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DESIGN AND ANALYSIS OF ROBOT MANIPULATOR WITH CATIA V5 R14

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ABSTRACT
Simulation of robot manipulator motion in a highly productive and intuitive environment is an attractive area of investigation.
Generally, the purpose of this paper is to show an importance of simulation during development and design of production process. Simulations can help the constructor of real manipulator to define required technical specification of manipulator in phase of production process design. Simulation is used as a communication tool to functional and technical specifications and allows constructor to see how all components of production system would be work together as whole system.
This paper focuses on a kinematics simulation of manipulator. It's developed model of three link planar arm which end-effector moves in a straight line and constant orientation. Simulation of manipulator motion is performed using program CATIA V5 R14 – DMU Kinematics Simulator. It allows creating model of mechanism easily and in a short time so that its motion can be tested in virtual environment by simulation before real-time work of mechanism in real environment.
Keywords: kinematics simulation, kinematic model, CATIA V5

1. INTRODUCTION
Today, simulation of system becomes very attractive area of investigation and power tool in design and optimization system. One of most important reasons is that simulation allows design system in the short time and quickly analyze of its work in virtual environment before committing of physical prototype testing. Also, simulation is the best way to observe collision between parts during assembly of complex system, collisions between components during their motion, etc.
By re-running of simulation, after changing of some geometrics parameters in mechanism model, it permits analysis accomplished effects on behaviour system that leads to optimization of mechanism design. Software products for simulation of mechanism motions, in the most cases, have possibilities to observe the time changing of some parameters and analyzing of them. There are many software products, used for simulation of mechanism motion as ADAMS, Matlab, Pro/Engineering and Mechanism/Pro, etc. In this paper, it's used CATIA V5 R14 for design, simulation and analysis of three link planar arm motion.
From kinematics viewpoint, robot manipulator is set of bodies with constrained motions among them. Mostly, whereas bodies have small length and relatively large cross-section, bodies can be treated as rigid. In [7] it solves the inverse position kinematics problem of manipulators with double universal joint wrist. Also, numerical singularity analysis is presented for manipulators with offset wrist in [7].
As pointed out in [8], kinematic simulation can be realized in a few steps, Fig.1. First, it's necessary to draw 3D model of links in *Part design* module, after that it creates mechanism in *DMU Kinematics* module, where all kinematic stuff will be placed, for example fix a part. The third step is defining of joints where CATIA V5 R14 allows creating revolute, prismatic, cylindrical, screw and spherical joint, after that it's necessary applied commands to joints which represent the motion forces.

2. KINEMATICS OF ROBOT MANIPULATOR

In order to show importance of simulation, three link planar arm (Fig. 2) is considered in this paper. It consists of three links connected with three revolute joints with angle rotations θ_1, θ_2 and θ_3. The direct kinematics model of this structure is given in [2,6].

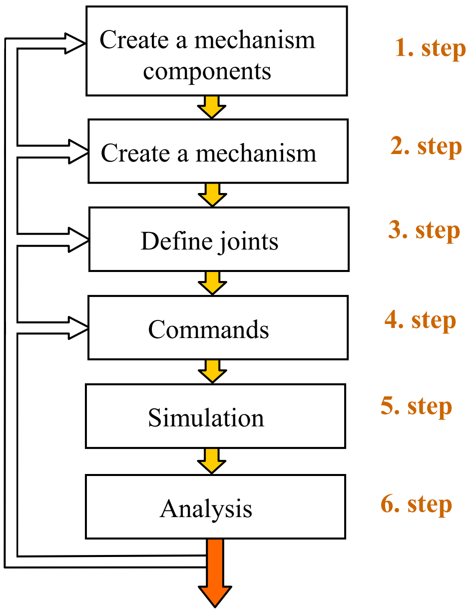


Figure 1. Simulation steps

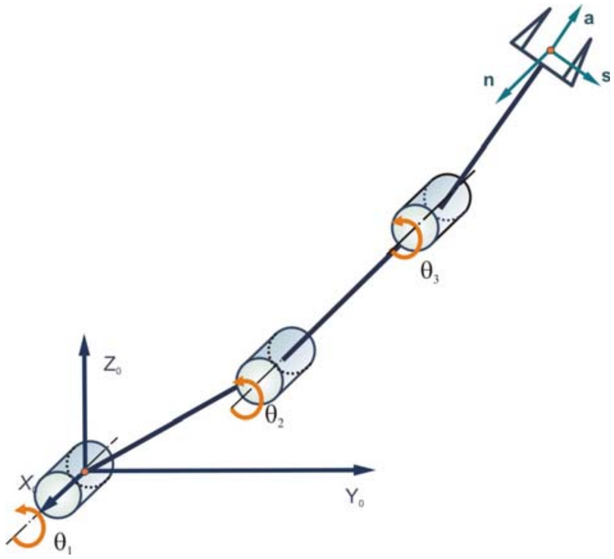
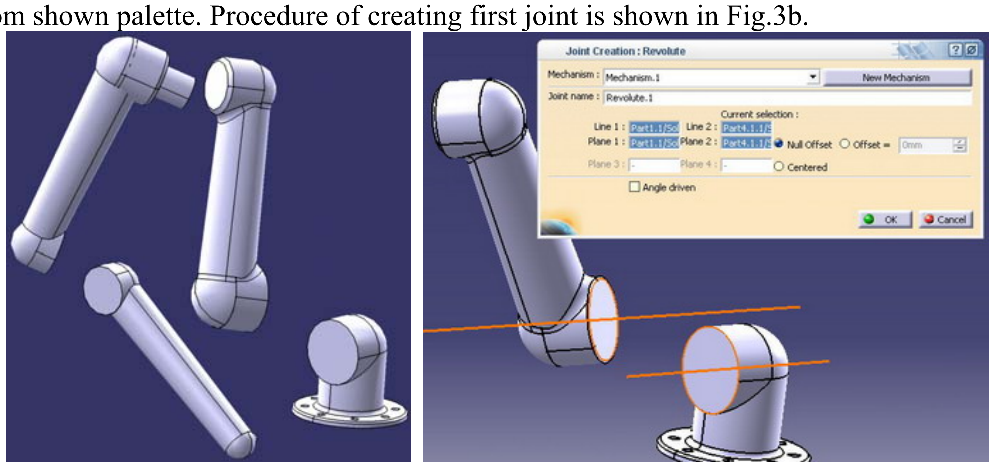


Figure 2. Three link planar arm

For simple kinematic structure as three link planar arm, it's possible to find closed form of inverse kinematics and it's also given in [2, 6].

3. MECHANISM DESIGN

After all mechanism components are created in *Part design module*, mechanism design can be realized in following sequences: introduction step by step previously created components using command *Insert→Existing components*, Fig.3a, create of the mechanism with command *Insert→New mechanism,* select the base as part which remains fixed by command *Insert Fixed Part*, create joints with command *Insert→New joint*, where in the case of three link planar arm it's chosen revolute joints from shown palette. Procedure of creating first joint is shown in Fig.3b.



a) *b)*

Figure 3. Design phases of robot mechanism in CATIA V5 R14

With command *Apply material,* it's assigned material - steel to the created mechanism. Finally, it's necessary to define a command for each degree of freedom of mechanism. For revolute joint it needs to define one command (Fig.4a).

a) b)

Figure 4. a) Apply command to joints, b) Information about successfully mechanism design

Information, shown in Fig. 4b, confirms successfully performed previously mentioned design steps.

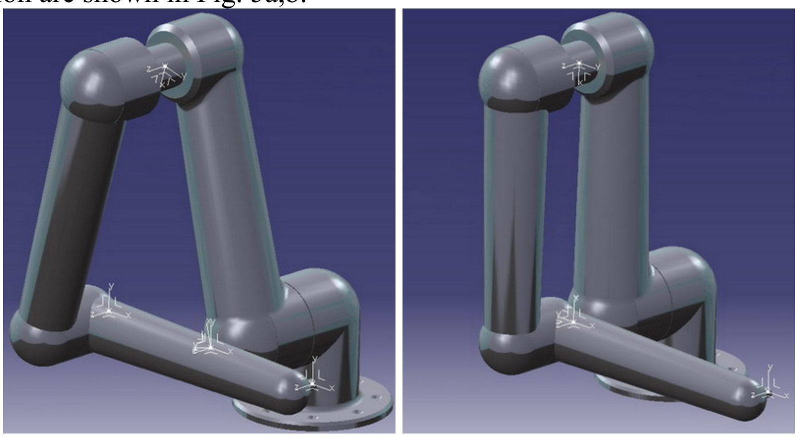
4. KINEMATICS SIMULATION

As pointed in [5] the simple kinematics analysis gave an important input to optimization of mechanical design of robot: "The workspace shape and size for a jointed manipulator might be substantially improved, if the manipulator links are the same length and the wrist link is as short as it can be designed", so that length of each link is assumed of 0,5m. Tip of arm follows a straight line with constant orientation. Trajectory is defined in workspace by:

$$\begin{matrix} X = 0,25 + 0,14 \cdot t,\ Y = 0,\ Z = 0;[m] \\ \phi = 0,[rad] \end{matrix} \qquad 0 \le t \le 5,[s]. \tag{3}$$

The coordinates *X*, *Y* and *Z* determine the end-effector position, while its orientation is determined by angle ϕ formed by the end-effector with the axis X_0 of fixed frame and it is given by the sum of joint variables.

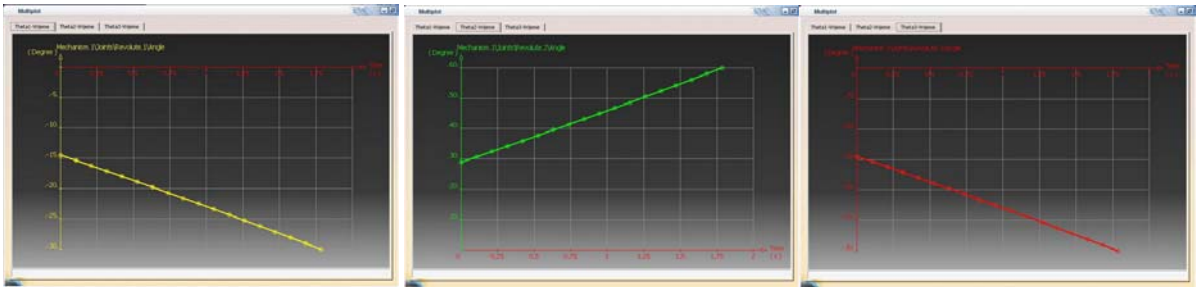
CATIA V5 allows performing simulation motion on two ways: First, by *Simulation with Command* where it's necessary define boundary angles for each degree of freedom and time needed for motion. Second way is realized with *Simulation with Laws*, where it fills in expressions which represent joint variables in term of the time. Second manner is chosen herein [4], because end-effector has to follow trajectory defined by (3). Introduction of Eq.(3) in inverse kinematic model gives expressions of joint variables in term of the time. Filling in of mentioned expressions is realized with *Tools→Formula f(x)→Add Formula*. Simulation is performed over 1,7857 s. Postures of three link planar arm before and after simulation are shown in Fig. 5a,b.



a) b)

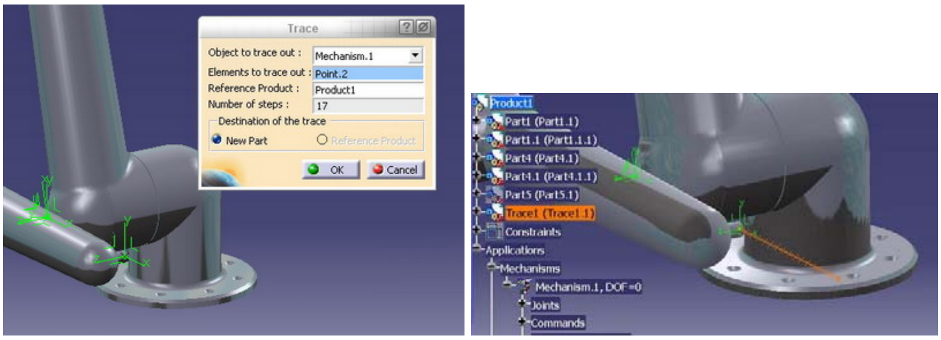
Figure 5. Posture of three link planar arm: a) before, b) after simulation

Time histories of joint variables are shown in Fig.6a-c.



a) b) c)

Figure 6. Time history of joint variable of: a) first, b) second, c) third joint



a) b)

Figure 7. a) Window of command Trace, b) Written trajectory

CATIA V5 R14 permits tracking trajectory of some mechanism point with command *Trace* during simulation. It's necessary to define point which will be tracked and part of mechanism as referent in which trajectory will be tracked (Fig.7a). This allows to see trajectory as shown in Fig.7b.

5. CONCLUSION

Simulation of three link planar arm whose trajectory is given in workspace is carried out in this paper using CATIA V5 R14. Simulation gives virtual representation of task performing, enabling verification planned trajectory, disclosure possible collision between mechanism and virtual environment, collision between parts during their assembly without performing of expensive experiment with real systems. One of future investigation directions is development of complex virtual environment which will represent of real environment of real work process. CATIA with modules enables simulation of industrial manipulators, but for more complex simulation processes, for example simulation of robot manipulator in TIG welding process, it's possible to use software product Delmia, also of Dassault Systemes.

6. REFERENCES

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