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PERFORMANCE ANALYSES OF HIBRIDE CONTROL PRODUCTION SYSTEMS USING SIMULATION

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Abstract: The objective of this paper is to develop a simulation model to study the performance of a typical single line, multistage pull production systems namely: Kanban – Conwip and Kanban – Base stock. The customer demand and setup number have an exponential distribution between: 160 and 360 products/day and 2 and 8 setups. The entire manufacturing line was simulated for 825 hours, which include 75 hours warm – up period. The performance measure is WIP (Work in process). The simulation results indicate that the setup numbers have a smaller and negative influence on the WIP and the influence of demand is bigger than setup number.

1. INTRODUCTION

In 1996, [1], the method obtained by combining Conwip with Kanban was introduced, while in 2000, a new hybrid obtained by combining Kanban and Base Stock methods was introduced in literature, [3].

The production control method Kanban-Conwip combines local control of production using kanban with the global control of stock using CONWIP. In this method, the information needed to start production is sent to the entire system with the help of the CONWIP card and production at the level of every stage is limited with the kanban card. This flow of information can be stopped at any moment if the finite products stock is not finished when the customer's order is received.

The Kanban–Base Stock method was initially applied to a production system with more processing operations and only one type of product to be achieved. The research was performed with the theory of waiting threads, with synchronized positions, in order to be able to use both Kanban and Kanban – Base-Stock control methods, [3].

The operating mechanism of Kanban–Base Stock method is relatively simple, the information containing the start of production is sent as in the case of the Base stock method and the quantity of products for every stage of the production process is controlled with the kanban card.

In this method production is controlled with two parameters: number of kanbans and quantity of finite products in the interoperation stock - Si.

The simulation, modelling and analysis of manufacturing systems for performance improvement have become increasingly important during the last few decades. Modern computer aided simulation and modelling tools help to visualize, analyze and optimize complex production processes using computer animations within a reasonable amount of time and investment.

Simulation was used in studies because of two main reasons. First, it was used to assess the compared performances between the pull flow system and other types of systems, for example systems with order points of manufacturing ROP, and push flow systems [4], [7]. Second, it was used to identify the determining factors to implement successfully the pull flow system [2], [5], [6].

Next we will present and analyze the performances of a production system controlled with the help of the Kanban-Base stock and Kanban-Conwip control method through WIP (Work in process).

2. THE SIMULATION MODEL

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The models of the system were built according to the descriptions previously given a few assumptions were made to simplify the simulation process. The most important assumptions were the following:

- number of products – two products, PA and PB;
- the technological process needed for product manufacturing, that implies the same sequence of operations, table 1.

Table 1. The sequences of stage

No.	Stage	Number of workstations
1	Turning	1
2	Gear cutting	1
3	Chamfering	1
4	Brush gear	1

In order to accomplish the operations within the technological process a single machine is needed for each type of operation; the machines are placed in the order of accomplishing the operations within the manufacturing process.

- processing time, table 2;
- machine failure – down time, table 2;
- changeover time , table 2;
- setup time, table 2;
- the time needed for the operator's lunch and rest, table 2;
- machine failure – up time, table 2 - it shows the average time of good operation until a failure reappears, or the average time of good operation until a failure appears or between two successive failures, table 2;
- the running time of a tool – it is given by the longevity of a tool and is specific to each type of tool, table 2;
- setup cost – 129.05 [u.m./h];
- production cost - 96.5 [u.m./h].

Table 2. Production cycle times

No.	Stage	Processing time [mi/op.]		Breakdowns			The time needed for the operator's lunch and rest [mi/day]	Machine failure – down time [mi]	The running time of a tool [mi]
		Product PA	Product PB	Machine failure – up time [mi]	Setup time [mi]	Changeover time [mi]			
1	Turning	1.89	1.89	15	5	3.1	60	1002	378
2	Gear cutting	1.96	1.93	28	11	7.0		1083	7840
3	Chamfering	2.76	2.7	5	9	5.4		1231	29000
4	Brush gear	3.4	3.38	8	11	6.0		2195	19750

When the system is in initial phase, all the interoperation stocks have Si containers which have kanbans attached from stage i, representing the level of the base stock. The Kanban – Base Stock works as follows. When demand to release from stock arrives to proces it is divided into 5 demands, each one being transferred to the control panel of each stage and the last one joins the final stock demanding the dispatch of a product container to the customer. At this point there are two possibilities:

- if a container with a stage i kanban is available in the stock of the stage, the kanban for stage i is removed instantaneously and a kanban of stage i+1 is attached; at the same time, the pair (container–stage i+1 kanban) is sent to stage i+1; stage i kanban is transferred upstream to panel Ki containing the signal to demand the production of a new container for stage i;

- if there is no container available in the stock of stage i+1 it awaits on panel Ki+1 until a new container arrives in stock, at the same time, order Di waits on the control panel of stage i; the new finished container will be sent immediately to stage i+1 and the kanban attached will be sent to panel Ki instantaneously.

Kanban–Base Stock is a hybrid method to control the production line which depends on two stage parameters: number of kanban cards ki, i = 1…N, and level of the base stock of that stage, Si

The number of kanbans corresponding to each operation and each type of product remains the same for all operations; each operation will have a kanban for product PA and another kanban for product PB.

The level of the base stock will be the same during all working stages and its value depends on the customer's demand, table 3.

Tabel 3. Base stock

Demand	360 products	240 products	160 products
Si – base stock	45	30	20

The way a line works when it is controlled with the Kanban – Conwip method is presented in following. Within this model the information about customer demand is controlled with the CONWIP method and there are stock limits for every stage according to Kanban control.

When the system is in initial phase the interoperation stocks contain ki containers specific to stage i; each container has a stage i kanban and a conwip card attached. The Kanban – Conwip works as follows. When demand to release from stock arrives it demands the release from stock of a container with finite products for the customer. At this point there are two possibilities:

- if a container is available in stock, it is sent to the customer immediately after removing the kanban of stage 4 and the conwip card; the kanban is transferred upstream to panel K4 containing the signal to produce a new container for stage 4 and at the same time the signal to release a new container from stage 3 stock, and the conwip card will be transferred to the conwip panel to authorize the release of a container with semi products;
- if there is no container available in the product stock, the demand is delayed and awaits until a new complete container from stage 4 arrives in stock; the new finished container will be sent immediately to the customer and the kanban and conwip card attached will be sent instantaneously to panel K4 and conwip panel, respectively.

It similarly happens in the case of kanbans which arrive to panels K3, K2 and K1.

The semi products are released from stock only when there are cards both in K1 and conwip panels. So, the information about the customer's demand is transferred upstream the model through the kanban signal and to the first stage through the CONWIP card.

If at a certain stage i, a container is not available in stock, no kanban is transferred upstream, and the authorization to send a container upstream is temporarily stopped; it is resumed when a container becomes available in stock. Furthermore, the Conwip method will limit the production stock in progress, because, even if a kanban is available for this

stage, the semi products will not be released to the model unless all containers with parts running in the entire model are under the limit of the Conwip.
Each operation has a kanban for product PA and another kanban for product PB.
In the model there will circulate 4 conwip cards, CA, for product PA and 4 conwip cards, CB, for product PB.

The simulation of models within the research was performed using the SIMAN code developed by the Arena Rockwell programme to model and simulate processes, version 13.1. Arena is a programme to model and simulate processes which combines the easy use found in high-level simulators with the flexibility offered by simulation codes. It manages to obtain these performances through a range of basic modular elements with the help of which very complex systems can be created after a good understanding of logic mechanisms.

Even if real experimentation of models is not possible, any simulated model requires verification and validation. Within these researches the verification and validation of the simulated models involved the following stages:

- determining the warm-up period;
- determining the simulated period;
- validating the models.

In order to determine the warm-up period each model was run 10 times on a period of 115 hours, and during this time the measurements were made at every 5 hours.
The results obtained are presented in figures 1 and 2.

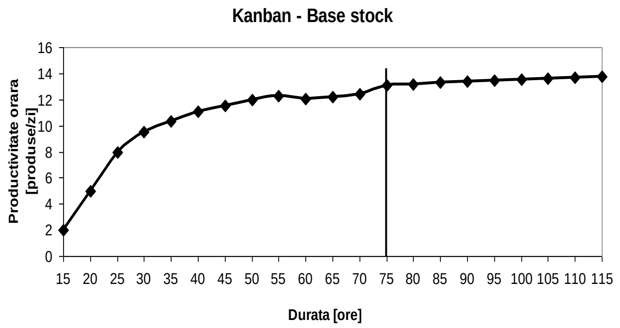

Figure 1. Mobile media for Kanban – Base Stock model

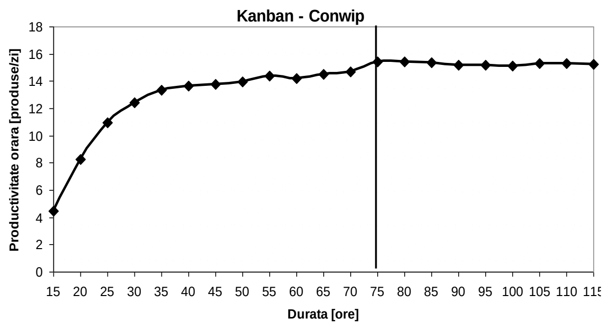

Figure. 2 Mobile media for Kanban – Conwip model

A warm-up period, Wp, of 75 hours will be chosen for both studied models. The period of simulation is determined by multiplying the period of loading the system by 10.

$$Ps = Wp \cdot 10 = 75 \cdot 10 = 750$$

The verification and validation of the operating mode of the models were performed with help of the animation specific to the ARENA software as well. After the models were rolled with animation, it was noted that they work according to the description made in this chapter.

3. EXPERIMENTAL

Following the experimental researches regarding the dependence of the WIP on the demand and setup number, we have established that the main WIP can be expressed by a relation, such as:

$$Sp = a \cdot D^b \cdot n_R{}^c \quad (1)$$

where a, b, c, d are constant and D and nR represent the demand and the setup number.
This dependence may be linearized by logarithmation:

$$\lg Sp = \lg a + b \lg D + c \lg n_R \qquad (2)$$

By substituting: lg(Sp) = Y; lg(a)=Ao; b=A1; lg(D)=X1; c=A2; lg(nR)=X2, we obtain the linear equation (3).
The values X1, X2, are known to be imposed values, and the value Y is measurable. In order to determine the equation one has to determine the A0, A1, A2 and A3 coefficients.
If the relation of dependence Y = Y(X1, X2,) can be expressed by such an equation:

$$Y = Ao + A1X1 + A2X2 \qquad (3)$$

then Y depends linearly on the X1, X2 variables.
This equation represents the mathematical model chosen to characterize the process or the phenomenon. One can reach the linear dependence of a value with many variables through mathematical artifices.
Starting from the data presented in table 4, meaning the admission parameters of the process, we have established an experimental factorial and fractional plan of the type 22. This plan is presented in table 5.
The total level of WIP is directly determined by simulations. After simulation the experimental data, table 6, obtained on the basis of the research plan presented in table 5.

Table 4. The values of the admission process parameters

The parameter		The real value	The normal value
Demand [EA]	Dmin	160	-1
	Dmed	240	0
	Dmax	360	1
Number of setup	nRmin	2	-1
	nRmed	4	0
	nRmax	8	1

Table 5. The experimental plan

Exp.	The standardized values of the independent variables	
	D	ts
1	-1	-1
2	1	-1
3	-1	1
4	1	1
5	0	0
6	0	0

Table 6. The values of the independent variables and those obtained for the dependent variable

Exp.	Real value		Sp Kanban-Base stock	Sp Kanban Conwip
	D	tS		
1	160	2	147	240
2	360	2	384	540
3	160	8	140	239
4	360	8	372	540
5	240	4	229	360
6	240	4	228	361

An empiric relation was obtained in what concerns the influence of the demand and number of setup on the main WIP. The relation obtained after working on the data in table no. 6 is:

$$Sp_{KBS} = 10^{-0.46154} \cdot D^{1.19459} \cdot n_R^{-0.02905} \quad [ea]$$

$$Sp_{KC} = 10^{0.17077} \cdot D^{1.00257} \quad [ea]$$

4. CONCLUSIONS

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The main conclusions which can be drawn after the analytical modelling are:

– the model chosen to represent the experimental data concerning the interoperation stock was adequate for all control methods applied to the production line;

- the interoperation stocks increase with the increase of daily demand and decrease with the number of adjustments made per day;
- daily demand has the greatest influence on WIP, the number of adjustments has the least influence and in the case of Kanban – Base Stock method it can be neglected.

Table 7. Logarithmic values of WIP

Metodă / Stock	Kanban-Base Stock	Kanban-Conwip
lg Sp	2.36435	2.5562

The influence of control methods on interoperation stocks is maintained even when varying the input values, as can be seen in graphs, fig. 3, 4. To achieve the graphs, an input value was varied in turn and the other one was kept at the level of the central value.

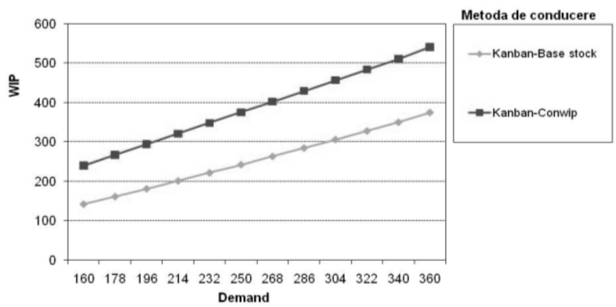

Figure 3. Influence of control methods on interoperation stock when varying daily demand

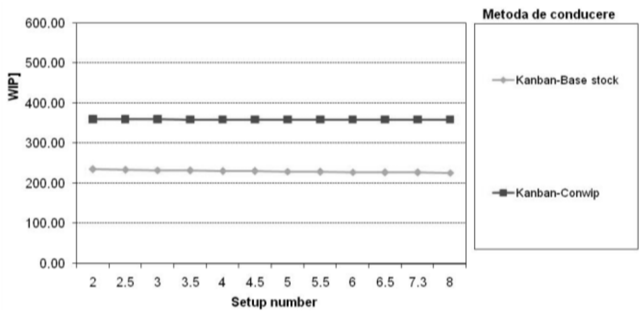

Figure 4. Influence of control methods on interoperation stock when varying the number of adjustments

It can be observed that the method of management used has an important influence on the WIP level.

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