A Feasibility Study for Implementing a Cellular Manufacturing Solution for a Foil Cutter Production Line

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Track: Operations Planning, Scheduling and Control

With the objective of improving the throughput of an existing foil cutter production line, a feasibility study for implementing a cellular manufacturing approach was undertaken. Given the layout, machine types and capabilities, product mix and corresponding monthly requirements, the simulation software ARENA was used to simulate the existing operation, from the press room through assembly and the final packaging for distribution. Our simulation as well as the initial investigation for data gathering produced eye-opening results. A unified cellular solution was determined to be both operationally and ergonomically inadequate. However, a cellular arrangement for a portion of the production line was found to be superior to the existing arrangement. The study results and recommendations are currently being implemented in a manufacturing plant in New England.

Introduction

The major objective of this study was to improve the throughput of an existing foil cutter production line using computer-based simulation given the current layout, machine capabilities, and monthly delivery requirements. The project was undertaken for a manufacturer of shaving cutters in the New England region.

The Product: The foil cutter production facility manufactures foil and shaft details, which are then assembled to form a foil cutter assembly. The foil cutter assemblies are components used in the manufacture of new electric shavers, and are also sold as replacements for existing shavers. Five different foil cutter assembly part numbers are manufactured at this facility. Of the five part numbers, two belong to ladies shavers with 23 and 25 foils per cutter assembly. Three part numbers belong to men shavers with 25, 28, and 30 foils per cutter assembly, respectively.

The Facility: The foil cutter production facility is housed in a large factory and comprises only a portion of the total floor space of the facility. There are four distinct areas that are used for the manufacture of foil cutter assemblies, the press room, assembly, special coating, and packaging. The different process areas are within the same building but the travel distances are rather significant, and require movement of material with handcarts between the different areas.

The Process: There are many steps in the manufacture of foil cutter assemblies and only an overview is provided here. The raw material arrives in flat stock coil and wire rolls. They are stored in a point of use manner in the press room. The foils are blanked out of the flat stock coil while the pins are machined from the wire. The completed foil and pin details are then stored in tote bins at a Kanban storage area, which is located between the press room and the assembly area. When the details are needed, they are transported to the assembly area via the tote bins and loaded into the automatic feeders. The foils are pressed onto the shafts by automated staking machines. The assemblies are then transferred to the centerless grind area and loaded into an automatic feeder prior to grinding. Once ground, the foil assemblies are washed, and then lubricated with a special coating. Finally, the completed foil cutter assemblies are inspected and packaged for shipping.

Data Furnished:

Observation – The team met with the manufacturing/plant managers and toured the foil cutter production facility prior to starting the project. Each team member was allowed to view the process in operation and ask as many questions as needed to become familiar with the process. This step also helps with the communication between team members and production facility staff.

Operation Sheets – Operation sheets for each of the foil cutter assemblies were furnished to the team. The sheets were used to calculate the process time in minutes per part for each of the machines that are in the model. The operation sheets were also used as a cross-reference, along with the detail part blueprints and process flow charts, so the transfer of material could be accurately modeled.

Factory Layout – A scale, two-dimensional layout of the facility from CADKey was provided. The file was converted to a standard graphics file (.dfx) and imported into ARENA for use as a scale background for the computer simulation model

Process Flow Charts – Foil cutter assembly flow charts were provided. These flow charts show the assembly structure, and machine steps required to complete the foil cutter assemblies. Detail part quantities and machine flows were used in the ARENA model.

Weekly Customer Requirements – The required weekly customer requirements were also provided to us. The customer requirements were used to benchmark the ARENA model and to calculate the TAKT time for each of the different assemblies. TAKT time is the total available time divided be the customer requirements over the same time period. The weekly requirements of assemblies were also used to calculate the weekly requirements of the detail pins and foils.

Data Analysis:

Machine Process Times – The process time for each operation was extracted from the operation sheets provided. The times in the operation sheets, hours per 100 pieces, were then converted to minutes per piece, which could be used in ARENA.

TAKT Analysis – From the available working time and weekly production requirements, TAKT times were computed for each model of foil cutter assembly. TAKT time is the total available time divided by the customer demand over the same time period and is often referred to as the heartbeat required to keep up with demand. The total available time is the working time and does not include breaks or lunch period. TAKT times corresponding to different pieces of equipment on the production line may be juxtaposed to graphically illustrate where the restrictions (bottlenecks) in the processes occur. This allows management to make decisions pertaining to equipment and personnel utilization and plant capacity. See Womack (1996) for more on TAKT time.

Part Travel Distances – Process flowcharts were used to document travel distances between different operations within the plant during subsequent visits. The distances (feet) between machines and storage areas were input directly into ARENA.

Simulation Model Development

Analysis Software: The production line was modeled using ARENA Version 3.03 and HiSpeed$im Version 1.1 from Systems Modeling Corporation. The ARENA software is used to model a variety of production and service industry models, while HiSpeed$im is used specifically for high-volume processing operations. The large size of the computer model requires the professional versions of the said software to be used to run the models.

Modeling Approach: The difference in the production capabilities in Cell 1 (Press Room) and Cell 2 (Assembly) necessitated the use of three individual simulation models. Two models were created for Cell 1, which required the ARENA HiSpeed$im, and one model was used for Cell 2, which used the standard ARENA simulation software. ARENA HiSpeed$im enabled us to build and run simulations at processing rates that take place at hundreds, even thousands, of pieces per minute. Cell 1 has punch presses that produce over 1,400 pieces per minute and is an ideal situation for HiSpeed$im. Both the Foil and Pin fabrication models were developed for Cell 1 using HiSpeed$im. The third model, Cell 2 Assembly, represents a production rate that averages about six pieces per minute and uses the standard ARENA software.

Modeling Assumptions:

Unlimited Raw Material Supply – The raw material for the foils and shafts arrive in coils and are stored next to the press-room. It was assumed that a supply of this material will always be available and the presses will never be starved.

Assembly Stations Are Always Loaded With Details – The assembly presses are supplied with shafts via a vibratory feeder and with foils via magazines. It was also assumed that the supply of shaft and foil details is scheduled such that the assembly machines are always loaded. This assumption can be verified by examining the results of the simulation from the pressroom area.

Due to the nature, complexity and size of the foil production facility, three separate models were developed. The results from Model 1 and Model 2 were input to Model 3, as presented below.

Model 1 – Pins Production

A decision was made to break down the process of cutter assembly manufacturing into two separate cells. The first cell, Cell 1, would consist of all the equipment necessary to produce the cutters and pins that eventually would be assembled in Cell 2.

Pin Model Overview: There are three steps to the Pin component production process, “machine’, ‘clean’, and ‘store’. Four Escomatic Swiss style machines constitute the ‘machine’ operation. These machines utilize similar part geometry with the exception of the overall length. With the exception of Escomatic #2, each machine is dedicated to a single part number. The Escomatics are modeled with Basic Machine Modules and all four converge (Merge) to a small cleaning unit called the Jensen Cleaner. An alkaline cleaner, it washes the residual coolant film that remains on the pins from the prior Escomatic lathe operation. It can process about 10,000 units per minute. The Jensen Cleaner is modeled with a Basic Machine Module. Upon completing the cleaning cycle, the pins are then transferred to a Kanban storage area, which is modeled with a Palletizer and Storage Module. Specifications, such as production rates, losses, changeover, reliability, and scheduled stops for the equipment on the line is implemented according to the actual operation information. The Palletizer and Storage Modules were used to model the Kanban holding areas. One pallet is equivalent to a Kanban tray of 15,000 pins. These pins will be accumulated from the Jensen washer one Layer of 5000-piece at a time. The time used for this module is equal to the time it takes to process the pins in the Jensen washer. The storage will permit 100 pallets equivalent to 6.6 weeks of pin production. The detailed description of the modeling approach and ARENA Modules selection for the Pins fabrication portion is given in Cini et al, (2000).

Model 2 – Foil~~s~~ Production

The HiSpeed$im was used in the Foil Model as in the Pin Model described above. There are four steps in the Foil production process: Machine, Clean, Heat, and Store. The machining equipment in this process consists of three Bruderer presses. These machines also use similar part geometry with the exception of the foil produced by Bruderer P-25. The Foil Model begins utilizing three Basic Machine Modules representing the Bruderers. The Bruderer P-15 parts goes directly to a Palletizer Module and on to the Storage Module. The other two presses (Bruderer P-16 and P-25) converge to the Jensen cleaner, which is also modeled using a Basic Machine Module. After completing the cleaning cycle, the foils are then transferred to the Blue M Oven, which is modeled with a Basic Machine Module. This process is a kind of heat treatment to lower the defects and increase uniformity of the foils. After the Oven’s cycle, the foils are then transferred to a Palletizer and Storage module representing the Kanban holding areas. Specification regarding various production rates, losses, changeover, reliability, and scheduled stop were input in the Machine Modules as appropriate. We have assumed at all Bruderer stations that the material, stainless steel coils, would always be available on demand. This would not be a constraint, and that there would always be a coil of material ready to continue production. A detailed description of the approach and ARENA modeling details for the Foil fabrication is given in Cini et al, (2000).

Model 3 – Foil Cutter Assembly

Assembly Model: The Assembly Model, developed with ARENA version 3.03, mimicked the flowchart for each of the products. A Server Module is used to simulate each of the Presses, which are assembling the foils to pins. At this point, products are assembled into batches of 500 where they are then sent as a batch into the Crest cleaner. Upon completion of processing through the Crest cleaner, the parts are split out of the batches back into singular parts. The reason the simulation has to be performed this way is that the parts will be processed one at a time in the next operations, which is either, Royal Master centerless grind for the TA and WDF, or carrier assembly for the DA and XLR part types. After completion as individuals at these Server Modules, the parts then get batched again for processing through the Jensen cleaner. Upon exiting the Jensen cleaner, the parts are split back into individual pieces, then re-batched into the appropriate size groups for the special chemical coating operation. After the special coating is completed the parts are again split back into individuals.

The duration of time for each piece of equipment to be working and when it is activated and deactivated was handled using Schedules. The production system, which we are simulating, consists of a two-shift operation with a varying number of operators on each shift. In order to make the scheduling work in the appropriate manner, each day was simulated as 1,020 minutes, or two shifts of 510 minutes. Included in each of these non-working times are two 15-minute rest breaks, one 35-minute lunch break, and a final 20-minutes wash-up break at the end of the shift. Therefore the net working time was 432 minutes per shift. Actual simulation of the process consisted of several replications of 1,020 minutes. The reason for this was to bring the line into a steady state of operation condition before extracting and analyzing meaningful data. The results obtained in the first replication were discarded since the production line had been started empty and idle. The results obtained from the remaining replications were used for analysis and subsequent report writing purposes.

Results and Analysis

Upon careful verification and validation steps, the simulation models were run to obtain results statistically similar to the actual operation. The model results accurately matched those of the actual weekly production and equipment utilization. A careful examination of various runs of the model reveals several interesting facts. First, there is not a significant difference in production output between models using actual route times and a model using zero route times, or instantaneous transfer between pieces of equipment. However, there is a significant difference in the model variants where downtime is concerned. There are several reasons why the route times are not making as substantial an impact on production output as one might think. The reason is that the model has been set-up under the assumption that as soon as a batch of material is ready to be moved to the next operation, it occurs. In other words, the model is simulating the use of a dedicated material handler to transport product from station to station. It is also assuming that the material handler is always available to move the material when it is required. The original information, which was given by the project sponsor, was that the lead person is acting as the material handler. The use of a dedicated material handler in this situation was not necessarily a bad idea. The reason being that the manufacturer’s revised-production requirements put them in a position where they will either be unable to or have great difficulty meeting the current product demand with existing capacity.

At the start of this project one of the primary objectives was to create a cellular arrangement. Some of the primary benefits of cellular manufacturing are more efficient use of floor space, more effective equipment layout and reduced material handling. The scenario, which is being modeled in this case, will most certainly benefit from a cellular arrangement. This will enable the manufacturer to make more effective use of their floor space. It will also substantially improve workflow in the manufacturing area creating a system, which is much less chaotic than the existing one. A direct result of this will be shorter travel distances between equipment, thereby reducing transport times for the material handlers.

One of the realizations that the simulation has brought to light is the fact that this production system is one, which will actually perform better modeled as a continuous flow system. A continuous flow system is one where all servers or manufacturing equipment is staffed and producing continually, not moving along with product from server to server within the system as would normally be done in a cellular-type system. The reason is mostly because the production requirements are so large that the inefficiencies created as the result of operating in one-piece flow environment would be detrimental to the throughput. This is a case where working in a continuous flow manner will be the most effective production scenario. This is not to say that a cellular arrangement should not be used. It will have several significant advantages over the existing production line. However, it should be noted that moving to a cellular arrangement would not yield a significant improvement in production output.

Another observation which became apparent upon analysis of the simulation results is that although there is a typically 20% downtime on the carrier assembly operation for the DA & XLR products, this should not adversely affect the manufacturer's ability to deliver products on a weekly basis. However this is at just about the limit which can be tolerated. Downtimes greater than 20% would definitely affect the ability to meet customer requirements.

The simulation has also confirmed that the Jensen cleaners in the assembly area are a bottleneck. Additionally, with the new and revised production figures, this becomes more of a problem that it has been in the past. The simulation in its current state indicates 89.45% utilization. This is at a level of production, which will not satisfy requirements. Therefore, this utilization issue will only become worse at a level where we are trying to meet the current production requirements.

The results of the simulation magnify some of the problems facing the manufacturer. The first, is that there are certain products which the manufacturer will have a difficult time producing without adding either more equipment, personnel, or hours to production. Secondly, there appears to be a certain amount of excess capacity on other product lines. The existing production line configuration does not provide a clear visibility as to what products are being produced, which operations are starved, or which operations is a bottleneck.

Therefore, the move to a cellular arrangement would hold an obvious advantage over the existing line. The cellar arrangement will enable a casual passer by to quickly identify which products are in production. Point of use storage should be incorporated right at the operations with the appropriate replenishment triggers set so no time is wasted due to starvation of the equipment. Part queuing areas should also be established directly at the cells in plain sight with trigger levels clearly marked in order to signal an operator to rotate to this operation and begin work as soon as they complete the current tasks. Indicators of daily requirements should be established within each cell and updated several times a day in order to enable all who are concerned with the state of production of the cell. This type of an early warning system would provide ample time for action to be taken in a timely manner in order to ensure the on-time delivery of products. In addition, maximum level indicators should be set to inform the operator when they have made the appropriate amount of production at that particular operation and when it is time to move down the line to another task. Working in this manner will help the operator be focused on producing the right product needed as well as compressing throughput because the operators will be moving smaller lots through the production line rather than waiting days for large lots to be produced.

Recommendations

Based on the results of this simulation study, several recommendations were made to the manufacturer as follows.

1. Keep the pin and foil production as is but address some of the ergonomics issues. This will require equipment upgrades, improvement of the infrastructure and paying attention to the aesthetics.
2. Move to a cellular arrangement for the assembly area. This will require workstation redesign and training.
3. Use common batch sizes. This may require some redesign work as well as capital expenditure.
4. Incorporate a faster cleaning mechanism. This will require new equipment.
5. Incorporate a line-balancing initiative to be continuously employed. This will require job redesign and training.
6. Assign a dedicated material handler to transport material from machine to machine.
7. Implement a quick-change tooling in the assembly presses.

References

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Acknowledgement

This article is based on a team project report. We would like to thank the team members: Colin Cini, Richard Diaz, Martin Klein, Almo Santoso, and Stephanie Rothberg for their contributions to the project as well as their dedication to the team. Our many thanks and appreciation also goes to the sponsoring manufacturing company and its personnel, especially the Production Operations Manager who provided much help and enthusiasm in completing the project.