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HYBRID PRODUCTION PLANNING SYSTEM IN MAKE-TO-ORDER COMPANY - CASE STUDY

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ABSTRACT. This paper presents hybrid production planning and shop floor control system in make-to-order manufacturing of complex products. It presents the general idea of multi-hybrid system and selected practical aspects of its creation and its implementation. The construction of this system is based on the planning and executive levels and main aspects of its integration and its support tools. The research was carried out in HCP S.A. Poznan (Diesel Engines and Generating Sets Factory). HCP S.A. Poznan is the producer of high-power marine engines. The lead-time of the final product manufacturing is between 9 months and 1 year, and takes about 40.000 hours per one engine. The main problems of this production system are high share of the work in progress and long lead-time, which, as a result, causes many expenses. The flow of material streams is extremely complex and represents "A-plant" class, according to V-A-T classification, including significant internal constraints ("bottlenecks").

Key words: hybrid production planning system, MRP/TOC, Push/Pull strategies, Make-to-order manufacturing.

INTRODUCTION

The complexity of environment in which the contemporary machines production enterprises work as well as a large number of internal and external restraints influencing the organization of the flow of material streams make necessary to create more and more effective production managing systems. At the same time, the diversity of specific manufacturing environments causes the fact that there are no standard solutions, which completely fulfil the requirements at the operational level. Practically in every case in manufacturing practice, there is a need for the process of the development of dedicated solutions, based on general guidelines of existing planning and shop floor control systems. The reason for this is the fact that planning and shop floor control systems "hide" their true potential at the level of detailed specific solutions, usually customized individually, or formed according to the needs of current functional requirements. They are the processes of constructing of dedicated solutions, which are not sufficiently performed by production managers. The needs of the industrial practice recognized during the consulting and research work, cause the discussion of the problem of the development of the dedicated planning and shop floor control production systems. The transformation process in the companies operating in traditional way is difficult and long. The literature focuses mainly on cases of the successful implementation. However, taking into account the practical experiences, the introduction of the concept of Lean as well as TOC systems in the production area may bring many difficulties during the implementation. Moreover, the transformation of a large company may not be succeeded at all. One of the important reasons of such a failure is poorly chosen the "path of

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transformation", mainly incorrectly formulated concept of a target system of the production planning and shop floor control.

The aim of the paper is to provide a framework methodology for the construction of a dedicated planning system in order to avoid this "wrong way" of the transformation.

THE DESCRIPTION OF A MANUFACTURING ENVIRONMENT

THE GENERAL DESCRIPTION OF MAKE-TO-ORDER MANUFACTURING SYSTEM

The make-to-order manufacturing system means to manufacture small quantities of goods from a large product range, and the production process is initiated by an individual customer order. The flow of materials is realized in a technological framework, characteristic for the conditions of make-to-order manufacturing process. A technological framework consists on the managing of the company space in such a way, that the workstations performing the identical stages of a process or of a group of operations are situated together.

The make-to-order manufacturing system is a manufacturing activity of the most unstable character at workstations and at the lowest level of their specialization. The goods are manufactured individually, or with some repeatability, but this repeatability usually occurs at irregular and hardly predictable time intervals. The following features characterize it:

- the range of the production is diverse,
- the machine resources are universal, adapted to perform various operations,
- all-purpose instrumentation and low level of instrumentation, common means of control,
- highly qualified labourers as well as engineers and technicians,
- working time norms are not precise,
- no work assignment and the need of abilities to perform a large range of works,
- technological preparation of production is of frame (general) character,
- small possibilities of the mechanization and the automation of the production,
- it is based on the batch-job production system,
- it is also based on operational managing of the loads of workstations.

Make-to-order manufacturing has a no-stream form without any rhythm, which does not show any or only minimal repeatability of operations at specific workstations, which causes high frequency of changeover.

The presented organization of production processes leads to specific problems of this manufacturing environment, such as:

- low level of the production stability,
- high manufacturing costs,
- difficulties in planning and task scheduling at the operational level.

In business practice, these issues are the potential areas of irregularities, which unfortunately quite often occur in manufacturing activities. These disturbances destabilize company operations, negatively affecting its financial results.

IDENTIFIED GROUPS OF PROBLEMS

The research of a manufacturing environment, taking into account both its internal organization and external relations on the market of suppliers and customers, has revealed a number of reasons, which lead to the problems of general character. The identified problems have been grouped into categories according to their reasons [Domański and Hadaś 2009]. These categories are suppliers, customers and the inside of a company. The group of problems from in the category "Suppliers" includes a company's strong dependence on its subcontractors. It is connected with the high specialization of suppliers, which makes it more difficult to diversify the supply sources. The strong market position of suppliers leads to the difficulties in executing the punctuality of deliveries as well as their synchronization with the manufacturing and the assemble process. The low quality of deliveries is another problem, which is often revealed not until the phase of the production. It can seriously disrupt the whole production scheduling.

Another recognized category of problems is the numerous issues connected with internal functioning of the planning and controlling area of the production flow. The problems of coordinating of the dependent demands for components are the most serious. The final product generates a demand for a large number of components, which are used in the processes of sub-assemblies and the final assembly. The complex "topography" of the logical structure of a product presents type "A", in which numerous material streams converge in one, very complex product [Umble 1992, Hadaś Ł., 2006]. The practice of the release of production of the components in so-called economic order quantities, completed from various manufacturing orders, presents the additional difficult challenge. The other significant problem is the issue of managing the critical resources of a manufacturing system. So called "bottlenecks" not only limit the capacity of the system but they also considerably affect the operation costs [Hadaś et al. 2009]. Therefore, it is essential to maintain the continuity of its work.

The assignment of orders to workstations (machines) which are not critical resources is another important issue. Because of low level of the repeatability of tasks and the general way of planning, it is particularly difficult to determine the right sequence of completing orders and controlling their status. An inaccurate assessment method is used very often in such cases. The method makes it possible to estimate the percentage of the work, completed at a specific workstation, based on the work time used at specific group of operations. In such a case, it is difficult to synchronize the work of the machines with the critical resources of a manufacturing process.

In the category of "Customers" the main problem is a high individualism of received orders as well as frequent changes in the specification of a product even if it was already manufactured. The make-to-order manufacturing is characterized by the fact that the range of technological modifications often leads to the production of a very new product.

The estimated workload needed to complete the given stages and numerous unexpected complications make a planning process a more difficult one. Additionally the practice of construction changes while the order is already processed prolongs the process of the construction and the technological preparation of the production.

All the above-mentioned factors lead to the main problems of this manufacturing environment. The most important problems are the punctuality of the order fulfilment, too long manufacturing process and consequently, a high level of work in progress. These factors in turn, cause high costs of implemented processes, and therefore affect the competitiveness of the company on a global market. The dedicated system of the planning and controlling of the production flow should definitely take into consideration the identified problems and the main features of this manufacturing environment.

DIRECTIONS OF SEARCHING FOR SOLUTIONS

While looking for the solutions to the existing situations, inappropriate ways of action in a company (internal situation) must be reduced and a strong position among business contractors (external situation) should be gained and well-established (see Fig. 2). The strong dependence on external suppliers, who offer components of a high unit value and the technological specialization, clearly reduces the competitiveness of a company. On the one hand, there are serious problems to find alternative sources of supply or the absolute lack of them. On the other hand, the tight work scheduling of key suppliers considerably affect the lead-times of the completion of the manufacturing orders of a company. This situation is obviously taken into consideration at the stage of the order acceptance (defining deadlines for completing them), but it makes the company less competitive on the market. To improve the situation in this area, relations with suppliers have to be changed, by the closer cooperation with suppliers and the implementation of the long-term orders planning system. It is a process, which requires a lot of time for negotiations with business partners, but both the demand for components and the possibility of achieving requirements that are more regular can be an argument in contacts with suppliers.

The synchronization of supplies with real requirements for materials and components has to be the priority in trade contacts. The present situation is conducive to big shortages of most needed materials, which often forces sudden changes in manufacturing schedules. Therefore, the control methods in the area of supplies must be improved and better connected with the stage of production orders planning.

Taking into account the area of production orders transfer to workstations and groups of homogeneous stations, the system of orders issuing needs to be reorganized. The urgency of orders has to be taken into consideration in the relation to specific processing stages, and especially bottlenecks. Due to the identified role of critical resources of a manufacturing system, it is vital to implement a practice of buffering critical resources in order to protect the continuity of their work and to adapt other production resources to their capacities. The creating of such a system allows controlling the production throughput and the costs of work in process [Encyclopedia of Production 2000].

The company uses to schedule orders into a certain group of components, which are the part of respective orders for final goods, and therefore this practice should be considered. First, such actions and their conditions need to be analyzed to decide which are profitable and which influence negatively on production cycles and consequently on work in progress. The basic assumptions in the analysis whether the accumulation of orders is justifiable include the cost of materials, time of changeover for given orders and logistical aspects of purchasing of parts or materials such as the quantities of purchased raw materials and the frequency. The system of orders planning should take into account the accumulation of orders on the planning level and clearly identifies the desired sequence of completing them, so that workstations will precisely identify the sequence of tasks without the need for continuous correction and controlling them.

BUILDING A HYBRID SYSTEM - FRAMEWORK METHODOLOGY

The purpose of the research was to search for the best solution for the analyzed production conditions. The methodology of constructing a dedicated system of the planning and shop floor control was created during the research. The used methodology consists of the following sequence of operations (see the picture 1).

The first step is the analysis of the factors of the selection of a system of the production planning and shop floor control. The factors, which influence the environment of a manufacturing system, are defined at this stage. The next step includes independent analyses on the level of planning and the level of the flow of material streams (steps 2a and 2b). The purpose of these analyses is to select the planning logic as well as the flow logic for "the factors of choice" identified in the first step. The next step is to determine the possibility and the operational way of integrating of both levels (the planning level and the level of flow controlling). The created “core of integration" constitutes the basis for building a hybrid system. The next fourth step is connected with the implementation of selected support tools. They support the realization of functions at the planning level and the flow level. It is a level of so-called horizontal integration, which is process integration in the planning chain and the physical flow chain. The fifth step is to create the final structure of the model of a hybrid model. The further developments of the model / the concept of a dedicated system are connected with the stage of its verification during the implementation and the operational functioning.

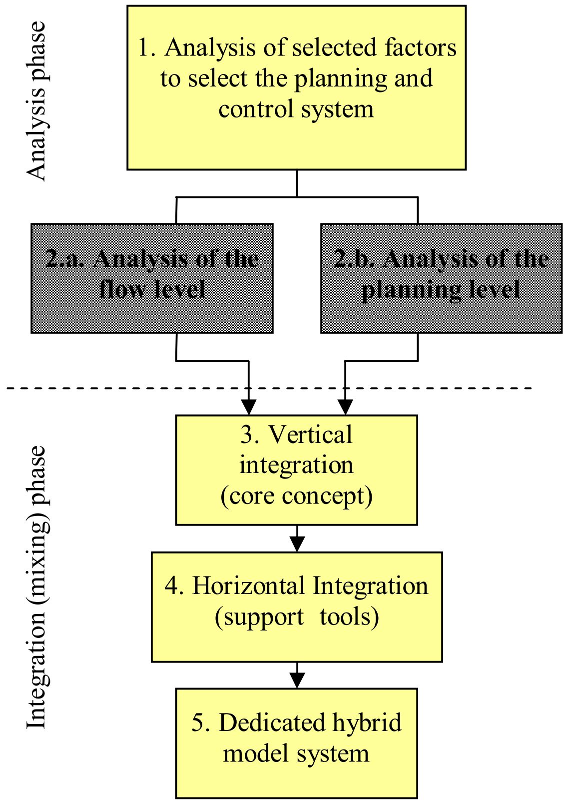

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Fig. 1. Framework methodology of constructing a dedicated system of planning and shop floor control
Rys. 1. Ramowa metodyka budowy systemu planowania i sterowania przepływem produkcji

FACTORS OF SELECTION OF A SYSTEM OF PRODUCTION PLANNING AND SHOP FLOOR CONTROL

The main selected factors to select a system of planning and shop floor control are [Hadas and Cyplik 2007] the complexity of a product and the complexity of the flow of material streams, the qualitative and quantitative variability of the production (the work, the level of internal and external disturbances, the structure of manufacturing potential (including the occurrence of strong internal restrictions).

They are two groups of factors connected with the product features affecting the complexity of material streams and with the structure of manufacturing potential and its availability. The main factors of selection were described in the presented case study (see point 2.1). Then basic groups of manufacturing environment problems were defined (see point 2.2) as well as their potential solutions (see point 2.3). The result of this three – stage analysis was to find the base for selection of the optimum method of planning and managing the flow of material streams.

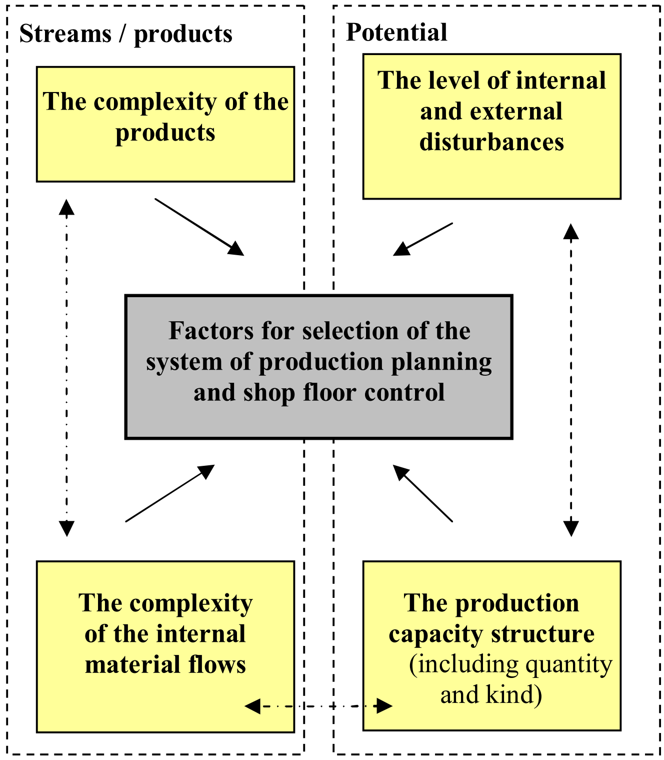

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Fig. 2. Factors of selection of a system of planning and shop floor control and their mutual correlations
Rys. 2. Czynniki wyboru systemu planowania i sterowania przepływem produkcji i ich wzajemne korelacje

Therefore, the determination, which „factors of choice" remain constant and which will change in the process of transformation, is a critical aspect of this analysis. It is very important that the developed model of a hybrid system should support improvement processes and not to preserve the unfavorable status quo.

DECISION LEVELS AND DIRECTIONS OF INTEGRATION

Two basic decision levels have been distinguished in the method of constructing a hybrid system (see picture 3). It is the level of planning and the level of the flow. Both levels are considered independently and only at the next stage the possibility of integrating them is analyzed.

MRP, JIT and TOC systems have been analyzed at the planning level as well as their planning compatibility in these manufacturing conditions. "Push" and "pull" hybrids have been analyzed at the level of the flow of material streams. Different aspects connected with the logic of launching orders in these management concepts, that is the location of schedules in the stream of values, initiating and organizing the flow by means of buffering, were examined.

The key issue was to form buffers (time buffer or stock buffer) as well as their location in material streams (global buffering or local buffering). The examined parameters were the level of the work in the process and the lead-time.

The results of analyses helped to formulate guidelines for constructing "a core of integration" which connects the planning level with the flow level (shop floor control).

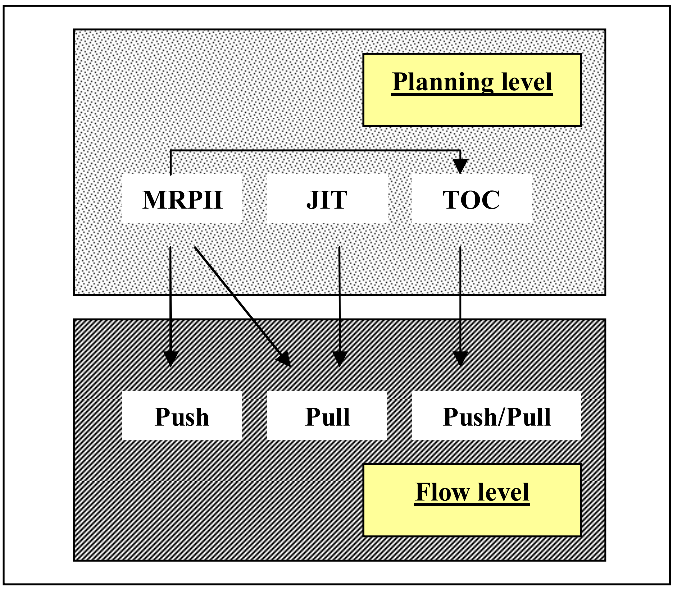

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Fig. 3. Main decision levels in the model of constructing hybrid systems
Rys. 3. Główne poziomy decyzyjne w modelu budowy systemu hybrydowego

MODEL OF A DEDICATED HYBRID SYSTEM

In the long-term and medium-term perspective, an enterprise applies a planning model based on the MRPII logic [Wight 1984]. This model encompasses both the long-term planning of the use of potential based on critical resources and the medium-term balancing of the production capacities in the cross-section of professional groups. Due to high variability of work and the length of a production process, this practice is rational. Thus, the reorganizing of systems of the planning and controlling the flow of production has to consider the practice of both long-term and medium-term planning, which is justified in the characteristics of operating of an enterprise.

A model of constructing a hybrid system of the planning and shop floor control consists of three basic levels: strategic, planning and operational (flow) (see picture 4). The strategic level is the area reserved for the top management, whose task is to make strategic decisions about the development directions of an enterprise. This level is not a subject to analysis in the presented model, because it is generally accepted that the decisions made on this level are carried out on lower levels. Therefore, the way in which the planning level and the operational level function, results from decisions made on the strategic level such as the market strategy or the product range.

The planning level is dominated by MRP logic [Orlicky 1975], which has to be enriched, however, by the effective configuration of logistics flow parameters. It is not enough to base the functioning of the whole field of the supply and the production exclusively on a typical lot size model. The lot for lot model which results directly from the gross requirements does not take into account both existing limitations in the area of organizing production and the supply itself. It is also useful to apply the classical inventory management methods, which make it possible to optimize the stock level from the point of view of the desired logistics service level [AIPICS 2008]. This case shows that the lack of an accurate configuration of the MRP class system in the scope of the delivery lot quantities as well as the safety stock are the main reasons for their low effectiveness. Another aspect of the MRP logic, which requires support, is a way of orders queuing. Applying a classic FIFO priority may appear insufficient in the conditions of the high variability of material streams as well as a high level of disturbances [Hadaś et al. 2009]. Such a result occurs particularly in the process of the determination of a sequence of actions, which precede operations carried out on critical resources of a manufacturing system. One way of solving this problem can be using genetic algorithms for building sequences of orders and operations carried out at bottlenecks. The MRPII logic, which is used for planning in a long-term and medium-term perspective, is complemented at the operational level (the level of the flow of material streams) by TOC concept (Theory of Constraints). The management on the operational level should exploit critical resources and subordinate all other manufacturing resources to their rhythm of work. The DBR mechanism [Goldratt and Cox 2000] (Drum - Buffer - Rope Solution) is a method which allows the logistical control of the flow of material streams in accordance with the rhythm of the work of constraints. This solution only works effectively if the practice of managing buffers based on "traffic light analogy" and the implementation of the flow of production according to "the roadrunner idea" are used. These solutions are applied in order to intensify the flow of material streams by replacing local buffers with concentrated global ones as well as by effectively managing their size. The practice has shown that in the conditions of make-to-order manufacturing with a high variability of work and a long lead-time, buffer management based on classic TOC tools was difficult and ineffective. It was necessary to create a method of buffering critical resources [Hadaś et al. 2009], which takes into consideration the average machine load on non-critical resources, as well as the possibility of occurring so called wandering bottlenecks. It was definitely the most significant modification of classical solutions, which make up the presented hybrid system.

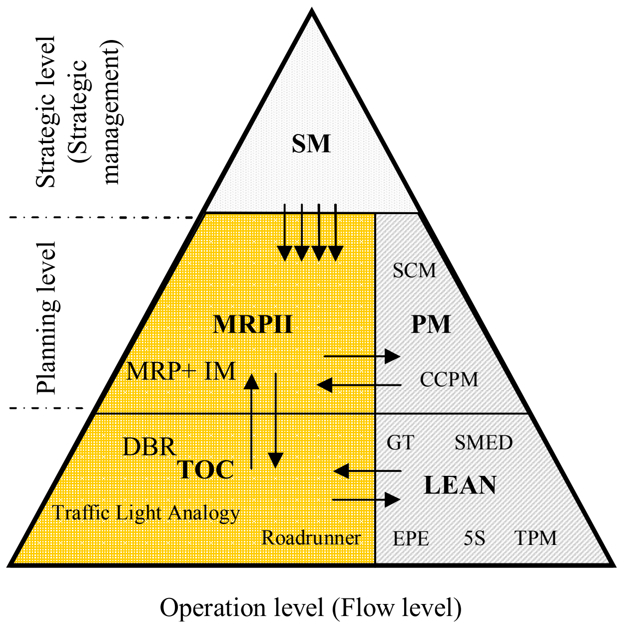

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Fig. 4. Schematic diagram of a system of planning and shop floor control in the conditions of make-to-order manufacturing.

Rys. 4. Ideowy schemat systemu planowania i sterowania przepływem produkcji w warunkach jednostkowego wytwarzania złożonych wyrobów

The concept of MRPII on the planning level as well as TOC on the level of the physical flow of material streams constitutes a specific core of integration of a hybrid system of the planning and controlling the flow of the production. Therefore, the MRP/TOC hybrid is the basis of the functioning of the model. It combines the effectiveness of the aggregated planning with the effective flow subordinate to critical resources [Hadaś et al. 2009].

The core of integration of a dedicated system is supported by solutions from the area of the project management as well as the lean management on the operational level (see picture 4). The manufacturing of non-standard complex goods with a long lead-time is in many aspects similar to the project management. There is a particular similarity between estimating the time length of specific actions within the framework of the construction and the technological preparation of the production, the coordination of supplies from major contractors and complex processing and assembly stages. The existing network of operations forms a system with many critical paths and numerous feeding streams. Planning the sequence of operations in such a huge network of reciprocal dependencies requires resorting to the practice of the project management. Many concepts of the project management have been analyzed here, beginning from Traditional Project Management (TPM) through Adaptive Project Framework (APF) to Extreme Project Management (EPM). Concepts that are more modern highlight the flexibility and the speed of operations that is so called agility in the project management. In the conditions of the high variability as well as appearing disturbances, it is undoubtedly a valuable skill, but when coordinating activities within the framework of the internal and external stream of values it is particularly desirable to secure the punctuality of completing them. It is usually done by means of extending and optimizing many local time buffers. Such a solution is not fully effective in case many potential lengthy disturbances occur. Meeting deadlines of specific stages of a project would require using too major reserves. The practice of adding a time reserve to every operation is not effective as the reserve time is often wasted, that is the work is not transferred to the next contractors although it has been completed earlier. The concept, which counteracts this frequent practice, is the CCPM method (Critical Chain Project Management) [Goldratt 2000]. This method is used in the presented mode of the planning and controlling the flow of the production in order to improve the risk management by means of concentrating buffers in the critical stages of the stream of values.

The Lean Management together with the whole set of devices of the process improvement is the concept which supports functioning of a system on the operational level [Ohno 1988]. Beginning with the tools of creation the stream of values, through the ones responsible for forming workstations (5S), the analysis of the intensity of the flow of material streams (EPEI - Every Part in Every Interval) to increasing time availability of machines (SMED, TPM) [Hirano 1988]. It should also be mentioned here, that using "lean" devices does not contradict the idea of TOC concept, which is the basis of constructing a hybrid system. In this specific "meeting", TOC indicates desires places of focusing attention on relevant issues, "lean" in turn, provides a lot of tools which can help to solve them.

CONCLUSION AND FUTURE RESEARCH

In every case developing and implementing a complex hybrid system of planning and the shop floor control is not an easy task. As there are no universal MRP, JIT or TOC models, there is not a single universal model of combining them. The existing models within both the framework of specific concepts and their integration are always of a general nature. In the case of a specified manufacturer, we have to carry out a thorough reliable analysis of the needs and possibilities of adapting those detailed solutions, which are desired from the point of view of organizing of the given production. In constructing one's own manufacturing system, it is particularly important to determine interdependent elements, their division into the key and the supportive ones, and then the schedule of the cascade implementation and measuring achieved results. All the factors mentioned above cause that despite their great similarity on the general level, hybrid systems "hide" their true potential of benefits in the area of detailed solutions. These solutions are strongly dependent on the competences and the commitment of people who implement them. They have to "understand" the manufacturing system and have the idea of how to reorganize it.

Works are also continuing in other companies. For example, it is now the MTS company with push logic of flow and wide range of products assortments (1,200 items) which is transforming to a hybrid MRP / JIT pull system with pull logic of flow and mix of decoupling point (MTO MTS, ATO and ETO for product groups).

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HYBRYDOWY SYSTEM PLANOWANIA PRODUKCJI W WARUNKACH JEDNOSTKOWEGO WYTWARZANIA WYROBÓW -STUDIUM PRZYPADKU

STRESZCZENIE. Artykuł prezentuje ramowy proces budowy dedykowanego systemu planowania i sterowania przepływem produkcji w warunkach jednostkowego wytwarzania złożonych wyrobów. Autorzy prezentują generalną ideę budowy systemu hybrydowego oraz wybrane aspekty jego tworzenia i implementacji. Konstrukcję rozwiązania kształtują poziomy planowania i wykonawczy oraz główny rdzeń integracji i jego narzędzia pomocnicze. Badania były realizowane w Fabryce Silników Okrętowych (W2) HCP Poznań. Głównymi problemami systemu planowania i sterowania przepływem w tych warunkach są wysoki poziom robót w toku, długi cykl realizacji oraz w efekcie wysokie zaangażowanie kapitału. Przepływ strumieni materiałowych jest ekstremalnie złożony, reprezentuje tzw. "A-plant" (według klasyfikacji V-A-T) z silnymi ograniczeniami potencjału ("wąskimi gardłami").

Słowa kluczowe: hybrydowy system planowania produkcji, MRP/TOC, strategia push/pull, jednostkowe wytwarzanie wyrobów (make-to-order).

HYBRID SYSTEM DER PRODUKTIONSPLANUNG IN BEDINGUNGEN DER AUFTRAGSFERTIGUNG - FALLSTUDIE

ZUSAMMENFASSUNG. Der Artikel präsentiert den Rahmenprozess des Baus einer System zur Planung und Steuerung der Auftragsfertigung von komplexen Produkten. Die Autoren präsentieren eine allgemeine Idee zum Bau eines Hybridsystems und ausgewählte Aspekte seiner Entstehung und Umsetzung. Die Planung- und Durchführung-Ebenen wie auch die Hauptintegrationskern und ihre unterstützenden Werkzeugen bilden die Lösung. Die Untersuchung wurde in HCP SA Poznan durchgeführt. Die Hauptprobleme der Planung und Steuerung der Fertigung in diesen Bedingungen sind der hohen Anteil der laufenden Arbeiten und langen Vorlaufzeiten, und als Ergebnis das hohe Engagement des Kapitals. Der Materialfluss ist äußerst komplex und vertretet so genannt A-Werk (nach V-A-T Klassifikation) mit starken Kapazitätsengpässen ("Bottlenecks").

Codewörter: Hybrid-System der Produktionsplanung, MRP/TOC, Push/Pull Strategien, Auftragsfertigung.

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