MichiganEngineering

Improving Tuttle Springs Operations

Introduction
Tuttle Springs located in Chelsea, Michigan was established in 1982 as a company dedicated to the design of springs. The company specializes in high stress springs -- springs that can withstand force without fatigue. With an increase in demand from the automotive industry, Tuttle Springs eventually became a manufacturer of the springs they designed. Currently, the biggest customer of these springs is the automotive industry, which makes up 61% of customer orders. The furniture industry's demand, which makes up 21% of Tuttle Springs' orders, follows that of the automotive industry.
At this time, the manufacturing process of one of their Exhaust "SAO" Spring consists of eight separate operations. Tuttle Spring aims to improve their current production process of the Exhaust "SAO" Spring while continuing to produce high quality products and deliver orders to their customers on time. Our team is planning to analyze the current process by applying the following lean concepts:

- Determining takt time
- Developing continuous flow where possible
- Implementing supermarkets
- Including a pacemaker process
- Distributing products evenly over time at the pacemaker process
- Creating an "initial pull" by releasing pitch at the pacemaker process
- Shortening changeover times and running smaller batches

Current State Observations and Analysis
As you can see from Appendix A (Current-state value-stream map), Tuttle Springs currently operates the plant with eight different processes which are: Receiving raw materials from the supplier, Coiling, Stress relieving, Grinder, Tumbling, Heat setting, Inspection, Pack and ship. (Please refer to the Appendix A for more details of each process)

Although the company has shown fairly good performance and quality in manufacturing the springs, the current process is not lean for the following reasons:

1. Overproduction: Products are being manufactured at a rate faster than the rate of customer demands, and hence there is excess inventory.
2. No continuous flow: An operator physically needs to move parts from one process to another, and every processes take in and out the batches of products. However coiling and stress relieving is a continuous flow assuming that once the springs are cut, they go directly to the conveyor belt located within the stress relieving oven.
3. “Push”: Each process works to optimize their individual processes rather than the whole system.
4. Process-oriented: The layout shows that the machines are grouped together by similar functionality rather than process sequence.
5. Monthly schedule: The plant gives a monthly schedule to each process.
6. Pack size: The pack size is large, 5,500 pieces per pack.
7. Infrequent delivery to customers: The plant delivers relatively large size batches to the customer.

Therefore, we can eliminate the above problems by applying the lean concepts to the current process with the following guidelines.

1. Determining takt time: According to our calculation, average takt time is 7.85 seconds. In developing our future-state value stream map, we will consider this takt time and ensure that our production rate becomes closer to the takt time.
2. Developing continuous flow where possible: In order to develop continuous flow, we will combine the first 3 processes: Coiling, Stress Relieving, and Grinder. In addition, Inspection and Pack/Ship processes will be combined. We will assume that we can engineer the processes for the combinations.
3. Implementing supermarkets: We will develop supermarkets between each process that will allow the pacemaker process to control the inventory based on customer demand.
4. Including a pacemaker process: Inspection/Pack and Ship cell will take on the role as pacemaker because it is the continuous process closest to the customer. In addition, here you can control the flow of raw materials.
5. Distributing products evenly over time at the pacemaker process: We are only focusing on one product type for this project, therefore we cannot level product mix. However, we will reduce the pack size and level work distribution, which allows even distribution of the production of SAO springs throughout the day.
6. Creating an "initial pull" by releasing pitch at the pacemaker process: According to our calculation, pitch is 43,175 seconds/box. Minimum pitch is 27,500 seconds/box, and maximum pitch is 77,000 seconds/box.
7. Shortening changeover times and running smaller batches: We cannot apply this concept to our current state map, since we are not looking at the other springs manufactured by Tuttle Springs.

Future State Recommendation

Takt Time

Our first step in developing our future-state concepts was obtaining the customer demand rate and takt time. The customer demand rate was given as 8,250 pieces per day. The takt time was obtained by calculating the quotient of the working time available per shift (32,400 seconds) divided by the customer demand per shift (4,125 pieces) – approximately 7.85 seconds per part. Our goal is to produce only what the customer wants when the customer wants it; therefore, knowing the customer demand rate and takt time is crucial. The takt time indicates a limit on the amount of time allowed to produce a spring in order to meet demand. This means that each processing step in the production of the exhaust spring should not take longer than 7.85 seconds to complete. Ideally, each process should take precisely 7.85 seconds to complete in order to avoid overproduction; however, this is not feasible since not all processes are 100% reliable. Our recommendation for the immediate future is that each process be completed in less than takt time in order to compensate for production problems.

Building to a Finished-Goods Supermarket vs. Building Directly to Shipping

The customer's demand rises and falls unpredictably, ranging between 4,750 pieces per day and 11,750 pieces per day. With a large lot size of 5,500 springs and delivery to the customer just once a week, the current state does not accommodate for fluctuations in demand very well. To accommodate for these fluctuations, the company would either have to carry safety stock or risk falling short of the demand. We recommend negotiating with the customer, requesting to decrease the lot size to 2,750 springs and to allow for more frequent, daily delivery. This smaller lot size would lead to decreased inventory and would make it possible for the company to accept smaller orders. Tuttle Springs would then be able to feasibly deliver to its customers more often. This would allow the company to better accommodate to sudden changes in demand. Ideally, the lot size would be just one spring; however, this is not possible in the immediate future because the current processes have significant lead and changeover times. The reliability of the current processes is uncertain and continuous flow in the immediate future is obviously not possible; therefore, we recommend that the company build the exhaust springs to a finished-goods supermarket.

Continuous Flow

In Tuttle Springs' current state, a substantial amount of inventory clearly stagnates between processes. Continuous flow would eliminate this stagnation of inventory and therefore we recommend establishing continuous flow wherever possible. The cycle times of the inventory and pack-and-ship workstations were not too far apart; therefore, we believe that achieving continuous flow through these workstations is possible in the near future. Likewise, the coiling, stress-relieving, and grinder workstations all have similar cycle times. We believe that achieving continuous flow through these three workstations is also possible in the near future. The cycle time of this combined process is faster than that of the following tumbling process. Integrating tumbling into a continuous flow with coiling, stress-relieving, and grinding would require slowing the combined process's cycle time and thus is not practical. This would result in the underutilization of the coiling, stress-relieving, and grinding workstations; therefore, it would be more practical to run the combined process as a batch operation and control its production with a pull system. We also noticed the cycle time of the heat-setting workstation is slower than that of both the processes preceding it and following it. Incorporating heat-setting into a continuous flow with these processes would mean slowing the cycle time of both tumbling and inventory/pack-and-ship in order to avoid tumbling from overproducing and for heat-setting to keep up with inventory/pack-and-ship's demand. Indeed, it would be more practical to run the tumbling and heat-setting processes as batch operations and control their production with pull systems.

Supermarket-Based Pull Systems

Although Tuttle Springs cannot achieve continuous flow throughout the production of the exhaust springs, a lean value stream can still be implemented by utilizing supermarket-based pull systems where continuous flow is not possible. By utilizing pull systems, the need for production control to provide each process with a schedule would be eliminated.

We previously recommended that Tuttle Springs produce exhaust springs to a finished-goods supermarket. We also recommended that a supermarket for the coiling, stress-relieving, and grinding process, the tumbling process, and the heat-setting process be implemented. A raw-materials supermarket and packaged-goods supermarket should also be set up in order to control their shipment.

Since the combined process of coiling, stress-relieving, and grinding has such a short cycle time, we need to implement a supermarket and use withdrawals from that supermarket to control its production. The combined process's customer is the tumbling process. The combined process's cycle time of 1.6 seconds, the longest of the individual process' cycle times, is significantly faster than the tumbling process's cycle time of 720 seconds. Thus, when the tumbling workstation's operator removes a bin from the supermarket and a production kanban is sent to the combined process, the combined process would be able produce enough parts to replace the withdrawn bin well before the tumbling workstation is done processing it. Assuming that the customer complies with our request to decrease the pack size to 2,750 springs per box, we recommend that this also be the bin and kanban size. Since the coiling/stress-relieving/grinding process can replenish what the tumbling process uses quickly, just one bin or 2,750 parts should be stored in the supermarket.

Likewise, since tumbling has a much shorter cycle time (360 seconds per pack) than heat-setting (6600 seconds per pack), we need to implement a pull system to control tumbling's production. Clearly, when the heat-setting workstation's operator removes a bin from the supermarket and a production kanban is sent to the tumbling workstation, the tumbling workstation will be able to produce enough parts to replace the withdrawn bin well before the heat-setting workstation is done processing it.

While heat-setting has a cycle time of 6,600 seconds per box, inspection/pack-and-ship has a cycle time of 1,800 per box (the longest cycle time of the two individual processes). The heat-setting process clearly has a longer cycle time than its customer process, so the set up of a supermarket between them is recommended. If replenishing what has been withdrawn from the heat-setting supermarket on a bin-by-bin basis, the inspection/pack-and-ship workstation would have to wait 4,800 seconds until it can process the next bin. Thus, we recommend that Tuttle Springs keep a minimum of 5,500 springs in the supermarket. This will allow for replenishment delay while meeting the demand of the inspection/pack-and-shop process.

In attempts to reduce the need for raw-material inventory, we recommend that Tuttle Springs implement a pull system at the receiving dock. It is very unlikely that the company's supplier is willing to collect and manufacture according to kanban; however, it is still possible to control the shipment of the steel coils according to the downstream process' usage. We recommend that Tuttle Springs attach a withdrawal kanban to each coil and have those kanban sent to the production control department whenever a coil is used. This would allow production control can place its orders from their supplier based actual raw-material usage. Assuming that the steel springs are used in the production of just the exhaust springs, the need for large raw-material inventory is diminished. Since the supplier will be shipping according to the downstream process's needs (it is not likely that the supplier is willing to ship more than once a day), we need to store just two coils in the supermarket (each coil yields 6,000 springs) in order to have sufficient material to meet the customer's demand for exhaust springs.

Since the kanban size we recommended is just 2,750 springs, just 2,750 springs will be manufactured at a time; therefore, we need to implement a pull system at the shipping dock as well. It is impractical to ship just a batch of 2,750 springs (this would require the company to ship three times a day in order to meet daily demand), so Tuttle Springs needs somewhere to store this batch of finished exhaust springs before the total demand is accumulated. Storing the daily demand of 8,250 springs in this supermarket makes sense because this supermarket will be the closest to the customer. This amount is also sufficient because shipments to the customer will be made daily.

Pacemaker Process

By utilizing supermarket pull systems, Tuttle Springs needs to schedule just one process in the future value-stream – the pacemaker process. Material transfers downstream from the pacemaker process to the finished-goods supermarket must flow continuously; therefore, we recommend that the inspection/pack-and-ship process be the pacemaker. We cannot make any process further upstream the pacemaker since we are planning to set up a supermarket between the heat-setting and inspection/pack-and-ship processes. By leveling the workload at the pacemaker process, we can distribute the production of the exhaust springs evenly throughout each work day. To attain a level workload, we recommend placing a load-leveling box near the inspection/pack-and-ship workstation from which the operator will pull withdrawal kanban one-at-a-time at the pitch increment of 21,588 seconds (takt time times pack size = 7.85 seconds/piece x 2,750 pieces/pack). Thus, the consistent increment of work we recommend Tuttle Springs release and take away at the pacemaker process is 21,588 seconds. This increment of 21,588 seconds is roughly a third of the available work time per day of 64,800. Again, a kanban size of 2,750 springs is ideal since this is exactly a third of the daily customer demand of 8,250 springs. Therefore, Tuttle Springs would complete production of one-third of the daily customer demand within one-third of the available work time and meet the daily demand of the customer after three increments of work are released.

Process Improvements

In order for Tuttle Spring's future state to progress as we have recommended, improvements must be made in the actual processes as well. Although we did not consider changeover time in developing our previous recommendations because we do not know enough information about the other products Tuttle Springs manufactures, reduction in changeover time in each current-state process is recommended in hand with reduction in lot size. Both improvements would allow for better accommodation for fluctuations in demand. Since the changeover time of inspection is currently just 60 seconds, it is feasible to decrease it to zero seconds in the immediate future. The changeover times of the remaining processes, except pack-and-ship, are significant; therefore, reducing them to zero is not likely in the near future. We decided that it would be more realistic to reduce these changeover times by 50 percent. Specifically, we would like to see heat-setting's cycle time decrease from 1,200 seconds to 600 seconds, tumbling's changeover time decrease from 600 seconds to 300 seconds, and coiling, stress-relieving, and grinding's combined changeover time decrease from 14,400 seconds to 7,200 seconds. We assumed pack-and-ship's changeover time is already zero, so we don't need to make any improvements here. Furthermore, we recommend improving the reliability of each process by increasing their uptime. Fortunately, the uptime of each of the current-state processes is either 100% or near 100%. Since the uptime of pack-and-ship is already 100% there is no need to improve here. The 90% uptimes of the inspection, tumbling, grinder, stress-relieving, and coiling processes can be easily increased to 100% in the near future. We thought the 80% uptime of the heat-setting process would be more difficult to increase to 100% in the immediate future, so we aimed to increase it to just 90%. These process improvements are what will make our future-state concepts possible and are reflected on the drawing of the future-state value stream map (see Appendix B).

Indeed, our future-state recommendations lead to a substantial amount of waste reduction and pave Tuttle Springs' way towards lean manufacturing. This is reflected in our improved production lead time. With the implementation of our recommendations, the production lead time reduces from 19.44 days to 4.78 days. This is an incredible reduction of 75%.

Implementation Steps

In order to move from the current state to the future state the changes being made to the system has to start within the pacemaker loop. The pacemaker is the process that tells the rest of the processes how many parts need to be made. By implementing changes elsewhere in the system before implementing the changes at the pacemaker, the ending system could end up being no where close to the intended future state.

During the first month, our team would introduce smaller pack sizes, daily shipment of finished parts, increase the uptime of inspection, and develop a continuous flow from inspection to pack and ship. Through the completion of these steps we would see a pack size of 2,750 pieces per box, 8,250 pieces delivered each day, the inspection uptime will be 100%, and the inspection/pack and ship cell will be operated by one person and contain no works in progress between stations.

In month 5, our team will finish implementing the changes in the pacemaker loop by developing a pull system that contains the finished goods supermarket, and would eliminate the monthly schedule. The finished goods supermarket will contain only one day's worth of finished goods. Also in month 5, our team will begin implementing the changes in the heat setting loop. The heat setting uptime will be increased to 90% and a pull system containing the heated parts supermarket will be developed. The heated parts supermarket will contain only .66 days worth of heated inventory.

Starting in month 6 the heat setting changeover time will be reduced to 60 seconds, and our team will begin changes in the tumbling loop. Our team will begin to develop a pull system that will contain the tumbled parts supermarket, and will also eliminate the monthly schedule. The tumble parts supermarket will contain only .33 days worth of tumbled parts inventory.
Month 7, will contain the last of the changes to the tumbling loop and see the start of the changes to the coiling/stress relieving/grinder loop. The changeover time for the tumbling loop will be reduced to 300 seconds, and the uptime of the tumbler will be increased to 100%. Also, a continuous flow will be developed from coiling to stress relieving to grinder. The new cell will contain only one operator, and no works in progress between the machines.

The overall changeover time for the coiling/stress relieving/grinder loop will be reduced to 7200 seconds during month 8. While in month 9, the uptime of the coiling/stress relieving/grinder cell will be increased to 100%, and the team will develop a pull system using a grinded parts supermarket and eliminating the monthly schedule. The grinded parts supermarket will contain only .33 days worth of grinded parts inventory.

The last change to the system will be implemented in month 10, and will occur in the supplier loop. A pull system will be developed, eliminating the monthly schedule and containing the coil supermarket, which will contain only .73 days worth of coil.

People Issues

Moving from current state to future state, one of the most important factors is managing the people involved with the changes – the operators. We need to make sure certain changes are documented and implemented as standard work. Without the standardization of steps for the operators, any benefits that should come from structural or procedural changes will not be fully realized. People also need to be coached on how to accept any added or different responsibilities. For example, we are consolidating the coiling, stress-relieving, and grinding duties into one work cell. This will require one of the operators to learn how to operate all three pieces of equipment. Sadly, this will require the other operator to be reassigned to another job around the plant. This reassignment issue will have to be handled face-to-face and it will need to be put in the proper context. They will want to know why they are being reassigned and they will think that someone may be OUT to get them. The management responsible for implementing this consolidation effort will need to make sure the displaced operators know why changes are being made. We are also consolidating the inspection and pack-and-ship steps. The same considerations as the coiling/stress-relieving/grinding apply as far as operators are concerned. Changes that are not "standard work" need to be discussed with the operators that are affected, such as how material and information flows to their area. This seems like a necessary step in order for them to accept and actually implement the changes suggested by management (i.e. point kaizen). This is relevant for the successful changeover from a push system to a pull system regulated by "kanban".

Implementation Schedule Remarks

We should be able to completely overhaul the system in around twelve months. We are assuming that certain changes like push-to-pull steps only take one or two months. We are also assuming that we can achieve the aforementioned change-over time reductions (see attached yearly implementation schedule). Inventory reduction to zero WIP could take longer than we have initially estimated. This is because we may have underestimated the time required to properly determine material flows to the processes that are going to zero WIP.