DEVELOPMENT AND USE OF METAMORFIC MACHINE SYSTEM

Defining the problem of development and use


The new metamorphic parallel mechanism proposed in this paper is based on a modular structure of metamorphic machine system. In the following, the process as well as the parameters of the task based kinematics design is presented. The structural as well as the kinematics indices used for optimization are described. Finally, concluding remarks and future research directions concerning task-based design are closing this paper.

Development of metamorphic structure

In research and development is metamorphic structure of mechanical systems (MMS) are characterized as a modular system with the ability to flexibly selfreconfigure own kinematic and functional structure for the targeted compilation of "new" machine with other functional properties and technical parameters.

Key words: producing technical, operating technical, machine system, metamorphic structure.

INTRODUCTION

One of the current tasks of theoretical and engineering tasks of manufacturing technique is innovation of approaches to the construction manufacturing machine, calling the need to extend its functional possibilities of not only expanding the scope of construction of kinematic structure of its action mechanism, but also flexible management of change functionality of kinematic structures (behaviour) when operating the machine. Approaches to the construction manufacturing machine to "classic" kinematic structures do not cover already existing requirements in particular the flexibility of the machine for multi-production manufacturing processes (change in product mix, changes to objects interactions, ...), respectively, the flexibility of the machine to the work function and operation status (changing work tasks, scheduling ...). How potential direction of the solutions of the new approach to the construction manufacturing machine begins to elaborate a theory of mechanisms with variable (variable) structure in the application form of metamorphic - self-guided machine structure (metamorphic - variability, metamorphic - convert / transform shape, form, metamorphosis - conversion, transformation, change in shapes). This direction give to manufacturing machines new quality (structure and scope of the structure, change function, change properties), based on the controlled reconfigurability its kinematic and functional structure, thereby when using the original machine modules creates limited new machine variants with desirable new features and parameters.

DEVELOPMENT OF METAMORPHIC STRUCTURE

DEFINING THE PROBLEM OF DEVELOPMENT AND USE

The paper presents the base of knowledge from the field of architecture and evolution of metamorphic parallel mechanisms (MPMs), which are a class of mechanisms that possess adaptability and reconfigurability to change permanent finite mobility based on topological structure change, were introduced. The contribution presents the characteristics of MMR, suggests theoretically to the design approach to solve them. It analyzes selected specific issues problems associated with their development use. MMR submit proposals for solutions, even as machine system on the principle of metamorphic - self-regulating structures.

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The main (kinematics) function of machinery and equipment, the execution status changes (position and orientation) of the manipulated object / tool O in the fiducially (reference) space from, i.e. O status (the effect of manipulation) is the expression of a certain type of relation R in the space Z.

\[ R(O; Z) = \varphi \]  

(1)

Kinematics structure of the machine and system determines its functional and physical characteristics in relation to the effect of the output of the action mechanism of the machine and device M (superposition of discrete movements of dance elements in the kinematic structure) to express them so. kinematic function FM. Function expresses relation RM function M and Z. This shall be expressed by the values of the features of the \( X_1 \), \( X_2 \), ..., \( X_n \) kinematics structure of machinery and devices, generated by the respective actuators based on the control instructions.

\[ RM (M; Z) = \varphi_M = FM(X_1, X_2, ..., X_n) \]  

(2)

The system model of the machine and device indicates that the output of the action mechanism M is attached to the final tool H, their mutual bond (position, orientation) is determined by the relation RH.

\[ RH (H; M) = \varphi_H \]  

(3)

In terms of the main functions of the machine and device is relation RO objects O with a tool H, similarly defined as

\[ RO (O; H) = \varphi_O \]  

(4)

subsequently state of the object O in the space Z, the relation \( \varphi_H \), \( \varphi_O \) (relations can be constant, respectively. variable), is a parent of a function \( \varphi \) of kinematic features FM

\[ R (O; Z) = \varphi [FM; \varphi_H, \varphi_O] \]  

(5)

while machinery and tools (implemented kinematic structure) have a constant relation \( \varphi_H \), \( \varphi_O \). An implementation of FM function in the general interpretation determine the characteristics of the kinematic chain machinery and tool with define character of the mobility (the ability to change the relative position between input and output, character of mobility is the principle of physical implementation).

Reconfigurability of kinematic and functional structures of machinery and devices, in these circumstances, means the development of movement structures by the management of variability relation RH and RO within the structure of machinery and device, development by increasing / decreasing the number of members, who implementing the kinematic function FM, development by increasing the proportion of active members (at the expense of passive) on the resulting mobility kinematic chain.

Principles changes kinematics structures can be derived from the theory of mechanisms with variable (variable) in accordance with changes in the structure and properties of the following forms:

1. Change the distance members kinematic chain.
2. Change the number of degrees of freedom mechanical system attached.
3. Change of use of hybrid connections.
4. Change the connection the other members of the kinematic chain.

Task- based kinematics design of metamorphic machine system can be stated as follows: Given a specific kinematics task or group of kinematics tasks synthesize the optimal structure of a metamorphic machine system and determine the optimal anatomy and task location in the metamorphic machine system workspace for task execution with the highest possible performance.

The design parameters of this problem are the following:

1. The number of DOF (number of the active joints) (n).
2. The number of the pseudo joints (p).
3. The succession of the active joints and pseudo joints in the serial Chin.
4. The relative position and orientation between the axis of the consecutive active joints and pseudo joints.
5. The optimal anatomy of the serial metamorphic machine system defined by the parameters \( \theta_{\text{p}} \) of the (p) pseudo joints for each task.
6. The optimal placement of each task in the workspace of the metamorphic machine system defined by the variables \( \theta_i \) of each active joint for a given anatomy.

In order to design an optimal performing metamorphic robot all these parameters should be taken into account simultaneously. This is a very difficult optimization problem since the design parameters are many and heterogeneous. The type of the universes of discourse of the parameters is either discrete (\( \theta_{\text{d}} \)) or continuous (\( \theta_{\text{c}} \)), while they are also either sets of objects (number and types of modules, succession of modules in the structure chain) or numbers (\( \theta_{\text{n}} \), \( \theta_{\text{r}} \)). For example, for a metamorphic structure with 3 active joints and 2 passive joints there are three possible combinations for the location of the pseudo joints in the serial kinematic chain, and a lot of combinations for the
relative orientation among them. This structure can be represented by objects, while the parameters by numbers.

An example of a metamorphic mechanism structured as such is illustrated in fig. 1 along with the process of its metamorphosis from its initial form to a required one. The mechanism consists of two active rotational joints, two rigid links and two pseudo joints which will facilitate its rapid reconfiguration. In fig. 1(a), the mechanism is shown at its reference anatomy, where all pseudo joints in the machine system lattice are considered to be at their starting configuration where their angles are set to $0^\circ$. Therefore in fig. 1(a) the pseudo joint angles are $\theta_a = \theta_b = 0^\circ$. In this reference anatomy the twists of the active joints $\xi_1$ and $\xi_2$ are parallel.

(figures 1(b) and 1(c)). The reconfiguration is conducted by first rotating pseudo joint b by $90^\circ$, which results in the anatomy depicted in fig. 1(b), where the pseudo joint angles are $\theta_a = 0^\circ$ and $\theta_b = 90^\circ$. Next pseudo joint a is rotated to $\theta_a = 90^\circ$ so the mechanism is transformed to the desired anatomy fig. 1(c) where the pseudo joint angles are $\theta_a = \theta_b = 90^\circ$. In the new metamorphosed anatomy the twists of the pseudo joints are perpendicular, while also the relative lengths of the mechanism have changed. Pseudo joints also allow the operator to achieve anatomies of a metamorphic machine system that are not currently favoured in machine design, i.e. in D-H representation presenting link twists different to the standard $0^\circ$ or $90^\circ$ of current machine systems or in screw representation consecutive joint twists being either parallel or perpendicular. The link twist is the angle between two successive joint axes (joint twists) if these are projected on a plane whose normal coincides with the mutual perpendicular to the successive joint twists.

During the design phase of metamorphic work cells the key issues to be addressed are, the determination of the degrees of freedom of the robot which are defined by the active joints, the structure (topology) of the metamorphic machine system, taking into account the type of the joints and the number of pseudo joints, the optimal anatomy of the metamorphic machine system for the highest possible task execution performance and the optimal placement of the task in the workspace of the metamorphic machine system.

CONCLUSION

The complex problem of solutions and metamorphic structures applications mechanical systems - MMS is gradually becoming a highly topical subject in theory but also practical multi-professional production techniques. It is a logical consequence of the changes of ratio cost to the differentiated and concentrated operations, the price of building components and modules as well as the impacts of the criteria for assessing the effectiveness, quality and agility. Subsequently the issue of MMS has its own space for a solution in conditions with high modularity their solutions which are widely applied principle of modularity.

REFERENCES AND NOTES


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