IMPACT OF WORK IN PROCESS ON THE LEVEL OF INTEROPERABLE STOCKS

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Abstract

Systemic approach allows to see the production enterprise as a complex system of production and auxiliary facilities. In process approach, manufacturing makes the stream of materials flow through individual production cells in a mixed (serial - parallel) system, in a discreet way (in steps). Processing times are different at each stage. Element that connects individual production facilities are interoperable landfills, which perform the functions of semis storage departing from object N and magazine of deliveries for the next (N + 1) or another station. Chart flow of deliveries and acceptances at the time takes the stepped form. Parameters of steps depend on the processing time and batch size. In the actual manufacturing process (even in the long term), lines of supply and efficiency do not run parallel. The article presents the impact of work in process on interoperable inventory levels for the unit production on request.

Keywords: Work in process (WIP), production system, production continuity

1. INTRODUCTION

The common element that combines different approaches to production logistics is property flows. Hence, new concepts and tasks of production logistics arise. As a way to eliminate waste *(muda)* J. P. Womack and D. T. Jones [1] recommend the lean approach (*lean thinking*) by creating a stream of values in the enterprise. In the lean approach, one has to go outside the company in order to look at all the actions that make up the process of developing and producing a particular product. According to J. Burton *lean* may be defined most simply as a process of continuous elimination of waste. Access to large spaces leads to the accumulation of large stocks, which leads to the generation of excess manufacturing in the course of wip (*work in process*) [2]. In the terms proposed by M. Rother and J. Harris [3], the most important task in manufacturing systems is the maintainence of continuity in the flow of materials, as well as the constant improvement (*kaizen*) of continuity. In relation to supply chains, P. Nyhuis and H. P. Wiendhal [4] state that the primary purpose of production logistics can be determined by the ability to increase supply and the reliability of supply at the lowest possible cost of logistics and production. Currently, there are many methods and techniques that can be used in the production-related activities of the enterprise. All customised solutions that contribute to improving the productivity of manufacturing processes may be of help here. For analysis of the correctness of material flow in production processes, P. Nyhuis and H. P. Wiendhal proposed nine basic laws of production logistics (9 LPL). In several laws WIP is an important element of the dependence of production. Work in Process (WIP) is that part of a manufacturer's inventory that is in the production process and has not yet been completed and transferred to the finished goods inventory. This account contains the cost of the direct material, direct labor, and factory overhead placed into the products on the factory floor. The formula for WIP is:

Work in process = (operating inventory goods in process + raw materials used during the period + direct labor during the period + factory overhead for period) - ending inventory

2. PROBLEMS OF LOGISTICS ENGINEERING IN THE PRODUCTION PROCESS

The development of the SCM concept forces the companies to transform from functionally-oriented to process-oriented organizations. Therefore, the means to achieve this goal should be flow control methods. In relation to supply chains, Nyhuis and Wiendhal [4] said directly that: The fundamental goal of production logistics can thus be formulated as the pursuance of greater delivery capability and reliability with the lowest possible logistic and production cost.

The algorithm enabling the analytical consideration of material flow processes in a production company will be presented below.

Table 1 Process-describing values designation

Value designation	Value description
$i, j = 1, 2, \ldots n$	consecutive numbers of production equipment UP, i.e. $(i \in PD, j \in PD)$
$k = 1, 2, \ldots p$	batch number of the material MT flowing between the equipment, $(k \in MT)$
$s = 1, 2, \ldots st$	consecutive numbers of transport equipment TD, $(s \in TD)$
$m = 1, 2, \ldots ma$	warehouse number MA, $(m \in MA)$
$M^{w}_{i,j}(k)$	shipment moment of the *k* batch of material from point *i* to point *j*
$M^{d}_{i,j}(k)$	delivery moment of the *k* batch of material from point *i* to point *j*
$t^{s}_{i,j}(k)$	total time of transport cycles (loading, transport, unloading, return) of the *k* batch of materials, with transport means *s* from point *i* to point *j*
$\Delta t^{m}_{i,j}(k)$	time spent by the *k* batch of material at buffer *m*, between points *i* and *j*
$t_j(k)$	time of the *k* batch of material crossing the point *j* (time of *k* batch service on equipment *j*)
$t_{pj}^{(a)}$	time of conversion of the *j* equipment for the production of (*a*) products

If the values describing logistics processes are (see Table 1), then the delivery moment of the *k* batch of material from point *i* to point *j* is given by the formula:

$$M^{d}_{i,j}(k) = M^{w}_{i,j}(k) + t^{s}_{i,j}(k) + \Delta t^{m}_{i,j}(k) \quad (1)$$

- shipment moment of the *k* batch of material from point *i* to point *j*:

$$M^{w}_{i,j}(k) = M^{d}_{i-1,j}(k) + t_i(k) \quad (2)$$

- shipment moment of the *k* batch of material from point *j* to point *l*:

$$M^{w}_{j,l}(k) = M^{d}_{i,j}(k) + t_j(k) \quad (3)$$

however, two cases should be taken into consideration:

- if: $M^{d}_{i,j}(k) < M^{w}_{j,l}(k-1);$ *(case 1)*

the moment of delivery of the *k* batch of material to the *j* production equipment is earlier (before) than the moment of shipping the previous (*k* - *1*) batch of material from the *j* production equipment to the *l* equipment, the material before the *j* equipment is stored for the period of $\Delta t^{m}_{i,j}(k)$;

- if: $M^{d}_{i,j}(k) > M^{w}_{j,l}(k-1);$ *(case 2)*

the moment of delivery of the *k* batch of material to the *j* production equipment is later (after) than the moment of shipping the previous (*k* - *1*) batch of material from the *j* production equipment to the *l* equipment, the *j* equipment awaits (is in “downtime”) for the period of $\Delta t_j(k)$.

Figs. 1 and **2** contain a graphical representation of the flows:

- for the manufacturing device PD:

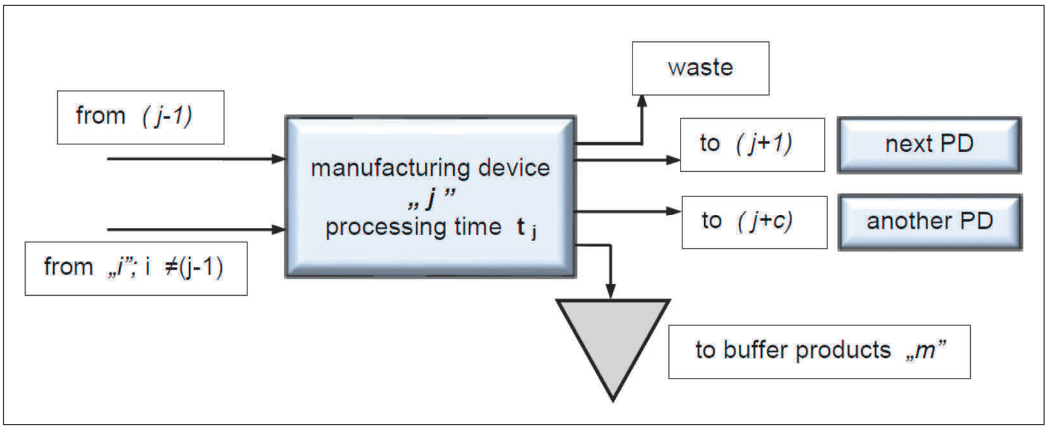

Fig. 1 Scheme of material flow through the manufacturing device PD

- for the transport device TD:

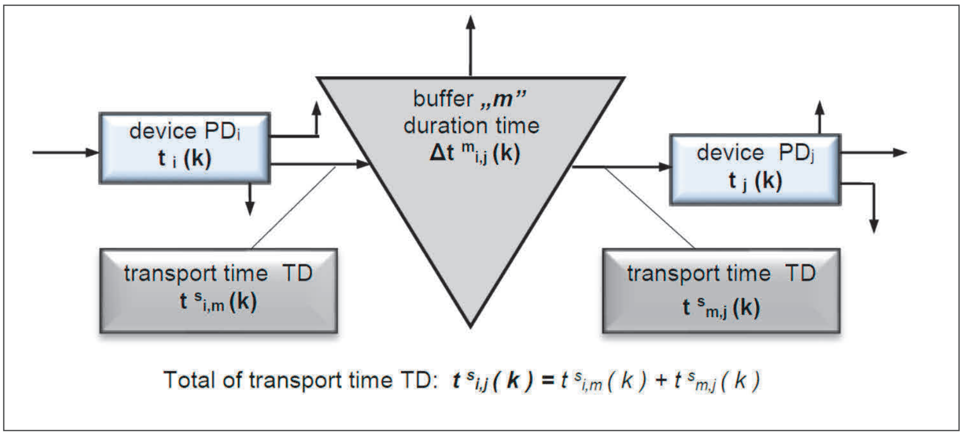

Fig. 2 Diagram of material flow

Every process is exposed to a degree changeability of the input value, this cannot be avoided. This can be minimized by applying a buffer at the start of the system, but eliminating this occurrence is impossible. Delays in delivering the processes input material may cause the workstation co cease functioning, while waiting for parts to arrive. Therefore if it is assumed, that declines of utilization values are unacceptable, a high level of WIP must be maintained in order to minimize variables [5]. Third Basic Law of Production Logistics describing dependencies between utilization of the workstation, throughput time and WIP. The Third Basic Law of Production Logistics states [4]: *Decreasing the utilization of a Workstation Allows the WIP and Throughput time to be disproportionately reduced.*

Throughput time is the time between finishing, which occurs before the observed process, until the end of the observed process. Its components are inter-operation time, which is the time from finishing the previous process, until the start of the observed process and operation time, which is the set up time and the time dedicated to processing, which is the duration of the process itself. If the start of the setup is known, then the operation time may be calculated analogically to the throughput time, but the dependencies between other parameters of the process - the work content and maximal possible output rate. The Inter-operation time is calculated by deducting one value from the other. These definitions derive from the Throughput element in the funnel model definition.

Utilization of a workstation is the ratio of the average and maximum output rate, possible to achieve in the output of the process, expressed in percentage. The value of this parameter may get reduced, e.g. by malfunctions, outages, the process being blocked, or the speed of the process being reduced. As mentioned earlier, from the economic standpoint, it is profitable for this value to be maximal. The full potential of the possessed machinery may be fully used then. In relation to Utilization it is worth mentioning *Output Rate*, of which the average value is connected with the sum of Work Content during reference period, which results from the ratio of the output value to the reference period. A graphical interpretation of this value is depicted in the Throughput Diagram in **Fig. 3**.

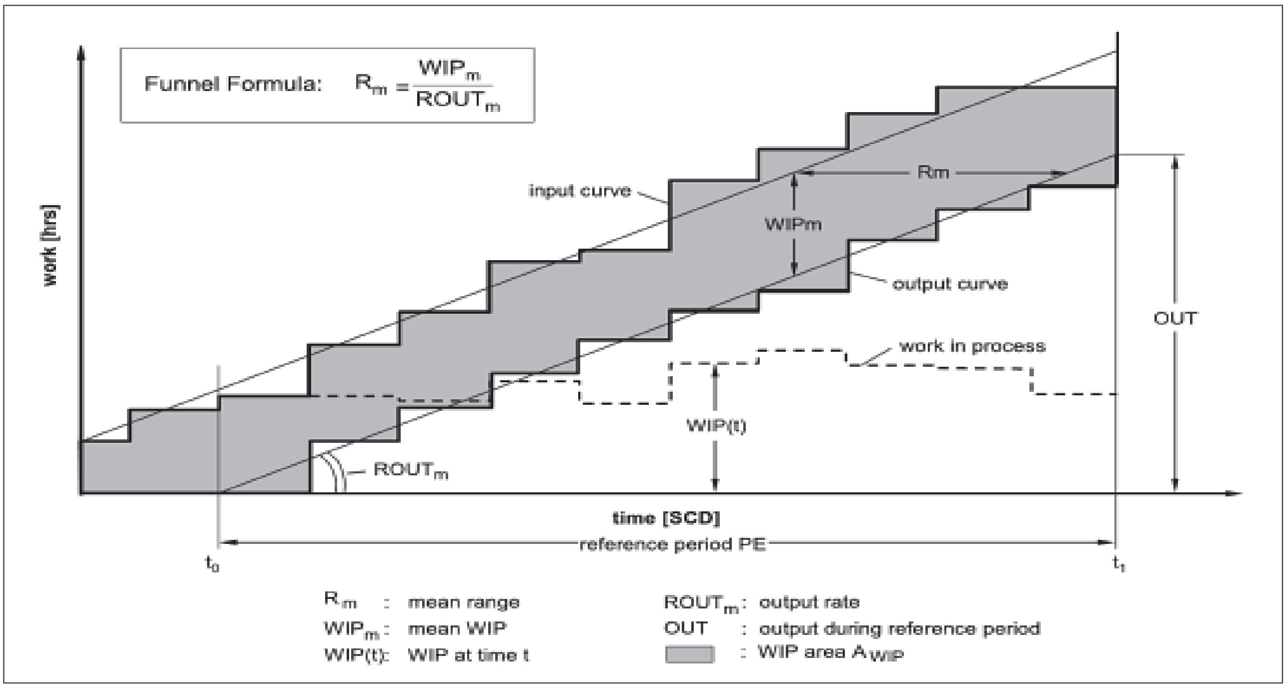

Fig. 3 WIP and Output Range in the Throughput Diagram

These nine laws of production logistics LPL [3] should serve to facilitate the understanding of logistics processes on the production floor. When analyzing the laws below, the main targets set for production logistics should be taken into consideration, concerning the process parameters mentioned in the said dependencies. This has to do with the assumption that the aim is to reduce work in process (WIP) and shorten and standardize the time of transition and homogenization of the Work Content structure. In fact, these may be different, depending on the circumstances and priorities adopted in enterprises for individual processes, but in most cases the assumptions are consistent with reality.

3. EXAMPLE OF SOLVING THE PROBLEM OF WIP IN THE PRODUCTION OF REFRIGERATION EQUIPMENT

The analyzed plant consists of 9 stations and buffers (warehouses). These buffers are arranged between groups of machines run the same technological operations. The material input is plate in coils supplied in a given quantity to store the input as change (480 minutes) in the case of painted sheet or two changes (960 minutes) for the other plates. Coils sheets are taken to a first station where they are cut into sheets of different lengths. The dimensions of the sheets cut from one circle depends on the type of cut sheet. Done sheet metals are stored in buffers (every type of sheet in a separate buffer), where you get to shearing. After cutting the sheet set number of elements of a suitable size, they are deposited on a pallet arranged in the vicinity of equipment in different places of the hall. The next stage of the production process is the bending of the cutout sheet in order to obtain the desired shape. Thus prepared items are stored in a warehouse for semi-finished products, where it is transported to painting, foaming or assembly hall. The block diagram of the production process is shown in **Fig. 4**.

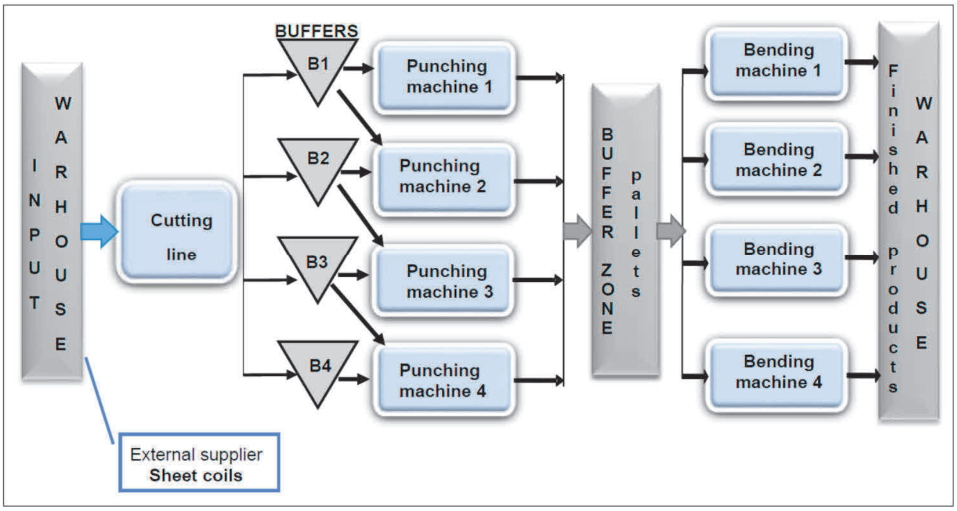

Fig. 4 The structure of the technological process

Fig. 5 shows the layout of the production line model in the program Witness in 2014.

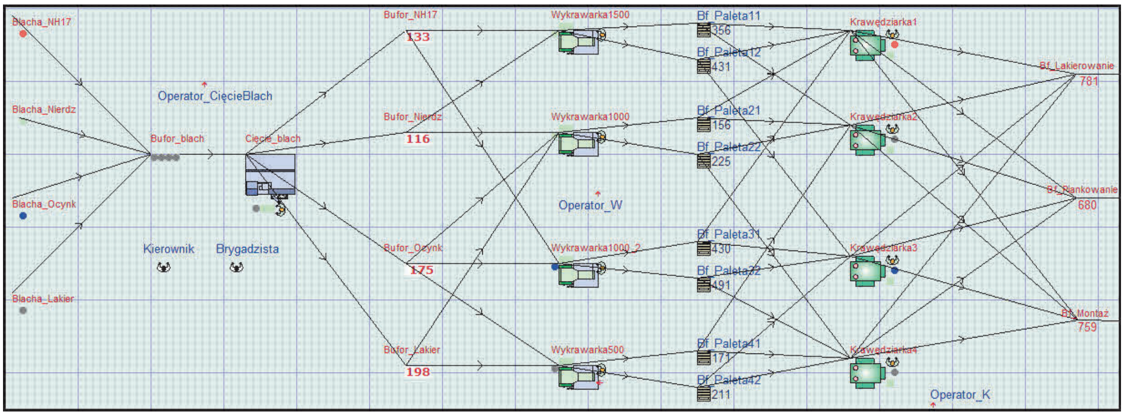

Fig. 5 Scheme of the production line in WITNESS 2014

This model was performed simulations of production processes for 1,440 minutes. For each station on the production line has been analyzing states. With tables and graphs are presented weight machines and workers over 3 changes eight hours (1,440 minutes). Data on the volume of production, range of plates, durations of technological operations, possible device failures obtained from the actual object. Many of the size have been described by functions of probability. For example, number of items on the exit of the punching machine 1000_1 is described gamma distribution, and number of items on the exit of punching 1000_2 is described triangular distribution. The incidence of failure to punch machines 1000_1 and 1000_2 shown by the gamma distribution and fault repair time described a normal distribution. Cycle times for each bending machine are described using a normal distribution. Conversion folding involves changing the bending radius sheet by exchanging the upper and lower strips profiling and adjust the clearance between the slats bending. Frequency setting (set-up) bending machine is described a normal distribution. Time between failure for each bending machine is described using a normal distribution. After working on punch and bending machines elements of the sheet goes to the warehouse of finished parts, where depending on demand are transported to painting, foaming or straight to the assembly hall. The figures 6 and 7 show states of punching and bending machines.

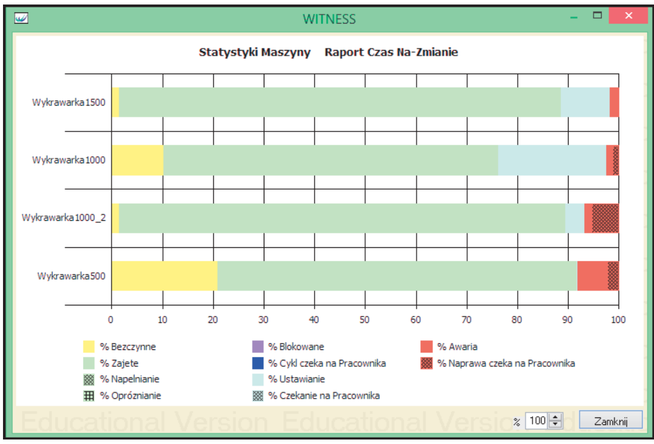

Fig. 6 Charts states - punching machines

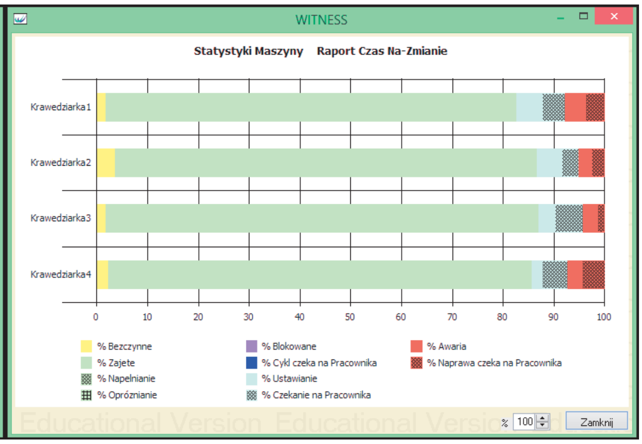

Fig. 7 Charts states - bending machines

The calculations relevant statistics were obtained using time machines and each machine operators. Based on statistical data obtained during the simulation made production line was developed in the Witness proposed changes to the organization of the production process have been developed.

4. CONCLUSION

The main objective of modernization of the line was to minimize costs and work in progress WIP (overproduction) and reorganization of storage space, especially buffers between the machines. The second goal was the greatest use of working time of machines and workers, as well as reducing the duration of retooling and repairs. The limitation resulting from demand for sheet metal parts the company was required minimum volume of production. Thanks to these changes reduce the size of the batch of cold rolled supplied to the line, which allowed to eliminate overproduction and reduce the number of elements stored in the buffers interoperable. In addition, the production line has been removed punching most vulnerable to failures. Also introduced intermediate four separate buffers for each type of sheet to organize a buffer space between the process of punching and bending sheet metal process.

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