DEVELOPMENT AND APPLICATION OF 2D DYNAMIC MODULE

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The paper presents primer base of knowledge in the field of development of modules of machine systems, including their formation into specific assemblies in accordance with development, manufacturing and utilization strategy. The paper is based on elaborated strategy of architecture and development of reconfigurable machine systems, which was used at searching for new possibilities and principles of solutions and at elaboration of non-standard conceptions of 2D motion modules. In addition, the paper elaborates the module of machine system with integrated and reconfigurable effects with high internal and external compatibility. Elaborated reference structures of motion modules were used in practical phase of solution under construction of 2D motion module with reconfigurable impacts for synchronous movements in two axes, or for movements in one of these axes.

Keywords

producing technique, operating technique, dynamic module, integrated kinematics

1. Introduction

In machine systems research, the innovation tends to controlled and locomotion modules, related to their use in broad spectrum of demanding technical operations with optical systems and precision positioning. The development and application of the modular base is dominated by themes such as: adaptation, multi-functionality and reconfigurability of the locomotion module with an emphasis on complex, concentrated solution of functions within the machine node. Innovation in the use are focused on building elements, i.e. consistent results with the drive mechanisms of transfer and transmission of energy, organization, control and sensor technology.

2. Solutions specific

A. Focus

The related subject of "motion modules" are supporting lines of the ultralight gear mechanisms based on new types of materials, drives with high redundancy, the emphasis is on testing of propulsive nodes under extreme dynamic regimes, increasing positioning accuracy and flexibility of control. In terms of compact solutions it comes to the search for new principles of transformation and development of functions of motion modules [Valencik 2000] for an efficient adaptive method for movement control in one, two or more axes.

Therefore the focus on adaptation, multi-functionality and reconfigurability should be closely linked to flexibility and variety of product supply, particularly in terms of the following issues:

- variety of uses of the engine type, sensor technology, mechanical components and their link to the type of control system used in the machine and production system,
- flexibility and positioning applications of propulsive mechanisms in supply as a tightly integrated machine system sets or custom applications required by client as an additional equipment to new or rebuilt machinery and production system,
- modular solutions applied in a wider range of products to accept the type of representatives from simpler cheaper to the ones demanding sophisticated solutions with an emphasis on high accuracy and reliability of the module,
- designing motion modules as mechanotronic units with the necessary aggregation of mechanical, electronic and control functions, compatible with the required technological functions in the machine and production system.

B. Object

The object of solution is a motion module (MM), which represents a positioning node in terms of design and a landmark node of machine system. MM configuration is derived from the principles of power generation, its method of transformation of mechanical movement and operation of power transmission components. Integration of individual functional blocks is emphasised (drive, transformation and transmission of kinetic energy drive), which is further developed into the integration of multiple motion axes forming a complex unit. The specific of the solution is an immediate adaptability to technological regime changes of machine system, peculiar to the new technologies.

3. Definition of New Principles and Solutions

A. Definition of motion module

There has been accepted certain definitions for the needs of project configuration of motion module production from the point of view of user as well as design perspective:

- *2D motion module* is compact mechanotronic solution. It combines engine, transformation and transmission unit, work table fixing in a given position and a movement sensor attached on the drive or the work table.

- *2D motion module* is a standard or custom product providing the required functions of tool positioning or workpiece positioning in one or two NC axes. It is technologically compatible with a certain group of modules of other machining and production systems. In this case, its technical characteristics are closely tied to the final determination of technology focused on the workpiece which is produced by the machining system. The 2D motion module can be designed according to the base of verified motion modules with the accessories from the basic technology focus. Following such method, we can achieve maximum degree of modularity and optimal choice of technical parameters in relation to the price of the product.

B. Principles of development

Present practice is based on serial linked units implementing kinetic functions in addressing the concentration of functions and activities. Such solutions require increased demands on the spatial arrangement of elements and for the overall concept of kinematics chain, as well as the implementation costs. This encourages the development of new solutions concentrating kinetic functions into a single point in a compact integrated design. The question is characterized by the integration of solutions:

- multi axial motion module concentrating mechanism movements,
- multiple motion module driving the mechanism,
- adaptable motion module regulating the speed of the mechanism.

Each of these solutions corresponds to a specific concept [Valencik 2000, 2004]. Multi axial 2D motion module is described and elaborated in more details.

4. Non-Standard solutions concepts

A. Impact Factors

Motion modules are the most variable elements of machining system with regard to the immediate connection with the reference, bridging, tool and workpiece modules and transposing the interaction between the workpiece and the tool. However, the design is the problem. In order to meet clients requirements and demands there have been developed different scopes for the design using

present technologies, applications and capabilities now available. This observation, in relation to the potential practical requirements of applications of motion module, opens the search for methodological tools and technical support focused on engineering training for the modernization and development and the use of motion modules [Valencik 2011].

Analysis results of machining systems applications show that the motion module solutions are affected by several factors and functional ties, which affect the overall effectiveness of the application. Some of them are:

- analysis of nature of application environment (the subject of an interactive environment, design and technology linkage, interaction) confirms the fact that motion module solutions are influenced, particularly by virtue of its workspace (position, shape, size, input), by technological dislocation of axis (location, access, function), interactive relation of various systems (function, identifying, blocking, movement – forward-backward), energy (distribution, transformation, branching flow), mechanical (unification, separation, variability) and by the nature of technology/process of handling (processing/handling tools, process parameters),
- analysis of the application environment shows the influence of load and capacity, precision and accuracy, stability of performance, sensor equipment (level of intelligence), sorting and reconfigurability of motion module, the universality of the motion module and adaptability of motion module onto the motion module solutions,
- impact analysis of machining motion module system solutions confirms present influence of power, precision of positioning, kinematics and dynamic properties, design parameters (the mechanical flange and connection, the mechanical interface) connecting mechanisms, software and energy source of mutual ties.

The function and properties of the motion module of machining system have a significant presence. They are a limiting and enriching factor of functional skills, not only of machining systems, but also for an interactive environment [Lipson 2000]. Motion modules work as interfaces with functional ties to the technological tools and object of manipulation / of processing technology, space technology machinery and production systems, mechanisms and working spaces and additional peripheral equipment.

B. Systematization of the motion modules

The issue of motion modules has reached different level of knowledge in theoretical as well as in engineering field. Past experiences suggest that frequent principles of design contains the machine nodes, in particular the use of motion module. The main function of the motion module systems in relation to technology tools, object of manipulation / technology (NP) and the given working role of automated machine work, is to ensure activities related to material and technology transformation (change of location, position and orientation, fixing and transformation of the instrument/subject flow) as required by the manufacturing process [Valencik 2004]. This can be addressed by different concepts of movement, various principles of design of technical solution of mechanisms of motion modules. They generally deal with derives from the basic model-Fig. 1 representing the complete structure which is made up of these elements:

- reference block-R – serves as the base of the mechanical structure of the motion module, the function of a mechanical link to connect the module with mechanical systems, but also links the energy (power) wiring, control circuits (control and signal system, control - Blocker System) machine system
- Energy Block-E – acts as a drive (rotational, translational output) providing movement, power and performance parameters of the motion module
- transformation and T-distribution block - serves as a mechanism ensuring the transmission and conversion of primary energy on the kinetic power
- P-transmission block - serves as a mechanism through interactive elements (flange / clutch, energy and information collection and distribution member) executes direct contact with related modules of machining system.

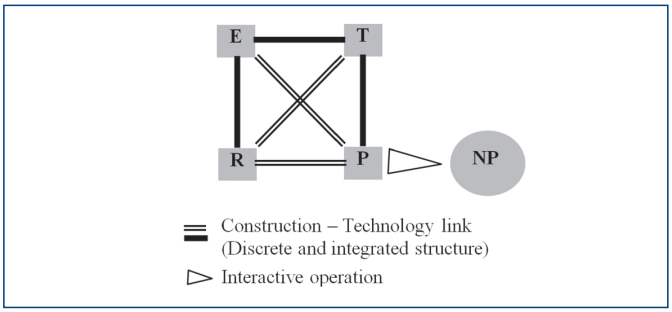

Figure 1. *The basic model of the motion module*

The basic model comes from a conventional principle of generating energy, as it transforms the mechanical movement and operation of power transmission / interaction element, which is usually associated with various forms of structure (discrete, integrated).

Non-standard solutions in the motion modules Fig. 2 can be achieved by inclusion of other elements between the reference and the transmission block to allow movement reconfiguring (pool, division, change the meaning, nature and character) to improve machining system performance. These elements include features such as:

- active complementary block – D_a – serves as a supplementary mechanism with novel concept of transformation and distribution members which extend the kinetic possibilities of machining node or of the whole machining system. In comparison with traditional solutions, it is capable of unification, division, change the meaning, nature and character of the movement in two or more axes,
- additional passive block – D_p – serves as limits definition, flexible elimination of possible inaccuracies in positioning / orientation of motion module for the machine string. This feature is provided by "straightening" the position and orientation of the motion module through special mechanical contacts with related modules of machining system (MSS).

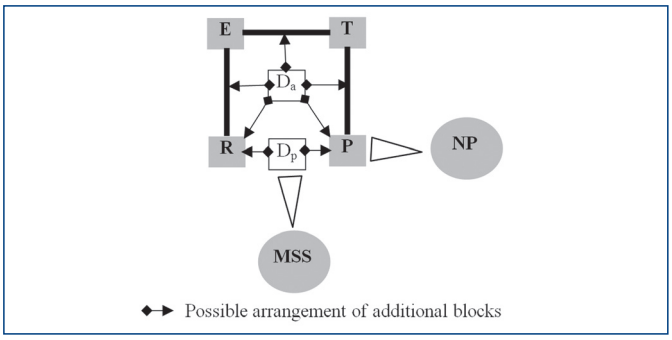

Figure 2. *Advanced model of motion module*

Basic and extended model paves the way for profiling various configurations and type of structures, but does not address the functional and technological modularity providing control of motion module (motors/drives, transition elements, regulatory, management and control features), and level of intelligence (sensors).These factors are dependent on the type of used machining system and the needs arising from the application.

C. Profiling the motion module with respect to functional and technological modularity

In the development of construction components, modules and integrated assemblies, as documented here, the requirements for functional and technological level of modularity constantly increases. Functional modularity is defined as aggregation of functions of individual elements of a modular chain design, which, in the case of motion module, is based on the systems approach. Technological modularity design is defined as individual structural elements aggregated in the motion module compatible with the technological requirements of the machining system. As a rule, this profiling represents the level of technical parameters, requirements arising from the disposition of technology, power supply, signal and control signals, including requirements for closure of the module-Fig. 3.

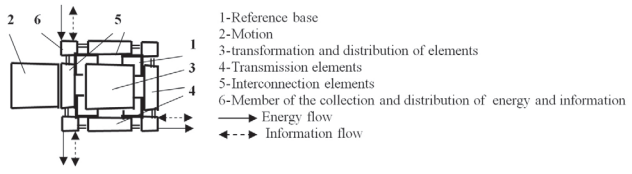

Figure 3. *Compatible motion module*

There are critical connection methods (hubs) in the interface between mechanical, energy and motion control functions of the module, either the flange / 5 /, clutch / 4 / or joint bus and distribution base of energy supply, measurement and control signals / 6 /. The higher integration can result in unification of part base, such as a common output-connecting element (turntable).

It is important to distinguish the degree of compactness of the individual components and technology compatibility from the point of user view. Compatibility is defined by: i.e. module structurally and functionally capable of interfering energy, cooling, managing connections needed for final technology (service) process on the machine.

5. Output for Aplication

A. Reference solution

The concept of 2D motion module comprises transmission and transformation mechanisms in an integrated unit. It respects the fundamental requirement to ensure the rotation, sliding and general movements, which are necessary for operations in order to change the location, position and orientation of the object (instrument), without changing the position of the beginning of local coordinate systems. Queries on motion integration in several coordinate axes are technically feasible through the module as propulsion, transmission and transformation member whose profile has the form of:

- parallel system,
- integrated serial system.

Parallel kinematics consists of several parallel, length- adjustable mechanical rods, which length is permuted by motor or automatically. Rods make an integrated system of motion axes that are connected to the frame and the working unit through ball or shaft joints. The main advantage of parallel kinematics is the realization of incremental movements in conformity with the common coordinate system.

In the latter case there is a non-standard integration [Valencik 2006] of two, serial-arranged movements of nodes into a module with integrated movements – Fig. 4. The essence of the solution is to transform the serial kinematics into compact kinematics unit with reconfiguration effects of motion generation and transformation of the kinetic forces. The shape of the module can be transferred in modifications:

- displacement-displacement,
- displacement-rotation,
- rotation-rotation.

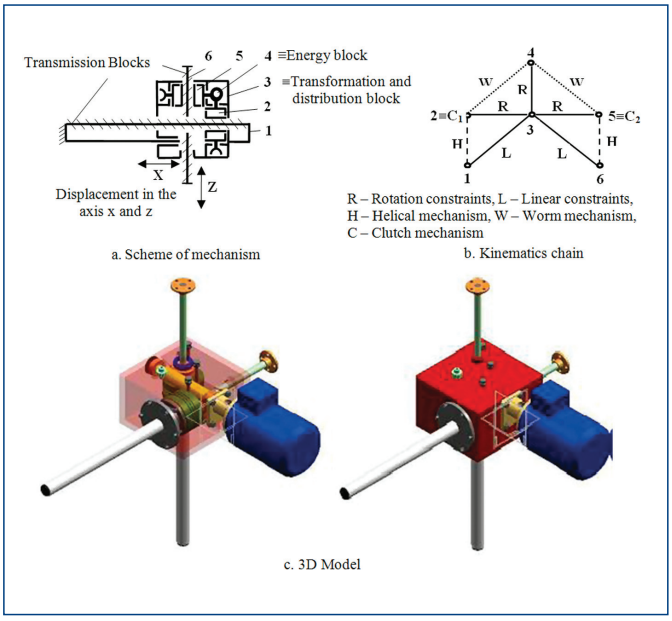

Figure 4. *2D motion module with integrated movements*

Solution depicted in Fig. 4 integrates movement (displacement in the axis x and axis z). It consists of energy, transformation, distribution and transmission block. The major difference from traditional solutions is the presence of transformation-distributing block and transmission block where the transformation-distributing block is the key element in profiling. This solution is able to distribute and unify motion in an automated mode according to the required function of positioning in one or two coordinate axes. More complex operations in terms of technology and handling processes can be done using the above described module, taking into account the needs of positioning in one or more axes and optimal division of movements among the tools and workpieces.

B. Sector of application

Development program of 2D motion modules is closely related to innovation and modernization program of automated manufacturing processes and it is based on the application of automated machining systems. Concept of 2D motion modules are applied particularly to: modular solutions for machining and production systems,

- expansion of peripheral devices on machining and production systems (moulds, weldment, shape and spatially complex products of wood, metal and glass),
- modernization of older generation of handling and machining technology, retrofit of propulsive and positioning sets with current axes extending them as in new technology,
- ensuring operational engineering and production contracts, type of system- integrator providing work with higher demands on flexibility universality.

In terms of technological determination it deals with:

- tables for clamping workpieces and pallets,
- modules for tools storage,
- adjustable folding and rotary table (cradle) for machining in five directions
- arms for driving the working member (tool, technology head) in connection with the positioning tables for simultaneous machining of components in multiple axes.

The modules are particularly useful for building working and positioning modules executing simultaneous movements in order to provide high maneuverability movements in a particular location [Valencik 2011].

Typical products of manufacturing group of 2D motion modules are workpiece and tool axes of machining systems, work-axes of tools / workpiece in these designs:

- two and multi axial index tables, rotary, tilt and moving tables,
- two and multi axial positioning arms, pillars, and floor consoles, stands and consoles (Fig. 5),
- two and multi axial positioning portals, horizontal and vertical.

Model concept of positioning arm – Fig. 5 develops the object- tooling module (functional, technological features) into an integrated system of machining system generated for specific application (for example, operational activities of manipulation / technology). The specific of the solution is the fact that integrated kinematics X – Z consists of two vertically arranged transmission units (horizontal, vertical) connected together through a common energy-transformation-distribution module. Horizontal transmission unit is linked to a reference base, while ensuring the autonomy movement of energy-transformation-distribution module in the X-axis, which contains the vertical transmission unit for the module tool movement in the axis Y. Movements are diverted from the common propulsion system using a transformation member which ensures distribution of the kinetic power in the dependent and independent modes of action towards the horizontal and vertical unit. Energy-transformation-distribution module is a higher level of integration, which leads to the unification of part base, such as common output-connecting element (turntable), common brake and position measuring solution in whole module, and new forms of integration of individual components.

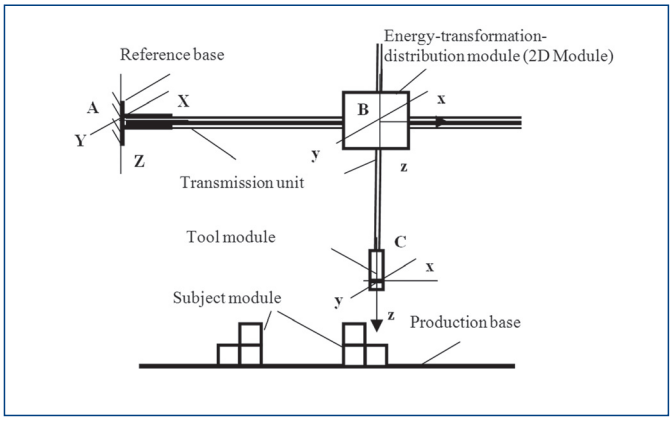

Figure 5. *Positioning arm with the application of 2D motion module*

The solution is designed to implement undemanding workloads and tasks (transmission and operational procedures for handling and profiling of the object) with simple regimens of positioning and orientation. It represents a special-purpose manufacturing module with low implementation costs.

6. Conclusions

The paper defines module of machining system with integrated and reconfigurable movements. It shows that the implementation of these modules will help to respond to changing conditions and positions in technology efficiently and flexibly and will make handling tasks requiring special arrangements of positioning and orientation easier.

Although the solutions lead to technically more complex kinematic structures capable of reduction and mutual transformation of kinematic chain members, the result is a new configuration options for handling, manufacturing and supporting technology which is leaner and creates inventive combinations of new and more technical-economic impact.

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