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The method of the production flow synchronisation using the meta-rule conception

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Abstract: The subject matter of that paper is the method of the production flow synchronisation boiling down to the determination of distributed control procedures using the meta-rule conception. The presented approach relates to the system behaviour in time when the system does not work in the steady rhythm that is in the transition state. The proposed method is dedicated to production planning and control in the systems realising the concurrent multi-assortment rhythmic production.

Keywords: Production flow synchronisation; Transition state, Distributed control procedure

1. INTRODUCTION

The issues concerning production planning and control in systems being in a steady state, in which concurrent multi-assortment rhythmic production is realised are the subject matter of many publications [1, 2]. In a system being in a steady state production orders already accepted for the realisation in a certain rhythm are accomplished. It has been proved that the fulfilment of the system balance condition and the buffer capacity condition ensure the deadlock-free behaviour of a system being in a steady state. On the basis of those assumptions the method of the fast verification of production orders has been formulated. That method is useful for the preliminary determination whether the given production order can be accepted for the realisation in the system. However, practical observations have proved that it is necessary to extend the method into the system behaviour in the transition state i.e., in time when the system does not work in the steady rhythm.

2. PROBLEM FORMULATION

The considered system class includes distributed control systems realising concurrent multi-assortment rhythmic production. Between each neighbouring pair of resources the inter-resources buffer having the limited capacity is allocated. The steady state of the system is defined by the local dispatching rules determining the number and the sequence of the processes executed at the given resource. The transition state of the system means that the system does not work in the steady rhythm. There are three possible transition state phases: the starting-up, the cease and the transient. The starting-up phase takes place when for the realisation is allocated a set of production orders into the empty system or a single production order into the system in which some production orders are already realised. Similarly, the cease phase applies to the final production completion or single process completion. The transient phase consists in the transition from one expected steady state of the system to another one also realised in the certain rhythm. Assuming that the local dispatching rules describing the steady state of the system are given, the main problem can be formulated. The following question arises: *Which conditions should fulfil the distributed control procedures ordered to the transition state phases in order to synchronise the production flow into the expected steady state of the system?*

The presented method of the production flow synchronisation boils down to the determination of distributed control procedures using the meta-rule conception. The meta-rule consists of the three parts adequate to the starting-up, the dispatching and the cease rules. The first part of the meta-rule is the starting-up rule that is executed once and assures the production flow synchronisation into the expected system cycle. The second part of the meta-rule is cyclically executed and guarantees the steady state of the system. The third part is the procedure of the production cease and it is executed once after the cyclic realisation of the local dispatching rule [2]. The presented method using the meta-rule conception is based on the technique of the preliminary filling-up of the inter-resources buffer before the production start in the system being in the steady state. The local dispatching rule guarantees the steady state of the system and should cause the synchronisation into the expected steady state of the system. However, the arbitrary allocation of the dispatching rules to resources may cause a deadlock. In order to avoid that situation at the resources the starting-up rules are allocated. They ensure the filling-up of inter-resources buffer before the production start in the system being in the steady state. Analogically, it is necessary to delete an additional number of elements, allocated during the starting-up phase from the inter-resources buffers after completion of production in the steady state. That process is realised by the cease rules.

3. THE STARTING-UP PHASE

During the starting-up phase the starting-up rules are determined. The starting-up rules should guarantee deadlock-free system behaviour and synchronise the production flow into the expected steady state. The determination of the starting-up rules consists of the following stages: the identification of the basic cycles in the system structure, the determination of the multiple of the process realised during the starting-up rule and the determination of the processes realisation sequence in the starting-up rule.

For the identification of the basic cycles occurring in the production system the concepts from Graph Theory are used [3]. It is possible because a graph is a model that enables the description of a production system structure. The elementary contour according to Graph Theory is adequate to the basic cycle in the production system structure. Thus, the identification of the basic cycle requires the identification of the elementary contour in the graph [4]. For the identification of the graph contours the contour graph algorithm including the depth-first search algorithm with backtracking is used [5]. The result of that stage is the list of the resources belonging to the basic cycles.

The multiple of the process realised during the starting-up rule has to guarantee preliminary filling-up of the inter-resources buffers. If the number of the elements placed into the inter-resources buffer allocated between each $(M_i, M_k)_j$ pair of the neighbouring resources is equal to the number of the P_j process realised at the M_k resource according to the local dispatching rule, then the sufficient condition of production flow synchronisation is fulfilled.

The starting-up rule is realised only once before the production start in the system being in the steady state. At that stage the multiple of the processes realised during the starting-up rule is determined, but very important information about the processes realisation sequence in the starting-up rule yet is unknown.

The processes realisation sequence should be determined for the resources belonging to the basic cycles, which at the first stage has been defined. The starting-up rule allocated at every shared resource belonging to the basic cycle that occur in the production system structure should ensure the right processes realisation sequence. There is the $(M_i, M_k)_j$ pair of the neighbouring resources occurring in the basic cycle. For the $(M_i, M_k)_j$ pair the P_j process whose the next operation at the M_k resource should be realised according the production route at first at the M_i resource is accomplished. That processes realisation sequence guarantees the deadlock-free system behaviour.

4. THE CEASE PHASE

The starting-up rule realises the preliminary filling-up of the inter-resources buffers and the additional number of elements in the system is allocated. The additional elements should be deleted from the inter-resources buffers after the entire lot completion according to the cyclically executed of the local dispatching rules. The cease rule application enables that task realisation. The determination of the cease rules is realised analogically to starting-up rules and consists of the following stages [6]: the identification of the basic cycles in the system structure, the determination of the multiple of the process realised during the cease rule, the determination of the processes realisation sequence in the cease rule. The cease rule is realised only once after the production completion in the system being in the steady state. Moreover, the cease rules realisation guarantees deleting the additional intermediate products from the inter-resources buffers.

5. THE TRANSIENT PHASE

In the considered systems concurrent multi-assortment rhythmic production is realised. Hence, the production flow in those systems is changeable. Into the system in which some production orders are realised frequently new production orders are reported. When the new production order is accepted for the realisation the transient phase can takes place. It means that it is necessary to transit from one expected steady state of the system to another one also realised in the certain rhythm. There are two following possibilities: the transition with the system emptying and the transition without the system emptying [2].

The transition with the system emptying consists in the direct application of the starting-up rules and the cease rules. The process of the transition from the steady state described by the T_1 system cycle to another steady state described by the T_2 system cycle is divided into two stages. First, all production processes realised within the confines of the T_1 system cycle are ceased using the cease rules and at that moment the system is in the S_0 zero state, which means that the system is empty. Secondly, the starting-up rules are applied and the system transits from the S_0 zero state to the steady state described by the T_2 system cycle. That way of solving the problem guarantees the transition between two steady stages of the system without the deadlock occurrence. Anyway, the approach consisting in the transition with the system emptying is ineffective, because it requires relatively long time. Frequently the same number of the same elements is first removed from the inter-resources buffers using the cease rules and then filled-up into them using the starting-up rules. In order to eliminate that disadvantage the approach consisting in the transition without the system emptying has been formulated.

The approach consisting in *the transition without the system emptying* obtains the zero state of the system. In order to cease the production processes it is necessary to execute only that part of the defined cease rule, which is applied to the processes requiring the completion during the transient phase. Similarly, in order to start-up the production processes it is necessary to execute only that part of the defined starting-up rule, which is applied to the processes requiring the start during the transient phase. That modification introduced to the presented approach considerably improves the effectiveness of the system work.

6. CONCLUSIONS

The presented approach extended the method of the fast verification of production orders into the system behaviour in the transition state. The transition state of the system in contrast to the steady state is characterised by the non-rhythmical system behaviour. The system behaviour in each transition phase is different and requires the distinct analysis. The method of the production flow synchronisation boils down to the determination of distributed control procedures using the meta-rule conception. The meta-rule consists of the three parts adequate to the starting-up, the dispatching and the cease rules. The proposed method aids the decision process connected with production planning and enables to generate the distributed control procedures ensuring effective production resources utilisation. On the basis of the method authority software has been formulated, which is a useful tool for enterprises realising concurrent multi-assortment rhythmic production in the changeable environment. The modified method of the production flow synchronisation using meta-rule conception can probably be successfully applied in the manufacturing assembly systems. The presented problem is the subject matter of the future research.

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