WYBRANE PROBLEMY INŻYNIERSKIE
NUMER 2
INSTYTUT AUTOMATYZACJI PROCESÓW TECHNOLOGICZNYCH
I ZINTEGROWANYCH SYSTEMÓW WYTWARZANIA

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CASE STUDY: PRODUCTION ORDERS SCHEDULING IN MULTIVERSION AND MULTIASSORTMENT PRODUCTION SYSTEMS – PART I

Summary: This paper presents the issue of task scheduling, which aims in establishing a sequence of tasks, which maximizes the utilization of company's production capacity. The problem belongs to the NP-hard class, optimal method of solution has not yet been found, only approximate solutions have been offered. Regardless of specific production system, while considering reception of new tasks into the system, current review of the state of the system is required in order to decide whether and when a new order can be accepted for execution. In this paper, the problem of task scheduling is limited to determining the field of possible solutions to the problem of appropriate prioritization of production (production orders) which in turn will be accepted for execution on the assembly line in the car industry company. Simplified structure of the production system, orders transition paths and scheduling concepts within the system limitations have been presented.

1. Introduction

For many years, studies on the issue of optimization of scheduling and resource allocation have been conducted [1-6]. Optimization problems, both continuous and discrete are classified as NP-hard problems, due to their theoretical and computational complexity. These problems are encountered very often in the case of complex production systems, where on limited resources products must be finished within a specified time. Scheduling problem is to determine the sequence, in order to utilize resources remaining at the disposal of the company. Regardless of specific production system, its structure and organization, while admitting further orders it is required to review the current state of the system, and to decide whether and when a new order can be accepted for execution.

In literature many attempts to solve scheduling problems, e.g. with genetic algorithms can be found [7]. Unfortunately, as every solution, they have their advantages and disadvantages. In most cases, to obtain the best results time-consuming tuning of algorithm to a problem class is required.

Computational complexity and size of practical problems unequivocally eliminate the exact algorithms from consideration (due to the fact that a solution must be given within the prescribed time), leaving only the application of heuristic algorithms, allowing solving problems in a short time and with sufficient precision. Research on heuristic algorithms, which provide solutions to issues where it is impossible or inefficient to use exact solutions are a very rapidly developing field of science [8-16].

Appropriate tasks scheduling leads to many benefits including: higher utilization of material resources (in this case, machines and tools), increasing the saturation of the production line, the appropriate management of employee time, and its optimum exploitation. This translates directly into increased productivity and reduces unit costs, on the basis of the so-called economies of scale.

2. Formulation of the problem

For the purpose of considered issue, the actual production system has been limited to a section located at the assembly department (*Fig. 1*).

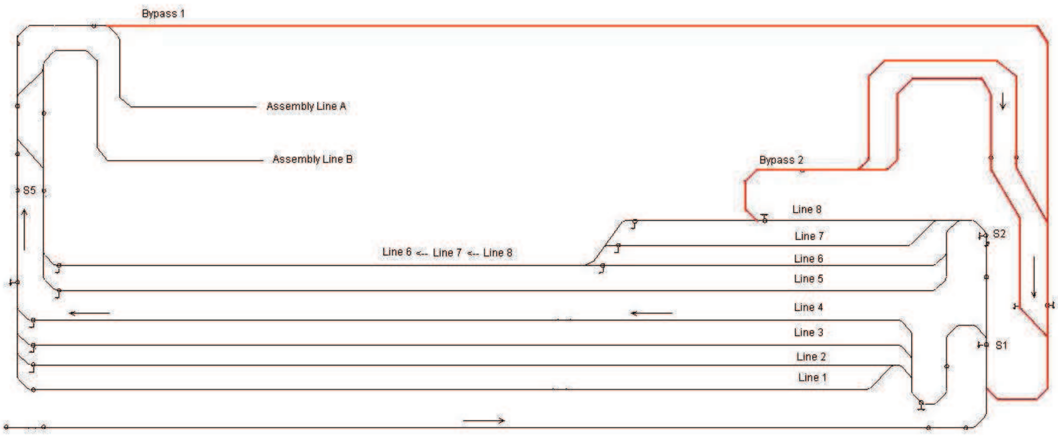

Fig. 1. Simplified diagram of a conveyor lines on an assembly department

Considered system consists of two assembly lines (A and B) unsynchronized with constant flow, into which production orders are distributed from a single buffer. Lines consist of several groups of assembly stations, on which various assembly and control operations are performed.

Three different car models are assembled in the plant, each with a large number of versions. For the purpose of scheduling problem, based on current research on the nature of production and the quantities and types of vehicles, produced versions were divided depending on the workload and labor factor into the classes from 1 to 7, where 7 indicates the most work- and time-consuming process of assembling the vehicle

Transportation is realized through a chain-driven conveyor. During the passage along the lines of the assembly department, the car body is equipped with parts specific to the task identification number, until the complete vehicle descents of the the line for a final inspection and transfer into the finished goods warehouse.

The conveyor moves at a constant speed through the whole line, setting a steady rhythm of production. An additional element, which allows greater freedom in determining the sequence of orders on the line, is so-called “bypass” - the part of conveyor line, into which the body may be sent to, in the case it can not be completed for various reasons. In the system there are two such places, first identified as a bypass 1 (long bypass) (*Fig. 2*), located on the exit of the buffer, but before entering the assembly lines.

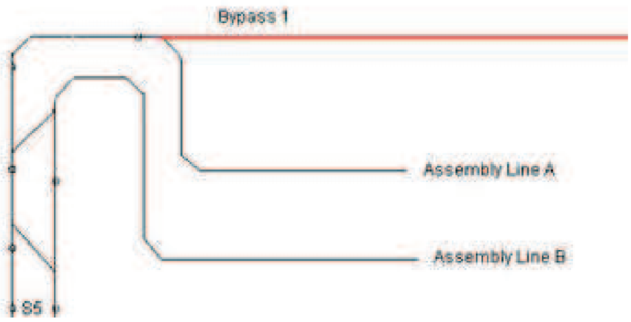

Fig. 2. Bypass 1

Bypass 2, which begins with a thread 8 in buffer (short bypass) (*Fig. 3*), a shorter route sends the body back to the beginning of the buffer.

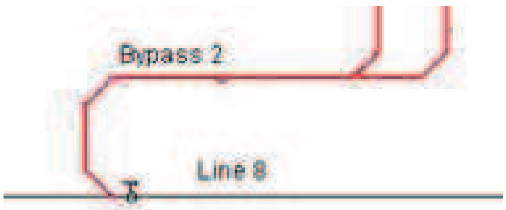

Fig. 3 Bypass 2

Buffer out of which orders are transmitted into assembly lines A and B, consists of eight threads, limited by a certain capacity. In this case, only a buffer and a section of the conveyor just before and after it are locations where it is possible to establish a sequence of admitting orders on line, and so to perform proper scheduling of production orders. Sequencing in the previous department – body shop, is not effective, since the car bodies are mixed in the next department – paint shop, because of the colors to be imposed on them. When after part availability check the information about shortage of some components required for the assembly process of particular car body is given, the car body should be directed to bypass, and therefore again to the input of buffer.

The capacities of buffer lines have been shown in Table 1. Each car body coming into the buffer has a specific identification code (ID). Orders selected for admission to assembly are released from the ends of various threads and get to the station S5. There, the decision is taken, on which of the assembly lines (A or B) should the vehicle be assembled. The choice of one of six orders that currently are on the exits of the lines is given.

2.1 Purpose

A sequence of tasks should be established to:

- Minimize completion time of a specific set of tasks (for the need of experiment a cut of production plan will be adopted),

- Provide adequate saturation of the line, the appropriate utilization of human resources,
- Accomplish production orders on time.

Tab. 1 Storage capacity of the buffer lines

Line number	Capacity [pc.]
1	24
2	24
3	25
4	25
5	25
6	23
7	8
8	7

3. Possible solutions

Field of possible solutions has been adopted as a three sets of scheduling rules: R_1, R_2, R_3. Before admitting any car body to assembly, availability check of all required parts will be performed. When a deficiency is detected, car body will be sent to bypass.

3.1 Rule R_1

The orders brought to the buffer according to the R1 rule are assigned to the appropriate line according to a predetermined position depending on a class of labor factor, obtained after reading the identification code. Each of the seven classes is assigned to a single thread, the line 8 is reserved in case of filling the remaining threads, for special orders and also as a entry to bypass 2 (*Fig. 4*). Admitting next car body to assembly is performed by another set of rules, which consider actual state of assembly line and demand for specific vehicles according to daily production plan.

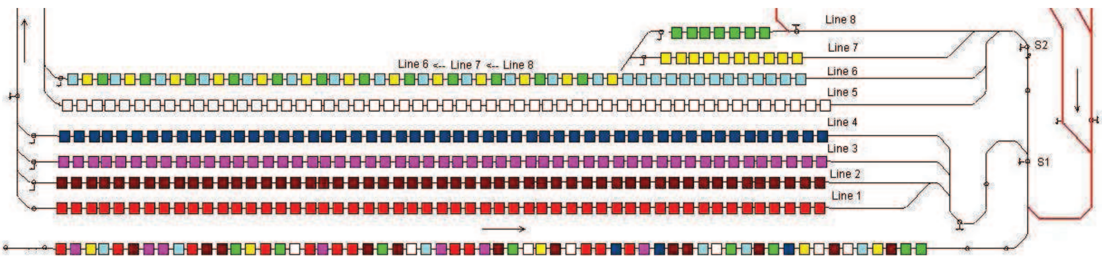

Fig. 4. Car bodies arranged according to R_2

3.2 Rule R_2

The orders brought to the buffer are allocated to the appropriate line in such a way, that the result is a sequence of car bodies, which in turn one after the other may be admitted into the assembly lines. In this solution, appropriate sequencing of orders is transferred from the output of the buffer, to its entrance. The lines are filled simultaneously, taking into account the previous body, which has been placed on them (*Fig. 5*). It will be impossible to introduce into the line two class 7 bodies one after another, as it would affect the production effectiveness. If there isn't any other option available to assign the body to a different line, such a body would be directed to the line 8 and further to the bypass.

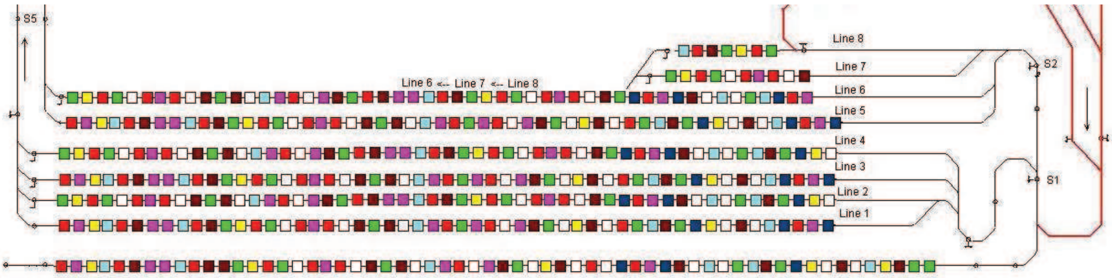

Fig. 5. Car bodies arranged according to R_2

3.3 Rule R_3

In the case of R3 rule orders will be assigned randomly to the line, which at the moment has the smallest number of car bodies (in case of an equal number of orders in each line- the first randomly selected). Admitting next car body to assembly will be performed by another set of rules, which consider actual state of assembly line and demand for specific vehicles according to daily production plan.

4. Accepting orders for assembly

To be able to accept a particular order for assembly, using a calculation algorithm, simulation will be performed for each of the six bodies, possible to be introduced. Based on the analysis of the results the decision of acceptance or refusal of the order is made. This algorithm takes into account factors relevant to the proper functioning of the line after the order is admitted for assembly, and also considers which order will appear as a consequent. If one of the bodies at the buffer output can be accepted for assembly, bodies located in the following places will be analyzed. There is a possibility to send the first body from the line to the bypass, and hence there is a possibility to consider admitting the second in line to the assembly.

Each order admitted for assembly must satisfy certain conditions:

- There is a difference in classes between two consecutive orders not smaller than 3, in the case of admitting orders with classes of six or seven.
- There is a difference in classes between two consecutive orders not smaller than 1 (and it has to be lower), in the case of admitting orders with classes of four or five.
- The introduction of the car body does not lead to excessive crossing of the local labor factor, while it is not possible to introduce another order to compensate transgression of the parameters.
- It is not rejected due to the higher priority value of another order.
- On the line there has been no unplanned downtime, preventing completion of the order.

5. Summary

Appropriate sequencing of production orders in the case of mass multiversion and multiassortment production is a key factor, since it has a significant impact on efficiency throughout the enterprise. Identifying and applying a set of rules provides more efficient planning of the sequence of orders, and hence better utilization of resources remaining at the disposal of the company. Through the use of computational algorithms, and automatic analysis of the resulting sequence, rates of production can be checked in a real time, and so improvements can be proposed and implemented. The issue in later stage can be developed due to many factors, such as the form of the buffer, or balancing of the assembly line.

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