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ARRANGING TASKS OF THE LASER CUTTER USING THE DYNAMIC CLASSIFICATION IN CONDITIONS OF UNIT AND SMALL BATCH PRODUCTION

Abstract

In conditions of unit and small batch production a very important role is played by time of product availability for the customer. Despite using modern management techniques setup time still play an important role in the production cycle time. In the examined companies the relation between rearmament times to processing times is still high. The above researches inspired the author to prepare the method of setup times' reduction through proper arrangement of tasks in the operational production plan. Optimization of the daily production plans is based on two-level division of scheduling and arranging tasks. The method was validated in conditions of the production practice for unit and small batch manufacturing. An example of arranging tasks for the laser cutter was given. The presented method is one of elements of the computer aided expert system for SME.

1. INTRODUCTION

In contemporary systems of the production very important role is played by time of product availability for the customer In principle this kind of production is more expensive than the mass one, therefore flexibility, short series, uniqueness of the product as well as shortening of the production cycle determine the competitiveness of this kind of production.

The production cycle consists of, among others: the processing time and times of rearmament. Despite using modern management techniques e.g. SMED technique in the conditions of unit production in SME, times of rearmament still play an important role in the production cycle time. In the examined companies of the SME sector the relation between rearmament times to processing times is still high and amounts from a few to several per cent of the processing time.

The above researches inspired the author to prepare the method of rearmament times' reduction through proper arrangement of tasks in the operational production plan. In order to do that the notion of a classifier of a new kind was introduced – the classifier working at the level of task of production process operation. The task of the classifier is to aggregate tasks into organizationally similar groups which allow for implementation of tasks within the group: in sequences, without rearmament or by significantly shortening the above process.

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The above classification is based on features of tasks having influence on rearmament times and optimization of tasks arrangement. Using standardized classifiers for this purpose is not sufficient and in some cases can be harmful.
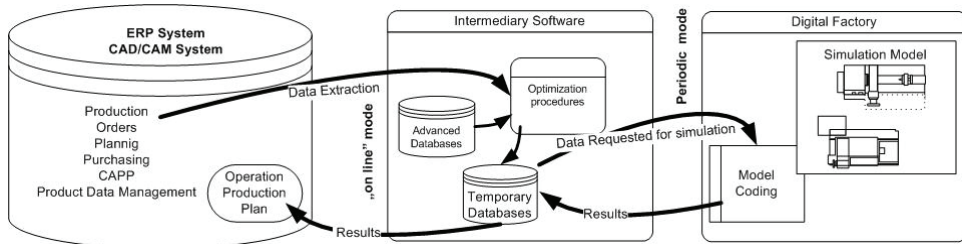

Fig.1: General concept of presented solution

The principled conception consists on applying of the expert system consisting of three elements (see Fig. 1):

1. ERP class system - collecting primary data about the product and production plans (e.g. orders from customers, the database of machines and devices, the worker and their qualifications),
2. module of optimization of arranging tasks and operational controlling working in „on line ” mode,
3. module of the simulation being an element of the digital factory - working in a periodic – "off line" mode. This module is destined for the periodic verification of the method.

The article is focused on the module of optimization of arranging tasks and operational controlling. Focusing on the work the bottleneck and improving it are essence of this approaching. Increasing the productivity of the bottleneck follows through the dynamic classification of tasks in the operational production plan.

A periodic simulation of the bottleneck's work is an additional element providing with the effectiveness of the method. Using tools of this type in the "on line” mode demand the purchase by enterprises of such systems. At present costs of the license are too high for this approaching. So applying the periodic mode is a good enough solution. An automatic data preparation through the module of middleware is additional improving the method.

2. OVERVIEW OF APPLIED SO FAR METHODS

The review of applied so far solutions concerned on the following areas: recognizing part similarities, Group Technology (GT), setup time reduction and acquiring data from the container of the ERP class systems.

Manufacturing based classification began to evolve in the 1940s. It is bases on the idea that parts do not have to look the same to be similar. Although they may appear to be different, they can be manufactured in the same way. It becomes possible to develop a classification system

that groups parts according to their manufacturing characteristics [5]. Analyzing literature it is possible to find a lot of methods of recognizing part similarities. The most important are: classification and grouping. Classification is a term from statistical sciences and it can be defined as a procedure in which individual items are placed into groups based on quantitative information on one or more characteristics inherent in the items (referred to as traits, variables, characters, etc) and based on a training set of previously labeled items [6].

The main problem in initiating a group technology based manufacturing system is that of grouping parts into families. Three methods for accomplishing this grouping are [1]: visual inspection, parts classification and coding, production flow analysis. As a first step, the development of manufacturing groups requires some measure of parts classification. There are a number of coding and classification systems that are now in the public domain.

Coding is connected with creating a code which consists of symbols reflecting features of the classified element. Currently many classification systems are used in practice [2], [8], eg. Opitz code, CODE code, Miclass code, CADAM code. At present there are used advanced techniques for part classification e.g. neural networks [6] and the fuzzy logic [7].

The changing world economy has caused an increase in the use of just-in-time manufacturing, which results in a trend toward short-run, multiple-product manufacturing. The frequent product changeovers make it imperative to improve setup operations and shorten line changeover times. The simplest way of the reduction setup time as making a distinction between internal setup tasks, for which production equipment must be stopped, and external setup tasks that permit equipment to continue to run [11]. The target of single setup, or reducing setup time to less than 10 minutes. Above named SMED principles are one of standard techniques Lean Manufacturing [9].

3. PROBLEM FORMULATION

Effective company management, require the right quality data that can be provided by integrated information system. Therefore, the bigger number of small and medium enterprises (SME) have decided to introduced ERP class system although they have recognized that the introduction process is difficult and expensive [4]. However, the alternative solution cannot be easily found. In the majority of companies the introduced ERP systems were not fulfilling expectations in the area of operational production control. Companies need efficient tools of decision-making process which could work in "on line" mode.

Applied so far methods of classification are applicable mainly in the construction and technology design phase. At the stage operational management the criteria used in the design phase are insufficient. The most important reasons limiting the use of standard classification systems include:
1. The subject of classification.
2. Stability of coding,
3. Singleness of assigning a code to the element.
4. Assumed features of classification.
5. Existence of variants of the production process.

Ad.1. In each of the mentioned methods the subject of the classification itself is the element. The criterion of classification is mainly construction features or technological features. The subject of classification should be situated much lower, at the level of production

process operations. At this level of classification criterion the organizational features play the basic role.

Ad.2. Built on the basis of construction and technological features the classifiers are of stable character, based on features which do not change their value. The change of the parameters value entails a change of construction-technology change and therefore practically a change of the classified object.

Ad. 3. In the presented solutions the given element belongs to the group only once. In elements designed in recent years such a scheme is not sufficient. It is connected with using new materials and technologies. The example can be a washer made from plastic. From the designer – mechanic's point of view it can be used for mechanical connections – as a screw washer. From the point of view of the constructor – electrician the same washer can be used as an insulator. In view of the above, what should the marking look like?

Ad. 4. In static classifiers the organizational features do not play the key role but in the cases of tasks arrangement described below it is quite the reverse.

Ad. 5. Very rarely in contemporary production systems do we not use alternative courses and that is why using one code to mark technologies is not sufficient.

Given the potential advantages of the concept and the emergence of the interactive computer, there was a flurry of group technology efforts in the late 1970s and early 1980s. As the 1980s unfolded, many of them were abandoned [5]. The problem was that the design or engineering office did not like to be hemmed in by the requirements dictated by manufacturing standardization and vice versa. At present methods of the production causes transferring classification area from the design part to the area of operating management. A need for the optimization of the work of the bottleneck also exists, which in conditions individual and job-lot production is moving between machines. Only by increasing throughput (flow) at the bottleneck process can overall throughput be increased [3].

On this purpose it is possible to use methods of classification and grouping and through the optimization of sequencing tasks on the bottleneck to get reduction setup times. Classification has automatic (software) and dynamic (organizational conditions are also taking into consideration) character, actives in "on line" mode. The above method of classification doesn't require encoding. The point of new approach is shown on fig. 1, details on fig. 2.

4. SOLUTION METHOD

Optimization of the daily production plans is based on two-level division of scheduling and arranging tasks. The first step is scheduling backwards without balancing of resources (image 2). It allows find bottlenecks. The next step is focus on bottlenecks. We can reduce bottlenecks through the exchange of process' alternatives (see in [10]). The next step is scheduling backwards with balancing of resources. As a result of this action we receive our daily work plan. Using the 2nd degree–optimization the daily work plan is further processed. The further processing is applied to operation plans from the nearest period in the round of tasks for the given position group – the production nest. The length of the period depends on the production type and on the articles produced. In conditions of unit and low-serial production the period of processing assumes values from 1 to 5 working days. Tasks of the operational production plan were subject to grouping. As a criterion of grouping the most crucial features from the perspective of rearmament times were assumed. After tasks grouping the group is manufactured without a division into fragmentary tasks. With such an arrangement the preparation-finishing times are shortened.
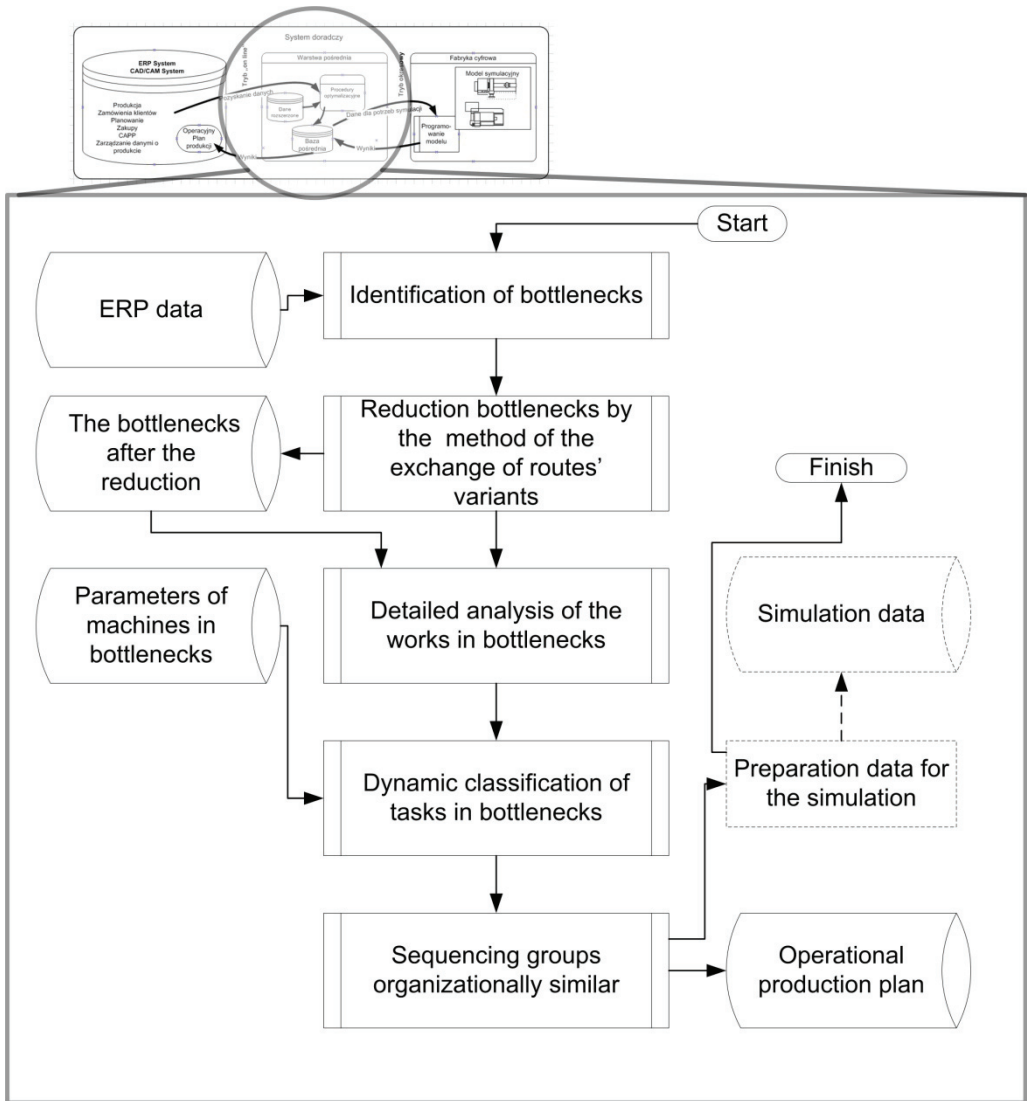
Fig.2: Detailed concept of presented solution.

This results in the effect of implementing tasks in the first day of the next day round but in the arranged groups round. As a limitation to the assignment to groups the organization parameters were assumed, such as the delivery time, the task priority, customer code, operation release. Assumption of limitation disturbs the schedule of tasks in a way which does not give(results in) side effects in the form of lengthening the cycle of some orders – while the effect of aggregation results in reduction of work consumption mainly on the side of

rearmament times. The fact of introducing the positive feed-back into the system leads to fast consideration of disturbance (in plus or in minus) in the next day schedule.

The basic element of the above method is defining features of the article which have impact on the rearmament times. The above features are defined from the perspective of position of machines and process production operations. For example for the varnishing line the major influence on the rearmament times is the colour of the varnished elements. Regardless of shape (which does have influence on processing time) if in the round of tasks there are elements painted the same colour then the line will not be rearmed. Using standard construction classifier in this case – where the subject of classification is an element and not the operation can have unwanted effects. The groups would be created for elements of the same kind –while from the point of view of the painting operation the variety is more welcome.

Designing the production process we do not know in what sequence the elements will be made and as a result we assign the full setup time in the base (in PDM or ERP class software). While if we arranged the tasks properly we could lower the setup times to a great extent. Preparation setup times cannot be lowered to zero but let us assume that we are able to assess the lowering of setup times for the remaining elements which constitute so prepared group.

Membership in the group is not limited. The basic limitation is the demanded production time. The group cannot be joined by too many elements because while performing the tasks for the whole group we perform them too fast than it is needed and we absorb the resources. Although we shorten work consumption we lengthen the unit production time. We are searching for an optimum in a multi-criterion optimization of length of cycles, work consumption and production costs. In fact the process of classification itself has a dynamic character which depends on the organizational conditions. Creating of such groups in a manual way would not be useful either, that is why it requires IT support. We could even risk assigning the attribute to the method: automatic.

Membership in the similar elements group is based on the criterion of similarity at the level of production process operation. The criteria are rather static but the given element – and in fact the task of the production process operation can dynamically belong:

- to different groups in different operations of the production process,
- due to organizational limitations, to different groups fulfilling even the same statistical similarity criteria.

Taking into account the above assumptions a heuristic method of arranging was created and verified by tests in real conditions. The individual steps have been presented below (Fig. 3.):

Step 1. Bottlenecks searching.
Step 2. Bottlenecks reduction (exchange alternatives of production process)
Step 3. Defining parameters of tasks which have influence on changeover times.
Step 4. Defining the influence of features on arrangement of tasks.
Step 5. Defining the set of tasks subject to arrangement and values for features from the set of tasks.
Step 6. Classification into organizational groups similar at the level of production process operation and positions group.
Step 7. Arranging organizationally similar groups in the operational production plan.
Step 8. Calculating time of tasks with consideration of arrangement of the created groups.
Step 9. Assignment of tasks to positions according to the membership in a group.
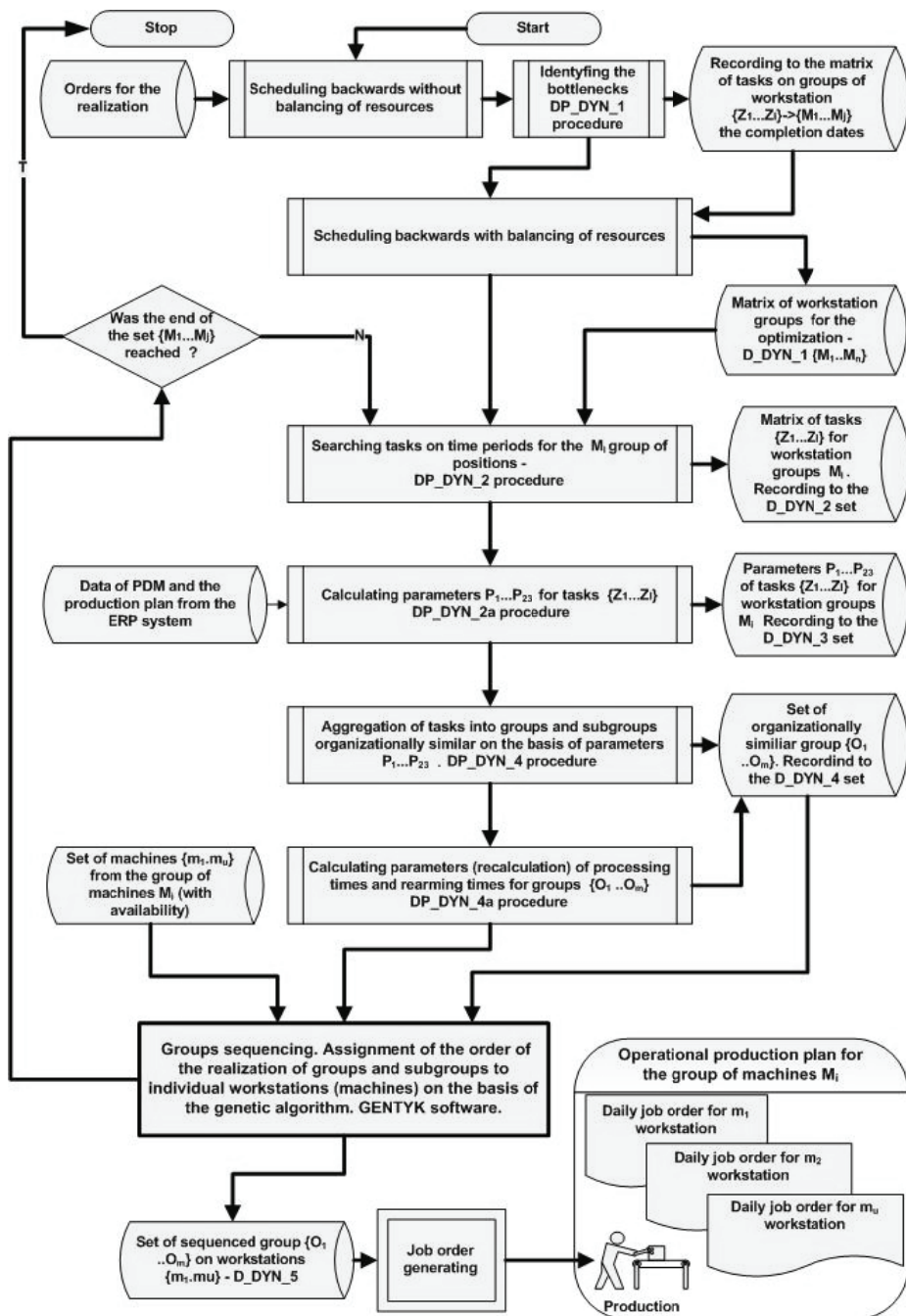**Step 10.** Verification of the process with registration of the operation.

Fig. 3: Method of building operational production plan (dynamic classification)

Step 1 and step 2 were presented in [10], so in this paper we focused on next steps. In the third step we are making a division of position groups into types homogenous in respect of parameters having influence on rearmaments. For each element of the set of machines M_X $=\{m_1, m_2, \dots m_n\}$ we will make a choice of parameters having influence on rearmament times so we will assign $m_1:\{p_{11},p_{12},..p_{1k}\}$, $m_2:\{p_{21},p_{22},..p_{2l}\}$, …, $m_n:\{p_{n1},p_{n2},..p_{nm}\}$. The assignment of parameters itself will not be sufficient; there should also be influence of the above parameter on reducing rearmament time given. The above influence will be hard to define in the zero-one logic thus principles of blurred logic were used. The above parameters will constitute the basic criterion in classification and creating of groups. The criterion itself can assume static values but membership of the given task to the group will take a dynamic character dependent on the organizational features or limitations used.

Apart from the choice of parameters limitations should also be introduced in the division into groups. The major limitation to membership in a group will be the time criterion. Tasks with the planned performance deadline distant from the first task performance deadline can be rejected from the membership in a group. In the above way a dynamic classifier is created according to task features at the level of production process operation which causes that depending on the classification moment the same element can be classified differently. In one case it can be assigned to a group and in the other it can be rejected.

The features have positive, negative or neutral influence. In order to define the influence of features on the tasks arrangement process the matrix of membership in organizationally similar groups were created for each of these kinds. In order to do that from each of these groups the dependence on features was defined and kind of influence for this type of connection was defined – influence meant assignment to the organizational group and the method of calculation of rearmament time for so created organizational group (organizationally similar).

Notation:

n- number of jobs (Id) to be scheduled, $\quad$ m- number of machines in the workshop

$\mathcal{F}work_{Id_ij}$-process time of job i on machine j, $\mathcal{F}setup_{Id_ij}$ – setup time of job i on machine j.

$\mathcal{F}_{Id_ij}$-complete time of job Id_i on machine j, $\quad$ q – amount of jobs' groups.

Complete time of job Id_i on machine j - $\mathcal{F}_{Id_ij}$

$$\mathcal{F}_{Id_ij}= \mathcal{F}setup_{Id_ij} + \mathcal{F}work_{Id_ij}$$

(1)

If the tasks have not been arranged and the organizationally similar groups have not been created then total duration time on machine m:

$$\mathcal{F}_j= \sum_{i=1}^{n} \mathcal{F}_{Id_ij}$$

(2)

In the case of creating groups: If $\mathcal{F}_{O_k}$ means the summary duration time of group O_k and $O_k:\{Id_i, Id_{i+1,\dots,} Id_{n,}\}$ then finally task duration time is calculated as:

$$\mathcal{F}_{O_k} < \sum_{i=1}^{n} \mathcal{F}_{Id_i}$$

(3)

The $\mathcal{F}_{O_k}$ is calculated according to one of 3 equations:

1. In case of recalculating of setup times:

$$\mathcal{F}_{O_k} \cong fsetupO_k(p_1, p_2, \dots p_t) + \sum_{i=1}^{n} \mathcal{F}work_{Id_i}$$

where $fsetupO_k(p_1, p_2, ... p_t)$, is a function of the recalculation of setup times for the group O_k, dependent on the set of parameters $\{p_1, p_2, ... p_t\}$ of the machines.

Complete time for set of jobs on machine j- $\mathcal{F}_j$ is calculated as:

$$\mathcal{F}_j = \sum_{k=1}^{l} \mathcal{F}_{O_k} \cong \sum_{k=1}^{l} (fsetupO_k(p_1, p_2, ... p_t) + \sum_{i=1}^{n} \mathcal{F}work_{Id_ik}).$$

(5)

2. In case of accepting of the largest time of setup from all tasks as the setup for the group: $\mathcal{F}_{O_k} \cong \max_{1 \leq i \leq n} \mathcal{F}setup_{Id_i} + \sum_{i=1}^{n} \mathcal{F}work_{Id_i}$

(6)

Complete time for set of jobs on j machine - $\mathcal{F}_j$ is calculated as:

$$\mathcal{F}_j = \sum_{k=1}^{l} \mathcal{F}_{O_k} \cong \sum_{k=1}^{l} (\max_{1 \leq i \leq n} \mathcal{F}setup_{Id_ik} + \sum_{i=1}^{n} \mathcal{F}work_{Id_ik}).$$

(7)

3. In case of accepting of modified (increased) the highest time of setup from all tasks as the setup for the group:

$$\mathcal{F}_{O_k} \cong \max_{1 \leq i \leq n} \mathcal{F}setup_{Id_i} * \zeta_j + \sum_{i=1}^{n} \mathcal{F}work_{Id_i}$$

(8)

Where: ζ_j is a rate of increasing the highest setup time for j machine. ζ_j is calculated on the basis of data from the knowledge base of the expert system

Complete time for set of jobs on j machine - $\mathcal{F}_j$ is calculated as:

$$\mathcal{F}_j = \sum_{k=1}^{l} \mathcal{F}_{O_k} \cong \sum_{k=1}^{l} (\max_{1 \leq i \leq n} \mathcal{F}setup_{Id_ik} * \zeta_j + \sum_{i=1}^{n} \mathcal{F}work_{Id_ik}).$$

(9)

After creating organizationally similar groups there were new tasks created for which the rearmament time should be calculated. It was pessimistically received that group rearmament time equals the highest time of the individual rearmament of a task from the group. In the below case we will receive a new set of the following processing and rearmament times.

5. THE EXAMPLE OF IMPLEMENTATION THE METHOD FOR LASER CUTTING

5.1. Description of the production system

The production system consists of 200 machine groups and about 300 machines. At the same time in the production system in the queue can be c 200 000 tasks. Productive capacity of the enterprise equals about 80 000 hours monthly. Essential meaning apart from machines are also the human resources. In a system at the same time can be even a few hundred thousand tasks. Tasks must be realized according to the manufacturing route. The manufacturing route can run by a lot of departments. Production tasks have the Make to Order (MTO) system of manufacturing, with the different priority of the performing, as well as with different deterministic dates of the production. For some types of products a production is carried out according „to the store " rule (MTS). It concerns the level of elements mainly. Above orders have the low priority of the performing. In the production of products and elements setup times have essential meaning. Bottlenecks are appearing periodically on a small number of workstations. Bottlenecks have "moving" character.

5.2. Description of the workstation

The company owns 2 laser cutters about similar technological parameters. One of machines has the greater power and he can work different formats of metal sheets. . It means that in certain scopes of processed metal sheets an exchangeability of applying exists. Additionally after applying the appropriate instrumentation a possibility of processing of profiles exists. In the studied example a working of machines Bystar 3015 and Bystar 402 were examined.

5.3. Examinations

Analyses were carried out basing on three different samples of data – F 1, F 2, F 3. Every of them demonstrated the different intensity of production orders in different period of times. Samples were taken in the period of c 3 months. Individual steps of the course of examinations were gave in next subsections. For example for the sample F1 3665 production orders, 58 758 elements and 202 601 operations of a production process appeared in the production plan.

In the first step of the method bottlenecks were identified. It correspond with TOC (Theory of Constraints) principles. Exceeding of the availability of resources were accepted to analyze in the week's arrangement (see Fig. 4.) .
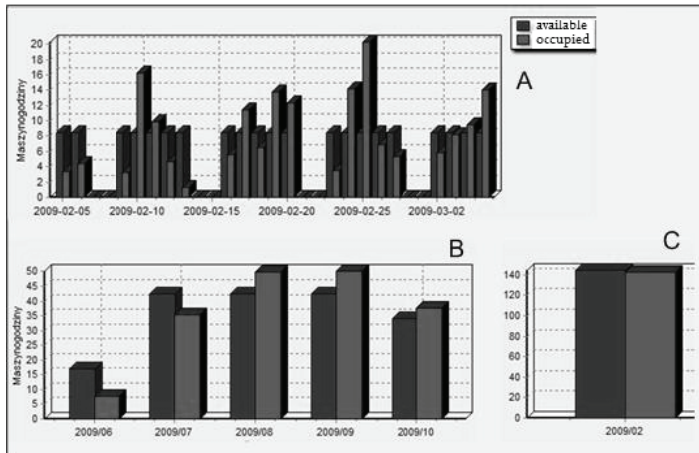
Fig. 4: The overloading being found in a laser fine cutter in period from 05 - 02 - 2009 to 05 - 03 - 2009 in the daily (A), weekly(B) and monthly (C) aggregations

Przeciążen Tydzień ▾							
Grupa S ▾ 2009/05	2009/06	2009/07	2009/08	2009/09	2009/10	2009/11	Suma
DPTR	0,63		5,09	28,87	17,44	0,61		52,65
DPTS	4,07					0,80		4,87
DSTR				15,01	54,26	1,22		70,49
DWST	3,93							3,93
HART			7,66					7,66
LAKP					11,53			11,53
LSRW	**0,26**		**12,90**	**34,79**	**34,44**			**82,39**
MJKC	3,55	19,36	29,49	55,49				107,88
OPKW	26,21	33,10	27,99	1,10	1,33			89,73
OSTS			15,14	69,31	48,25			132,70
PHD1					13,78	6,59		20,37
PLAK	0,09		11,64			31,23		42,97
PMDL	14,00				21,60	48,22	24,23	108,05
PMS1	23,70					0,08		23,78
PSLS1	9,58							9,58
SZCZ	0,93							0,93
TKLJ						2,22		2,22
TKP3	6,67					13,30		19,97
TPTS	10,29							10,29
WPR1	6,57							6,57
ZGPP	22,65							22,65
ZGRB	8,22	38,25	6,43					52,90
Suma	141,35	90,70	116,34	204,57	202,62	104,28	24,23	884,10

Fig. 5. Overloading for the LSRW workstation (laser cutter) in hours in weekly aggregations

In all three cases chronic bottlenecks, i.e. being overloaded in the entire analyzed period appeared. Also "moving" bottlenecks were observed. (Fig. 5.).

5.4. Preliminary classification of parameters and their influence on grouping

The influence of features on the setup time was given in table 1.

Tab. 1: The influence of features on the setup time and the membership in groups organizationally similar – group of laser cutting machines.

Code of the feature.	Kind of the assignment	Method of calculating the setup time	Comments
P1	0/+++	See P2.	The full agreement of coding the element always has the very strong positive influence or neutral influence.
P2	+++	Change of material the sheet to the profile: Setup = 0,21h. Change of the thickness of metal sheets: Setup = 0,14 h Change of the metal sheet Setup = 0,06 h. .	It is fundamental criterion of the membership into the group. Change of material the sheet to the profile require additional devices. The change of the thickness of the metal sheet requires the change of the head cutting. Additional condition: The change of the head is appearing for determined ranges of the thickness of the metal sheet. E.g. for the thickness of the sheet below 3 mm of the head isn't changing. After every change of the sheet its positioning take place.
P12	+	0,1 h	Very divergent dimensions can have the influence on the additional equipment of a workstation with whom one should provide or rearm
P20	--,----		Parameters from P20 to P23 these are limitations of the membership in the group. P 20 is suggesting not to arrange elements into groups about really divergent priorities of the executing. As they have negative character they will be applied as ruling out. For P20 we will accept the divergence above 2 steps as expelling from the group.
P21 ,P23	---,----		The due date scheduled plans will be a basic parameter dividing groups organizationally similar – we will accept, that if the due date of assignments on the group is above x working days next groups are being created. In the computer program it will be entrance parameter for forming a group.
P22	--		Freeing the operation is one of elements limiting forming a group. If the operation earlier wasn't freed in practical conditions then performing the task is impossible. On the basis of this parameter a conditional membership in the group is appearing.

5.5. Set of tasks of the laser cutter in the analyzed period

The first step consisted of preliminary grouping of tasks. As the criterion parameters were chosen P 2 and P 21. (Fig. 6.). In the next steps were created clusters considering remaining criteria (e.g. batching) (Fig. 7.) After new calculating setup times (according to equation no 5) reduce from 31,40h to 26,82 h was received. An author's software GENTYK were used for the dynamic classification and calculations setup times.
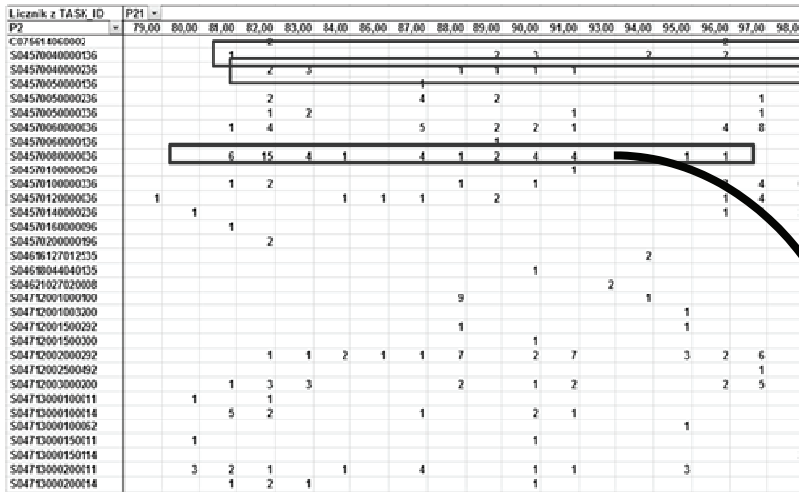
Fig. 6. Preliminary grouping into groups organizationally similar
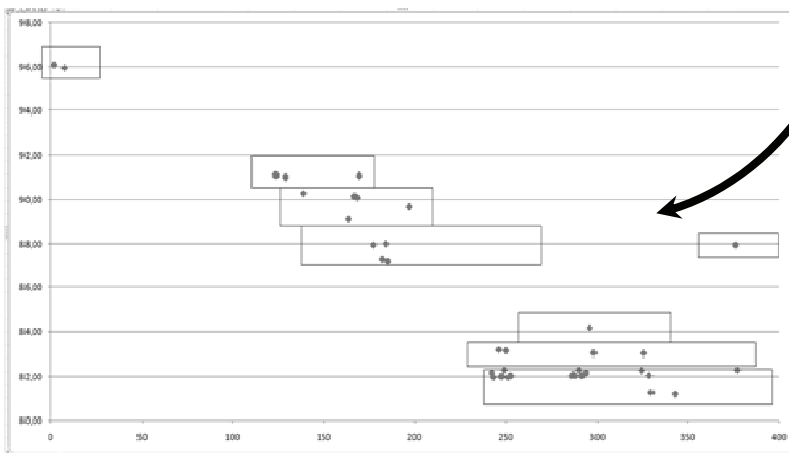
Fig. 7. Secondary grouping into groups organizationally similar

In the process of locating groups of tasks for resources genetic algorithm (implemented in GENTYK software) were used.

6. CONCLUSIONS

The method which has been introduced in this paper gives more possibilities in the area of profitability of IT projects in future. This approach seems to be, an excellent tool for decision making model for SME enterprises. In consequence this method can be an alternative for expensive and hardly implemented scheduling methods. Constrained-based scheduling with dynamic classification are an efficient tools for solving real-life scheduling problem in "on line" mode.

For the method to be effective the following conditions should be met: preparation of the knowledge base with a special attention to availability of the data from the point of view of features having influence on rearmament times, tasks parameters data bases, principles of processing of the process of dynamic creation of organizationally similar groups, cyclical (daily) classifications of tasks into organizationally similar groups, process support with the use of IT apparatus: ERP system, additional APS class applications allowing for automatic creation of the groups.

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