced batches of finished product using machining operations using industrial robots during rapid prototyping and production of final products.

4. Conclusion

At the article the proposal of micrologistics system analysis on the example of robotized rapid prototyping system are presented. Described methodology (simulation in virtual reality and real prototype manufacturing) is used during the laboratory didactic classes in the field of rapid prototyping techniques. Realized technology represents a preliminary study for the research project which consists in creation of rapid prototyping cell with machining robot. It's provides the basis for the further research on the use of computer simulation in an automated and robotized production using alternative methods for current manufacturing techniques. Activities in this area are intended to shorten the time from placing the order for a new product to its delivery to the final customer and reduce whole production costs.

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