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USING SERIAL INDUSTRIAL ROBOTS IN CNC MILLING PROCESESS

BY

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Abstract. Industrial robots are usually been used for pick and place tasks (welding, painting, soldering, mounting) because these processes require only point to point motion control. On the other hand, milling processes require trajectory planning and control, which are hard to be implemented for industrial robots. However, some CAM software packages have developed methods for using industrial robots in CNC milling. In order to do that, kinematic models of the robots have to be developed by the user. This paperwork presents the process of developing two such models for a KUKA KR 6-2 and an ABB IRB 1400 industrial robots.

Key words: kinematic models, industrial robots, CNC milling.

1. Introduction

Even CNC machine tools are the most recommended manufacturing equipment for the machine building industry, there are still some drawbacks

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linked with their use (Altintas, 2000). Most of these machines are able to control only coordinated 3 axis linear displacements, being so-called 3 axes milling machines. In order to manufacture complex shapes, 5 axes continuous control is required more and more often. However, 5 axes milling machine are still very expensive and not so widely available. This research tried to offer some solutions in order to use serial industrial robots, which have in fact 5 to 6 controlled axis for manufacturing.

Point to point movements requires an accurate reaching of the coordinates of the final point, without path control and is used for welding, painting and pick-and-place task (Zhang et al 2005). Serial industrial robots are well-suited for these tasks, because of their accuracy and flexibility. The robots are able to reach the final point of the trajectory for an unlimited number of movement cycles and the coordinates of point can be changed very easy.

Manufacturing processes, on the other hand, particularly milling, require an accurate control on the entire path (seen as the trajectory of the tool, or toolpath). Not only the coordinates of the final point have to be reached with great accuracy, but the tool has to pass to every point on the trajectory. Of course, the coordinates of the intermediate points are calculated using linear and circular interpolation algorithms. Using serial industrial robots for manufacturing processes is still a cumbersome process, due to two main reasons (COMET 20111, Chen & Hu, 199, Pan & Zhang, 2008). The first one is the difficulty of path control, which can frequently lead the robotic structure into singularity points. The second reason is the low rigidity of the robotic structure, which is not well-suited for cutting processes such as milling and/or drilling.

2. The 3D Kinematic Model of the KUKA KR 6-2 and ABB IRB 1400 Robots

This research was targeted to use the serial industrial robots KUKA KR 6-2 and ABB IRB 1400, which are available in the laboratories of “Lucian Blaga” University of Sibiu, for milling complex parts (Fig 1). For generating the toolpaths and the program for controlling the robot, the SprutCAM software package was used.

The CAM program is able to control the paths of the end-effecter of the robot, also keeping the robotic structure outside singularity points. However, it is also required to check the collisions between the mobile elements of the robotic structure. In order to do that, the user has to build a 3D kinematic model of the robotic structure, according to the following steps:

- building the 3D geometric model of the robot and saving it as .igs file (usually, the manufacturer of the robot provides this model. The 3D models used in this work was downloaded from the KUKA and ABB websites, http://www.kuka-robotics.com and http://new.abb.com/products/robotics);

- dividing the 3D geometric model into the main moving components of the robotic structure (together with the robot frame, which is fixed);

Fig. 1 − The KUKA KR 6-2 robobot (*a*) ; The ABB IRB 1400 robot (*b*).

- opening each component into SprutCAM workspace and saving it in .osd format;
- creating an .xml file which defines the kinematic and geometry of the robotic structure (SprutCAM provides a template .xml file, which can be modified by the user.

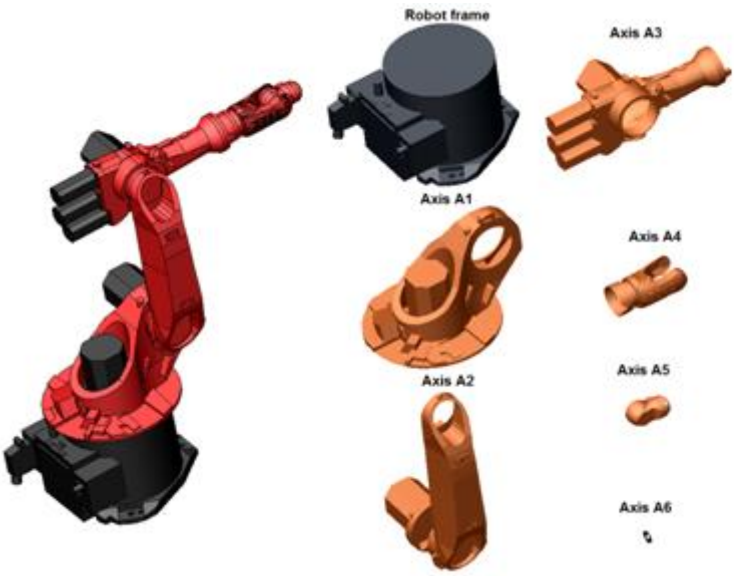

Fig. 2 − The 3D geometric model and the main modules of KUKA KR 6-2 robot

In Fig. 2, the 3D geometric model of the KUKA KR 6-2 robot is presented, together with the main moving components (modules). The main components are the robot frame and the rotational axes, from Axis A1 to A6.

In order to edit the .xml files, the dimensions presented in Fig. 3 (KUKA KR 6-2) and Fig. 4 (ABB IRB 1400) have to be measured on the robots and introduced within the files.

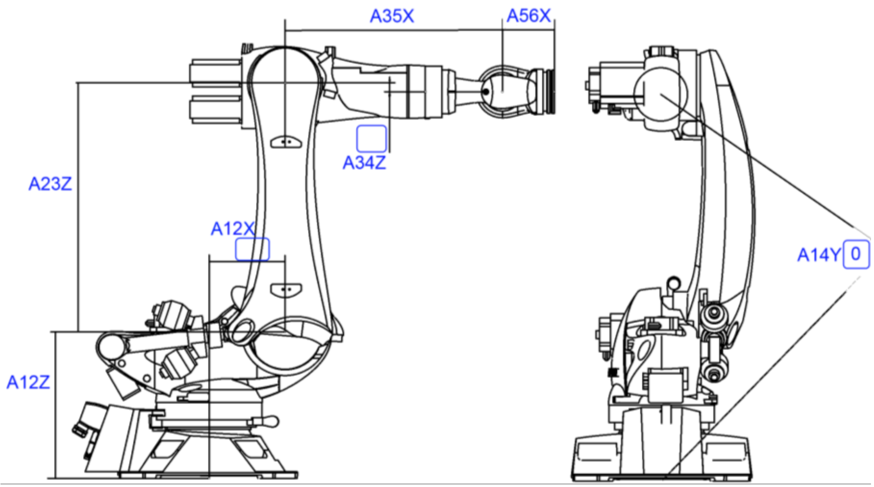

Fig. 3 – The characteristic dimensions of the robot which have to be introduced in the .xml file for KUKA KR 6-2 robot

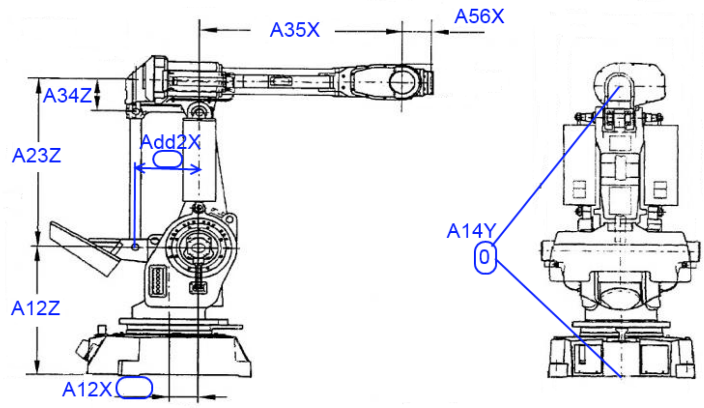

Fig. 4 – The characteristic dimensions of the robot which have to be introduced in the .xml file ABB IRB 1400 robot

Aside from the characteristic dimensions from Fig. 3 and Fig. 4, the .xml file should also include the angular limits for each rotational axis.

A synthesis of the linear and angular dimensions required for the 3D kinematic model is presented in Table 1.

Table 1
Dimensions for the 3D kinematic models

Linear dimension	*Value [mm]*	*Angular dimension*	*Maximum value [˚]*	*Minimum value [˚]*
KUKA KR 6-2				
A12X	260	Axis A1	185	-185
A12Z	675	Axis A2	35	-155
A23Z	680	Axis A3	154	-130
A34Z	-35	Axis A4	350	-350
A35X	670	Axis A5	130	-130
A14Y	0	Axis A6	350	-350
A56X	115			
ABB IRB 1400				
A12X	145.2	Axis A1	170	-170
A12Z	475	Axis A2	70	-70
A23Z	600	Axis A3	70	-65
A34Z	120	Axis A4	150	-150
A35X	720	Axis A5	115	-115
A14Y	0	Axis A6	300	-300
A56X	85			
Add2X	170			

3. The Milling Unit

In order to use the robots for milling processes, a milling unit, as robot end-effecter had to be designed (Fig. 5).

Fig. 5 − The milling unit

A Proxxon Micromot 50/EF milling/drilling machine was used as working unit, together with a Proxxon Micromot NG 2/E voltage transformer. The unit allow a continuous speed control between 5000 – 20000 rpm and has an overall weight under 2 kg. Also, due the reduced working voltages (between

12-18 V), the systems allows the use of coolants. The overall power requirement for the milling unit is 40 W.

Fig. 5 presents the milling unit consisting of the milling/drilling machine, the fixing elements and the mounting flange, coupled with axis A6 of the robot, which were design and produced by the authors.

4. Simulation

In order to generate the program for driving the milling unit of the robots, the SprutCAM software was used which is able to generate the toolpaths for manufacturing the parts and also to perform a realistic simulation of the manufacturing process.

The software package is also able to post-process the generated CL DATA file (cutter locations data file) intro a control program of the robot using KUKA and ABB specific programming syntax.

By means of the 3D kinematic models developed by the authors, any collisions, not only between the tool and the part but also between the moving elements of the two robotic structures, which may occur during the milling process could be identified and removed.

Fig. 6 and Fig. 7 presents a screenshot of the 3D kinematic models of the two robots during the milling process. The screenshots were captured during the roughing phase, at the beginning of the manufacturing process.

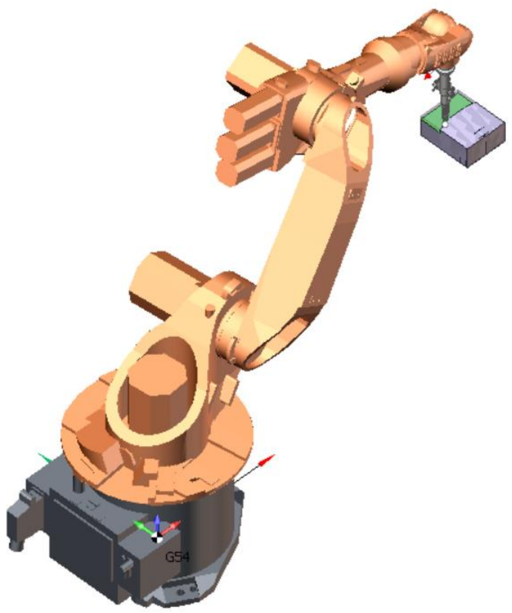

Fig. 6 − Screenshot from the milling process simulation – KUKA KR 6-2

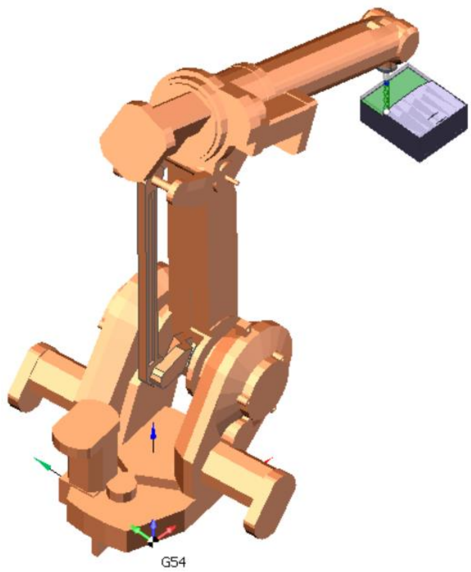

Fig. 7 − Screenshot from the milling process simulation – ABB IRB 1400

5. Conclusion

This paper introduces an approach of using serial industrial robots for manufacturing parts by CNC milling instead of using classical CNC milling machines. Two 3D kinematic models which allows the user to identify potential collisions between tool and workpiece and between the moving elements of the robot were built for a KUKA KR 6-2 and an ABB IRB 1400 robots. Also a milling unit used as end effector for the robots was designed and physically implemented. The milling unit was also included in the 3D kinematic models.

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UTILIZAREA ROBOȚILOR INDUSTRIALI SERIALI ÎN PROCESELE DE FREZARE CNC

(Rezumat)

Roboții industriali sunt utilizați de obicei pentru sarcini care presupun poziționarea precisă a unui efector final (cum ar fi sudura, vopsirea, lipirea, montajul) deoarece aceste operații necesită doar un control al mișcării de tip punct cu punct. Spre deosebirea de acestea, procesul de frezare necesită o planificare și un control al traiectoriei pe toată durata prelucrării, deoarece în acest caz, pe lângă atingerea cu precizie a punctului final, este importantă și respectarea formei piesei prelucrate. Controlul traiectoriei este dificil de implementat în cazul structurilor robotice seriale, din cauza posibilității apariției punctelor de singularitate. Cu toate acestea, unele soluții software de tip CAM au dezvoltat metode și strategii care permit utilizarea roboților industriali în procesele de frezare. Pentru aceasta, este necesară dezvoltarea de către utilizatori ai unor modele cinematice pentru roboții utilizați. Lucrarea prezintă dezvoltarea acestor modele pentru roboții KUKA KR 6-2 și ABB IRB 1400.