

Edward MICHLOWICZ*

SUBASSEMBLY FLOW CONTROL WITH THE KANBAN SYSTEM AS A COMPONENT OF LEAN MANUFACTURING AT A PRODUCTION ENTERPRISE

Abstract: The paper analyses the Kanban system introduced at a company manufacturing multiple types of rotors for electricity-powered engines. The system comprises two loops of Kanban cards: the production card loop and transport card loop. The main assumptions for the system is the capacity minimisation for buffers between operations and streamlining the information flow between individual production cells. The analyses use the 7M, 5S and SMED methods, as well as a combination of the ABC and XYZ classification methods for materials. The introduction of the Kanban system significantly reduced warehouse stocks and improved communication between individual production lines.

Keywords: production system, Kanban system, ABC – XYZ methods, SMED, buffers.

1. Introduction

The strategies known as “lean” have been used with growing frequency in management. Depending on the area of application of such strategies, we may speak of lean management, lean office, lean administration etc. J. Womack and D. Jones, known for their research in the area, have even proposed “lean thinking” (Womack, Jones 2008) as a way, a method to eliminate waste and create value at various types of enterprises.

Throughout the paper, however, the notion of lean manufacturing will be used purposefully to emphasise that the analyses performed primarily relate to a company’s production functions. Nevertheless, treating an enterprise as a system, the introduction of lean management should be striven at, with lean manufacturing considered a subsystem of enterprise management only, with all the consequences of interrelations among subsystems identified at the enterprise.

The development and determination of a lean strategy for an enterprise requires much research to be done. To this end, the Value Stream Mapping (VSM) may, for instance, be used to create a continuous flow (Rother, Harris 2001).

* AGH University of Science and Technology, Krakow, Poland

The analysis of the specific task of creating a continuous flow considered herein has led the author to propose that the Kanban system (Kornicki, Kubik 2009) should be applied to control the flow of specified subassemblies included in the ready product.

The main idea of the Kanban system consists in the direct control of the flow of materials and control of production process. The method is designed to shorten processing time and reduce stocks, while simultaneously execute the production task in a timely manner. It includes matching the quantities of the products manufactured with number of orders and quality control at each phase of the production process. This is known as a pull-flow and it supports totally eliminating or minimising the use of warehouses between such operations or production lines which depend on one another.

Logistics and production cards are frequently used to discriminate between what is called the sides of the Kanban system. The main objective of those cards is furnishing information on the flow of materials during the production process. A Kanban card displays the identifier of a material reference. It also bears other data, such as the number of parts in a container, reference name, flow path (from where and where to), as well as other data, as needed. Actually, a Kanban card identifies a given batch x of material or product.

Depending on the process involved, a card reflects a specific task:

- A production card, which, at the beginning of the process, reflects a batch (quantity) of a product, serves as a production order, later it is a production notification, to finally, at the process conclusion, relate to product transfer to a warehouse.
- A transport (logistics) card, conveying information on a given quantity x of given material, at the beginning of the process serves as an order for the supply of the given material, confirmation of the supply to a given production site, information on material consumption and, thus finally, as information to be included in the next supply order.

Recently, Kanban card circulation has with growing frequency been supported by IT systems, with use of Automated Identification tools (e.g., bar codes or radio tags). When used within a traditional model (as paper sheets), the cards are difficult to be identified quickly and also render the real-time tracking of production-related processes and events difficult.

The Kanban system should operate according to clearly defined rules:

- each consecutive line in the production process has to initiate the flow from the preceding stand (for this reason, such a system is known as a pull-flow system);
- a product which is not covered by an order in the form of a Kanban card is neither manufactured, nor transported;
- one card only may be assigned to a given product container and the container should contain a fixed number of products, as specified in the card;
- card flow is executed in accordance with the FIFO principle;
- any card has to include unanimous information on the product production venue, destination and storage place.

It is of utmost importance for the correct operation of a system that the number of cards in the flow be specified. This is connected with the numbers of products stored in containers and production capacities of the machinery involved, both at producers and customers. Thus, the number of customers receiving a given product and machine breakdown ratio should be taken into consideration. There are numerous ways of determining the number of cards in the flow, such ways depending on the nature of a production system and type of product flow.

The most general formula for the number K of cards in the flow reads as follows:

$$K = \frac{p \cdot t(1 + s)}{i} \quad (1)$$

where:

- K – the number of cards in the flow,
- p – the daily average demand for the product,
- t – the average flow time of a given card,
- s – the capacity of a security buffer,
- i – the number of products in a single box of a given transport container.

The appropriate determination of the number of cards in the flow is very important for uninterrupted production. The number of cards should prevent both production interruptions (and thus prevent the customer line from waiting for the product) and overproduction, thus preventing unnecessary product storage.

In the Kanban system, the information flow starts only with a customer's order placement. The direction of that information is opposite to the direction of materials flow in the production process. The signal triggering a production order is sent not to the start but to the end point of a line. The employee operating at the last stand along the line receives a production order for a batch of a given product. The materials necessary for production are then taken (sucked) from the previous stands, where the materials needed there are taken from stands which are closer still to the beginning of the line and so on, thus replenishing the stocks of products forwarded to the next stand. Such a solution enables the flow of materials to be synchronised with the work rhythm at the last stand.

The implementation of the Kanban system requires that, after the mapping of the value flow at the discussed production facility of an enterprise, the following actions should be performed:

- 7M analysis,
- 5S analysis,
- SMED implementation (if there is any changeover problem),
- classification of subassemblies used to manufacture the products with:
 - ABC method,
 - XYZ method (classification of order regularity by variability ratio),
- selection of subassemblies to which the JiT will be applied (based on the results of classification combining the ABC and XYZ methods).

Additionally, all parameters necessary to characterise the Kanban system (loops, cards, stocks and operation durations) should be computed.

2. Research object and tasks to be executed

The object of the research is a production line (at an automotive company), where electric engines and drivers are manufactured for central locks, sunroofs, safety belt stretchers, windscreen wipers, as well as for photocopiers, coffee expresses, hospital beds etc. These engines and drivers are mainly produced on manual or semi-automatic lines. All components used in the production are supplied by external suppliers.

The company also manufactures ready subassemblies, used later to assemble an engine. These subassemblies include rotors, rotor casings and transmission casings. The semi-products are used internally to manufacture engines or sold to external customers. The company's products are assembled in cars of such makes as VW, Ford, Fiat, Land Rover and Mercedes.

The engine production process comprises numerous operations, both manual and automated ones. Production planning for the production line in question is a complicated task. The process requires high precision in the manufacture of both individual subassemblies and the final product. The process is very difficult, as any allowable deviation from the engine predefined dimensions or functional parameters is very little. Therefore, each product has to be checked frequently (Michlowicz, Hładun 2009). The final operations are engine balancing and testing. Thus it is of utmost importance that rotors be stored for as short a time as possible, because it sometimes happens that workmanship errors are revealed only on the ready engine production line.

The initial analysis of materials flow in the engine production processes has led to the conclusion that the rotor line (LIN.WIR) is among the company's most important strategic units.

Basic data concerning the LIN.WIR line is as follows:

- broad range of products (50 variations, known as “references”),
- large number of production orders (several dozen thousands per month),
- frequent changeovers during a single production shift,
- long changeover duration (around 60 minutes).

The LIN.WIR line products (rotors) are delivered to four ready engine production lines in line with the predefined relations, that is, each production line supports the manufacture of specified engine references.

Problems relating to the execution of production tasks result in:

- frequent shutdowns of all lines (rotor and engine lines),
- generation of excess stocks,

From this in turn there follows:

- need to modify the system.

For these reasons, the rotor line was selected for optimising materials flow through the implementation of the Kanban system.

This is outlined in Figure 1.

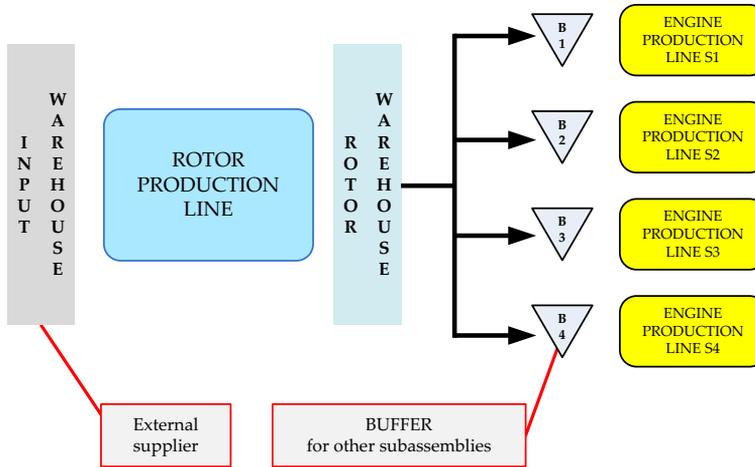


Fig. 1. Chart of the system discussed

The outcome of the implemented measures should include:

- implementation of the Kanban system for these references which should be manufactured according to the Just in Time principle,
- minimisation of stocks at the LIN_WIR warehouse.

A team composed of several people, appointed to execute the project, performed the following tasks:

- initial tasks:
 - loss analysis based on the 7M method,
 - implementation of the 5S method,
 - implementation of the SMED method,
 - analysis of references classification with the ABC and XYZ methods for all engine references (data was sourced from the company's database – supported by the SAP system),
 - selection of references for which it is advisable to apply the Just in Time principle (selection based on the result sourced from the ABC and XYZ combination matrix);
- supplementary tasks:
 - full identification of materials flow (value stream map),
 - computation of parameters necessary to introduce the Kanban system;
- system implementation to the production and control of flow between the rotor line and four engine production lines.

It was further assumed that for references controlled with use of the Just in Time principle an interoperation warehouse may be established to act as a buffer (referred

to as the “little warehouse” or $M1$), while for the other references the previous system may be maintained with the buffer $M2$.

Figure 2 outlines the suggested system with the references R_i ($i = 1, \dots, 50$) assigned to individual production lines $PROD_j$ ($j = 1, \dots, 4$).

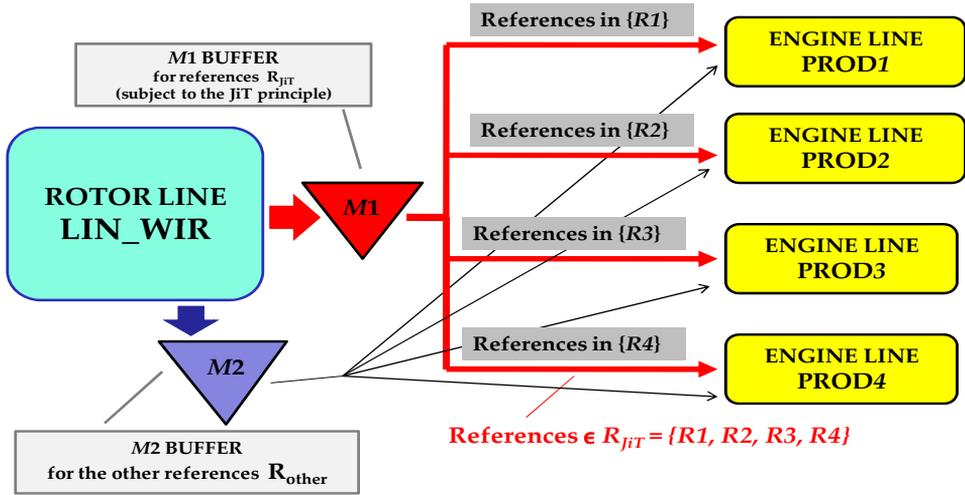


Fig. 2. Assignment of references to individual production lines

3. Analysis of initial tasks

The study omits the description of loss analyses (Kornicki, Kubik 2008), organisation and arrangement with the 5S method (Kornicki, Kubik 2008), as well as changeover streamlining with the SMED method (the use of external changeover process enabled the line downtime to be shortened from 60 to 15 minutes).

A very important action along the path to the implementation of the Kanban technique is the preparation of the materials ABC and XYZ analyses supporting the selection of products for which the use of the Kanban system is reasonable. Data necessary for the preparation was sourced from the data base of the company’s SAP IT system. The analysis was performed for all 50 products going through the LIN_WIR line.

The analysis results (obtained based on the data made available by the company’s supplies department) are arranged in tables (ABC analysis results and XYZ analysis results).

The analyses having been performed, a combination matrix for the ABC and XYZ methods was built. The matrix reflects the entire range of the rotors produced (Tab. 1). The specification set forth in Table 1 was the source of accurate information on the selection of product types for which it would be reasonable to apply the Kanban system. The fields including subassemblies (rotors) which are marked with the combinations

AX, AY and BX sourced from the matrix and for which the application of the Just in Time principle is reasonable are highlighted in the table.

The analyses performed reveal that, among the fifty references covered by the analyses, for as few as nineteen the use of the Kanban technique may be considered. The orders for the other references are irregular or very infrequent. Thus it is unreasonable to let them occupy space at production lines. Appropriate storage (M2) was separated for those references, where they will be stored temporarily.

Table 1. *Combination of the ABC and XYZ methods*

| Forecast accuracy | Subassembly reference | | | | | |
|-------------------|-----------------------|---------|---------|---------|---------|---------|
| | A | | B | | C | |
| X | 473-067 | 473-755 | 475-879 | 472-138 | 474-175 | 478-014 |
| | 475-451 | 470-397 | 476-455 | 474-252 | 484-426 | |
| | 477-555 | 480-396 | 471-171 | 485-251 | 480-619 | |
| | 477-215 | 470-685 | 469-940 | 474-253 | | |
| | 475-382 | 477-627 | | | | 476-601 |
| Y | 470-607 | 474-923 | 474-923 | | 471-995 | |
| | | | 469-939 | | 474-192 | |
| | | | 475-873 | | 470-345 | |
| | | | | | 476-220 | |
| Z | | | 471-693 | | | |
| | 476-454 | | 476-454 | | 475-878 | |
| | 474-176 | | 479-778 | | 474-987 | |
| | | | 485-885 | | 477-123 | |
| | | | 469-967 | | | |
| | | 471-163 | | | | |

The semi-products for which it is reasonable to use the Kanban system are:

- **AX group:** 473-067, 473-755, 475-451, 470-397, 477-555, 480-396, 477-215, 470-685, 475-382, 477-627;
- **AY group:** 470-607, 474-923;
- **BX group:** 475-879, 472-138, 476-455, 474-252, 471-171, 485-251, 469-940.

The results of the analysis also supported a further subdivision of the nineteen selected references, such a subdivision designed to synchronise the references with the production process. The LIN_WIR line puts out rotors for four other production lines: PROD1, PROD2, PROD3 and PROD4. Consequently, each product included in the AX, AY and BX groups has to be assigned to a specific line.

Table 2 sets forth the assignment of products (rotors) disclosed in Table 1 and manufactured on the LIN_WIR line to the engine production lines to which the rotors are supplied.

Table 2. Assignment of individual subassembly types to receiving lines

| PRODj line | PROD1 | PROD2 | PROD3 | PROD4 |
|------------|--|--|------------------------------|---------------------------------------|
| Product | 477-555, 477-627, 470-607, 474-923, 469-940, 474-252 | 475-451, 475-879, 476-455, 471-171, 472-138, 485-251 | 470-397, 480-396, 470-685 | 473-067, 477-215, 475-382, 473-755 |

Following the analyses, a specific solution for the Kanban system was suggested. It was assumed that the production on the RL line will be exclusively controlled by Kanban cards:

- production cards – between subassembly little warehouse and the producer line;
- logistics cards – between the customer line and rotor warehouse.

The circulation of production cards is effected in the following way:

- each box has to bear its own card and to be stored together with the card in the buffer at the production line,
- if a given box is collected by a logistics employee, the Kanban card is detached and inserted in a special card holder.

Figure 3 presents the chart of the suggested Kanban solution.

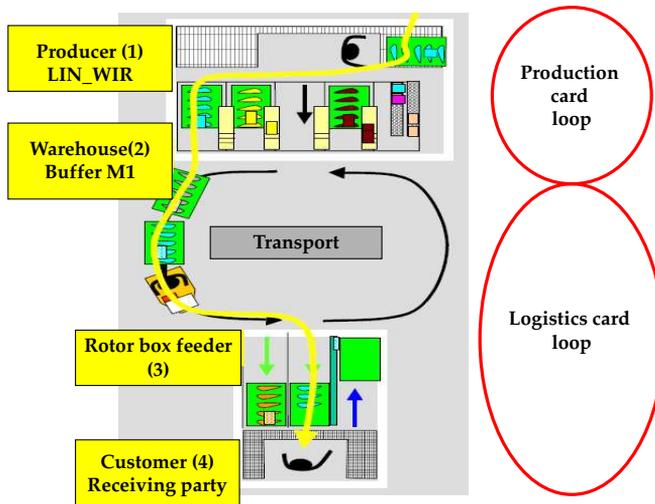


Fig. 3. Suggested solution for the Kanban system

The top part of the figure depicts the semi-product producer (1), that is the LIN_WIR line. Below, the little warehouse (2) is located, called the M1 buffer, between the producer line and the subassembly receiving party (the four PROD_j lines). In the bottom part of the figure, there are depicted the rotor box feeder (3) and the customer (4), receiving semi-products manufactured on the LIN_WIR line. This is the last link of the system, where the engine manufacture completes. Appropriate levels and numbers of boxes supplied to the customer (receiving party) lines through placing them on the feeder were determined by computation.

The two card circulation loops are also depicted in the figure:

- production card loop – between the semi-product buffer M1 and the producer line (LIN_WIR),
- logistics card loop – between the customer lines (PROD1, PROD2, PROD3 and PROD4) and the semi-product buffer M1.

4. Efficiency analysis for the producer line

Data necessary for the analysis primarily include:

- efficiency measurements for each of ready product production lines (PROD1, PROD2, PROD3 and PROD4) and the rotor production line (LIN_WIR),
- breakdown ratio measurements for each of production lines, necessary for the determination of emergency stocks.

Stock levels refer to Kanban storages, where semi-products are stored temporarily before being collected by a logistics employee and delivered to the customer line.

Based on the historical breakdown data, the average TRP values (a machine usage rates) are computed. The ratio reflects the rate of production equipment usage (effective production) relative to the entire time planned for production:

$$\text{TRP} = \frac{\text{effective production}}{\text{production time}} \quad (2)$$

where:

effective production – the product of the number of good parts manufactured and the time TT (tact time),

production time – the time planned for production of a given product, reduced by scheduled shutdowns, that is employee breaks, tests, changeovers, machine preventive maintenance etc.

Based on breakdown data, the average TRP values (a machine usage rates) are computed.

Table 3 sets forth measurement results and information on the projected production volumes, as well as on the number of shifts for individual lines.

Table 3. *Data necessary to perform analysis*

| Line | TRP [%] | TT [s] | Number of pieces per shift | Number of shifts |
|---------|---------|--------|----------------------------|------------------|
| LIN_WIR | 85 | 17 | 1,296 | 3 |
| PROD1 | 79 | 74 | 350 | 3 |
| PROD2 | 81 | 74 | 350 | 3 |
| PROD3 | 77 | 65 | 400 | 3 |
| PROD4 | 87 | 96 | 270 | 2 |

The next phase of the analysis required logistics data to be collected, including:

- time of rotor delivery from the LIN_WIR line to the production lines PROD j ,
- number of rotors in a single Kanban container.

Based on the analysis, it was decided to store rotors in boxes housing 44 pieces each. The mass of a box with rotors is too large for the box to be stored on the racks used at the company. Therefore, it was suggested that semi-products be stored on special trucks with a capacity sufficient for storing five boxes on a single truck. The trucks are arranged in appropriate driveways. The driveways are marked with relevant numbers identifying the type of product stored and appropriate warehouse area (Michlowicz, Hładun 2009).

The computation of parameters governing the M1 buffer (little warehouse) requires the following data:

- TT times (Tact Times) for each production line: TT_{PROD1} , TT_{PROD2} , TT_{PROD3} , TT_{PROD4} ;
- TT time for the rotor line: TT_{LIN_WIR} ;
- number of rotors per box: p ;
- changeover time for the LIN_WIR line: T_{pz} ;
- machine usage rates TRP for the LIN_WIR line: TRP_{LIN_WIR} ;
- emergency stock (used upon the breakdown of the supplier line LIN_WIR) for each production line: Z_p ;
- number of reference changes on the LIN_WIR line during a single production shift: I_z ;
- planned production time during a single shift: T_p ;
- number of receiving lines: L ;
- number of shifts per week for receiving lines: Z_{PROD1} , Z_{PROD2} , Z_{PROD3} , Z_{PROD4} , Z_{LIN_WIR} .

Figure 4 presents the chart of the suggested storage solution.

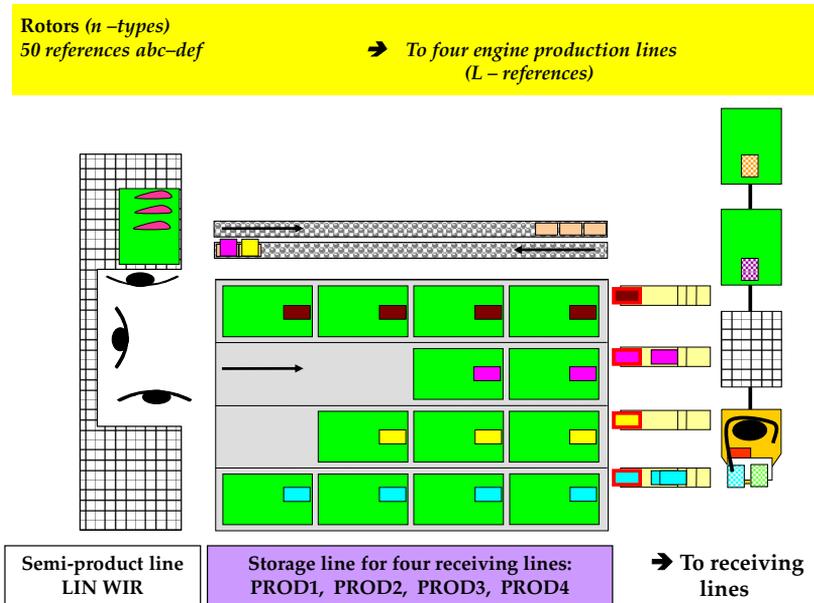


Fig. 4. Chart of the suggested storage solution

The following computations were also performed:

- loss time T_s during reference change on the LIN_WIR line;
- time scheduled for the production of a single batch, based on the efficiency of the LIN_WIR line;
- volume of the production batch P (pieces);
- time T_{dost} after which the delivery of rotors to the last line commences;
- emergency time for the production using one box for each of j receiving lines: T_{bezp_PRODj} ;
- required stock time for each of j receiving lines: TZ_PRODj ;
- required capacity of the $M1$ buffer with the emergency stock increased by 10% depending on the efficiency of each of j receiving lines: $MPRODj$;
- checking computation correctness against the weekly demand of receiving lines, number of reference changes and the efficiency of the LIN_WIR line;
- aggregate number of rotors which the LIN_WIR line should manufacture within a week for all four receiving lines;
- number of rotors which the LIN_WIR line is able to manufacture within a week in the three-shift work regime; the shift duration has been reduced by the machine changeover time: $SLIN_WIR$.

Tables 4 and 5 set forth the results of computations for different numbers of reference changes I_z ($I_z = 2, I_z = 3$ and $I_z = 4$) during a single production shift (assuming 44 rotors per box and 5 boxes per truck, that is a total of 220 rotors per truck).

Table 4. Capacity of the M1 buffer behind the rotor production line

| Production line | Computed capacity [pieces] | Capacity rounded up to the nearest full truck [pieces] | Number of trucks |
|-----------------------------|----------------------------|--|------------------|
| Number of reference changes | | | |
| $I_z = 2$ | | | |
| PROD 1 | 644 | 660 | 3 |
| PROD 2 | 644 | 660 | 3 |
| PROD 3 | 729 | 880 | 4 |
| PROD 4 | 508 | 440 | 2 |
| Number of reference changes | | | |
| $I_z = 3$ | | | |
| PROD 1 | 451 | 660 | 3 |
| PROD 2 | 451 | 660 | 3 |
| PROD 3 | 509 | 660 | 3 |
| PROD 4 | 359 | 440 | 2 |

Result analysis was based on identifying the difference between the required demand for rotors from the four receiving lines PROD j and the actual rotor output from the semi-product line LIN_WIR, for different numbers of changeover changes on the LIN_WIR line (Michlowicz 2009).

Table 5. Balance of rotor supply and demand (for one week)

| Number of reference changes I_z | Demand for rotors $\sum_{j=1}^4 S_j$ | Output of rotors S_{LIN_WIR} | Balance $S_{LIN_WIR} - \sum_{j=1}^4 S_j$ |
|-----------------------------------|--------------------------------------|---------------------------------|---|
| 2 | 19,200 | 21,248 | +2,048 |
| 3 | 19,200 | 20,488 | +1,288 |
| 4 | 19,200 | 19,694 | +494 |

Table 6 sets forth the parameters governing the M1 buffer, based on the computations performed.

Table 6. Parameters of the designed Kanban buffer

| Number of trucks | Warehouse length | Number of rotors in warehouse | Receiving lines | | | |
|------------------|------------------|-------------------------------|-----------------|-------|-------|-------|
| | [mm] | | PROD1 | PROD2 | PROD3 | PROD4 |
| 1 | 400 | 220 | 220 | 220 | 220 | 220 |
| 2 | 800 | 440 | 440 | 440 | 440 | 440 |
| 3 | 1,200 | 660 | 660 | 660 | 660 | 660 |
| 4 | 1,600 | 880 | 880 | 880 | 880 | 880 |
| 5 | 2,000 | 1,100 | 1,100 | 1,100 | 1,100 | 1,100 |
| 6 | 2,400 | 1,320 | 1,320 | 1,320 | 1,320 | 1,320 |
| 7 | 2,800 | 1,540 | 1,540 | 1,540 | 1,540 | 1,540 |

The information triggering the production on the LIN_WIR line is a change in the capacity of the Kanban buffer by a number larger than one production batch. The signal itself is the number of Kanban cards which are to be delivered from the customer lines (PROD j) to the producer.

The quantity of a production batch was computed assuming three reference changes during a single production shift. The computations included:

- the number of production cards in the warehouse circulation for individual lines K_{PRODj} ,
- the level K_p of signal triggering the production of a given product.

The computations performer lead to a conclusion that it is three reference changes during a single production shift that ensure the best production. For such arrangement, the buffer (warehouse capacity) between the production line LIN_WIR and semi-product receiving party PROD j is the least. Moreover:

- no overproduction is observed on the line (in contrast to what was observed prior to system implementation),
- each type of product is manufactured “just in time”,
- the FIFO principle is applied to all semi-products.

In order to harmonise the customer’s (receiving party’s) line and logistics loops better, additional computation was performed including:

- computation of the maximum number P of boxes required during a single shift by each semi-product customer PROD j ,
- computation of the level Ml (number of boxes) of the buffer at a line depending on the number of logistics loops,
- computation of the number Q_i of rotors required by a line during a single logistics loop, according to the TT time,
- computation of the number Q_{R_i} of rotors supplied to a line during a single logistics loop.

Table 7 sets forth the results of computations for various numbers of logistics loops during a single production shift.

Table 7. Results of computations for various numbers of loops

| Production line | MI | Output Q_R [pieces] | Demand Q [pieces] | Security level (stock) |
|-------------------|----|-----------------------------|---------------------------|---------------------------|
| Number of loops 3 | | | | |
| PROD 1 | 3 | 132 | 117 | 15 |
| PROD 2 | 3 | 132 | 117 | 15 |
| PROD 3 | 4 | 176 | 133 | 43 |
| PROD 4 | 3 | 132 | 90 | 42 |
| Number of loops 4 | | | | |
| PROD 1 | 2 | 88 | 88 | 0 |
| PROD 2 | 2 | 88 | 88 | 0 |
| PROD 3 | 3 | 132 | 100 | 32 |
| PROD 4 | 2 | 88 | 68 | 21 |

The results presented lead to a conclusion that the best solution is to use three logistics loops (during a single production shift). The computations are actually very simple, which might tempt one to conclude that Kanban cards are superfluous. It would suffice to determine the types and appropriate numbers of logistics loops. The cards are very useful, though, for instance in the event of a failure of the customer's line. The established production regime is then corrupted and without Kanban cards the supply of semi-products would continue, unnecessarily crowding the warehouse.

The use of cards supports system self-regulation. If there does occur a shutdown of the customer's line, the logistics employee does not receive a signal in the form of a card which also serves as a production order, thus he discontinues supply of components and the production of a given component on the semi-product producer's line is not triggered. This is of utmost importance if the JiT principle is to be followed (here applied to nineteen references).

5. Conclusions

The paper describes the application of the Kanban system to controlling the flow of semi-products (rotors) during the production of specified products (engines for windscreen wipers). The object analysed comprised the rotor production system (LIN_WIR line) and four engine production lines PROD j (customers, receiving parties). The main assumption for the system was to minimise the capacities of inter-operation buffers and simplification of the information flow between individual pro-

duction units. The implementation of the system enabled rotor stock to be reduced significantly (by 34%). A number of factors contribute to buffer minimisation: from production capacities of the lines involved in the production process for a given product, to data on failures, to the number of changeovers during a shift.

The computations performed lead to a conclusion that the greater the number of changeovers per shift, the lower is the level of stock in an interoperation warehouse. However, changeover time is a loss, as it shortens the time of actual production. For this reason, the introduction of the Kanban system had been preceded by the implementation of the SMED method, which reduced the changeover time from 60 minutes to 15 minutes. The feedback between the Kanban and SMED methods contributes to the system efficiency significantly.

The computations and analyses performed also support a conclusion that the size of the buffer at a production line may be reduced if a larger number of logistics loops are implemented. Owing to this, subassemblies are collected from the warehouse only if they are actually needed and not to build a stock for, e.g., an entire business day. The implementation of the principle providing for the collection of a given component from the warehouse only if it is actually needed (according to the JiT principle) enhances the capabilities of logistics procedures in the scope of reducing the capacities of raw material and semi-product warehouses.

References

- Womack J.P., Jones D.T. 2009. *Lean Thinking – szczupłe myślenie*. Wydawnictwo ProdPress.com, Wrocław (in Polish).
- Harris R., Rother M. 2001. *Tworzenie ciągłego przepływu* (Creation of the Continuous Flow). Wrocławskie Centrum Transferu Technologii, Wrocław (in Polish).
- Kornicki L., Kubik Sz. 2009. *Kanban na hali produkcyjnej* (The Kanban System on the Production Floor). Wydawnictwo ProdPress.com, Wrocław (in Polish).
- Michłowicz E., Hładun Ł. 2009. *Analiza wprowadzania systemu Kanban na linii produkcji podzespołów* (An Analysis of the Implementation of the Kanban System on the Rotor Production Line). [in:] Bukowski L. (Ed.), *Wybrane zagadnienia logistyki stosowanej*, Wydawnictwa AGH, Kraków, pp. 137–144 (in Polish).
- Kornicki L., Kubik Sz. 2008. *Identyfikacja marnotrawstwa na hali produkcyjnej* (Identification of Waste on the Production Floor). Wydawnictwo ProdPress.com, Wrocław (in Polish).
- Kornicki L., Kubik Sz. 2008. *5 S dla operatorów. 5 filarów wizualizacji miejsca pracy* (5 S for Operators. Five Pillars of Work Stand Visualisation). Wydawnictwo ProdPress.com, Wrocław (in Polish).
- Michłowicz E., Hładun Ł. 2009. *Charakterystyka systemu Kanban po stronie producenta, logistyka oraz odbiorcy półwyrobów przy wytwarzaniu wirników* (The Kanban System in Rotor Production – From the Points of View of the Producer, Logistics Employee and Semi-Product Receiving Party). [in:] Bukowski L. (Ed.), *Wybrane zagadnienia logistyki stosowanej*, Wydawnictwa AGH, Kraków 2009, pp. 145–152 (in Polish).
- Michłowicz E. 2009. *System kanban w sterowaniu przepływem podzespołów* (The Kanban System Application to the Control of Subassembly Flow). *Gospodarka Materiałowa & Logistyka*, r. 61, nr 8, pp. 26–30 (in Polish).