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Petri Nets in the Group Technology of Prismatic Workpieces

Summary. This paper contains the problem of technologic operation modelling structure of prismatic workpieces treated within group processes. The possible use of a group treatment and advantages have been discusses. For the modelling needs the Petri Nets theory set has been used. The worked up method has been illustrated by a simple example. This work is supported by the State Commitee for the Sciantic Research under grant number 771379102.

1. Machining Process Structure Made on Machining Center

The problem has been limited to the operation made on machining centers because they decide about the final shape and value of the treated object. Such an assumption eliminates from a consideration a class a objects made within the mass production where unit - construction or specialization machines, automatized treatment lines are applied in a frame treatment. However the group technology use in a mass production has a very limited scale. Considering great variety of prismatic workpieces in designing automatization of such machining processes big problems occur which have not been solved on a broad basis so far.

Machining process (MP) structure can be analysed from a different point of view [7,8]. On the authority of a classical definition of MP it has been said that, MP frames made on numerically controlled machine are determined by a control program. Similarly the program structure is the very reflection of on MP structure. Discussing the MP structure such basic elements can be distinguished: setting, displacement position, operations [5]. It is useful to define the idea of so called complex operations, e.g. the group of operations made with one tool without its replacement, the change of setting and the position of a treated object without displacement (even partial one). Fragments of the control program of this type can be coded in a unified form, depended on a class treated objects, machine tool model and numerical control system installed on it. The complex operations are united in sequences which limits are determined by: replacement of a tool, rotation of a working table, base change, reclamping and of the higher division level of an MP roughing and precise treatment. Therefore the structure MP designing on machining centers consists in both rational, elementary operations clasification to complex operations and settlement of complex operations sequence. The process of operation clasification and settlement of order relations makes an optimatization field on these machining process. Summarizing these initial considerations it can be ascertaines that the machining process structure model should contain such relations between operations to be able to configurate on their basis explicit and rational process of this operation.

2. Possibilites and Advantage of Group Technology Use

The number of effectively used systems of machining process aid designing for prismatic workpieces is relatively small (compare to rotary workpieces). The great laboriousness of stereometry object description of this type is the main cause of such a state of affoirs. Therefore the greatest chances for an effective application have such designing systems which are restricted in their range to narrow object groups charakterizing with certain technological similarities. Taking into consideration convencional technologies, technological similarity in an operation rage economical treatement of different objects is possible on the same machine tool, of the same tooling range as a whole or similar machine tool set up. Furthermore, taking into account realization possibility of this operation on a numerically controlled machine, additional features should be added to the mentioned above ones, connected with an identical structural form of a control program and possibility of a limit to a certain final machining macrocycle which allows to complete machining of a whole group of objects.

Technological similarity depends on many features of a construction nature such as: size, shape, material, quality feature and puerly technological nature such as: size of production series, kind of a machine tool, tools that can treat shaped object surfaces. The group of object technologically similar is characterized by qualification of a group representative. Usualy it is the most complicated or certain imaginery object called synthetic, which is exposed to an action of all operations during production of all group objects. The treatment making capital of technological similarity of the following partions of objects is called a group treatment. The application of a rule of a group treatment carries a lot of advantages such as: shortage of technological production preparation period for new group representatives, minimalization of its arduousness, reduction of a test period, introduction of a control program, standarization of technological processes, toaling service arrangement, the rise of process engineers qualifications, creation of principle to unification of special instrumentation (tooling and machine-tool), simplification of a production by the creation of work centres, the use of more sufficient machine tools to the production of smaller series etc. The greatest advantages of introduction of group treatment method can be expected in plants with a fixed production range when small and average series are kept with the simultaneous and frequent introduction of new varied articles. It can be said [3] that group treatment methode is a matured methodology in a technological process designing. Considering the further, development, the problem of including this method to a newly created generation of computer systems of technological designing help, based on knowledge base processing in expert systems takes the lead. It is worth to call attention to the possibilities of using Petri net language in a logic modelling designing of this type [6].

As a practice proves automation of MP designing in a group treatment context in very efficient. It allows to make software time shorter of the whole object class similar technologically severul or even severul-hundred times. Generally speaking there are two methods of approach to the solution of this problem [4]. The first one consist in writing of a parametric program formulated in such a way to include all variable quantities in an object class in a form of direct or indirect parameters (counted by a computer or a control program). This method serves its turn perfectly for an object group for which the number of describing them variable parametres is maximally restricted to several ones. The control program code can turn out to be too complicated in some more comlex cases. The second methode is a formulation of so called synthetic program e.g. synthetic representative treatment, that comes within the range of explicitly coded treatment of all the possible forms and type dimension of a surface that can be treates in a considered object class. Therefore the program for an abstract object which however after "lock up" or elimination of some fragments can treat each object of a given group. Considering the great variety of object groups existed in mechanical engineering that can undergo group treatment, it is impossible to work out such a universal software package which would fail to include from some formed restrictions non-elasticity that would make its use difficult. However it is possible to give the general methodology of a procedure while program designing of this type.

3. The Model of a Structure of an Operation Represented by the Usage of the Language of Petri Pets

Topological properties of graph make it possible to modeling different relationships, such as: logical, condition/event type, time type, attributive, linguistic, semantic, of geometrical conections etc. Therefore, it is obvious that graph theory is frequently used to modelling of machining process. The concise review of possibilities, achievements and publications which refered to this problem was presented in the works [7,8]. Like was mentioned in the work [8], graphs usually showing interactions among treatment operations, leave ont of account other important relationships, such as: between operations and using tools, needed posiitions of a worked element, determination of its position relatively to the basing and clamping. Like was ascertained in first paragraph, the forenamed relationships are very essential components of an machining process structure.

A machining process can by considered as a condition/event process, in which three subgroups can be distinguished:

- static, which consists of the following elements: the current states of worked surfaces, tools, positions of a table of a machine tool, methods of basing and fixture;

- dynamic, wchich consists of the following elements: tretment operations, replacements of tools, rotations of working table re-fixture etc.;

- decisive, wchich consists of the folllowing elements: other events, which do not need time, such as - decisions to omit treatment of some surface, release of a possibility of a replacement of a tool, a demand of a change of a position of a table or re-fixture etc.

A further, more complicated systematics of events were presented in work [2]. When the first of above mentioned groups we consider as a set of conditions and the next two, in general, as sets of events and establish a relationship of incidence on these two sets; - then we obtain the structure of a bipartite graph with two distinguished subsets of graph vertices and the consequence we can consider some class of Petri net.

A class of "place/transition" (P/T) systems is a frequently used version of Petri net. This system is considered [1] as an order six-tuple:

$$PN=(P,T,E,K,W,M_0)$$

where P - a nonempty, finite set of places (conditions), T - a nonempty, finite set of transitions (events), E - a incidence relationship defined on elements of sets P and T (which correspond to directed arcs in net), K - a function of capacity of places, w - a function of multiplicity of arcs, M_0 - a function of initial marking. The above described system can be modified by imposing of some restrictions: namely we assume that the multiplicity of arcs is equal to 1 and only to 1 (therefore K can be omitted), the capacity of places is equal also to 1 (therefore W can be omitted) and finally we assign time of its duration to each event by using time function τ. The following system PN' is the result of these assumptions:

$$PN'=(P,T,E,\tau,M_0)$$

In addition, we can made a change in marking function. The dependence between the present state M and the directly subsequent state M' is determined in the following way:

$$M'(p) = \begin{cases} 0 \text{ if } p \in \bullet t \text{ i } p \notin t\bullet \\ 1 \text{ if } p \in t\bullet \\ 1 \text{ if } p \in \bullet t \text{ i } p \in t\bullet \\ \text{otherwise } M(p) \end{cases}$$

where:

$\bullet t = \{ p \mid (p,t)\in E \}$ - a set of input place of transition t,

$t\bullet = \{ p \mid (t,p)\in E \}$ - a set of output places of transition t.

This system can be called Petri net with binary marking function. The technological operation can be modelled using the system. An execution of single treatment 't111' is under several conditions, which are presented in Fig.1. Inputs are represented by conditions of demands and possibilities of an execution of the treatment. The event 't110' is the demand of the conditions, which make possible to execute the treatment (suitable tools, proper position of a table of working machine). The condition 'p110' means a state of waiting for fulfilment of these demands. In the course of

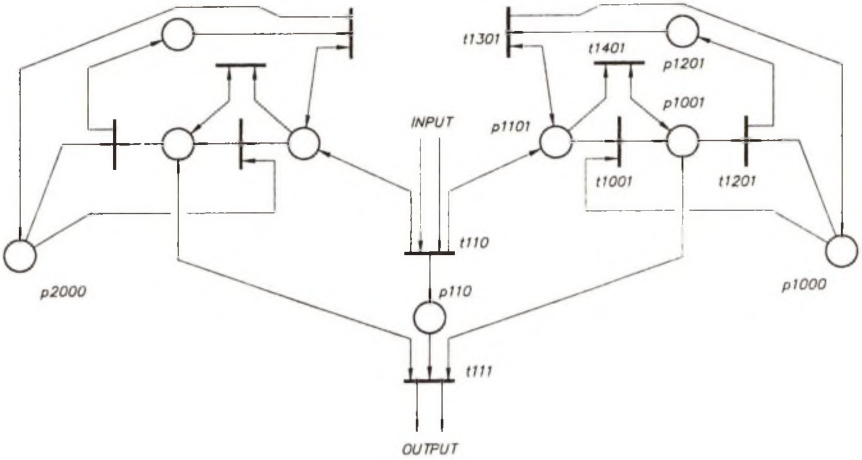

Fig.1. Model of basic treatment

things, outputs establish new state of working surface and make possible the continuation of an machining process. A replacement of a tool (if necessary) and rotation of a table of working machine (if necessary) should be made between the events 't110' and 't111'. It may be well to add that a structure of these blocks is identical (symmetrical). The subsequent events, for example in the block of a tool replacement are connected with: 't1001' - replacement of a tool, 't1201' - removal of tool, 't1301' - release of possibility of replacement of a tool, 't1401' cancelation of a need of tool replacement. The aforenamed conditions are completed by the following: 'p1000' - a possibility of tool replacement, 'p1001' needed tool is prepared (ready to work), 'p1101' - a demand of a tool, 'p1201' - needed tool is not prepared (not ready to work). By joining the blocks of tool replacements and of table rotation, we obtain a net which has a regular structure (presented in Fig. 2). The subsequent treatments should be set in order taking into consideration desirable technological succession of treatment of the same surface and also the succession of treatment avising from usage of the same tool. The net, in which these relationships are taken into account, is presented in Fig.4. It is an exmaple of the net worked out for the object showed in Fig.3. It is completed, additionally, by a check of neccessity and subsequence of fixing (the object should be treated in two fixtures) and should be looped in the treatment cycle.

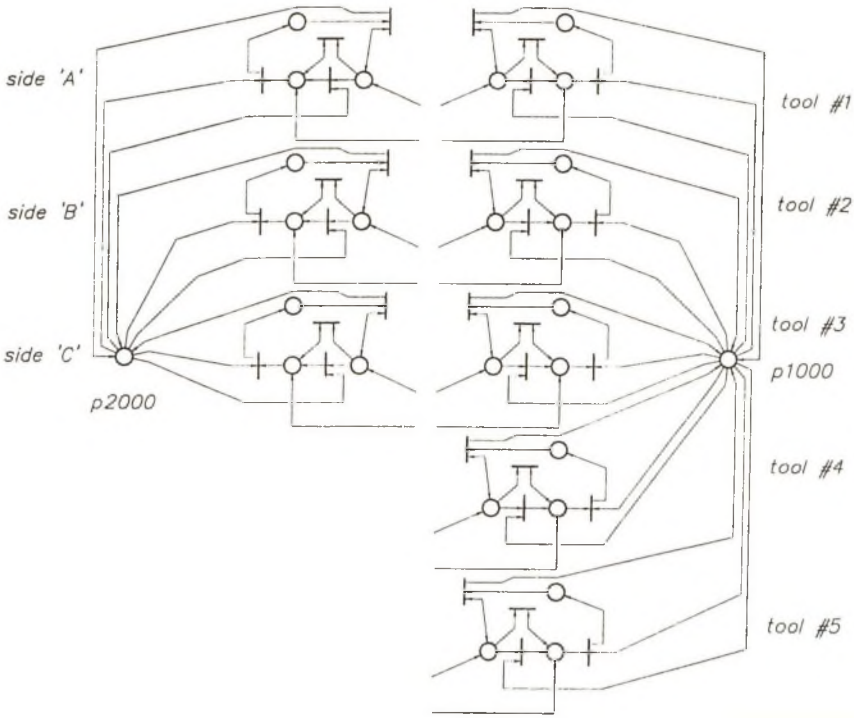

Fig.2. Control blocks of table rotation and tool replacement

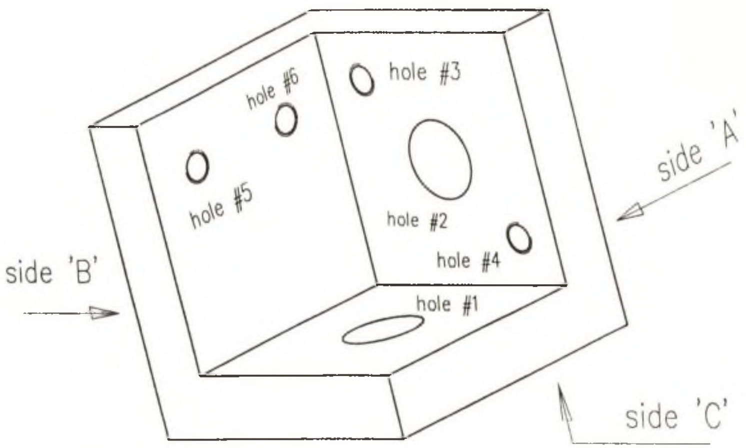

Fig.3. Model of treated object

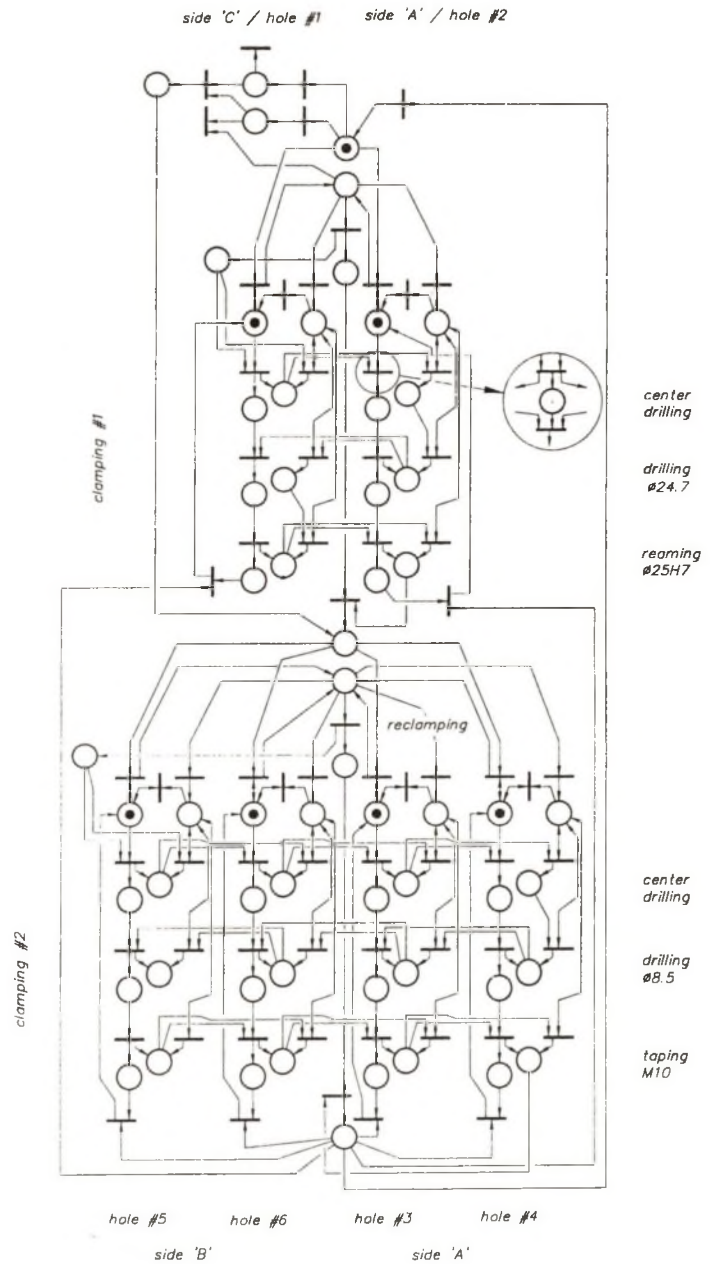

Fig.4. Example of model of course of technological operation

4. Concluding Remarks

The aim of the modelling of the structure of an operation is, above all, to facilitate and to aid desidn, optimization and creation of circumstances for automization of design among others by automatic generation of control program of working machine based upon the worked - out model. The proposed net structure enable us to make a very simple choice of one representation of group of objects which are technologicallly similar. It is prepared for synthetic representant, but by the proper initial marking (accceptance of M_0) we can trace a structure of an operation of arbitrary representant of a group. The net in this case is not changed and obviously does not loss its liveness i.e. the basic property which proved its corectness. The fact, that the worked out net is time Petri net, enables automatic calculations of duration time of operation or efficiency of working machine in a specified period of time. Assigning on arcs of graphs predicative functions (t,p), we can improve the possibilities of analysis of nets by several auxiliary tasks i.e. analysis of life of tool cutting edges or elements of quality control. It can be also stated that it not end of possibilities of application of Petri nets. Using of hierarchical, coloured Petri nets allows us to modelling of different objects which are treated not only in one technological group. An application of fuzzy marking makes it possible to fulfil the total multivariant optimization procedure of machining process of prismatic parts, as it was presented in the work [5]. It should be laid emphasis on the possibility of integration, by using of Petri nets, of technological modelling with problems of interstational transport and other problems in respect of organization of operation on work station.

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