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CONSTRAINT IDENTIFICATION IN SEMI-AUTOMATED PRODUCTION SYSTEM

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ABSTRACT

The production rate for an established semi-automated production line is expected to increase by 58%. The production line has throughput issues and it is difficult to identify which improvements that will resolve bottlenecks to increase system wide throughput. A Discrete Event Simulation model of the production line was developed to identify bottlenecks, test solutions, and quantify processing duration target levels to meet system throughput level goals. Primary bottlenecks were found in Factory 2 where multiple changes were identified to reduce pulse time by 32%. Secondary model uses include optimum manpower, batch size, and change over strategies for profiling machines and investigating the impact of adding another station in paint.

1 INTRODUCTION

The production rate for an established semi-automated production line is expected to increase by 58% in the foreseeable future with a possibility of 83% increase. The focus of this case study is bottleneck identification. A Discrete Event Simulation model of the production line was developed to identify bottlenecks and test solutions to increase production system throughput levels to meet future demand.

2 PRODUCTON SYSTEM DESCRIPTION

This production system produces 10 similar, but unique assemblies to form a single unit's worth of deliverables in a building that is divided into four Factories: 1) Preparation 2) Cure 3) Cut, Inspect and Assembly, 4) Paint. The initial system pulse rate (cycle time) was 66 minutes 41 seconds and is operated 24 hours per day for 6 days per week. Fast enough to witness material flow from one process to the next but slow enough to make bottleneck identification difficult. The production staff were assigned to specific sections of the factory and rarely moved to other areas. Therefore, it was easy to see "your piece" of the system but difficult to see the whole system and how the parts, tooling, machines, and buffers interacted. It was apparent that no one person understood how the entire system interacted.

Factory 1 prepares material and stores them in a warehouse buffer as an input to Factory 2 processes. Each of the 10 assemblies require three components each which are prepared on four different Factory 1 machines. Each component uses a tray resource for processing, transportation, and storage. Factory 2 has six unique stations, each with one to seven processing locations that collectively hold 20 large tools. These tools move in a defined pattern from one station to the next with no buffers between the stations. Automated material handling equipment move tools between stations and form a circular flow. "Dirty" tools are periodically removed from the circular flow for cleaning and refurbishment and replaced with a "Clean" tool from a 10 tool buffer. Factory 3 consists of CNC cutting equipment, inspection test equipment, and assembly processes. Factory 4 prepares assemblies for paint and paints them using an automated process.

3 BOTTLENECK IDENTIFICATION

The simulation model was used to identify bottlenecks, test solution concepts, and quantify target processing durations. The model also answered production questions such as staffing levels, batch size, system education, and the impact of adding a new station. The primary production throughput bottleneck was found in Section 2 and requires a 32% reduction in pulse time.

Factory 2 is divided in half where two automated material handling shuttles split the duty to move 20 active tools (two for each assembly) from one station to the next in a circular pattern. No buffers exist between stations and no tool could move without a shuttle. Each station position would progress through a predictable series of states: empty, loading, processing (only value added step), blocked, unloading. "Pulse" of the line is the time to complete a cycle through these states. Because there is only one transport shuttle available per station, no buffers, and sequential production process, all the stations are linked together and have the same pulse time which is set by the slowest station. To increase the production rate without large infrastructure changes, the pulse time must be reduced by reducing the processing time to desired levels at all stations to meet required throughput targets. The model revealed that the material handling design impacts station utilization and the need to reduce processing time to a level that accounts for material handling time delay.

One day per week the line is down for maintenance. To avoid creating defects, station 2 work must be initiated within a few minutes of station 1's five hour cure work completing. The current state process stops initiating station 1 work six hours before a weekly shutdown. During weekly startup, another five to six hours is needed to start the pulse again. This creates a weekly unproductive 11 to 12 hour hole in the production schedule that limits throughput. The model quantified the impact of a manpower scheduling change and increasing station two's processing locations to plug this hole.

When tools are removed from service for cleaning, the current state process interrupts the flow of tools and causes significant delays. Therefore, tool exchanges are minimized. First pass yield is not the same for each assembly which creates a shortage of specific assemblies to complete a full unit. To catch this assembly up, a 3rd active tool is added to Factory 2 at the expense of another assembly that has only one active tool. The result is a course selection mechanism for equalizing finished assembly quantities and creates an excess of some assemblies and not enough of others. The model showed how installing equipment to complete a tool exchange within a single pulse will lower the throughput cost and provides a more precise selection mechanism to level finished assembly levels to complete more units.

Factory 2's first station is a cure process with multiple processing stations to perform parallel work. Stations 4 and 5 have a single processing station each and all tools flow through these stations. This forces the first station to have a dwell time between starts so as not to cause issues later. The model quantified that a short dwell will create scrap because lack of processing space at second station. A long dwell will starve stations 2 – 6 of work and lower throughput. A balanced process is achieved when dwell time equals pulse time.

Eventually Factory 2 improvement will move the bottleneck to Factory 1 where a very sophisticated and impressive automated material prep process will become the constraint on a traditional 24/6 schedule. Multiple counter measures should be taken to increase output by 12% such as an alternative schedule, eliminating waste and unplanned downtime, or removing work from the constraint.

Simulation was used in Factory 3 to identify the optimum manpower strategy, batch size, and change over strategy for profiling machines. In Factory 4, proposed solutions to improve part quality by adding a new station were evaluated for their impact on throughput and capacity. The simulation was used to inform process owners how the automated paint system works and to propose efficient equipment use.

4 CONCLUSIONS AND RESULTS

Recommendations were eye opening to production leaders and long lead improvements are on order. As first pass yield and quality improvements are realized, throughput recommendations will gain more importance. Factory 2 pulse measurement has been automated and being incorporated into the factory management and decision making processes. Dwell time is better understood for its system impact when it's too short or too long. The model showed how all six stations are linked together and have the same pulse time equal to the slowest processing time station. The opportunities to improve pulse time is limited to processing time reduction due to the tool material handling system design.