KOMUNIKÁCIE COMMUNICATIONS

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ČINNOSTI MENIACE STAV OBJEKTU V PROCESE OBRÁBANIA A MONTÁŽE A ICH FORMALIZÁCIA

THE ACTIVITIES CHANGING THE STATE OF THE OBJECT IN THE MACHINING AND ASSEMBLING PROCESS AND THEIR FORMALIZATION

Obrábacie a montážne procesy sú diskrétne sekvencie činností spôsobujúce zmenu polotovarov na finálne súčiastky, v prípade montáže ide o kompletizovanie súčiastok do vyšších celkov. Pre počítačom podporované navrhovanie technologických postupov je potrebný dokonalý a formálny opis týchto činností. V článku sa prezentuje koncepcia formalizácie činností, ktoré menia charakteristiku súčiastky. Navrhnutá koncepcia môže byť využitá pre navrhovanie technologických postupov.

The machining and assembling processes are discrete sequences of activities causing the change of semi-products into the finished parts, and assembling the parts into the final product. In computer aided process planning the precise and formalized description of activities is necessary. In the paper a conception of formalization of the activities changing the part characteristic is presented. The proposed description may be useful for process planning.

1. Introduction

The automation of process planning procedure demands the exact recognition of the events which appear in the real machining and assembling processes. The recognition of these events and their formalized description make possible to build the events data base and allow the correct planning the structure of the process [1].

The machining processes are an ordered set of events based on the following discrete activities. In effect of these activities the object, a machined part, changes its state from a semi-product to a finished part.

The activities occurring in the machining process should be recognized and described in order to make possible the selection of right elements of the structure in the computerized semigenerative and generative process planning methods.

As it is known three kinds of activities may be distinguished [2, 3]:
- activities changing the state of machined parts by changing their geometrical and technological characteristics,
- activities causing a change of the position or localization of a part or tool,
- activities comparing the real state of the part with the demanded.

In the paper only the first group of activities will be further considered. This group is the most important in the machining and assembling process planning.

2. The machining transformer

The activity causing a change of the state of a machining part as effect of a partial change of features for a given surface or set of surfaces is called the machining transformer. Similarly, the activity creating a new object by assembling the same parts on a different level of complexity is called the assembling transformer.

In the most general formulation, a transformer describes the model of a dynamic change of the state of n-objects from which in like manner exert the forces (cutting or assembling) on the others in the determined kinematics conditions. Therefore, the transformer may be described by an ordered set of objects, their kinematics and elementary function which causes the change of their state [3]:

$$T = \{U\}, \{K\}, F \qquad (1)$$

where: $\{U\}$ - set of objects
$\{K\}$ - set of kinematics relations between the objects
F - function describing the dynamic relation between the objects

A more detailed analysis of this general description of the transformers shows that above definition the set of objects $\{U\}$ and function F must be differentiated.

Machining transformer T_m is a term for the activity in which the set of objects is divided in two subsets, parts $\{P\}$ and tools (instruments) $\{J\}$. The activity of transformers concerns the set of

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surfaces $\{p_i\}$ of the given part in the state P_i causing their change to the state P_{i+1} realized by the partial machining function f_M. Therefore:

$$T_M - (\{p_i\} \subset P_i), \{J\}, \{K\}, f_M \qquad (2)$$

where: $\{p_i\}$ - set of surfaces of the part in the state P_i which originate by machining change their geometric and technologic characteristics on the set $\{P_{i+1}\}$

$\{J\}$ - set of the tools (instruments) participating in the change of the characteristics

$\{K\}$ - Kinematics of part and tool

f_M - Partial function realizing the change and describing the dynamic relations between the tool and machined surfaces

So the machining process is described by the activity of the following transformers on the part in initial state (semi-product) P_P causing the final state of the part P_K. In this way, the activities of successive transformers cause the discrete change of state of the machining part. The selection of sequence of activity of particular transformers is based on technological knowledge (W) composed of rules (R) and principles (Z).

The machining process may be presented in the form of a sequence of the following changes of the state of the part occurring as a activity of transformers. Some of these states play an important role in the structure of machining process. Therefore:

$$P_p \rightarrow \{T_M\} \rightarrow P_K \qquad (3)$$

$$P_P \rightarrow [T_{M1} = (\{p_1\} \subset P_P), \{J_1\}, \{K_1\}, f_{M1}] \rightarrow P_1$$

$$P_1 \rightarrow [T_{M2} = (\{p_2\} \subset P_1), \{J_2\}, \{K_2\}, f_{M2}] \rightarrow P_2$$

$$P_2 \rightarrow [T_{M3} = (\{p_1\} \subset P_2), \{J_3\}, \{K_3\}, f_{M3}] \rightarrow P_3$$

$$P_{K-2} \rightarrow [T_{MK-1} = (\{p_{K-1}\} \subset P_{K-2}), \{J_{K-1}\}, \{K_{K-1}\}, f_{MK-1}] \rightarrow P_{K-1}$$

$$P_P \rightarrow [T_{M1} = (\{p_1\} \subset P_P), \{J_1\}, \{K_1\}, f_{M1}] \rightarrow P_1$$

3. The description of the machining transformer

A more detailed analysis of the structure of transformer description (Fig. 2) shows that the set of surfaces $\{p_i\}$ connected with the general part description can further be divided into three subsets:

$\{p_n\}$ - surfaces not machined in the process, i.e. raw surfaces of the prismatic part or connecting rod,

$\{p_m\}$ - surfaces machined in the given activity of the machining process,

$\{p_l\}$ - locating surfaces, coming into contact with the locating set of the machine tool or fixture taking away some degrees of freedom as necessary in the given machining activity.

Only the set $\{p_m\}$ changes this characteristic activity of the transformers, but the selection of demanded model of the transformers depends on the kind localization of the set $\{p_l\}$ in the structure of the part P_i. The important features of the surfaces in the machining transformer are:

- the type of the surface, outside *EX* or inside *IN*,
- their fundamental geometrical shape, as cylinder, plane. This form of surface may be described using the multi-literal code p_{iii},
- localization of the surface in the main co-ordinate system X, Y, Z, or planes XY, XZ, YZ, or special positions S.

The tool occurring into the transformer models is described more precisely too. For the description of the kind of the tool, or a set of tools, the multi-literal code J_{iii} is proposed. The description is completed by the definition of the tool position. Three positions can be distinguished: vertical *V*, horizontal *H*, and inclined *A*.

Kinematics of the part and tool is described by the character of the movement, main *M* or auxiliary *A*, kind of move of a part or tool, linear *L*, rotary *O* or composed *C*. In this way, the main own move of the part is described by index *MOP* and that of the tool by *MOI*.

Similarly, the auxiliary movement is described by the index AOP for a part, and *AOJ* for a tool. The main or auxiliary translocation of the part is designated by index *MP* or *AP* and that of the tool by *MI* and *AI*.

The partial or elementary function realizing the dynamic relation of transformers is the cutting function f_M. It is characterized by a letter code indicating the typical kind of machining f_{Miii}, in relation to the tool code I_{iii}.

Further, the position of the velocity vector of the main moving $\vec{V}_{MI}$, $\vec{V}_{MP}$ in relation to the machined surface p is described. It may be perpendicular $+$, parallel ¦ or inclined $<$ [3].

The structure of the description of the machining transformer TM is presented in Fig. 1. The lack of some features is indicated by "0" in the adequate place of the structure. A simple drawing helps to understand the description. An example of the description of the model of multitool, turning of cylindrical, external surfaces transformer is presented in Fig. 2.

The transformer model may be chosen from a set of transformers which can be realized in the given machining system, saved in the data base. The selected model is now parameterized to transform it in one of the structural elements of the machining process. To attain this, the parameterization must take into consideration the following demands:

- start localization of the part and tool in the CO system of the machine tool,
- end localization of the part and tool in the CO system of the machine tool,
- parametrical characteristic of the set of machined surfaces pm,
- parametrical characteristic of the tool,
- parametrical characteristic of the main and auxiliary motions,
- parametrical characteristic of the partial transformer function fM (v. e. velocity, way, sliding).

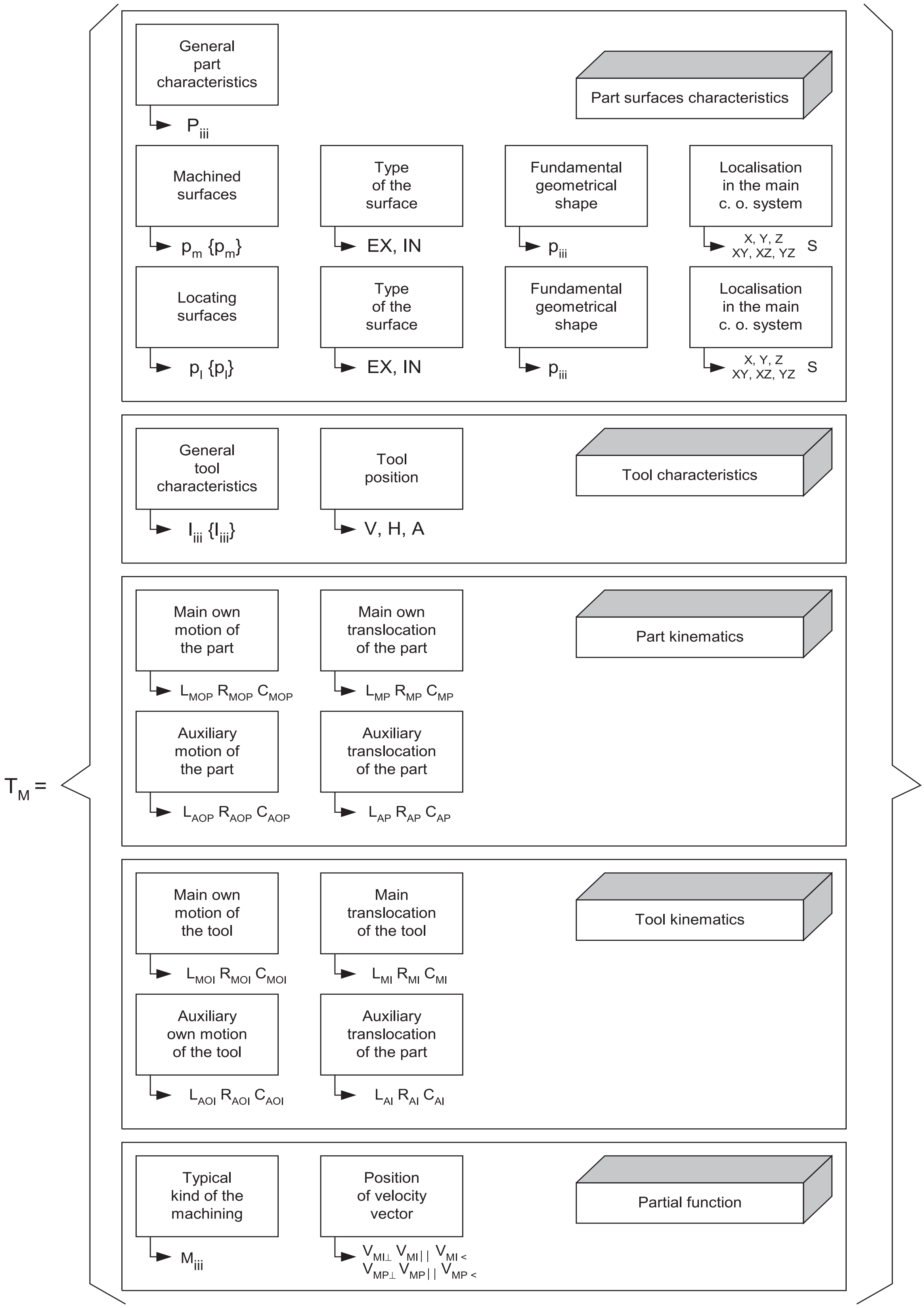
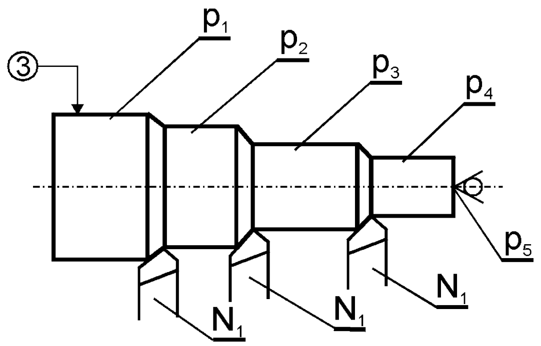


Fig. 1. The structure of the description of the transformer



$$T_M = \left\{ \begin{array}{l} \begin{bmatrix} (p_2, p_3, p_4), & EX, p_{CYZ}, Z, XY \\ (p_1, p_5), & EX, p_{1CYZ}, p_{5CON}, Z, XY \end{bmatrix} \\ \left[\{I_{NTP}\}_{1-3}, V \right] \\ \begin{bmatrix} (R_{MOP}, & 0) \\ (0, & 0) \end{bmatrix} \\ \begin{bmatrix} (0, & L_{MI}) \\ 0, & 0 \end{bmatrix} \\ \left[(f_{TNT}, \quad \bar{V}_{MI} \| \right] \end{array} \right\}$$

Fig. 2. The description of the turning transformer

4. The assembling transformer

The assembling transformer T_A is the activity in which in the set of objects participate at least two subsets of finished parts $\{P_{K1}\}$, $\{P_{K2}\}$. The activity of the transformer concerns the subsets of connected surfaces $\{p_i\}$, $\{p_j\}$ of the parts in final state P_{Ki}, P_{Kj}. In this way, a new complex object $Z_{A(i-j)}$ with different characteristic realized by the partial assembling function f_A is created. Therefore:

$$T_A = (\{p_1\} \subset P_{Ki}), \{p_j\} \subset P_{Kj}\}, \{K_A\}, f_A \quad (4)$$

where: $\{p_i\}$ - set of surfaces of the final part P_{Ki} that is connected with the set $\{p_j\}$ of the final part P_{Kj},
$\{p_j\}$ - set of surfaces of the final part P_{Kj} that is connected with the set $\{p_i\}$ of the final part P_{Ki},
$\{K\}$ - kinematics of parts P_{Ki}, P_{Kj},
f_A - partial function realizing the change and describing the dynamic relation between the parts surfaces.

The formalization of the description of the assembling transformer is more complicated than that of the machining.

In the machining process the succeeding machining transformers have already similar more or less complex structure, whereas in the structure of assembling process the transformer has a hierarchical character. Each next activity of assembling is realized generally on a more complex object. Furthermore, apart from the machined final parts, trade or special parts or sets are used during the assembly process. Kinematics of the assembling activities may be more complicated too. It is possible to state that the automation level of the assembling process is still very low, many activities are realized by the workers and exact formalization is not possible.

The automation of the assembling activities covers in great part simple robotised activities. Generally, the assembling process may be presented as follows:

$$(\{P_K\}, \{P_T\}, \{P_{SP}\}) \rightarrow [T_A] \rightarrow P_F \quad (5)$$

where: $\{P_K\}$ - set of machined final parts,
$\{P_T\}$ - set of trade parts or sets employed in the product,
$\{P_{SP}\}$ - set of special part or set employed in the product,
P_F - final assembled product.

The structure of the assembling process in the least level degree of hierarchy may be, therefore, described by:

$$P_{K1}, P_{K2} \rightarrow [T_{A1} = (\{p_1\} \subset P_{K1}), (\{p_2\} \subset P_{K2}), \{K_1\}, f_{A1}] \rightarrow Z_1^1 \quad (6)$$

One of the assembled parts must be treated as the basic or main part. This part is motionless in the given assembling activity.

If to the set Z_1^1 the next part P_3 or set of part $\{P_3\}$ will be assembled, then:

$$Z_1^1 \rightarrow [T_{A2} = (\{p_{Z_1^1}\} \subset Z_1^1), (\{p_3\} \subset P_3), \{K_2\}, f_{A2}]\ Z_2^2 \quad (7)$$

The hierarchical complexity of the assembling process and limited automation cause that the formalized description may be useful rather for the simple assembling activities. At first systematic of assembling kinds and methods is necessary. It is a separate, very large problem.

In some cases the elements of the presented machining transformers description may be adapted.

5. Conclusions

The above considerations allow to formulate the following general suggestions:

- in the computer aided planning the division and detailed description of main activities, especially machining and assembling activities are necessary,
- the proposed description takes into the consideration all the elements taking part in the activities transformers. It may be helpful in the complex description of other events occurring in the machining and assembling processes,
- in order to attain a better form of description and recording in the data base for the models of activities occurring in the machining and assembling process it is necessary to continue further research.

Reviewed by: A. Janáč, I. Kuric

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