Computer aided production planning – SWZ system of order verification

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Abstract. SWZ (System of order verification) is a computer implementation of the methodology that support fast decision making on the acceptability of a production order, which allows to determine not the best possible solution, but admissible solution that is possible to find in an acceptable time (feasible solution) and acceptable due to the existing constraints. The methodology uses the propagation of constraints techniques and reduced to test a sequence of arbitrarily selected conditions. Fulfilment of all the conditions (the conjunction) provides the ability to perform production orders. In the paper examples of the application of SWZ system comprising the steps of planning and control is presented. The obtained results allowing the determination of acceptable production flow in the system - determination of the manufacturing system parameters those that ensure execution of orders in time under the resource constraints. SWZ also allows to generate the dispatching rules as a sequence of processing operations for each production resource, performed periodically during the production flow in the system. Furthermore the example of SWZ and simulation system integration is shown. SWZ has been enhanced with a module generating files containing the script code of the system model using the internal language of simulation and visualization system.

1. Introduction

Today's market is characterized by very high dynamics, recent trends can be observed to shorten the product life cycle, to reduce production lot sizes and shortening deadlines and time of the execution of order (figure 1). This is due to increased interest in a diverse range of products [1, 2]. A good example of the production areas are subject to such changes is electronic or automotive industry, in which the last years of was a period associated with the implementation of the concept of lean manufacturing.

The main principles of Lean Manufacturing are focusing on processes and flows of value streams, continuous improvement by eliminating the losses, which in turn leads to the continuous value flow. Implementation of Lean philosophy requires the widespread use of tools supporting the management process and the evaluation of changes in production, changes in the configuration of production systems, planning, scheduling, and control at the operational level.

The response to these needs is the concurrent production of multi-assortment, characterized by the production of a diversified range of products at the same planning period and high flexibility. Concurrent multi-assortment production systems make it possible to better adaptation of manufacturers to market expectations, allow the implementation of a short product lot sizes, and readily respond to changes in demand. These systems usually consist of a series of workstations, on which production processes are performed in an asynchronous manner.
Multi-assortment production systems can be characterized by cyclic production. In relation to the manufacturing process, it is characterized by the rhythmic character of the production flow and the simultaneous realization of various products [3, 4, 5, 6]. In this type of production, regular repetition of the manufacturing operations performed on the production resources, in which for every constant period T, the same sequence of operations is repeated for the resources and after the last operation the return to the first operation in the sequence. Because the characteristic feature of rhythmic production is the work of resources and equipment according to cyclic schedule of production flow, its important parameters (utilization of machines, means of transport, warehouses, production costs, punctuality, etc.) can be defined algebraically. This raises the possibility of forming the specified indicators of production such as the resources utilization, the level of inventory of work in progress on a high level. Therefore, it becomes necessary to support decision-making process in the production planning and control, which, depending on the level include, inter alia, the following tasks:

- division of a production lot size on the production batches;
- determine the timing and sequencing of production batches in conjunction with the required demand of material and the required efficiency of production resources;
- allocation of production system resources for each production batch;
- scheduling of production operations of each production batch;
- production flow control in the system;
- system monitoring and responding to the deviations from plans.

Realization of these tasks is related to the need to determine the allocation of system resources for specific tasks, resulting from the production plan. In the following sections of the paper authorial software to support production planning processes at the operational level is presented, including the above-mentioned functional areas. The functions and structure of the system of order verification SWZ and practical example of the capabilities is shown.

2. System of order verification SWZ

In previous works [5, 7, 8, 9] it has been presented decision-making methodology on the acceptability of a production order. Methodology is based on a sequence of selected conditions testing for generating sets of local dispatching meta-rules assigned to resources. The method of determining meta-rules is based on the constraint propagation methods described in [7, 10, 11]. The conjunction of all defined conditions (for the production system and production order identified constraints) guarantees the possibility of order execution (feasible solutions) (figure 2). The conditions, which are used in the methodology, include [5, 8]:

- system balance condition - the number of products entering into the system is equal to the number of processes leaving that system during one system cycle,
- buffer capacity condition - the capacity of the inter-resources buffer is equal or bigger than the realization number of the process during one system cycle.
- due time realization possibility condition – processes included in the production order will be executed within the due time required by the customer.

Lack of solution provides information about the necessary abandonment of specified conditions of the order, or having to meet the needs associated with an increase in available resource productivity, buffers capacity, etc.

This methodology has been implemented in orders verification computer system. The SWZ - computer production orders verification system, assisting in the decision-making processes of the acceptance or rejection of the production orders for production planning.

SWZ system enables determining the control procedures assigned to resources in the form of local dispatching rules for the steady-states of production flow and the transient dispatching rules for the starting-up and cease phases of production, used during the initiation and termination of orders in the production system. The generated rules are designed to ensure the acceptable production execution quality (without deadlocks and starvations) and timely execution of orders. SWZ also generates information about the necessity to reject the production order which do not have a chance to perform in due date with the identified resource constraints. Developed and implemented algorithms and methodology support operations of enterprises in different areas: area of works organization in the enterprise, during the development process of product and manufacturing processes design, in activities related to the maintenance and throughout the monitoring of works progress process and utilization of resources.

In the case of a positive decision on the acceptance of the order for execution, SWZ system determines the production flow control rules. However, if the solution does not guarantee the timeliness and currently realized production flow without disturbances, SWZ indicates the direct reasons for the rejection of newly introduced order.

2.1. Specification of the manufacturing system
The data specifying the system are: the number of orders planned for implementation, the number of resources in the manufacturing system, the type of warehouse: central or interop, available storage capacity. In addition, can add further information about the status of each of the stocks in each unit of cycle time.

2.2. Specification of the manufacturing orders
Orders specification for execution in the production system includes the following information: the lot size of the order, required (directive or planned) due dates, number of operations for each process, production routes, cycle times and setup times of operations.

Input data for SWZ are entered by filling the system and order data sheets (figure 3). The system state during the starting up of new jobs should be selected prior to entering the data into SWZ. Data on
the setup and cycle time are entered into processes matrix (MPI) after the data on the number of operations for each production process.

2.3. Results of calculations
In case of order acceptance, a report is generated that contains:
- production batch size;
- job completion time for the accepted batch size;
- list of dispatching rules allocated to production resources, that coordinate the planned production flow in the system, including both a start-up rule and a cease rule for each phase of production,
- resources work schedule in the form of Gantt’s charts,
- resources utilization level during the operation of the system.

Additionally SWZ system was equipped with a module of automatic generation of production system simulation models for simulation and visualization uses data transformation technique (figure 3). In the process of data exchange and transformation into the input file for the simulation software, Extensible Stylesheet Language Transformations - XSLT is used. The XSLT processor transforms data stored in SWZ automatically into file for the simulation system. The generated file containing the internal programming language code of simulation system, creating manufacturing system resources, i.e.: machines, inter-operational buffers, warehouses, input and output buffers, and information resources, i.e.: tables containing data about the setup and cycle times on production resources, tables containing the sequence of operations on resources, data on processes routes [12].

3. Illustrative example
Let’s assume a production system, consisting of four resources M1 - M4. In the system three concurrent processes P1, P2 and P3 are performed (figure 4).
The production routes and times are recorded in the processes matrixes:

\[
MP_1 = \begin{bmatrix} 1 & 3 & 4 \\ 4 & 2 & 3 \\ 0 & 0 & 0 \end{bmatrix}, \quad MP_2 = \begin{bmatrix} 4 & 2 & 1 & 3 \\ 5 & 6 & 5 & 8 \\ 0 & 0 & 0 & 0 \end{bmatrix}, \quad MP_3 = \begin{bmatrix} 1 & 2 \\ 4 & 3 \\ 0 & 0 \end{bmatrix}
\] (1)

The first row of the matrix corresponds to the resources over which the route of the process goes; in the second line cycle times on proper resources are given; the third line contains set-up times.

This data are complemented by the following values: the size of orders: P1 – 100 pcs, P2 – 100 pcs, P3 – 200 pcs, the due dates: tz1 = 2000, tz2 = 2000, tz3 = 2300, inter-operational buffers capacity: for all buffers 5 pcs was assumed. For the input data entered into SWZ system calculation has been executed. The system suggested change of the production batch of P3 process to 2. After accepting this change, all orders were accepted to realization in the system. The following report in SWZ system has been generated:

Local dispatching rules LRRKZ:
R1=(1,2,3,3)
R2=(2,3,3)
R3=(1,2)
R4=(1,2)

Trr (starting-up phase) = 50
Trw (cease phase)= 54

Repeatability of rules:
The rule allocated to the M1 resource - 1 time(s). Rule R1 = 17
The rule allocated to the M2 resource - 1 time(s). Rule R2 = 12
The rule allocated to the M3 resource - 1 time(s). Rule R3 = 10
The rule allocated to the M4 resource - 1 time(s). Rule R4 = 8

System cycle : 17

Buffers data:
The required capacity of the inter-resources buffer allocated between resources M1 and M3 is 4. Real capacity is 5
The required capacity of the inter-resources buffer allocated between resources M3 and M4 is 2. Real capacity is 5

Rules realisation times at the resources :
Rule R1 = 17
Rule R2 = 12
Rule R3 = 10
Rule R4 = 8

Realisation times (steady state):
Process P1 = 1683
Process P2 = 1683
Process P3 = 1683

The coefficient of the system resources utilisation = 0,6911765

Figure 4. Production flow.
Rules containing the sequence of operation execution on resources in one cycle of the system have been generated. Realization times for the steady state and the maximum working time for starting-up and cease rules ($T_{rr}$, $T_{rw}$) were calculated. Resources utilization coefficient, which is in this case 69%, was determined.

In order to verify the correctness of the dispatching rules the simulation model of the production system for the Enterprise Dynamics simulation software has been automatically generated (figure 5).

![Figure 5. Simulation model.](image)

The results obtained from the system operation simulation are consistent with the results obtained on the system SWZ. The total job completion time $C_{max}=1725$ and is less than sum of realization times (for steady state) $T=1683$, max. time of starting-up phase $T_{rr}=50$ and max. time of cease phase $T_{rw}=54$.

4. Conclusions
A computer implementation of the support rapid decision-making methodology based on constraints propagation approach - SWZ system has been presented in the paper. The system aids an engineer in decision making, allocating the dispatching rule, which co-ordinates the production flow in the system (integrates the levels of planning and control). Two ways are possible: one for an empty system (usually when the set of orders is waiting for acceptance) and the other one for a system where other processes are performed (for a single order). The subject of further work in this field will be an extension of the methodology and SWZ system to transportation means, assembly processes and auxiliary operations.

References
[1] Wu C, Yu Shun F and Deyun X 2007 Computer integrated manufacturing Handbook of Industrial Engineering ed G Fellow (John Wiley & Sons: USA) pp 484–529
[2] Inman R A, Sale R S, Green K W and Whitten D 2011 Agile manufacturing: Relation to JIT, operational performance and firm performance Journal of Operations Management 29 4 pp 343–355
[3] Soltani S A and Karimi B 2015 Cyclic hybrid flow shop scheduling problem with limited buffers and machine eligibility constraints The International Journal of Advanced Manufacturing Technology 76(9-12) pp 1739-1755
[4] Bocewicz G, Wójcik R and Banaszak Z 2014 Cyclic scheduling of multimodal concurrently flowing processes Advances in Intelligent Systems and Computing 240 pp 587-598
[5] Skolud B and Krenczyk D 2001 Flow synchronisation of the production systems – the distributed control approach 6th IFAC Workshop on Intelligent Manufacturing Systems (Poznan: Poland) pp 127–132
[6] Kechadi M-T, Low K S and Goncalves G 2013 Recurrent neural network approach for cyclic job shop scheduling problem Journal of Manufacturing Systems 32(4) pp 689-699

[7] Krenczyk D and Skolud B 2011 Production preparation and order verification systems integration using method based on data transformation and data mapping Hybrid Artificial Intelligent Systems, Lecture Notes in Artificial Intelligence (subseries of Lecture Notes in Computer Science) 6679 pp 397–404

[8] Krenczyk D and Dobrzanska-Danikiewicz A 2005 The deadlock protection method used in the production systems Journal of Materials Processing Technology 164 pp 1388–1394

[9] Krenczyk D, Kalinowski K and Grabowik C 2012 Integration Production Planning and Scheduling Systems for Determination of Transitional Phases in Repetitive Production Hybrid Artificial Intelligent Systems, Lecture Notes in Artificial Intelligence (subseries of Lecture Notes in Computer Science) 7209 pp 274–283

[10] Dobrzanska-Danikiewicz A and Krenczyk D 2015 The method of the production flow synchronisation using the meta-rule conception Journal of Materials Processing Technology 164 pp 1301-1308

[11] Lorterapong P and Ussavadilokrit M 2013 Construction scheduling using the constraint satisfaction problem method J. Constr. Eng. Manage.-ASCE. 139(4) pp 414–422

[12] Krenczyk D 2014 Automatic generation method of simulation model for production planning and simulation systems integration Advanced Materials Research 1036 pp 825-829