THE PRODUCTION CONTROL WITH THE JIT-BUFFER

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Abstract: Although the philosophy of the JIT production is wellknown in many manufacturing companies as an ideal solution to shorten throughput time and to cut back on work-in-progress inventory, it cannot always be easily realized. The reason is, that there is no compact concept for the JIT production besides the KANBAN system above all in job-shop manufacturing.
And it´s true that the KANBAN system can fulfill the most important requirement for the JIT production, the rule circle with the pull principle, but it can be used only on a line manufacturing system because of the physical KANBAN box. Therefore the KANBAN system is an inacceptable solution to realize the JIT production in a different manufacturing system, for example in job-shop manufacturing system.
The essential development of the new concept **production control with the JIT-Buffer** was to realize the pull principle on the rule circle with the JIT-Buffer. The JIT-Buffer is virtual and filled with work hours for manufacturing orders. In order to manage the JIT-Buffer, the simulation is put in. The production control that is carried out in the simulation will be transferred in the real manufacturing system.
The advantage of the production control is, that it can be used on all manufacturing systems from line manufacturing system to flexible manufacturing system.

Keywords: JIT, simulation, job-shop manufacturing, production control, KANBAN

1. INTRODUCTION

1.1 Change of the manufacturing factories

In the last fifteen to twenty years, a strong structural change has occurred in the production program of most manufacturing factories. Until the 1960's, demands were not sufficiently satisfied because of the poorness of production programs, of mass production of similar products with few variants, and of manufacturing for an anonymous market. Increasingly saturated markets because of mass production led strongly to an order producing job-shop manufacturing, to the development of immense numbers of complete solutions for the customers' desires, and to the complex development of manufacturing structures.
The result of these developments was an increase of throughput time, which led to an increase of work-in-progress inventory; therefore, the manufacturing factories required a more coordinating system for production planning and control. The goal of these systems was to organize the production systems in order to cut back the work-in-progress inventory, to reduce the throughput time, and to keep delivery dates with high efficiency of capacities.

The classic systems of production planning and control (PPC) could not reach the goals despite massive use of computer systems. They could not manage the two important real manufacturing processes splitting and overlapping at the manufacturing; therefore, the attempt to manage the complex processes in job-shop manufacturing through the ppc-systems was a failure.

In addition, many of the job-shop manufacturing companies searched for a solution in the JIT-Production in order to adapt themselves to the structural change from the mass production for an anonymous market to the job-shop manufacturing with the goals of good delivery faith, short throughput time, low work-in-progress inventory, and high efficiency of capacities.

But a ppc-system with a concept of the JIT-Production is not widely known in the job-shop manufacturing. It is handicapped by the lack of a concrete concept for the conversion of the philosophy of the JIT-Production into practice. Specifically, if it is about the job-shop manufacturing, the conversion into practice is more difficult, because of the dynamic complex of manufacturing structure. The KANBAN-System is an excellent concept for the JIT-Production, but it imposes on the job-shop manufacturing a few restraints that make the use difficult. Thus, a new concept for the JIT-Production in the job-shop manufacturing had to be developed.

1.2 Simulation of PPC (production planning and control)

1.2.1 Simulation

According to the VDI guidelines 3633, the simulation is a reproduction of dynamic processes in a model to come to a realization that is transferable to reality. And Komarnicki defines: „Simulation is first technology that includes generation of a model, that is a copy of the real situation, and after it the experiments will be started by the model.

The generation of a model means the building of a model that should reflect a real system with dynamic processes. The simulation means the built model to experiment in order to know, how the model reacts to a certain input. In fig. 1 a graphic presentation and a mathematical model of a simulation model are shown.

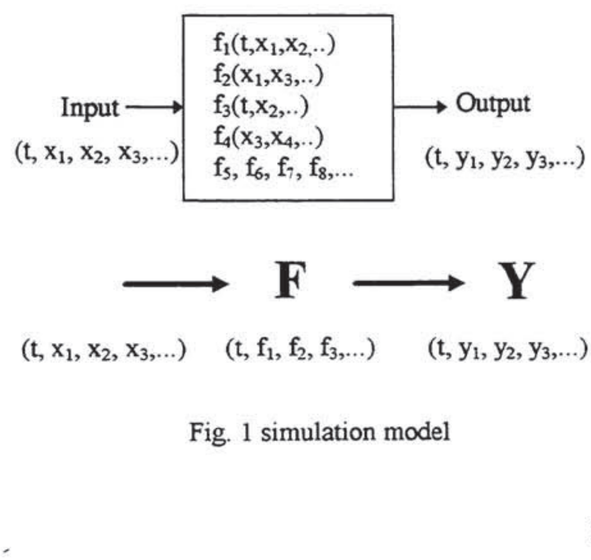

Fig. 1 simulation model

For the functions of the model $f_1, f_2, f_3, f_4, \ldots$ in fig. 1 one can find, that some of them are dependent on time and others independent of time. The dependent functions are the functions whose results or values change in time. The weather situation, work-in-progress inventory and number of visitors in a stadium, etc. are belonging to those. The independent functions are the functions whose results or values don't change in time: number of machines, number of seat places in a stadium, etc. The mathematical simulation model **F** is then a combination of all the functions and again a dependent function in time $\mathbf{F}(t, f_1, f_2, f_3, \ldots)$.

The values of the input variables $X(t, x_1, x_2, x_3, \ldots.)$ can be given in the function $\mathbf{F}(t, f_1, f_2, f_3, \ldots)$. After the processing of the values in the model the output values $Y(t, y_1, y_2, y_3, \ldots)$ can be get. By this process the model was experimented once. If the experiment is run successively for a time, then it is a simulation.

In fig. 2 circal of the simulation of the model is shown. After the circle the output variables $Y(t, y_1, y_2, y_3, \ldots)$ can be controlled and regulated for the input variables $X(t, x_1, x_2, x_3, \ldots)$.

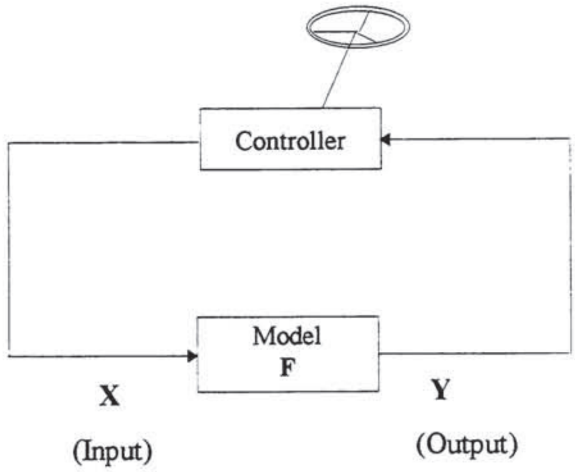

Fig. 2 Simulation

1.2.2 Simulation of PPC

Experts of the classic ppc-systems believe that only simulation can offer a solution to the combination of the dynamic processes in the job-shop manufacturing. Schmidt and Ortmann suggest for the ppc-system the use of simulation that shows in the computers the realistic material flow at processing and the waiting for orders. The goal of it's use in ppc-system is that it should bring dynamic processes of a production system and its material flow under control, but the present ppc-systems could not control it.

The effort of organizing dynamic processes realistically in the ppc-systems was often tried in a simulation. But there was no remarkable success in the job-shop manufacturing up to now. Lack of a leading concept is responsible for it. Actually the simulation itself does not mean a solution or a optimizing method, which leads automatically to the generation of a solution, but it imitates only the running process through the model technique. It implies that a concept must be developed and by means of it a model must be built to simulate the dynamic processes realistically.

If a model is built, it should be integrated in a ppc-system as seen in fig. 3.

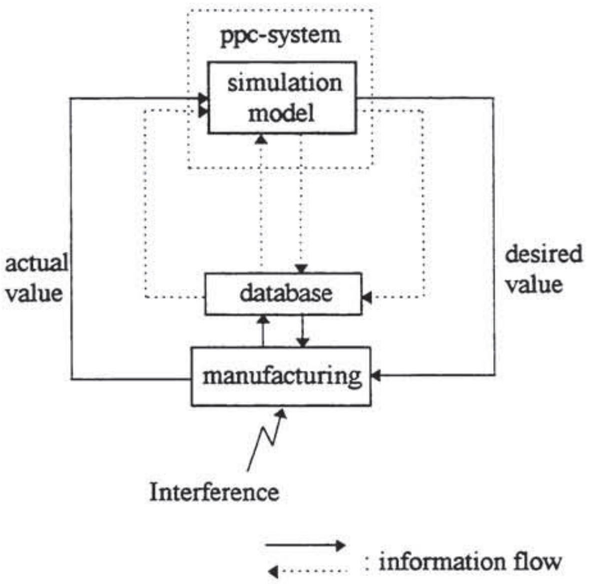

Fig. 3 simulation model in ppc-system

1.3 Purpose of the paper

The classic ppc-systems cannot reflect the dynamic processes realistically enough for production control. And the increase of job-shop manufacturing has made the development of a new concept necessary, which can organize a production system to the JIT production. In this paper is developed the production control with the JIT-Buffer in order to perform in the two conditions, to reflect the dynamic processes and to perform the JIT production. The production control with the JIT-Buffer should organize a production system of the job-shop manufacturing realistically for the JIT production, where different products are produced, many machines are set up, and stocks are often filled with surplus.

The simulation is used in the new concept and a simulation model will be built to reflect the dynamic processes of the production system. The simulation model should be integrated in a ppc system and control the whole production system for the JIT production. With that good delivery faith, short throughput time and low work-in-progress inventory can be reached.

2. PRODUCTION CONTROL WITH THE JIT-BUFFER

2.1 Conditions for the JIT production

Just-in-Time is a production strategy with the requirement to stand by or produce materials at the right time, with the right quality and quantity on the right place. The next figure shows the structure of the conditions for the JIT production and means: the more the conditions are met, the better the JIT production can be realized. In fig. 4 the conditions for the JIT production are presented.

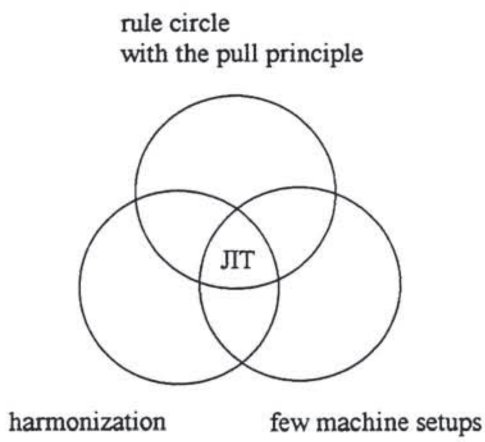

Fig. 4 conditions for the JIT production

2.1.1 Rule circle with the pull principle

The basic condition for the JIT production is the rule circle with the pull principle for the material flow to offer materials at the right time as seen in fig. 5.

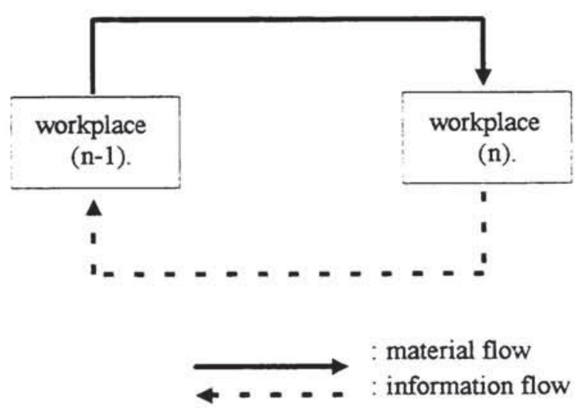

Fig. 5 rule circle with the pull principle

There must be designed an impluse rule (information flow) for the rule circle according to at what times a workplace pull material from the last workplace (material flow). The rule circle connects then the two workplaces with the information and material flow. If the rule circle is expanded from the two workplaces to all workplaces, the whole material flow can be included in the rule circle and controlled for the JIT production as described in fig. 6.

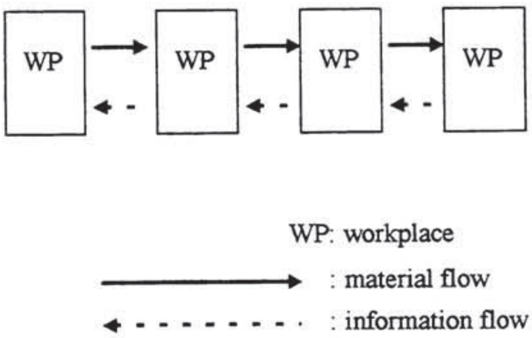

Fig. 6 material and information flow in the rule circle with the pull principle

2.1.2 Harmonization

Before a ppc-system tries the JIT production in manufacturing, already the manufacturing system should be harmonized or synchronized. The reason is, that the JIT production is possible only in a stable manufacturing system. The stable manufacturing system can be reached only by low variation of all production factors: piece-work-time, machine setup time, capacities, demands, etc. And low variation can be balanced by harmonization.

The harmonization means alignment of the working rhythm in the manufacturing system. The less products there are in the manufacturing, the easier the harmonization will be, for example in mass production, where there are only a few production factors to harmonize. The more different the products, the more difficult it is, for example in a special order manufacturing, because the different products lead to high variation of the production factors. And the harmonization in a job-shop manufacturing is not easy because of the variety of the production processes.

2.1.3 Few machine setups

Machine setup is rearrangement of a workplace for work on a new manufacturing order. During the machine setup the workplace will be blocked. This causes unstable material flow that can exclude the workplace from the JIT production. If there are many machine setups, the workplace will not realize the JIT production. And if the whole production system needs many machine setups, then the whole JIT production will be failed to perform. This problem characterizes the special order manufacturing. Only where there are few machine setups, e.g. line production, series production, the JIT production can be set in and run successfully.

2.2 Production control with the JIT-Buffer

2.2.1 JIT-Buffer

The beginning of the new concept was how the JIT production could be realized in job-shop manufacturing, where the KANBAN system could not be used because of some restraints. A fundamental hindrance for the job-shop manufacturing was the KANBAN box in which definite products must be taken.

Another instrument was needed instead of a box in order to take in many products from different orders of the job-shop manufacturing. For this purpose the JIT-Buffer was developed.

The JIT-Buffer is a virtual container that exists only in a simulation model instead of a real buffer in front of a workplace. The size of a JIT-Buffer will be measured not by volume but by time. In the JIT-Buffer many different waiting orders will be taken in together with the conversion to their work hours. Then the inventory of the JIT-Buffer (actual height) corresponds with the sum of their work hours.

$$H_{act} = \sum_{k=1}^{n} WH_k$$

H_{act}: actual height of the JIT-Buffer
WH_k: work hours for next process of the k-th wating order in buffer

In this way the buffer is not regarded any more as a physical stock, but as a stock with hours. This conversion of the buffer is clearer and more useful for a dynamic material flow in the job-shop manufacturing, because the inventory is directly related to the capacity of workplaces through the JIT-Buffer. And by the actual height H_{act} of the JIT-Buffer it can be easily recognized whether a workplace is overloaded or not.

2.2.2 Control by the JIT-Buffer

The new concept has to perform the most important condition for the JIT production, the rule circle with the pull principle. The JIT-Buffer is set in the rule circle as seen in the fig. 7.

The impulse to the rule circle, by which the products are pulled from the last workplace, is given through a limit of the JIT-Buffer. This limit is called „limit height“. The principle of the new production control is: the actual height H_{act} of the JIT-Buffer should be continually kept at the limit height H_{lim} as near as possible. Owing to the principle the actual height H_{act} can be held constantly.

- - → : information flow

⟶ : material flow

········ : limit height H_{lim} (desired value)

——: actual height H_{act} (actual value of the JIT-Buffer)

JB: JIT-Buffer on a workplace

WP: workplace

a, b: sequence of the works

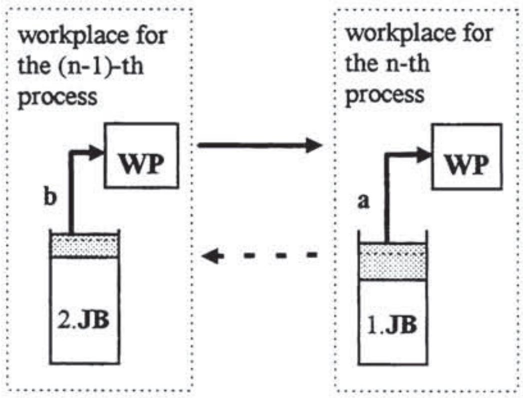

Fig. 7 rule circle with the pull principle in the production control with the JIT-Buffer

As soon as the workplace of the n-th process takes an order from the 1. JIT-Buffer (a in the fig. 7) and the actual height H_{act} goes under the limit height H_{lim}, a new order from the 2. JIT-Buffer will be taken on the workplace of the (n-1)-th process (b in the fig. 7) in order to reach again the limit height H_{lim} of the 1. JIT-Buffer. If the actual height H_{act} does not fall the limit height H_{lim} of the 1. JIT-Buffer in spite of taking a order, then a new order will be not taken from the 2. JIT-Buffer on the workplace.

In case there are many workplaces for the (n-1)-th process, one workplace must be chosen to reach again the limit height H_{lim} of the 1. JIT-Buffer. And if through the chosen order the actual height H_{act} of the 1. JIT-Buffer tops the limit height H_{lim}, then no other workplace can take any new orders for working.

2.2.3 Limit height H_{lim} of the JIT-Buffer

The JIT-Buffer is a buffer like a stock before a workplace. A definite limit is given to all JIT-Buffers. The sum of the work hours for waiting orders in the JIT-Buffer shouldn't be over this limit. It will hold the work-in-progress inventory low and realize the JIT production.

The higher the limit height H_{lim} is, the more the work-in-progress inventory and the worse the chance for success become. The lower it is, the less the work-in-progress inventory and the better the chance for the JIT production become. Naturally, if the limit height H_{lim} is too low, there can be a risk of loosing efficiency of capacities. Therefore it is very important to set the limit height H_{lim} exactly.

The task of the limit height H_{lim} is to take in the unstable material flow that is caused by inharmonization of some production factors, and to guarantee a stable material flow. The limit height H_{lim} will be set from parts of some production factors that couldn't be completely harmonized for the JIT production and that can lead to unstable material flow. The typical production factors that can't be completely harmonized in a job-shop manufacturing are piece-work-time, setup time and capacities.

$$H_{lim} = h_w + h_c + h_m + h_s$$

H_{lim}: limit height of the JIT-Buffer
h_w: part of the piece-work-time
h_c: part of the capacity
h_m: part of the machine setup
h_s: safety part

The limit height H_{lim} can be determined through the simulation of the built model. The separate determination of the parts will be wrong, because instability of a production factor can influence the instability of another production factor.

2.2.4 Conditions for the production control with the JIT-Buffer

Before this concept is set in a production system, the following conditions should be met.

a. Harmonization

The harmonization is an important condition for this concept, because different values of a production factor through various manufacturing processes in job-shop manufacturing should be aligned and harmonized. By means of the harmonization the basis for the stable material flow can be created. Without the harmonization this concept can't be realized in job-shop manufacturing. The high variation of the values of production factors can prevent the job-shop manufacturing from the JIT production. It's of particular importance to harmonize the piece-work-time and capacities.

b. few machine setups
The machine setup is an interruption of the manufacturing process and causes an instable material flow. Too many machine setups can remove the advantages of the JIT production that is obtained by the production control with the JIT-Buffer. Therefore it will be pointless if this concept is set in a production system with many machine setups.

c. Database
The simulation model needs actual data before every manufacturing period. The job of the database is to supply the simulation model with actual, reliable, correct and safe data before every manufacturing period in order to inform the model about actual situation of the material flow and to get reliable results after the simulation.

3. CONCLUSION

As seen in the KANBAN system the rule circle with the pull principle is the most important condition for the JIT production. The new concept can perform it by the JIT-Buffer. The essential point is that the JIT-Buffer is not a real but a virtual object and is located only in a simulation model that is built according to a production system. The JIT production through the JIT-Buffer can be shown in the simulation model before every manufacturing period. After the simulation the production system will be organized so that the real material flow is runned like in the simulation.

The application field of the new concept extends from mass production to job-shop manufacturing. The success of this concept will be dependent on whether the simulation model is built like a real production system and the material flow in the model is run realistically, e.g. splitting and overlapping.

It is still to hope that the production control with the JIT-Buffer will be applied in many manufacturing companies, above all in job-shop manufacturing companies. And the new concept will be important in the future for the automatical manufacturing that will take over more and more by the developing of the automation technique.

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