METHOD OF STUDY ON PART OF STATIC AND DYNAMIC RIGIDITY OF TECHNOLOGICAL INDUSTRIAL WORKS

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Abstract: *The problem of ensuring high rigidity of technological industrial robots under their modular-modular design and manufacturing is considered. A method is developed for dividing the chain dynamic system of an industrial robot into composite elements to determine the static and dynamic characteristics of a structure in parts. Based on the application of transfer functions, the relations connecting the dynamic characteristics of individual elements with similar characteristics of the entire structure are derived. The obtained relationships make it possible to determine the characteristics of dynamic stiffness of individual structural elements, as well as similar characteristics of the entire system according to the characteristics of its elements. The developed research method is expedient for using in development and modeling of "one-armed" finishing robots in parts.*
Key words: *robot, rigidity, compliance, ellipsoid, chain system, subsystem, transfer function.*

In modern automated production facilities, technological industrial robots (IR) are used to perform mechanical machining operations near machines. At the same time, the accuracy of machining of parts depends on the rigidity of the elastic system working in the cutting zone (Fig. 1). Static stiffness of the "one-armed" work along the X axis is defined as $C_X = P_X / \Delta_X$. On other axes - is similar. In [1, 2], it is shown that in static, the elastic properties of a machining machine, in particular IR, are reflected in space in the form of rigidity ellipsoids or compliance with the center in the cutting zone, which are built on the main rigidity of the system. In dynamic modes of operation, the ellipsoid changes its size depending on the frequency of the acting force P.

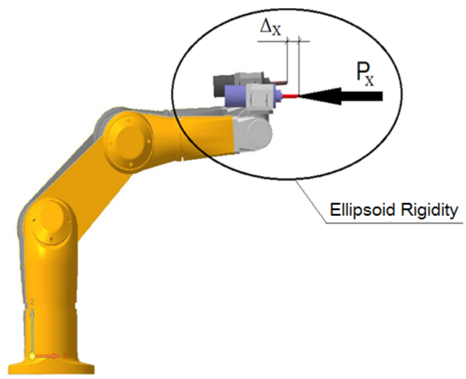

Fig. 1. The elastic properties of a robot machining:
PX - cutting force, ΔX - deformation

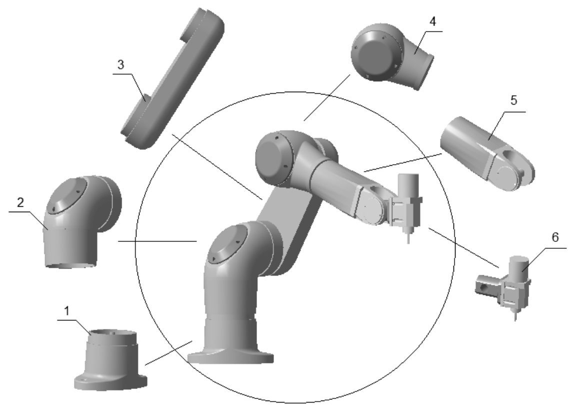

Fig. 2. Modular Robot Scheme:
1- base, 2-knee, 3-shoulder, 4-joint, 5-hand, 6-working body

A promising trend in the development of mechanical engineering is the principle of aggregation - the assembly of machine structures, including technological IR, from ready-made units and modules. Presence of unified elements, complete units, mechatronic modules allows creating various layouts of robots with a minimum of original elements (Fig. 2). This makes it possible to increase their flexibility, maintainability, ease of modernization, significantly shorten the terms of design and production, reduce the total cost of developing and manufacturing machines.

In the case of modular-modular design, the designer needs to know the static and dynamic characteristics of the individual elements (nodes, intermediate node, modules), on which it is possible to estimate the similar characteristics of the work as a whole. Most of the initial design parameters are determined by the characteristics of the elements quite simply, but the dynamic performance is an exception.

The aim of the work is to develop a method for dividing the chain dynamic system of a "one-armed" industrial robot into composite elements to determine the static and dynamic characteristics of the structure in parts.

Consider the dynamic model of the elastic system of "one-armed" work (Figure 3), which is a chain system with a finite number of n elements (nodes, intermediate node and parts). The elements are interconnected at joints, which are modeled by complex elastic-damping bonds $C = c + j \cdot h$, where c - is the joint stiffness, h - is the damping in the joint, and j - is the imaginary unit.

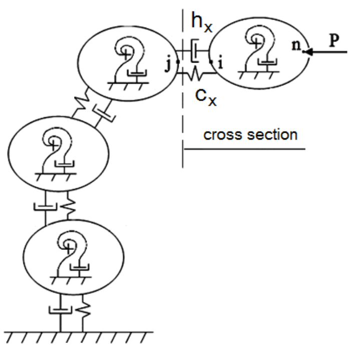

Fig. 3. Dynamic model of elastic robot system

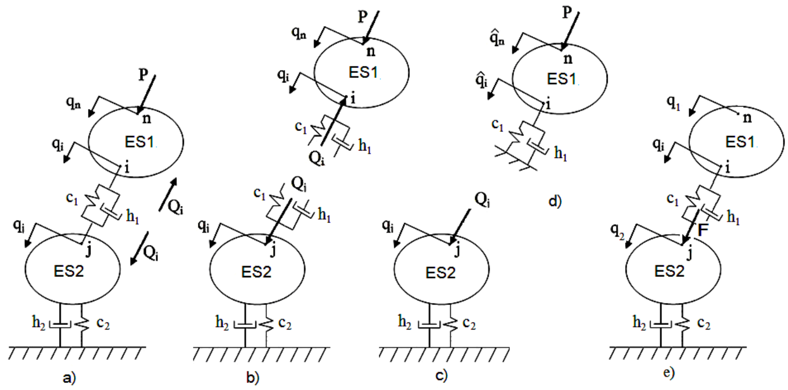

Fig. 4. A consolidated dynamic model (composed of two subsystems - ES1 and ES2)

In the cross-sectional areas along the joints of the elements (I, II, III, ...), a complete dynamic system can be conditionally divided into separate components of the subsystem. For example, we apply section I. As a result, we obtain a simplified integrated dynamic model of the IR, composed of two subsystems - ES1 and ES2 (Figure 4a). When the system is divided, the uncertainty of the non-anchored ES1 (Figure 4b) is overcome by fixing it to the "ground" (Fig. 4d). As a result, we obtain two separate fixed (partial) subsystems (Figures 4c, d), which can be investigated independently and obtained their characteristics in a calculated and experimental way.

To determine the elastic characteristics of the IR transfer function (TF) is applicable of the form S (p) and the corresponding S (iω) IF frequency, by means of which we obtain static (with ω = 0) and the dynamic characteristics of compliance of the whole structure and its parts [3].

We introduce new notation of the TF: for ES1 - V, for ES2 - U, for the whole system - W.

In the presented model the TF $V_{F_1}^{q_1}$ of the partial ES1 can be found in the complete system (Fig. 4e) from the matrix equation

$$V_{P_1}^{q_1} = W_{P_1}^{q_1} - W_{q_2}^{q_1} W_{P_1}^{q_2} \quad , \tag{1}$$

where the TF $W_{q_2}^{q_1}$ can be determined in a complete elastic system under the action of an external force F on ES2 (Figure 4e)

$$W_{q_2}^{q_1} = \left[W_{F_2}^{q_2}\right]^{-1} W_{F_2}^{q_1} . \tag{2}$$

The TF of a complete system can be found from the TF of its subsystems with the matrix equation

$$W_{P_1}^{q_1} = \left[E - V_{q_2}^{q_1} \left(E - U_{Q_2}^{q_2} C_{22}\right)^{-1} V_{Q_2}^{q_2} C_{21} \right]^{-1} V_{P_1}^{q_1} \quad , \tag{3}$$

where E - is the identity matrix.

These expressions show how a complete system to determine the TF independent partial subsystems ES1 ($V_{F_1}^{q_1}$ and $V_{q_2}^{q_1}$) and ES2 ($U_{Q_2}^{q_2}$), as well as in the known complex of $C = a + j \cdot h$

(units C_{21} and C_{22} of the matrix C) can pass from the TF subsystems ES1 and ES2 to the TF of a complete elastic system $W_{P_1}^{q_1}$.

In turn, the subsystem ES2 can be divided into component subsystems in a similar way, using, for example, section II. And so on sequentially along the chain (III, IV ...).

Thus, it is possible to find the static and dynamic characteristics of compliance of all constituent elements (nodes) of the IR in a calculated or experimental way.

Conclusions

The developed research method is expedient for using in the development and modeling of "one-handed" robots of chain type by parts (nodes), in particular, when analyzing and synthesizing their spatial elastic characteristics of stiffness or compliance.

This allows the design stage to determine the characteristics of the constituent elements of the static and dynamic spatial stiffness (compliance) of the cutting industrial robot design and construct the corresponding ellipsoids stiffness (compliance) of the elastic system. Based on the obtained elastic characteristics of the robot, it is possible to select the optimal processing regimes for processing and to predict the accuracy of the processed parts.

List of links:

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