Simulation of inventory level reduction by inserting unpacking stations in production supply processes

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Abstract: **This paper deals with questions of production supply of assembly plants. It is a general aim to resolve the trade-off between production supply service level and engrossed component stock level in production. On the one hand by pumping components to production in larger portions supply processes become simpler and quicker. On the other hand large portions cause high level of component stock. By inserting unpacking stations between warehouse and production lines, optimal system can be achieved. With the help of computer simulation software a model a single-stage kanban controlled production supply system was modeled where production lines receive components directly from warehouse. After that we simulated the effects of establishing unpacking stations that distribute components for production lines and determined the inventory level reduction.**

Keywords – **Production, inventory level, unpacking station, simulation**

I. INTRODUCTION

New trends of manufacturing systems concentrating fully on perfect customer fulfillment (e.g.: MCM - Mass Customized Production) emerged in the previous decades. Manufacturers are facing with the problem that mass production should be run according to diverse claims. Because of diversity large lots are split into smaller ones which results in set up time increase; which of course results in decrease of production capacity and increase of costs. In order to find optimal solution of these kinds of trade-offs several methods, philosophies exist. In this paper we deal with a narrow problem of which is a decrease factor of production costs that affect the mentioned trade-off at kanban system supplied manufacturers. The size of packaging units delivered from warehouse to production firmly influences inventory level and cost. In order to minimize this inventory level by unpacking packaging units into smaller ones may be one possibility. During our research we used logistic simulation software to validate the assumptions.

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II. REVIEW OF KANBAN PRODUCTION SUPPLY SYSTEMS

Kanban originates from the Japan word “sign”. Several researches were made in this topic Junior and Filho gives a broad overview of kanban features [9].

In production systems cards, empty boxes or digital signals indicates the consumption of production processes. Kanbans usually contain part number, lot number, part description, location, destination, quantity, lot quantity, and other additional information.

Reaching a pre-defined inventory level – e. g.: certain number of empty boxes accumulates at an inventory buffer – starts the supply process; inventories are filled with kanban quantity. By kanban philosophy WIP (work in process) level can be decreased drastically since only the used up quantity is ordered from warehouse or partner. However packaging unit quantity, size and material handling circumstances – e.g.: lead time - often strongly determine kanban batch size and affect WIP level. Also safety factor is built in the system; these are the causes why zero inventory level can not be achieved in manufacturing practice. The schematic figure of kanban material flow is illustrated on Fig. 1.

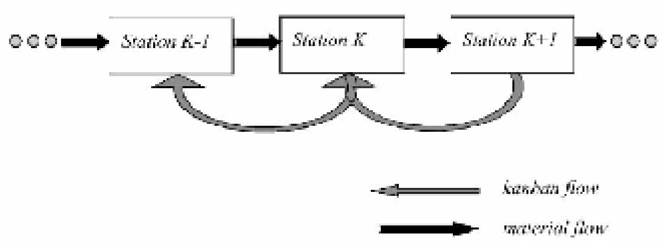

Fig. 1. Mechanism of the material and message flow in a Pull-type manufacturing system [3]

Just in time (JIT) manufacturing systems produce according to production schedule, which is generated by ERP (enterprise resource planning) systems based on customer orders. Purchase orders and incoming deliveries fit to production schedule; the right product is delivered / produced at the right time. According to Chan the most appropriate tool for supporting JIT manufacturing is kanban [3].

Sharma and Agrawal established a simulation model in order to aid control policy selection; their simulation result showed that in case of manufacturing systems the most preferred control policy is kanban [15]. Simulation is widely used to investigate features of manufacturing systems or whole supply chains applying kanban control policy – e.g.:

[5],[6],[10],[12]. Also applications of mathematical models confirm advantages of kanban [20].

The kanban size has a prior importance on determining in-process inventory level. The number of kanbans can be calculated with Toyota's formula [3], [4], [8] in Eq. 1.

$$n = \frac{d_a \cdot (t_w + t_{pc}) \cdot s}{k} \qquad (1)$$

where d_a means the average consumption of the particle during given period, t_w means the waste and waiting times, t_{pc} means the processing time, s is a safety factor, k is the quantity of kanban packaging unit, kanban box or container.

The demand of a production line is a stochastic value, methods to calculate variability of production lines exist [7]. Also optimal planning methods support demand estimation [14],[11].

An approach for determining the optimal location of inventory control points in serial production systems with pull control has been presented by Askin and Krishnan [2].

The trade-offs between optimal base stock levels, numbers of kanbans, and planned supply lead times are demonstrated by Liberopoulos and Koukoumialos [10]. When designing single-stage kanban system the main parameters are the workstation production capacity and processing rate, utilization factor of the system, number of servers in the system, and the ordering rate of raw material [1]. However kanban systems are getting more and more complicated Sarker and Balan indicate that the issues of raw material orders, WIP inventory and finished goods setups (batch sizing) have to be considered together rather than separately in order to minimize the total cost of the inventory system [13].

In adaptive kanban systems the number of kanbans changes according to the consumption and inventory level [17], [19]. The design of adaptive systems is supported by mathematical models (Genetic algorithm, Simulated annealing-based heuristics) [16], [17].

III. Building Simulation Model

During our research we have collected production data from electronic assembly company that used single stage kanban system. In this case operations on products are taken by only one single work center; material movement between work centers is not present.

In our research the current kanban system is compared with a modified system:

I. The current is a simple single-stage shop-floor kanban system in which raw materials are delivered from warehouse to work centers in the package provided by vendor. This means fix, non-optimal kanban number and quantities.

I. In the other version unpacking station is applied. We assume that by applying unpacking station inventory level would decrease smaller buffers at work centers and in warehouse is needed.

At many cases it is not recommended to unpack packaging units without proper identification process, because it would damage product traceability. This is problem is especially present at participants of automotive, industry, machinery, food industry, etc. If the connection between new package and the parent package is registered traceability is feasible.

We examined 5 raw materials used at 3 work stations. This survey is an initiative investigation to a broad company research; in the future this simulation model will be expanded to most problematic material. There is a company directive regarding raw material inventories namely the inventory located at shop-floor should not exceed inventory level enough for half an hour production. Of course if packaging unit quantity exceeds this half an hour inventory level, it can not be achieved. Considering this the installation of unpacking stations is not a possibility but compulsory.

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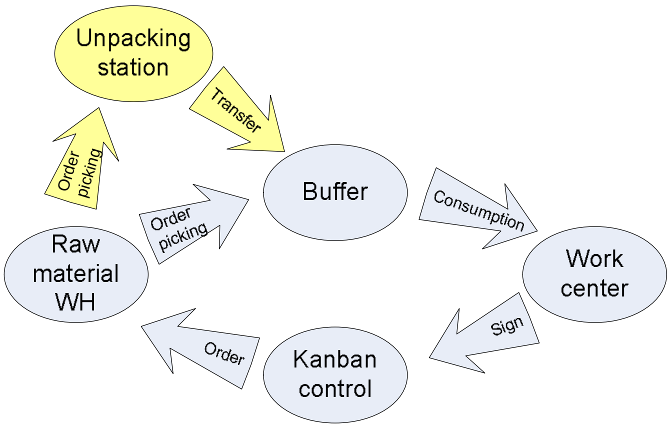

Fig. 1. Simple scheme of manufacturing system

Fig.1. shows the schematic model of current manufacturing system and manufacturing system installed with unpacking station. At each work center maximum 2 packaging units can be present, one with whole quantity and one in process. At the point when the whole packaging unit is opened a new kanban is forwarded to the warehouse, the order is picked and delivered to the work center.

Basic input data of the model are the followings:

- N_{RM}: quantity of raw material per finished good, retrieved form BOM list
- T_{CWC}: Cycle times of work centers
- Q_{PU}: Packaging unit quantities
- T_{CP}: Cycle time of picking process

TABLE I
INPUT PARAMETERS OF SIMULATION

Work center	Part 01	Part 02	Part 03	Part 04	Part 05		Throughput of production line (pcs/min)	Cycle time (seconds)
Work center 01	[illegible]	[illegible]	[illegible]	4	2		2	[illegible]
Work center 02	5	[illegible]	[illegible]	12	[illegible]		[illegible]	74
Work center 03	[illegible]		3	0			2	56
Quantity of packaging unit (pcs)	300	25	1 000	300	10			

The numeric data used for simulation are demonstrated in table 1. The size of packaging units are determined by the vendors, the company has some influence on it during the product and packaging design phase. The packaging unit quantity is usually size dependent. For example Part_05 is a larger box that is why the packaging unit quantity is only 10. Naturally in case of smaller kanban quantities more picking cycles should be made and higher kanban number should be determined and also unpacking would not have significance in the simulation. Based on simulation results the kanban number of Part_05 at Work center 01 is 3 so the maximum number of packaging units can be 12 (11 whole and 1 in use).

The picking process lasts at about 300 sec with normal distribution, the material handling between buffer and production process is negligible, it is contained in the processing cycle time of the production line. The operators have some extra time to unload buffers without setting back production. This time is calculated in the distribut

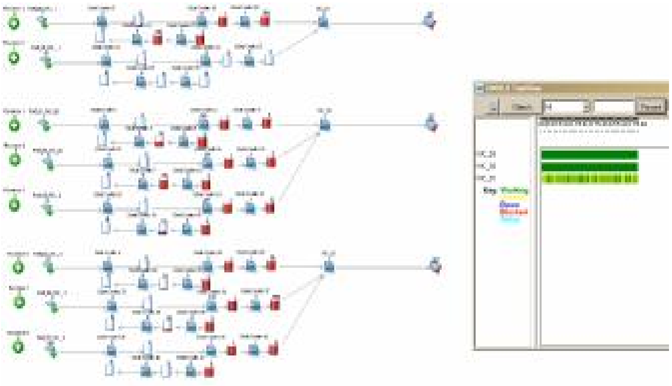

Fig. 2. Graphics of simulation model

The simulation was made by Simul8 software, the graphics of the model is represented on Fig. 2. In the first part of the simulation the material flow of units separately in reality picking cart is used, this negligence is not significant considering inventory relations.

IV. Simulation Results

A. Current single-stage kanban manufacturing supply control

After running model described in previously the inventory quantities engaged at work centers was collected (Table II.), which values were compared to results of improved system.

It is a common problem at kanban systems that kanban orders are put on when packaging unit consumption starts, since the inventory in one single packaging unit may cover several day long production (e.g.: tiny screws, microchip, micro compounds for SMT – Surface Mount Technology or other typical fields.

TABLE II.
RESULTS OF CURRENT SYSTEM

	WC_01	WC_02	WC_03	**Total**
Part_01		449		**449**
Part_02			39	**39**
Part_03		1553	1513	**3066**
Part_04	425	456		**881**
Part_05	54		17	**71**

B. Two-stage kanban manufacturing supply control with unpacking station.

The material flow between the raw material warehouse is interrupted with unpacking. However unpacking is not worth in all cases of packaging units. Table III. indicates that in cases of Part_02, Part_04 and Part_05 packaging unit is smaller than consumption during 30 minutes, which is the company directive, so unpacking has no advantage. In case of Part_01 the suggested modified packaging quantity is 150 (enough for 37 minutes), it is recommended to use rounded quantities when unpacking is made by operators and not by machine.

TABLE III.
RAW MATERIAL CONSUMPTION DURING 30MIN

	Part_01	Part_02	Part_03	Part_04	Part_05
WC_01	0	0	0	220	110
WC_02	121	0	48	291	0
WC_03	0	56	338	0	56
Consumption in 30 min	121	56	386	510	166
Packaging unit quantity (pcs)	**300**	25	**1000**	300	10
Number of kanbans	1	3	1	2	17

The situation is a bit complicated in case of Part_03. The packaging unit quantity is 1000 pieces; the total consumption during 30 minutes is 386. The problem is that the consumption difference between Work center 02 and Work center 03 is significant. In practice it is often too complicated to distinguish packaging quantities according to destination. Sometimes even adding information to each raw material is a very hard task. We took the simpler case when a common quantity is defined for both work places; 400 pieces. Although the inventory level will cover 44 minutes at Work center 03 and 310 minutes at Work center 02 least developed informatics system is capable handling this version.

TABLE IV.
RESULTS OF MODIFIED SYSTEM

	WC_01	WC_02	WC_03	Buffer	**Total**
Part_01		229		183	**412**
Part_02			39		**39**
Part_03		731	753	823	**2307**
Part_04	425	456			**881**
Part_05	54		17		**71**

By installing unpacking stations the shop-floor inventory of raw materials involved in unpacking decreased significantly. In case of Part_01 the decrease was 8,2% at Part_03 the decrease was 24,8%.

Considering kanban quantities the inventory of unpack station buffer is relatively low. (Part_01: 183, Part_03 823). The unpacking station coherences were demonstrated in this paper through a simple example, in practice much more production lines and raw materials are usually included. It can be assumed that the average inventory in the unpack station buffer would increase in a low rate as more work centers are included.

V. Conclusion

During the research single-stage kanban system was investigated at a electronic assembly-type manufacturing system. Two versions were examined: one without another with unpacking station. We assumed that the inventory level can be decrease radically in case of the second version; the aim was to determine the extent of this decrease.

After installing unpacking station the work centers stopped ordering separately from raw material warehouse, they ordered from unpacking station. Previously for example in case of Part_03 in the moment of delivering new packaging unit to work stations 4 packaging units were reserved in production.

As the result of this the main buffer of unpacked materials evolved at the unpacking station, the kanban quantities between the work centers and the unpacking station decreased. Smaller kanban quantities resulted smaller in-process inventory level, significant cost savings can be achieved by unpacking stations. The advantages come out especially at relatively large packaging unit quantities and high value products. The rate of cost saving can reach 25-30 % of the engaged inventory.

However we have to mention that unpacking may have disadvantages; it may damage or weaken traceability features. The other additional drawback is the extra information handling constraint and extra material handling processes may occur.

Further researches focus on the material flow intensity in case of different type of supply control policies. By installing unpacking stations the material movement tasks also change this way the utilization of resources modifies. Unpacking is an extra handling process, the deliveries from unpacking station to production lines should be solved a different way. It is not that obvious which version is the more cost-, and time effective, if unpacking stations cause a growth in material handling intensity than we are facing a new trade-off – for which simulation is an effective tool to investigate.

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