

STRUCTURAL SYNTHESIS IN DESIGN OF TECHNOLOGICAL COMPLEXES FOR HIGHLY EFFICIENT TREATMENT

L. M. Akulovich^a, L. M. Kozhuro^b,
M. L. Kheifets^c, and E. Z. Zeveleva^c

UDC 621.783.223:658.52.011+536.75

Based on a study of corteges of technical complexes, rational sets of assemblies and systems for flexible production modules and treatment centers that effect thermomechanical and electromagnetic treatment of surfaces of workpieces are proposed.

Reduction of periods of time for designing promising new technological processes equipped with tools, assembly units and systems, machines, and modules that form a unified technological complex, is among topical problems of modern machine building industry [1]. A key problem in designing a technological complex is the setting up of a structure that provides smooth operation and flexible readjustment of a complex for highly efficient treatment [2]. Rational reliability and adaptivity are provided in structural synthesis based on analysis of elements and study of corteges of the technological complex [3].

Analysis of Elements of Technological Complexes for Highly Efficient Treatment. A technological complex in the general case is considered as a hierarchical "man-machine" system [3] that comprises the following levels: I) functional elements that implement the principal movement, the feeding movement, and the tool movement; II) functional subsystems in the form of assembly units; III) functional systems that provide operational and transport movements, feeding and removal, and maintenance; IV) technological modules or assembly machines, and power and information machines; V) automatic and semiautomatic lines and sections that form the technological complex.

Each subsystem of the n -th level is an element of a subsystem of the $(n + 1)$ -th level. The makeup of the technological complex and each functional system and subsystem that are involved in a technological module and the functions of their constituent elements comply with the intention of the technological operations for which the given technological complex is set up.

In the general case each subsystem consists of several elements whose naming involves the names of the functions (movements) performed. During the technological process, a subsystem of a given type performs a certain typical function, i.e., a typical technological operation.

Plants for highly efficient turning, milling, and abrasive treatment, rotational cutting [4], electromagnetic facing [5, 6] plastic surface deformation [6, 7], and magnetic-abrasive polishing [5, 6] that have been designed to date are functional systems with a set of various subsystems (see Table 1).

The makeup and number of interlevel links of the elements of technological complexes for combined electromagnetic and thermomechanical treatment are analyzed using a two-digit numbering of the constituent systems and elements [8, 9]. The first digit corresponds to the level of the constituent: 1 denotes functional elements; 2, functional subsystems; 3, functional systems; 4, technological machine; 5, technological complex. The second digit is the ordinal number of each constituent of the given level.

Thus, the following code numbering is obtained for constituents of the fifth level: 51, technological complex for combined electromagnetic and thermomechanical treatment for surfaces of revolution; 52, the same for end surfaces; 53, the same for flat surfaces.

^aDesign-Technological Institute of Means of Mechanization and Automation, Minsk, Belarus; ^bBelarusian State Agricultural Technical University, Minsk, Belarus; ^cPolotsk State University, Novopolotsk, Belarus. Translated from *Inzhenerno-Fizicheskii Zhurnal*, Vol. 73, No. 4, pp. 813-818, July-August, 2000. Original article submitted August 24, 1998; revision submitted May 14, 1999.

TABLE 1. Interlevel Links between Elements of a Technological Complex for Treatment of Surfaces of Revolution

Technological complex (level V)		Technological modules for treatment of surfaces of revolution (level IV)				
		turning	abrasive	rotational cutting	electromagnetic facing with deformation	magnetic-abrasive
Functional systems (level III)	Functional subsystems (level II)	Functional elements (level I)				
Operating	for workpiece movement	rotational movement	rotational movement	rotational movement	rotational movement	rotational movement
	for tool movement	translational movement	translational and rotational movements	translational and rotational movements	translational and rotational movements	—
	for inward (feeding) movement	translational movement	translational movement	translational movement	—	—
	for movement of the electro-magnetic system	—	—	—	translational movement	translational movement
	for additional heating of the treated surface	electric-contact, electric-arc	—	electric-spark, electric-contact, and electric-arc	electric-spark and electric-arc	—
	for movement of feeding of the lubricating fluid	translational movement	translational movement	translational movement	—	translational movement
	for movement of feeding of the powder	—	—	—	translational movement	translational movement
Auxiliary	for adjusting movements of the tool	lateral and lengthwise movements	lateral and lengthwise movements	lateral and lengthwise movements, turn	lateral and lengthwise movements	—
Servicing	for movement of replacement of the part and tool	implemented by devices	implemented by devices	implemented by devices	implemented by devices	implemented by devices

We consider a technological complex for combined electromagnetic and thermomechanical treatment of parts with surfaces of revolution.

The fourth level of technological complexes is made up of technological modules by the method of treatment: 41, turning treatment; 42, abrasive treatment; 43, rotational cutting; 44, electromagnetic facing with plastic surface deformation; 45, magnetic-abrasive polishing.

The third level represents functional systems: 31, operating system that includes elements needed for fulfilling the designated purpose of the functional system; 32, auxiliary system that effects adjusting movements of the tool and the workpiece; 33, servicing system that provides replacement of the workpiece and the tool and filling of the facilities for feeding the powder and the lubricating fluid.

The second level is functional subsystems: 21, of the workpiece movement; 22, of the tool movement; 23, of the feeding movement; 24, of movement of the electromagnetic system; 25, of additional heating of the treated surface; 26, of feeding of the lubricating fluid; 27, of the powder feeding; 28, of adjusting movements of the tool that can coincide with the principal movements; 29, of replacement of the workpiece and the tool.

The first level involves functional elements that implement: 11, principal movement of the workpiece (111, rotational movement; 112, translational movement); 12, principal movement of the tool (121, rotational movement; 122, translational movement); 13, additional movement of the tool (131, rotational movement; 132, translational movement); 14, feeding (inward) movement (141, lengthwise movement; 142, lateral movement; 143, movement perpendicular to the plane of the lateral and lengthwise movements); 15, movement of the elec-

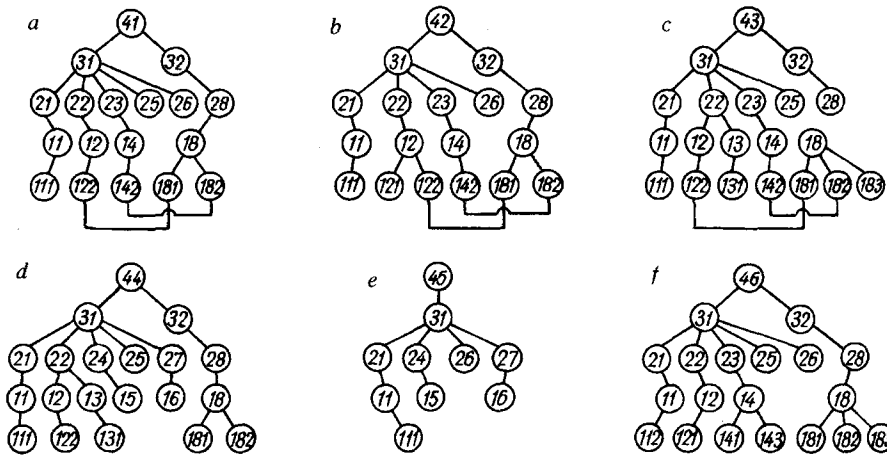


Fig. 1. Graphs of corteges of: a) turning treatment, b) abrasive treatment, c) rotational cutting, d) electromagnetic facing with plastic surface deformation, e) magnetic-abrasive treatment, f) milling treatment.

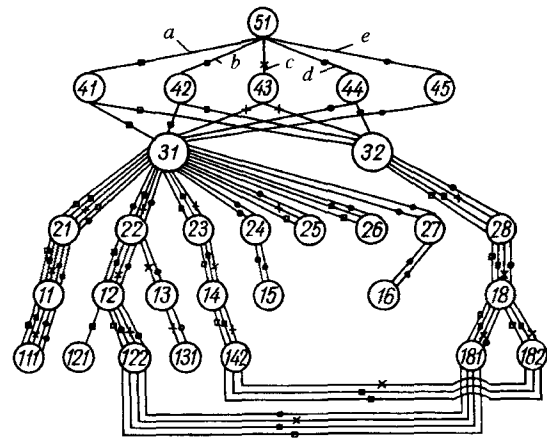


Fig. 2. Graphs of corteges of a technological complex for treatment of surfaces of revolution: a) turning treatment, b) abrasive treatment, c) rotational cutting, d) electromagnetic facing with plastic surface deformation, e) deformation treatment.

tromagnetic system; 16, movement of the facility for feeding the powder; 17, adjusting movement of the work-piece (171, lengthwise movement; 172, lateral movement; 173, movement perpendicular to the plane of the lateral and lengthwise movements); 18, adjusting movement of the tool (181, lengthwise movement; 182, lateral movement; 183, rotational movement).

On the basis of an analysis of the sets of constituent functional systems, functional subsystems, and functional elements, which are called corteges [3], we determine links between them.

Structural Synthesis of Corteges of Technological Complexes. Study of the graphs of corteges that are constructed on the basis of Table 1 (Fig. 1) permits establishment of the number of interconnections between the various levels that make up the technological complex.

All technological modules (the IVth level) include functional systems (the IIIrd level) 31 and 32 (operating and auxiliary), except for technological module 45.

Functional subsystem 22 (tool movement) is absent in technological module 45; functional subsystem 23 (feeding and inward movement), in technological modules 44 and 45; functional subsystem 24 (movement of the electromagnetic system), in technological modules 41, 42, 43, and 46; functional subsystem 25 (addi-

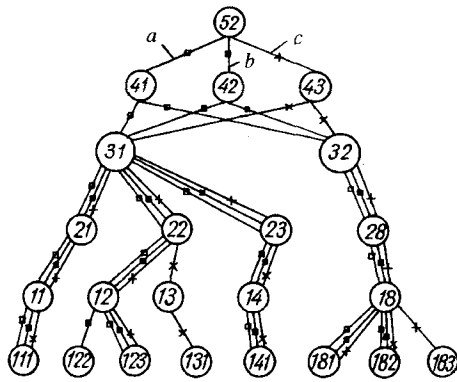


Fig. 3. Graphs of corteges of a technological complex for treatment of end surfaces: a) turning treatment, b) abrasive treatment, c) rotational cutting.

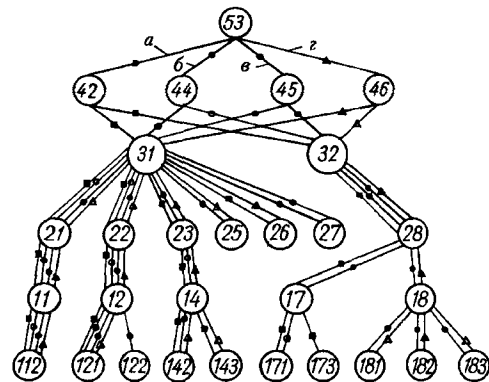


Fig. 4. Graphs of corteges of a technological complex for treatment of flat surfaces: a) abrasive treatment, b) electromagnetic facing with plastic surface deformation, c) magnetic-abrasive treatment, d) milling treatment.

tional heating), in technological modules 42 and 45; functional subsystem 26 (feeding of the lubricating fluid), in technological modules 43 and 44; functional subsystem 27 (dispenser), in technological modules 41, 42, 43, and 46; functional subsystem 28 (adjusting movements), in technological module 45.

Thus, in most cases technological complexes involve: functional subsystem 21 (workpiece movement) – rotation (111); functional subsystem 22 (tool movement) – translational movement (122); functional subsystem 22 (additional movement of the tool) – rotation (131); functional subsystem 23 (feeding or inward movement) – lateral movement (141); functional subsystem 28 (adjusting movements of the tool) – lengthwise and lateral movement (181, 182).

To design a universal technological complex for combined thermomechanical and electromagnetic treatment, we unify corteges and determine coincident links and functional elements [10, 11]. The match of corteges (Fig. 2) reveals the expediency of setting up a universal technological complex that combines highly efficient thermomechanical and electromagnetic methods of treatment of surfaces of revolution.

The structural synthesis of the elements based on the considered links permits identification of a number of unified units in the makeup of the technological complex [12]: 1) of principal movement, which provides workpiece rotation about the horizontal axis; 2) of the tool drive: a, of translational movement along the axis of rotation of the workpiece and inward movement and b, of rotational movement, whose velocity is determined from the forces applied during the treatment; 3) of feeding: a, of the powder for facing or polishing and b, of the working lubricating-cooling fluid; 4) of the drive of the electromagnetic system, which are used for: a, control over the technological process and b, control and regulation of the treatment quality; 5) that serve for: a, energy supply and b, control over the energy actions on the surface layer of the treated workpiece.

Unit 2, a can be made in the form of a lathe support, and unit 2, b is fastened to unit 2, a, which offers the opportunity to use the existing mechanisms of unit 2, a to implement some of the tool movements.

Let us consider the links (Fig. 3) between functional elements of a technological complex for treatment of end surfaces.

The match of corteges indicates that the units of the complex for treatment of surfaces of revolution are totally suited for treatment of end surfaces except that the principal movement should be replaced by tool feed (the translational movement should be replaced by lateral movement).

We next consider the links (Fig. 4) between functional elements of a technological complex for treatment of flat surfaces.

The match of corteges of the technological modules for treatment of flat surfaces shows the following: 1) the unit of workpiece movement provides translational movement, 2) the unit of tool movement provides

rotational movement, and 3) the translational movement of the tool in the technological module for magnetic-abrasive polishing can be replaced by feeding movement, and therefore, the unit will carry out one movement.

An analysis of the match of corteges of the technological complexes for treatment of surfaces of revolution and end and flat surfaces revealed that, for carrying out combined thermomechanical and electromagnetic processes, the operating functional system should be provided with [12] the principal movement, feeding movement, adjusting movement, and additional movement.

In the general case, for carrying out the set of movements, it is advisable to construct the technological complex from unified blocks that effect: 1) rotational movement of the workpiece, 2) rotational movement of the tool, 3) three mutually perpendicular translational movements of the table, 4) additional rotational movement of the tool, 5) adjusting turning movement of the axis of the rotational tool, 6) mounting of the workpiece on the table in treatment of flat surfaces, and 7) fastening of the tool in turning treatment.

Units 1 and 2 can be structurally united with the units that carry out adjusting movements for regulating the distance between the axis of rotation and the frame (table) of the complex, and units 4 and 5 can be integrated.

Thus, the structural synthesis of technological complexes for highly efficient combined thermomechanical and electromagnetic treatment of surfaces of revolution and end and flat surfaces showed the expediency of setting up universal technological complexes in the form of a flexible production module that consists of unified units that carry out principal, additional, and adjusting movements of the parts and tools and provide their mounting and fastening.

Unification of combined treatment of surfaces of revolution and flat surfaces using additional units permits the creation of flexible treatment centers.

REFERENCES

1. L. M. Akulovich, L. M. Kozhuro, M. L. Kheifets, and E. Z. Zeveleva, *Inzh.-Fiz. Zh.*, **72**, No. 5, 969-977 (1999).
2. B. Froment and J.-J. Lesage, *Production: Les techniques de l'usinage flexible*, Paris, Bordas (1984).
3. I. I. Artobolevskii and D. Ya. Il'inskii, *Bases of Synthesis of Systems of Automatic Machines* [in Russian], Moscow (1983).
4. L. M. Kozhuro, Zh. A. Mrochek, M. L. Kheifets, A. A. Shipko, and L. M. Akulovich, *Treatment of Wear-Resistant Coatings* [in Russian], Minsk (1999).
5. P. I. Yashcheritsyn, M. T. Zabavskii, L. M. Kozhuro, and L. M. Akulovich, *Diamond-Emery Treatment and Strengthening of Articles in a Magnetic Field* [in Russian], Minsk (1988).
6. L. M. Kozhuro and B. P. Chemisov, *Treatment of Machine Elements in a Magnetic Field* [in Russian], Minsk (1995).
7. P. S. Chistoserdov, B. P. Chemisov, L. M. Kozhuro, and L. M. Akulovich, *Technology of Dimension-Finishing and Strengthening Treatment* [in Russian], Minsk (1993).
8. M. L. Kheifets, L. M. Kozhuro, A. A. Shipko, et al., *Inzh.-Fiz. Zh.*, **68**, No. 6, 931-943 (1995).
9. M. L. Kheifets, L. M. Kozhuro, A. A. Shipko, et al., *Inzh.-Fiz. Zh.*, **69**, No. 1, 46-57 (1996).
10. P. I. Yashcheritsyn, B. P. Chemisov, and M. L. Kheifets, in: *Current Problems of Machine Science* [in Russian], Gomel' (1996), pp. 112-113.
11. P. I. Yashcheritsyn, B. P. Chemisov, and M. L. Kheifets, and E. Z. Zeveleva, in: *Current Problems of Machine Science* [in Russian], Vol. 2, Gomel' (1998), pp. 117-120.
12. P. I. Yashcheritsyn, L. M. Kozhuro, and M. L. Kheifets, *Vestn. Mashinostr.*, No. 3, 33-36 (1996).