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# KINEMATIC AND ANIMATION MODELING OF LINES OF PRODUCTION WORKS

*The paper presents cinematic and animation modeling of the movement of production robots. On the basis of the developed dynamic model the task of function of time for hinged coordinates is realized in the UM Input program. Animation of movement of links of work KR5 that allows the decision of problems of kinematics and dynamics is carried out. The capabilities of the software package "Universal Mechanism" allows you to create control systems that implement the kinematic and dynamic laws of control for the created robotic systems.*

***Keywords**: production robot, 3D model, dynamic model, model conversion, motion modeling.*

*У роботі представлено кінематично-анімаційне моделювання руху виробничих роботів. На основі розробленої динамічної моделі реалізовано в програмі UM Input завдання функції часу для шарнірних координат. Проведено анімацію руху ланок робота KR5, що дозволяє вирішення завдань кінематики і динаміки. Можливості програмного комплексу «Універсальний механізм» дозволяє створювати системи управління, що реалізують кінематичні і динамічні закони управління для створюваних робото-технічних комплексів.*

***Ключові слова**: виробничий робот, 3D-модель, динамічна модель, конвертація моделі, моделювання руху.*

## Problem's Formulation

The rapid development of robotics is due to the rapidly growing interest and high activity of specialists in research, education and production spheres. The priority direction of the development of robotic systems at the current level is the development, creation and implementation of an advanced system of automated design and control. Currently, the development of industrial robots consists of the creation of software modules for automated formation, and the study of mathematical models of the dynamics of robots both in general and their individual functional parts.

On the basis of technical achievements in the fields of mechanics, automation, electronics and informatics, the creation of electro-mechatronic systems is carried out, which are based on the coordination of the design principles of physically disparate components of mechanical and electrical systems. Such composition ensures the design and production of qualitatively new production robots with intelligent control and functional movements and ends with the transition to qualitatively new types of technology, which are widely covered in the scientific literature [1—3].

## Analysis of recent research and publications

The stages of the process of evolutionary development of robotic modular systems are described in works [4—6]. In these studies, the obligatory application of complex calculations of the structural parameters of robots is emphasized.

Most of the publications devoted to the creation of robots mainly reflect the design features of various models of machines of this class, as well as examples of their application in industry. Recently, works have begun to appear in which research is analyzed in certain areas of this important technical problem, especially areas related to the dynamic, intellectual, and sensory abilities of robots [7].

At the stage of preliminary assessment of the motor capabilities of production robots involved in technological processes, computer modeling of movements is used, which requires a large number of calculations. In mechanical engineering, robotic systems are used to perform a variety of tasks in order to create and produce qualitatively new high-precision products.

## Formulation of the study purpose

With the development of scientific and technical progress, it became clear that in order to increase the efficiency of the production of new parts, it is necessary to reduce the machine time for operations. To do this, it is necessary to calculate the exact parameters of metalworking, the time to install the workpiece to the clamping device and change the gears in the machine, which makes it possible to make the actions of the machine as accurate and repeatable as possible [8].

The purpose of this work is to reduce the time of calculation of changes in the generalized coordinates of robots and to reduce the trajectory of movement. Solving this problem allows for an increase in the productivity of a real robotic complex.

## Presenting main material

Production works used in mechanical engineering are complex spatial mechanical systems with five or six degrees of freedom, and sometimes more, which makes their modelling in a kinematic setting a difficult mathematical problem. At the same time, if you try to move from a kinematic animation simulation of movement to dynamic modelling, which describes the real behaviour of the simulation object, the analytical construction of a mathematical model of such a complex object as a production robot will become practically impossible [9]. Therefore, special computer systems of automated design, so-called CAD systems (computer-aided design), are used to model complex mechanical systems.

To create a 3D model of a production robot, the KOMPAS-3D CAD system can be used, which has all the necessary tools for building complex 3D models, including the creation of assemblies, which will be necessary for building a dynamic model.

Assembly of a 3D model of a production robot is performed with pre-designed parts and assemblies. The main components that determine the functional purpose of a production robot are links, which are rigidly connected parts.

We will use the ready-made 3D model of the KR5 production robot, available on the official website of the manufacturer — the company "KUKA Robotics" [10]. The 3D model of this robot, which is presented on the website in step format, will be loaded into KOMPAS-3D V12.

At the same time, the model file is converted into the format of this CAD system. The converted model will be a single 3D part consisting of separate bodies. Having selected the bodies, and the components of the robot, we will save them in separate files with the m3d extension. It is convenient to use numbering in the name of these files.

In fig. 1—3 shows the image of the zero link, which is the stationary base of the KR5 robot, and its third link, which performs rotational movements in the vertical plane. Next, a 3D model of the entire robot is assembled from the details corresponding to the parts of the robot and the assembly file is formed (Fig. 4).

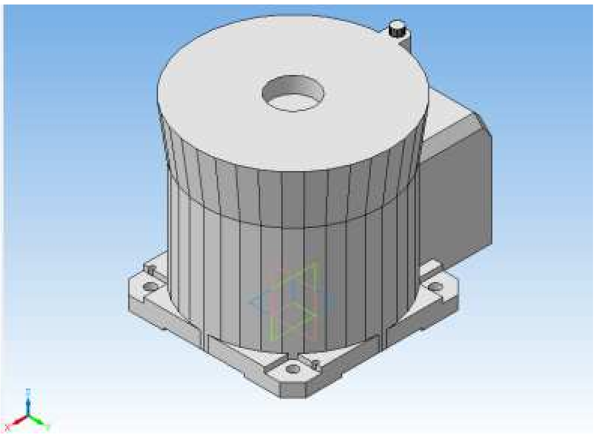

*Fig. 1.* 3D model of rack details

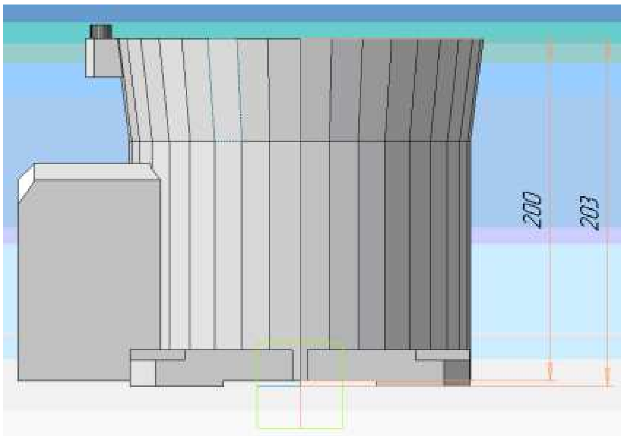

*Fig. 2.* The projection of the detail is stable

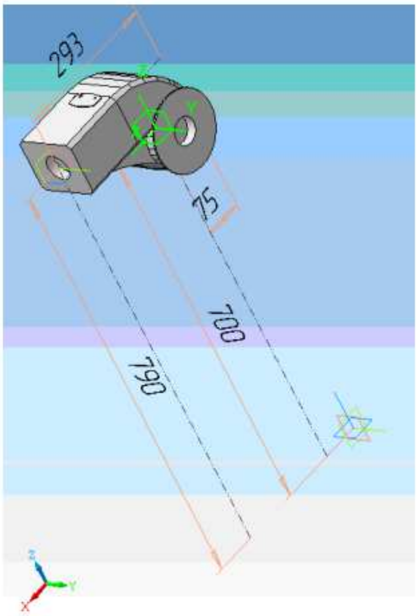

*Fig. 3.* The model of the third link

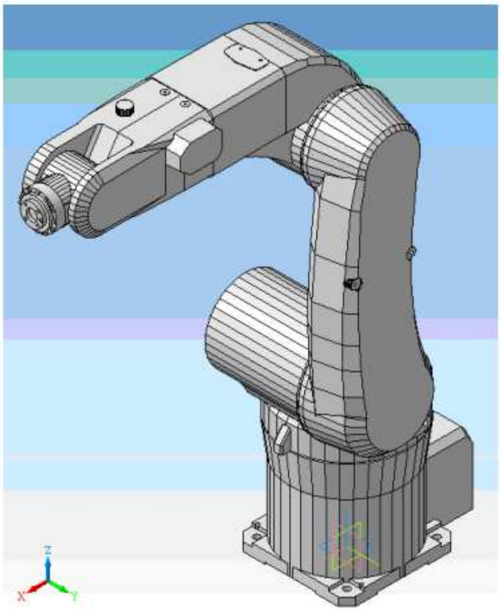

*Fig. 4.* 3D robot model

In addition to geometric images in the files of parts and assemblies, the CAD system stores information about the so-called mass-centering characteristics of the 3D model. These characteristics contain the value of the density of the material from which the parts are made, their mass and the coordinates of the centre of mass. To build a dynamic model of a production robot, we use the "Universal Mechanism" software complex [11] It is necessary to launch the UM Input program, which contains the necessary tools for creating dynamic models of complex mechanical systems.

To transfer a 3D model of an industrial robot to the UM Input program, you should use the menu commands of this program: "Tools" → "Import from CAD" → "COMPASS-3D". The feature of implementing data import requires that the corresponding CAD system be installed on the same computer as UM.

When executing the data import command, UM checks whether the application of the corresponding CAD system is active, in this case, KOMPAS-3D, and if it is not active, it starts this program and loads the selected assembly. At the same time, graphic images and mass-centering characteristics of each part included in the 3D model assembly are converted. After conversion, a new UM object is created. The UM object created during the conversion must contain the components of its body, which must be connected with each other by hinges. When converting the 3D model of the KR5 robot, an object consisting of 7 bodies is created by the number of parts Z0-Z6, corresponding to the links of the robot.

To simulate the movement of the KR5 robot on the basis of the developed dynamic model, we will use the possibility of assigning the time function for the joint coordinate implemented in the UM Input program. The program provides tasks of several types of the following functions: "Expression", "Function", "Schedule", "File", and "Curve". Let's choose the option to set the time function with an expression. For each joint, we set the expression wit, where wi (i = 1 ... 6) are variables that have the meaning of the relative angular velocity between the corresponding links (bodies) in this joint.

So, for the first hinge jZ1, the expression will have the form w1t. The value of the variable w1 must be set in a special window that opens after completing the time function expression. To ensure compliance of the created dynamic model with the real prototype, which has, unlike the model with five degrees of freedom, for the fourth joint jZ4, it is necessary to set the value of the variable w4 = 0. After completing the formation of the UM object, its dynamic model is saved in the input file. dat, which must be placed in a special folder (directory) with the name of the object.

Simulation of the movement of the object under study is carried out in the UM Simulation program, which can be launched directly from the UM Input program. The UM Simulation program implements a large set of tools for analyzing the movement of the object under study.

At the same time, it is possible to display an animation window on the desktop of the computer, in which the animation of the movement of the researched object will be displayed, as well as a graphic window for constructing graphs of the variables created by the researcher. Variables can be created by the variable wizard through the program menu: "Tools" → "Variable Wizard". As variables, consider the reactions (moments) jRMm (jZ1), jRMm (jZ2) and jRMm (jZ3 ) that occur in the joints jZ1-jZ3 during the execution of the movement for the given time functions, as well as the velocity projection v: x (Z6), v : y (Z6) and v : z (Z6) of the characteristic point of the sixth link (body Z6) in the basic (fixed) coordinate system.

Let's start the program for execution, setting the integration time equal to 16 s. In this example, the solution to the inverse dynamics problem for the KR5 robot is considered. The task is to determine the generalized forces, in this case, hinge moments, based on generalized coordinates, velocities and accelerations given by time functions for each of the joints of the dynamic model. The simulation results are presented in fig. 5.

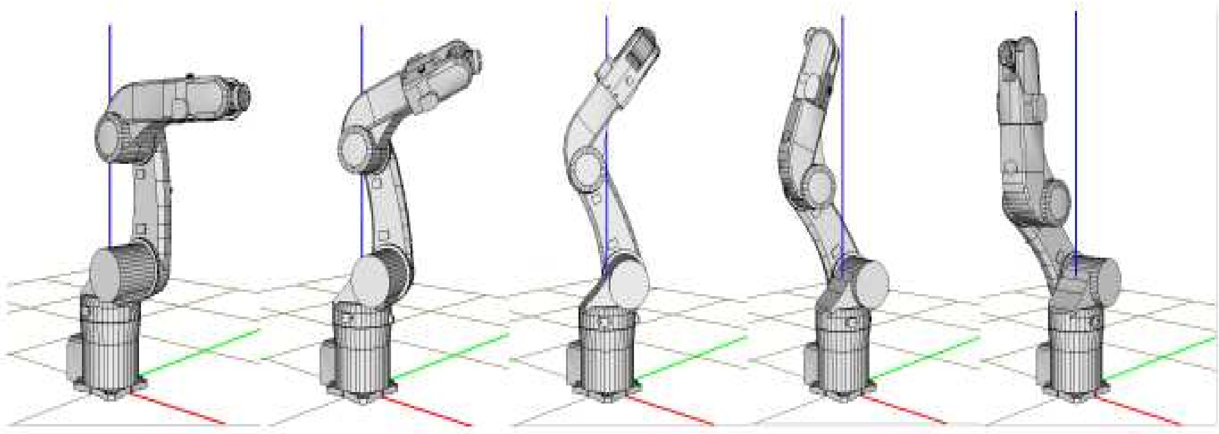

*Fig. 5.* Animation of the movement of robot links

Similarly, the solution to the direct problem of dynamics can be considered. For this, instead of the time functions used, the hinge moments must be specified for each joint. Such an opportunity exists in the UM Input program.

## Conclusions

1. An animation of the movement of the KR5 robot links was carried out, which allows for solving the problems of kinematics and dynamics.

2. The capabilities of the "Universal Mechanism" software complex allow you to create control systems that implement kinematic and dynamic control laws for robotic complexes.

3. In the future, it is possible to jointly model several objects, including several industrial robots and service technological and auxiliary equipment with them.

4. The possibility of modelling work processes related to material processing and ensuring the specified parameters of the quality of the surface layer of parts opens up.

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## КІНЕМАТИЧНО-АНІМАЦІЙНЕ МОДЕЛЮВАННЯ ЛАНОК ВИРОБНИЧИХ РОБОТІВ

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### Реферат

У машинобудуванні роботизовані системи використовуються для виконання різноманітних завдань з метою створення та виробництва високоякісних нових високоточних виробів. На етапі попередньої оцінки рухових можливостей виробничих роботів, які беруть участь у технологічних процесах, використовується комп’ютерне моделювання рухів, що потребує великого обсягу обчислень. Для попередньої оцінки рухових можливостей виробничих роботів, які беруть участь у технологічних процесах, використовується комп’ютерне моделювання рухів, що скорочує машинний час на виконання операцій. Необхідно розрахувати точні параметри металообробки, час на установку заготовки на затискний пристрій і перемикання передач у верстаті. Всі ці заходи дозволяють зробити дії машини максимально точними і повторюваними.

Для моделювання роботизованих систем використовуються CAD-системи (комп’ютерне проектування) — спеціальні системи автоматизованого проектування, які мають усі необхідні інструменти для побудови складних 3D-моделей, включаючи створення збірок. Основними вузлами, що визначають функціональне призначення виробничого робота, є ланки, які є жорстко з'єднаними між собою частинами.

Для моделювання руху роботи KR5 на основі розробленої динамічної моделі скористалися реалізованою у програмі UM Input можливістю встановлення функції часу для шарнірної координати. Крім геометричних зображень у файлах деталей і вузлів система САПР зберігає інформацію про так звані масоцентрувальні характеристики 3D-моделі. До цих характеристик відносяться значення щільності матеріалу, з якого виготовлені деталі, їх маса і координати центру мас. Здійснюється анімація руху ланок роботи КР5, що дозволяє вирішувати задачі кі-

нематики та динаміки. Можливості програмного комплексу «Універсальний механізм» дозволяють використовувати системи керування, що реалізують кінематичні та динамічні закономірності керування створеними робото-технічними системами.

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