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IMPROVING THE PRODUCTION FLOW AND EFFICIENCY OF THE MANUFACTURING SYSTEM SUPPORTED BY THE KBRS SCHEDULING SYSTEM

Abstract: An effective optimization process carried out in industrial conditions requires multiple actions in many different areas and the dynamic nature of the manufacturing system and its environment enforce its constant repetition. The paper presents selected techniques for increasing production flow efficiency that can be regarded as a first step of production flow optimization. The considered model was built on the basis of a real production system of mechanical industry, located in Silesia, Poland. A number of improvement actions was proposes, among which the most significant are: elimination of unused and slightly loaded resources, changing transportation lots between workstations, strengthening bottlenecks and optimization of a schedule. In the study the KBRS scheduling system [10] as a tool for solve complex scheduling problems and supporting particular simulations was used. In the result of carried out activities the significant improvements of the production schedule was achieved, in comparison to initial schedule.

1. Introduction

Scheduling, as a problem of distribution tasks to resources, applies to most areas of human activity. Particularly emphasized are these contemporary areas where human perception, without the support of software in certain situations, does not allow the proper planning of activities and decision-making[7].Although the area of scheduling is developed over decades and were received many researches, models, algorithms and methods, the production scheduling in practice is still a very serious problem [1]. It results mainly from the complexity of the scheduling task and the lack of effective, universal methods for obtaining high quality solutions [6].

The aims of presented analysis were minimization of required production time and optimization of the use of available production means in a typical mechanical engineering manufacturing company [2]. Considerable complexity of the model, typical for industrial conditions and scope of the research requires supporting by scheduling software [3].

2. The model of manufacturing system

The considered system consists of 67 machines (workstations), some of them are parallel. The set of selected 36 orders includes representatives of the most commonly executed processes. Lot sizes of orders are between 1-50 pcs. Processes comprise from 1 to 23 machining operations [2].All operations are divisible and resources are working according to the same calendar so it has been skipped in the planning process.

The proposed, initial production flow, organized manually is presented in fig. 1. The transportation of lots is carried out according to the serial or serial-parallel scheme of flow.

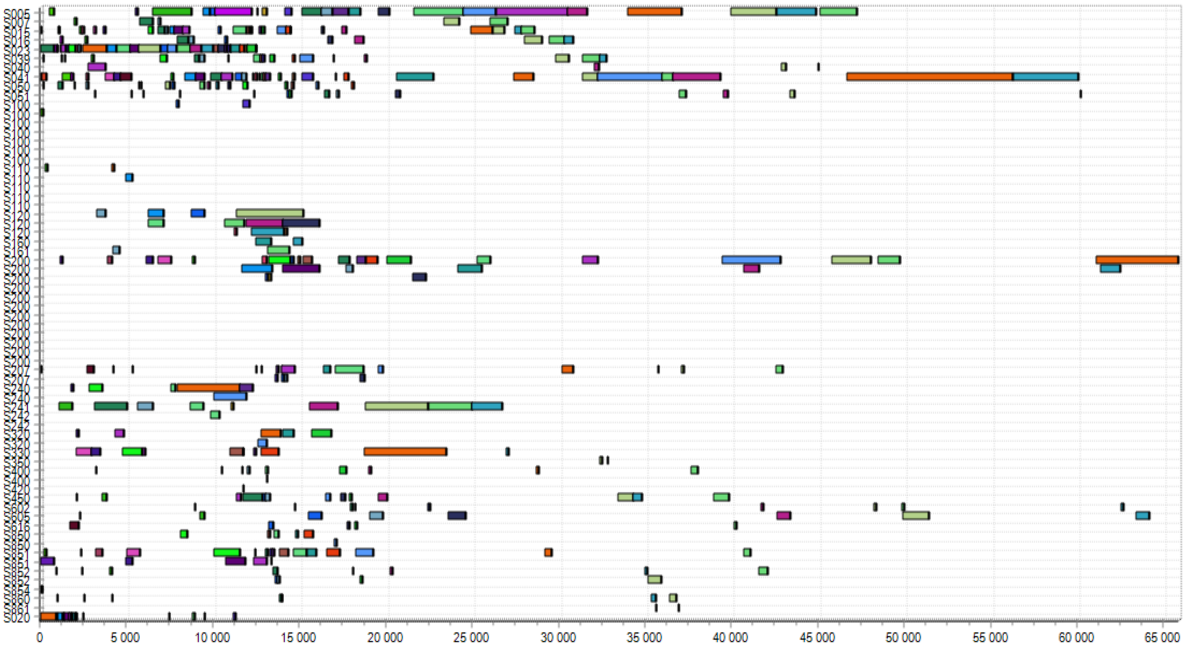

Fig.1.The initial production flow

3. Procedure of the production flow improving

Among the many possibilities[4,5,8,9], to shorten the production flow and improve efficiency in the use of machines the following basic activities were proposed:

- elimination of unused resources,
- changing of the flow of pieces in the lot,
- strengthening bottlenecks,
- optimization of a schedule.

It can be seen in fig. 1 that the company has many unused machines. Keeping unused or rarely used machines in the enterprise generates unnecessary costs related to e.g. servicing, maintenance and occupies sometimes strongly limited space in the production hall. Based also on historical data on machines load, it was proposed to eliminate 23 machines (~34%!). They were excluded from further analysis. The decision on use the outsourcing rather than maintaining individual machines requires an additional calculation in each case separately.

To determine potential benefits of independent flow the workpieces, each order should be considered to minimize the size of transportation lot. The following rules should be taken into account different rules: serial, series–independent and independent (independent flow is the equivalent to parallel in rhythmic production). In the serial scheme of production flow production whole lot is transported between machines so it causes that start of the next operation is performed after finishing of the previous operation on all pieces from the lot. The advantage of this approach is to minimize the number of movements between the workstations, the drawback - the need to store the whole lot in work-in-progress (w-i-p) buffers, usually located around machines. In the scheme of independent and series-independent lot is divided into smaller transportation lots, in many cases transport between the machines is done piece by piece. Independent flow has the lowest requirements for w-i-p buffers capacity; when parts are transported individually these buffers are sometimes not needed at all. The series-independent scheme of flow consists in machining pieces of lot as in the serial flow, but with transportation piece-by-piece as in independent one. This method allows for continuous machining without idle time between performing operations on successive parts. The key difference resulting from the using of a specific flow is the length of the production cycle. The shortest cycle is achieved by the independent and the longest –by serial scheme.

In order to estimate the extent of the differences in the given flow scheme three cases are simulated with serial series-independent and all independent flow for all orders in the set. Several simple rules and random search are used for obtaining different solutions with make span criterion. As shown in Figure 2, the best solution obtained by independent flow

id	schedule	Cmax	Cśr
1	H0.1;List[Z1,Z2,Z3,Z4,Z5,Z6,Z7...]	65840	20028,72
2	H0.2;revList[Z36,Z35,Z34,Z33,Z...]	79002	18785,97
3	H0.3;LPT[Z1,Z13,Z17,Z15,Z22,Z2...]	65840	22573,78
4	H0.4;SPT[Z35,Z34,Z36,Z33,Z31,Z...]	87046	17251,39
5	H0.5;Gupta[Z13,Z14,Z22,Z1,Z2,Z...]	67640	20464,61
6	H0.6;Palmer[Z8,Z4,Z16,Z22,Z17,...]	77060	21253,28
7	H0.7;Random[Z4,Z9,Z28,Z1,Z3,Z...]	65[illegible]40	19329,89
8	H0.8;Random[Z2,Z4,Z27,Z36,Z1,Z...]	66308	19237,95
9	H0.9;Random[Z14,Z2,Z31,Z4,Z23,...]	73628	18430,00

a) Serial

id	schedule	Cmax	Cśr
1	H0.1;List[Z1,Z2,Z3,Z4,Z5,Z6,Z7...]	45942	18066,55
2	H0.2;revList[Z36,Z35,Z34,Z33,Z...]	53202	15258,33
3	H0.3;LPT[Z1,Z13,Z17,Z15,Z22,Z2...]	44449	25546,00
4	H0.4;SPT[Z35,Z34,Z36,Z33,Z31,Z...]	56254	11744,19
5	H0.5;Gupta[Z13,Z14,Z22,Z1,Z2,Z...]	44454	18848,47
6	H0.6;Palmer[Z8,Z4,Z16,Z22,Z17,...]	45102	21063,00
7	H0.7;Random[Z2,Z27,Z4,Z6,Z7,Z1...]	43[illegible]64	18[illegible]72,70
8	H0.8;Random[Z2,Z29,Z3,Z18,Z7,Z...]	45880	16893,55
9	H0.9;Random[Z2,Z36,Z31,Z33,Z7,...]	53268	15198,39

b) series-independent

id	schedule	Cmax	Cśr
1	H0.1;List[Z1,Z2,Z3,Z4,Z5,Z6,Z7...]	40533	18877,76
2	H0.2;revList[Z36,Z35,Z34,Z33,Z...]	40040	16789,69
3	H0.3;LPT[Z8,Z4,Z22,Z17,Z19,Z32...]	36792	21216,34
4	H0.4;SPT[Z34,Z36,Z31,Z35,Z33,Z...]	38365	10776,63
5	H0.5;Gupta[Z13,Z14,Z22,Z1,Z2,Z...]	42474	20874,87
6	H0.6;Palmer[Z8,Z4,Z16,Z22,Z17,...]	40355	21979,38
7	H0.7;Random[Z22,Z20,Z14,Z30,Z3...]	33673	16763,44
8	H0.8;Random[Z20,Z23,Z13,Z2,Z1,...]	35935	16219,16
9	H0.9;Random[Z1,Z22,Z14,Z3,Z12,...]	34929	18135,49

c) independent

Fig.2.Makespans for different schemes of production flow

has completion time(C_{max}) more than 22% shorter compared to the series-independent and almost 50% shorter relative to the serial flow. These proportions are approximately preserved also in relation to specific scheduling rules. Therefore, increasing the number of transport operations, at least for selected processes should be considered.

Load analysis of individual machines can indicate a group of these, which are much more loaded than others. In presented case three workstations are selected: welding semi-automatic MIG, MAG and manual processing. The proposal to create additional parallel resources for them was considered. Fig. 3.presents results of searching the best solution in the case of duplication (a) and tripling (b) of these resources.

id	schedule	Cmax	Cśr	Fmax	Fśr	Fsum
7	H0.7;Random[Z13,Z20,Z11,Z1,Z30...]	18748	8988,34	18748,00	8988,34	3559382,00

a)

id	schedule	Cmax	Cśr	Fmax	Fśr	Fsum
7	H0.7;Random[Z17,Z1,Z15,Z1,Z30,...]	15619	6994,13	15619,00	6994,13	2769677,00

b)

Fig.3.Performance measures after duplication (a) and tripling (b) of selected resources

As can be observed ,after multiplying of most loaded machines, the time of order execution became much shorter: more than 44% with two and more than 53% with three parallel machines. Further changes didn't bring much better results. Flow times (*F*) in considered examples are equal to completion times because it was assumed that ready times of orders are $r_j = 0$.

In the process of optimizing the number of productive resources, strengthening bottlenecks, it is also worth considering the cost of eliminating positions that are very least loaded (e.g. one from parallel). Here, for given set of order, these are: boring and milling machine, heavy lathe and plate flattering press. The results of two simulations including these changes are presented in Fig. 4.

id	schedule	Cmax	Cśr	Fmax	Fśr	Fsum
7	H0.7;Random[Z13,Z36,Z1,Z36,Z30...]	15939	7000,92	15939,00	7000,92	2772363,00

a)

id	schedule	Cmax	Cśr	Fmax	Fśr	Fsum
7	H0.7;Random[Z1,Z11,Z27,Z3,Z21,...]	16230	6793,22	16230,00	6793,22	2690117,00

b)

Fig.4.Performance measures after removing boring and milling machine, and heavy lathe (a) and next plate flattering press (b)

In such situations ,slight extension of time for orders execution (~2% in case *a*, and a little more than 4% in case *b*) can be compensated by reduced costs of production system maintenance. In Fig. 5.the Gantt chart of final schedule(case *a*) including most of proposed improvements was shown.

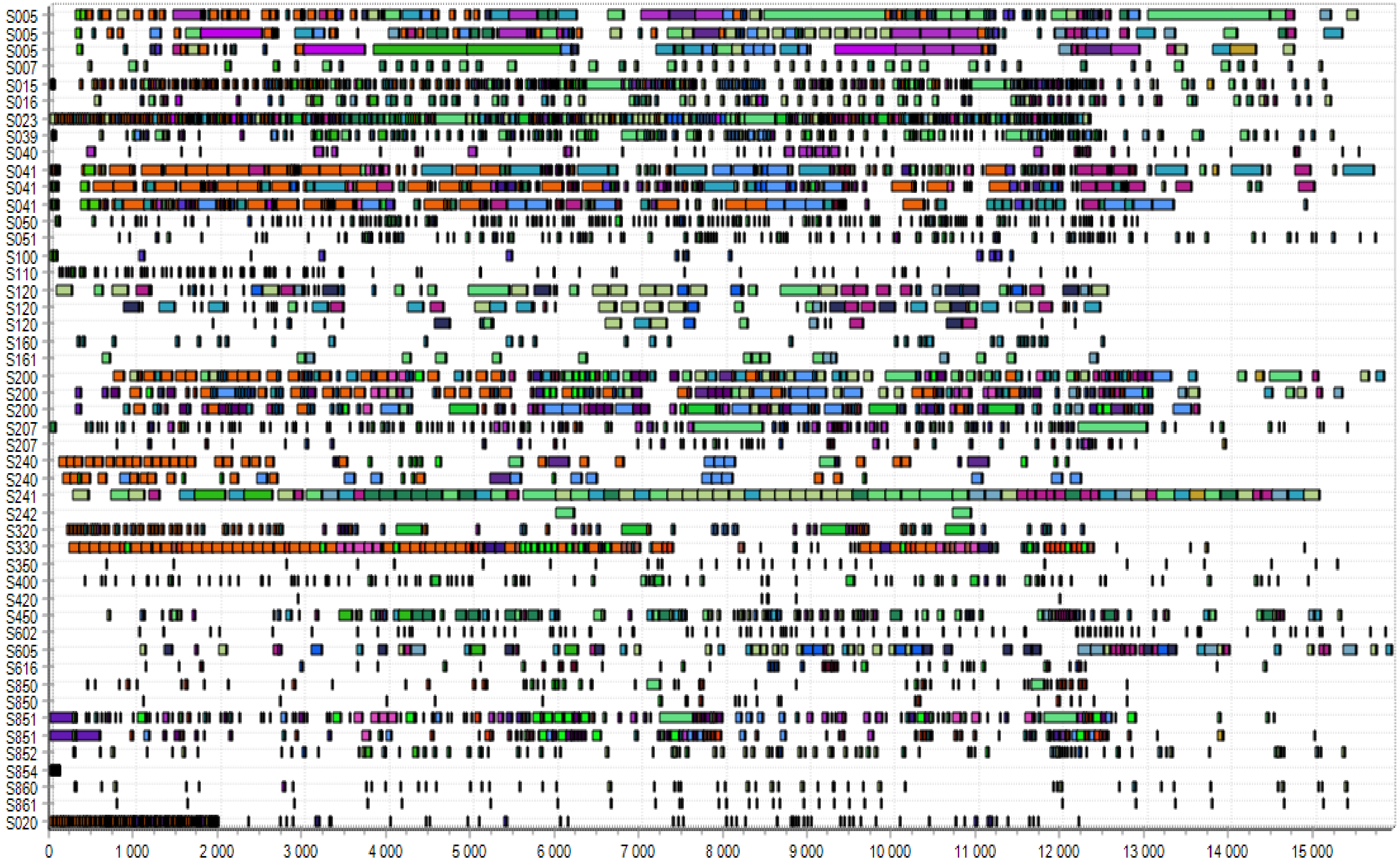

Fig.5.The proposed schedule of improved production flow

4. Conclusions

In this paper the way of optimizing the production flow based on data provided by the real production system was shown. The undertaken problem of optimization of the production system is a multidimensional task for which there is no a universal way of proceeding. Each real system has its own characteristics and constraints related to technology, hardware and human resources. So, there are various factors that should to be taken into account in the subsequent decision-making process and they have different degrees of severity. In such complex systems it is difficult to estimate the degree of approximation to the optimal solution (the best one).However, practically is sufficient to obtain an admissible solution instead of optimal one.

The basic actions carried out in this study were focused on detailed scheduling in various conditions and considering the impact of changes in the number of machines for the duration of production cycles. Using the KBRS software the simulations of many different cases of system configuration were analysed. The suggested modifications are proposal and may require additional studies before implementation (e.g. elimination of machines, changing how the flow of the party depends on the capabilities and efficiency of the transport system, the dimensions of workpieces etc. - Which should be considered independently for each job / process)

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