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THEORETICAL ASPECTS OF AUTOMATED DESIGNING SPATIAL FRAMEWORKS FOR TECHNOLOGICAL AND MACHINE-TOOLS EQUIPMENT

Yuriy Kuznetsov[1*], Dmytro Dmitriev[2], Serhii Rusanov[2], Anton Omelchuk[2]

[1] *National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute", Kyiv, Ukraine*

[2] *Kherson National Technical University, Kherson, Ukraine*

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ABSTRACT

This paper describes the modern development trend for multifunctional equipment for the complex surface cutting, many-coordinate manipulation, 3D printing and the others processing. The paper purpose is to analyze the behavior of MPS equipment in relation to the use of typical processing strategies (embodied in modern CAM systems) and the conformity of the output trajectories (consequently, the final product quality) to the processing accuracy criteria, taking into account frame layout rigidity for the general external influences (cutting forces, etc.), as well as the establishment of an hierarchy of selected strategies. Based on the results of series of calculations, the preliminary recommendations made.

INTRODUCTION

There is modern development trend for multifunctional equipment for the complex surface cutting, many-coordinate manipulation, 3D printing and the others processing. This is the using of spatial hinge-rood systems on the basis of the mechanisms with parallel structures (MPS) [1, 2, 3]. The most widespread structures such as "delta", hexapod, tricept have already become traditional [4]. However, using of MPS as machine-tools, requires calculation the stress-strain effect for the end-effector position accuracy [5, 6]. Thus, the use of many kinematic schemes for MPS is limited by their rigidity (stiffness) parameters, which directly affect the processing accuracy. The equipment frame configurations set, with guides and moving carriages drives, is multivariate set and it depends on the geometric properties of the frame layout [7, 8]. In particular, such layouts are usually constructed in the form of regular polyhedral (prisms, pyramids, octahedral) with symmetry, but even include not symmetrical figures. This technological equipment has the anisotropy of the parameters of linear and torsional stiffness in the working space relative to the frame layout; therefore, in order to determine the possibility of using equipment layout, it is necessary to determine the frame stiffness map of the moving spatial rod system with a end-effector that changes shape and to determine the frame stiffness map of the frame elements during 5-coordinate processing [9, 10] with calculating of the processing forces. So it is necessary to take into account not only the considerable influence of compiling framework design, but also the mutual orientation of the "frame - workpiece – end-effector" system.

AUTOMATED DESIGNING SPATIAL FRAMEWORKS

The paper purpose is to analyze the behavior of MPS equipment in relation to the use of typical processing strategies (embodied in modern CAM systems) and the conformity of the output trajectories (consequently, the final product quality) to the processing accuracy criteria, taking into account frame layout rigidity for the general external influences (cutting forces, etc.), as well as the establishment of an hierarchy of selected strategies.

Response analysis of framework system for external load should do, on the one hand, the complete decomposition of some elements groups with separate links that can be implemented by the finite elements method, on the other hand, the accounting of processing complex mode, which can make a substantial nonlinearity. Simultaneously the feedback for the external load changes should be analyzed.

Analytical solution of such nonlinear problems is almost impossible, on the other hand, the use of automated systems of general purpose (such as ANSYS, COMSOL Multiphysics, etc.) also requires significant time-consuming on the formation geometric models, analysis and task relationships, etc., especially with regard to sufficient flexibility, and, as a result, the variety of configurations of the frame of the equipment. It is convenient to model the MPS equipment in various conditions, using specialized software package, such as the toolkit “ToolsGlide”, “ToolsResponse” and “ToolsApps”. This software package is made to calculate and analyze the kinematic, static, dynamic reaction of the gliding equipment without external

[*] Corresponding author. E-mail: tareon@ukr.net

load limitation and can be specified as arbitrary time function and internal parameters functions with the system feedback support.

The “ToolsGlide” block in the software package is designed to solve the inverse kinematics problem for the given frame layout. It is implemented in the “ToolsGlide” CAD module. In order to make calculation and create visualization the system requires importing an MPN file (m-file, point, normal). That file contains information on the processing script and the workpiece (normal and tangent to each node along the trajectory, idle markers, etc.). An MPN file can be obtained directly from the CAM environment (for example, as a modified CLData file), or by using of CAD systems. It has been developed two algorithmic variants for solution of the inverse kinematic problem.

In order to analyze the structural response to the working external load in the entire range of technological processing, the “ToolsResponse” module; – separates static and dynamic loads – passes through the data exchange between the corresponding modules: kinematics (direct or inverse problems) – static response (the formation of stiffness coefficients tensors) – dynamic response. In order to determine the locations and directions with given stiffness, “ToolsResponse” module allows to automatically receiving forms of the tensor ellipsoids and the compliance ellipsoids for the whole processing cycle. This software module simultaneously determines variable dynamic value of the elastic displacement of the frame system end-effector at the load location with the obtaining of the components of the tensor of the reduced hardness coefficients (linear and torque). For the analysis of the stress-strain state of frame assemblies in the “ToolsResponse” module uses finite-element models for plurality of structural objects (console, beam, polygon, etc.).

“ToolsApp” module performs calculation of the cutting force components according to the processing technological modes, the size of the support platform and according to dynamic characteristics (vibrocharacteristic).

CONCLUSION

Based on the results of series of calculations, the preliminary recommendations made. First recommendation is preference of lower position for the typical trajectories by z-coordinate in the machine-tool working space. Second recommendation is using of the inclined guides frame layout that greatly increases the layout rigidity (stiffness) in comparison with the parallel guides frame layout. Third recommendation is choosing strategies with the least number of acute angle transitions. The accuracy increasing in the considered MPS frame layouts can be provided by adjusting the end-effector original trajectory on steps with changing its movement direction and the trajectory curvature.

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