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KANBAN-TYPE GRAPHIC MODEL OF SERIAL MATERIAL PROCESSING WITH STORAGE ON THE FLOW

Gheorghe BONCOI, Ionel NOVAC, Magdalena BARBU

Abstract: *The work presents a Kanban-type graphic model of serial material processing, with stocks on the flow, substantiated on the basis of Taiichi Ohno's work "Toyota Manufacturing System, an Alternative to Serial Production", Finmedia and SC IKAR MANAGEMENT CONSULT SRL Publishing House, Bucharest 2005, and Liker K. I.'s work "The Toyota Way. 14 Management Principles from the World's Greatest Manufactures", Mc Graw-Hill, Two Penn Plaza, New-York, 2004. The model underlays the reorganization of the manufacturing flows by Kanban processes integrated in a metal and PVC carpentry factory of Romania.*

Key words: *serial, integrated Kanban graphic model.*

1. CURRENT STATE AND GENERAL ASPECTS

In Romania, there are few relevant works [1, 3, 4, 6] treating the Kanban processes. The fundamentals of the Kanban processes are presented in [5] and reviewed more thoroughly in [1]. The work [7] develops some theoretical aspects of the Kanban processes.

The following notations will be used in the work: Sf – semi-finished products, Pf – finished products, i_{FM} – the input of the material flow from the input exo environment, e_{FM} – the output of the material flow into the output exo environment (market – Pi), I – information, M – raw material, FM – material flow, FI – information flow, PL – working post, Stl – work station, ST – storer, PRa – branching post, Pre – joining post, Pi – loading post, Pd – unloading post, DzM – material warehouse, OT – technological operation, SK – Kanban signal, C – request, ApM – material supply, Lv – delivery, Tp – transport, Al – feeding, Ev – disposal, E – execution in material processing; i – current index, natural number; $<(i-1), i, (i+1)>$ – partition of three consecutive material sequences, from the upstream input to the downstream output; $<t+i, t+(i+k)>$ – partition of two consecutive information sequences, from the downstream input to the upstream output, in which k is an integer number of material sequences interposed between two consecutive information sequences; T_c – the period of the material processing cycle, $\Delta T_c = T_{ci} - T_{c(i-1)}$ – the asynchronism of the cycle period of two consecutive working posts; $1 \le i \le q$, q-the number of working posts aggregated in series in the material processing system; $p_i = T_{ci}/T_{c(i-1)}$-the number of parallel posts working in Stl_i, Ca*i* – ST*i* accumulation capacity, SF – stock allowed on the flow, SS – allowed safety stock, SFa – manufacturing system.

2. KANBAN GRAPHIC MODEL FOR SERIAL MATERIAL PROCESSING WITH STORERS ON THE FLOW

2.1. Design Procedure for the Sequential Cycle

The partition of three consecutive working posts $<PL_{(i-1)}, PL_i, PL_{(i+1)}>$ making up the strictly ordered sequence $PL_{(i-1)}|PL_i|PL_{(i+1)}$ is considered, in which there is the single-valued correspondence $Ot_i \rightarrow PL_i$, and, for $1 \le \forall i \le q$, it provides the preceence condition $((i-1) < i) \Rightarrow (OT_{(i-1)}|OT_i)$ in the entire asynchronous process, with the asynchronism $\Delta T_{c(i-1)i} > 0$, $T_{ci} > T_{ci-1} \Rightarrow$ $\Rightarrow$ the manufacturing system requires storers $St_i \rightarrow PL_i$, $1 \le \forall i \le q$, with $Ca_i = \max SF_i$, which define a *serial asynchronous manufacturing system with storers on the flow, operating with Kanban processes* (Fig. 1). The following is performed in each PL_i: taking over, execution by processing and material delivery, through which FM and FI circulate alike. The material flow (M) has its input i_{FM} upstream and the output e_{FM}, downstream. The information flow (I) has its input i_I downstream and the output e_I, upstream. The partition of two consecutive working posts $<PL_{(i-1)}, Pl_i>$ (Fig. 1). A complex functional cycle between the two adjacent working posts consists of the strictly ordered activities, included in the following strictly ordered sequence: $(t+3)$ – –$SKC_{(i+1)}|(t+4) - Al_i|(t+5) - E_i|(t+6) - SKC_i|(t+7) - Al_{(i-1)}|$ $|(t+8) - E_{(i-1)}|(t+12) - SKC_{(i-1)}|(t+10) - Lv|Tp(Pf/Sf)_i|$ $|(t+11) - Lv|Tp(Pf/Sf)_{(i-1)}$. Isolating the current post PL_i, the complete functional cycle for a working post is based on the functional dual couple request-reply. The request is always an information, the reply-one or more material activities**.** Therefore, the complete functional cycle for a working post will be the strictly ordered sequence of elementary activities called sequences: $(t+3) - SKC_{(i+1)}|$ $|(t+4) - Al_i|(t+5) - E_i|(t+6) - SKC_i|(t+10) - Lv|Tp$ $(Pf/Sf)_i|(t+11) - Lv|Tp\ (Pf/Sf)_{(i-1)}$. It has been found that any SKC request Kanban signal is followed by two strictly ordered material activities: either feeding (Al)-execution (E) specific to PL; or delivery (Lv) (disposal (Ev))-transport (Tp) of the current ST downstream and bringing ST from upstream into the current post. The STs are mobile, movable between the adjacent PLs.

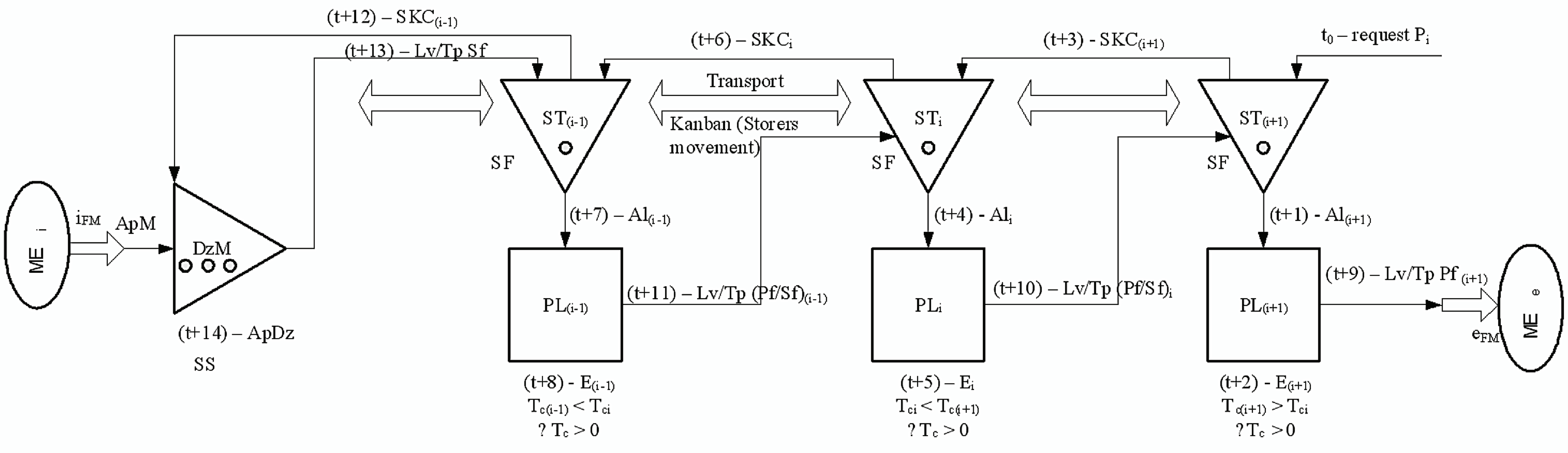

Fig. 1. Kanban serial graphic model, with storage on the flow.

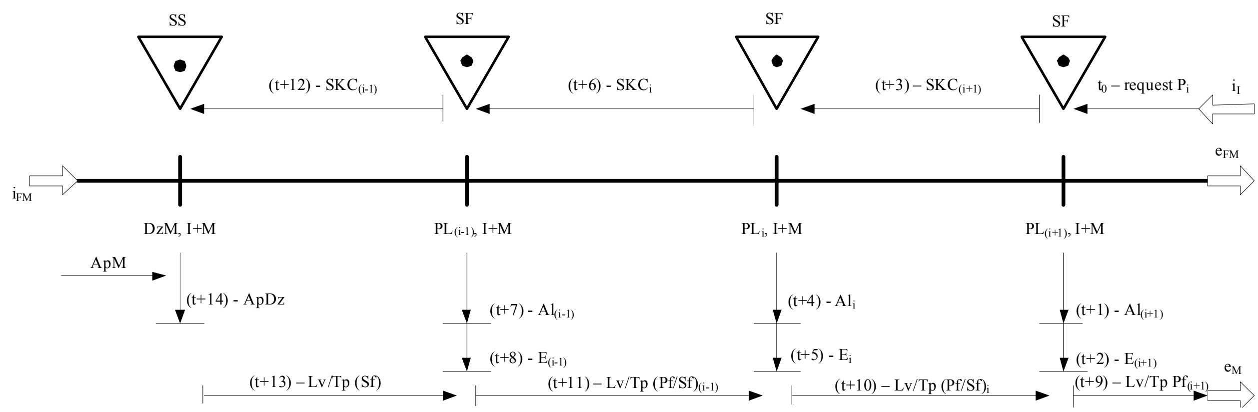

Fig. 2. Kanban serial graphic model, with storage on the flow.

Rule. Any SKC-type information sequence is always followed by three material sequences: Al|E|(Lv(Ev)/Tp) downstream or (Lv(Ev)/Tp) upstream.

A complete functional cycle for a PL is an open cycle, *with two inputs and two outputs as external couplings*, represented in Fig. 3, *while the sequences Ali and Ei are therefore internal couplings.*

A complete functional cycle for a partition of two adjacent working posts <$PL_{(i-1)}$, PL_i> is described above and it has been found that it is expressed by the joining of the complete cycles of the two adjacent posts, having similarly two inputs and two outputs as external couplings – Fig. 3. The other couplings become internal couplings.

Considering the diagrams in Fig. 3 and Fig. 4 as fundamental, they will be called *modules*.

Extending the research to the modules with *n* serial PLs, called *module of degree n*, we find that: the module is formed by joining n technologically similar PLs; a module, however big, always has an information input and output and a material input and output as external couplings, the remaining sequences representing internal couplings.

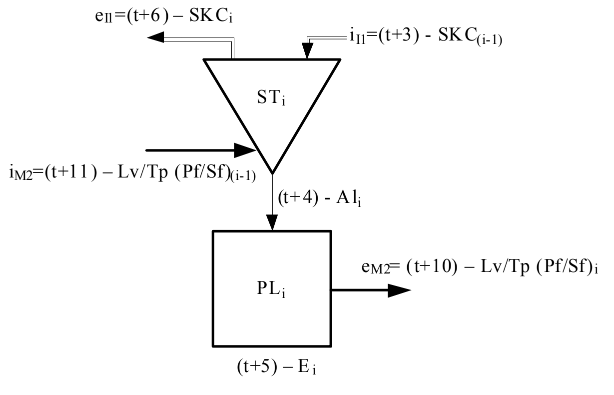

Fig. 3. Inputs-outputs diagram on a PL.

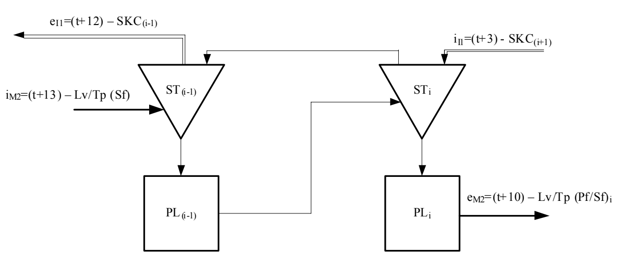

Fig. 4. Inputs-outputs diagram for a partition of two PLs.

This leads to the *conclusion that any manufacturing system, however complex, for any kind of material processing, can be composed by joining two types of basic modules: 1) an individual module made up of a PL and 2) a module of degree n, made up of n PLs, called group module.*

2.2. Material Cycle Design Procedure

The complete functional cycle of a Kanban manufacturing system is an open cycle (Fig. 2), having an input of the downstream information flow -i_I closing upstream by DzM, in the material flow, and a downstream material output e_M (output exo environment).

The *input exo environment (Emi) is determined by the raw materials supplier and the output exo environment (EMe) is the outlet of the finished products*, both being external couplings (input and output, respectively).

The *circulation of the information flow (FI) takes place from downstream in the upstream direction, and that of the material flow (FM), reversely, from upstream in the downstream direction.* This is an important property of the Kanban processes in relation to the processes carried out by „pushing".

In the Kanban-type manufacturing systems, two kinds of material stocks are accepted: *safety* allowed *(SS)* and *on the flow allowed (SF)* stocks, also called *standard* [5].

In Fig. 1, the Kanban graphic model is presented, and in Fig. 2 – the complete Kanban serial processing cycle, with stocks on the flow.

The central raw materials warehouse (DzM) becomes necessary only when the independence of the supply material processing is desired. Otherwise, there is no DzM.

The current working post PL_i, with the serial functional precedences imposed by the technological process, is considered as the initial point of the manufacturing cycle. In establishing the functional sequences of the manufacturing cycle, the following should be ensured: the priorities of the executions (E_i) for $1 \le \forall i \le q$, according to the precedences imposed by the technological process, always preceded by the SKC_i Kanban signals;

the existence of the semi-finished good in ST_i, otherwise, the previous execution of $Lv/Tp(Pf/Sf)_{(i-1)}$; of the feeding (Al_i), followed by $Lv/Tp(Pf/Sf)_i$, so that the continuity of the process (elimination of malfunctions) may be ensured, for the local manufacturing cycle in the current post PL_i to be carried out according to the ordered sequence of activities $\{SKC_{(i+1)}|SKC_i|Lv/Tp(Pf/Sf)_{(i-1)} |Al_i|E_i|Lv/Tp(Pf/Sf)_i,\ 1 \le \forall i \le q\}$, representing the *complete local manufacturing cycle of the current post PL_i* of the system.

Such a manufacturing system is that functioning in the actual production environment, which takes into consideration the set of disturbing factors of the system by the asynchronisms $\Delta T_{ci} > 0$, compensated by the stocks SF.

This way of structuring the manufacturing system separates the information flow (FI) from the material flow (FM), making possible their distinct location, and therefore allows the designer to adequately select the various solving techniques and procedures.

3. CONCLUSIONS

Such a manufacturing structure of Kanban type has been applied in an actual production environment and validated by animated and experimental simulation.

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Authors:

Drd. eng. ME I. NOVAC
Drd. eng. EcE M. BARBU
Ph.D. ME Gh. BONCOI, professor, "Transilvania" University of Braşov, I.E.S.P. Department, E-mail: magda.n@unitbv.ro