Implementing Toyota Production System (TPS) Concept in A Small Automotive Parts Manufacturer

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Abstract

This study investigates the consequences of implementing Toyota Production System (TPS) in the local automotive parts manufacturer production line. The production line consisted of three different processes and two inter-process buffers. A verified base model was created using WITNESS[TM] computer simulation software. Reducing WIP is the primary objective of the study focusing on varying the sizes of inter-process buffers. Results generated from the simulation indicate that reducing inter-process buffers simultaneously would produce significant effect in reducing WIP compared to reducing each buffer independently.

Keywords : Toyota Production System (TPS), Work-in-process (WIP), Bufffer strategy, Simulation, WITNESS[TM]

1. Introduction

The application of Toyota Production System (TPS) principles have led a to lean manufacturing in which production and assembly cells consisting of product-focused resources are closely linked in terms of their throughput times and inventory control. TPS aims to smooth work flow across a wide variety of products, eliminate waste, achieving high quality output, flexibility of operation and producing low total unit production costs. The economic benefits include reduced lead-time and higher throughput, smaller floor space requirements, and lower work-in-process [1-4]. The economic advantage of implementing TPS would be of great benefit to automotive parts manufacturers classified as small and medium industries (SMI). These companies cannot afford to tolerate high production costs due to the fluctuation of customers' demand. Adding buffer into production line was an alternative solution. Hurley [5] stated that an effective buffer management could protect production lines against variations in demand. Previous researchers focused on buffer allocation strategies to maximize throughput or minimizing work-in-process [6-9]. The results of experimenting strategies to minimize work-in-process in serial production line can be visualized using simulation modeling. A number of authors have investigated the merits of using simulation to assist with production line [10,11].

This study is conducted in a local automotive vendor company focusing on its major production line producing Lower Arm Bracket. The product went through three machines named after their respective processes; blanking, forming and piercing. Raw material comes in a form of sheet metal rolls. Beginning with blanking machine, sheet metal is cut into desired product specification. These blanks are then shaped in

the forming machine and finally underwent piercing process before shipping. The company is facing large volumes of work-in-process (WIP) due to demand fluctuation. Achieving leaner operation would be the aim of this study through implementing one of Toyota Production System (TPS) principles which is reducing WIP. A simulation model named Base Model is developed to mimic the actual production line using WITNESS™ modeling software. Base model verification and validation were assisted by the company's personnel and available production history data. Subsequently, bottleneck process determination using simulation model since it cannot be done by direct observation. The following step is to experiment proposed buffer strategies. Three main buffer strategies to reduce WIP will be experimented on the simulation model. Inputs to be incorporated into the base model were provided by the company. Verification and validation of the base model were done by confirming the process flow and the comparison between actual production output and data generated from simulation. Experimentation of the base model of the first main strategy involved reducing buffer size either individually or simultaneously of both inter-process buffers, thus developing further three experimental models as follows:

Strategy 1: The reduction of Buffer1 from initial buffer size.
Strategy 2: The reduction of Buffer2 from initial buffer size.
Strategy 3: The reduction of Buffer1 and Buffer2 simultaneously from initial buffer size.

2. Model Description

The existing production line is constructed as a three-station, asynchronous, serial production line (Figure 1), with increasing processing times, but without breakdown. An asynchronous production line is one in which each workstation can pass parts on when its processing time is complete as long as there is available buffer space in

the next station. This type of line is subject to manufacturing blocking, which occurs when production cannot be started until a downstream buffer position is free. The base model is operated in a 'push' mode, i.e. it is assumed that there is always a part or raw material available when needed at the first workstation and space is always available for the last workstation to store a finished part. By this it is assumed that the first station is never starved and the last station is never blocked. Consequently, we are interested in only two locations for inter-process buffers, Buffer1 and Buffer2 with initial capacity of 100 units and 50 units respectively. The initial capacity of these buffers also represents the actual storage space available in the production floor.
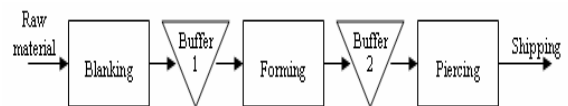

Figure 1. The three-station serial production line model.

Simulation software, WITNESS™ used in this study, visualize the base model as shown in Figure 2. Inputs to be incorporated into the base model were provided by the company. Verification and validation of the base model are done by confirming the process flow and the comparison between actual production output and data generated from simulation. The base and experimented models are simulated for a day's production time.
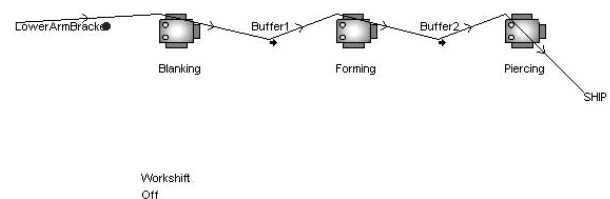

Figure 2. Base model and part flow as displayed in WITNESS™

3. Results and Discussion

Bottleneck determination using simulation model is straightforward according to the process or workstation with the highest utilization or busy state. As for the base model, piercing process is verified to be the bottleneck with 99.99% busy state (compared to 58.51% and 60.17% at blanking and forming process respectively).

The results on experimenting three proposed buffer strategies on the base model are depicted in Figure 3 and Figure 4((a) to (c)). Three lines represent three different buffer size reduction strategies are shown in both figures. The x-axis for both figures is the percentage of reduction from initial buffer size. The y-axis of Figure 3 is the average work-in process. On the other hand, the y-axis of Figure 4(a) to Figure 4(c) represents the utilization or percentage of busy state of the machines throughout the simulated production time.

Figure 3 displayed a significant decrease of average work-in-process when both buffers (Buffer1 and Buffer2) are simultaneously reduced. It had proved to be the most effective strategy compared to Strategy 1 and Strategy 2. As for the individual strategy, Strategy 1 performed better than Strategy 2 in reducing WIP. Apart from reducing WIP, the busy state of each machines are examined due to buffer size reduction strategies.
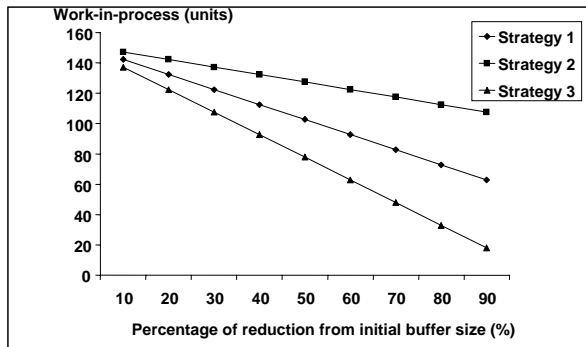

Figure 3. The resulting effect of inter-process buffer reduction strategies on average work-in-process

Plotted graph of Figure 4(a) displays The resulting effect of inter-process buffer reduction strategies on blanking process's busy state. The lowest possible busy state is achieved by Strategy 3 followed by Strategy 1 and Strategy 2.
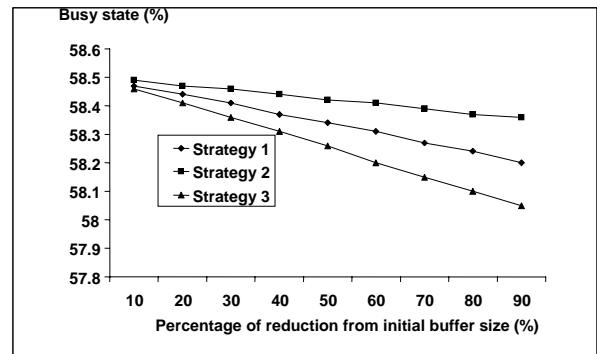

Figure 4(a). The resulting effect of inter-process buffer reduction strategies on blanking process's busy state.

However the busy state of forming and piercing processes are not affected. Buffer2's reduction decrease the busy state of forming process, imitating the effect formed by simultaneous Buffer1 and Buffer2 reduction (Figure 4(b)).
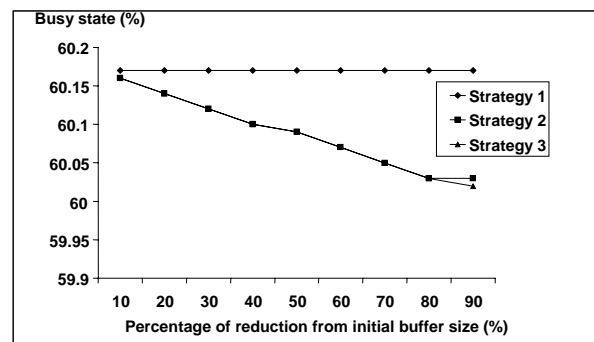

Figure 4 (b). The resulting effect of inter-process buffer reduction strategies on forming process's busy state.

Figure 4(c) exhibits that the busy state of Piercing machine is not affected by any of the three buffer reduction strategies.
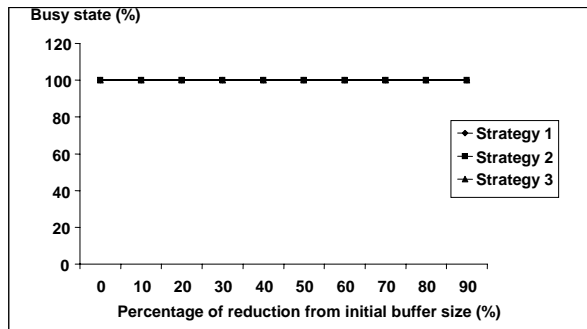
Busy state (%)

Figure 4(c). The resulting effect of inter-process buffer reduction strategies on piercing process's busy state.

Despite the reduction of WIP in all three strategies of buffer reduction sizes, production volume in all cases remain unchanged as depicted in Figure 5.
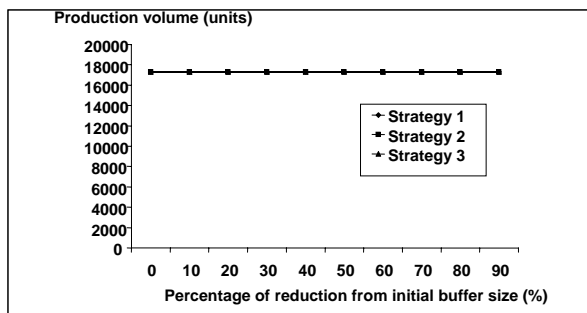
Production volume (units)

Figure 5. The resulting effect of inter-process buffer reduction strategies on production volume.

Identification of bottleneck in the production line studied is made possible using with an aid of simulation. Experimental models developed from base model unveil the potential of inter-process buffers of a short reliable serial production line in reducing work-in-process. The reduction of both buffer size produce superior result in minimizing work-in-process compared to be individually reduced. The company will gain the benefits of reduced work-in-process in which

inventory buildup costs would decline and variability in cycle time will be minimized.

Further influence of buffer size reduction is displayed on the busy state of the processes. In a reliable short production line with increasing processing times, busy state of a process is influenced by immediate buffer located after the process. Reducing the percentage of busy state of a process offers the advantage to the case study company to compensate any variability of cycle time.

Simulation results indicate that the case study company has the capability to gain control on work-in-process. Reduction of inter-process buffer size would consequently optimize the utilization of production floor space and other related costs.

4. Conclusion

As proven in the results of this study, reducing inter-process buffer size would significantly reduce work-in-process. Buffer storage create inventories and reducing them is essential to any JIT system particularly TPS. Reducing work-in-process reduces the time and space involved in manufacturing and holding inventory. The usage of simulation in the case study demonstrates its ability to identify the location of bottleneck process. Experimenting changes using simulation can easily be made to the existing system without disruptions.

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