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Dynamic LEAN Shop Floor SMT Material Control Starting ONLY What You Can Finish

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Abstract

In high mix (250+ Assemblies) environments, ensuring small batches are delivered in a timely yet flexible manner without large levels of safety stock and WIP requires the very best of LEAN Manufacturing practices. Dynamic Process Control's (DPC) Material Reservation Manager (MRM) has been designed to provide the tools for major reductions in floor stock and the ability to manage production schedules to maximise utilisation and productivity in this highly dynamic environment.

In line with the current need to dissect volumes into small (<100 unit) Kanban driven batches, using these tools can minimise losses from unplanned changeovers due to missing or un-locatable material.

Any combination of Kanban and ERP/MRP driven order batches can be dynamically loaded automatically in real time. In this example the operators on each of 5 SMT lines perform 'what if's' on each batch. Tracking material reels, matrix trays and sticks loaded on SMT equipment or stored in line locations outside materials controlled storage, we can then check there is sufficient material available to complete the order. If insufficient material is available on the line but is available in material's storage, it is reserved, picked and transferred to the line in time for the orders scheduled start. Shortages preventing production are flagged and the order rescheduled.

Using these tools can reduce waste and eliminate lost time waiting for parts that have been depleted or changing over due to those parts not being available. Every item of material outside of material stores is tracked as it is being used allowing for the application of material FIFO, the use of part used material before new and the real time enforcement of rules such as 'use by dates' and quarantines.

Introduction

The largest loss of productivity is changeovers. The largest reason for non-scheduled changeovers is due to material shortages. Eliminating these material shortages requires accurate stock levels and accurate knowledge of part locations. This process is further complicated by part attrition which consumes additional material outside that forecasted by MRP/ERP, and is usually compensated for by building in a fixed attrition percentages either globally or in more advanced setups by part number or part type. However if attrition levels are wrong we either end up holding too much safety stock or still creating shortages.

With the largest variable cost in manufacturing being material, by keeping site stock to a minimum we can drastically cut costs by increasing inventory turns and preventing depreciation of material that is not required. In contrast keeping site stock levels low increases the opportunity for stock outs, prompting unscheduled changeovers to other work orders which may also have insufficient stock to complete.

According to a study by the Aberdeen Group (TABLE 1), the average factory sees about five material shortages per line per week, almost 1 per day! After shortages occurring, production is at best delayed until material is located or worse stopped if there is no on site material available. With best in class still only averaging 3 stock outs per week there is a huge opportunity for improvement.

Definition of Maturity Class	Mean Class of Performance
Best in Class: (top 20% of aggregate performance scorers)	▪ On-time delivery at 96% with a 14% improvement year-over-year. ▪ Throughput at 93% with an 8% improvement year-over-year ▪ Stock outs at 3 averaged per line per week with a 37% improvement year-over-year ▪ Direct material usage variance at 2.9% with a 50% improvement year-over-year. ▪ OEE at 60% with a 9% improvement year-over-year.
Industry Average: (middle 50% of aggregate performance scorers)	▪ On-time delivery at 93% with a 9% improvement year-over-year. ▪ Throughput at 89% with an 2% improvement year-over-year ▪ Stock outs at 5 averaged per line per week with a 29% improvement year-over-year ▪ Direct material usage variance at 4.1% with a 17% improvement year-over-year. ▪ OEE at 65% with a 5% improvement year-over-year.
Laggard: (bottom 30% of aggregate performance scorers)	▪ On-time delivery at 80% with a 5% decrease year-over-year. ▪ Throughput at 84% with an 0% improvement year-over-year ▪ Stock outs at 7 averaged per line per week with a 21% improvement year-over-year ▪ Direct material usage variance at 28.2% with a 47% decrease year-over-year. ▪ OEE at 57% with a 5% improvement year-over-year.
Source: Aberdeen Group	

Table 1. Average Factory Performance Metrics

The main cause of these stock inaccuracies is not 'on hand' material in the tightly controlled confines of the material warehouse but material that has been issued to the production line. Of this material 70-90% is SMT material for placement from reels, sticks or matrix trays, which cannot be issued in quantities other than that it is supplied in, a 20,000 part reel or 64 part tray, and although not impossible it is unusual for this material to be returned to stores in all but the most tightly controlled 'kitting' environments. This results in large quantities of part used reels left as uncontrolled floor stock, either loaded on a placement machine, unloaded feeder or material trolley.

It is becoming increasing popular for companies to outsource parts of the supply chain to external contractors. By doing this material is often free issued on 'consignment' directly into onsite stock locations where it remains the property of the supplier. Receipt and payment for the material only being processed once it is moved from on-hand to floor stock. We need to ensure we are not picking material that is not needed for current work orders if all it will do is lay unused in a floor stock location after it has been paid for.

In an attempt to reduce changeover times where batch sizes are small due to high variety, common setups and preloaded offline setups are becoming increasing popular. The use of such techniques can drastically reduce changeover times from hours to minutes but result in a significant increase in floor stock. In most cases the cost of the additional feeders and equipment required to run with common setups is more than just justified, however the implications of having large amounts of material in floor stock are far more complicated. While a reel is loaded as part of a common setup it cannot be used elsewhere, requiring another full reel to be issued possibly doubling or more the floor stock level and requiring much more material than planning forecasted. Products that are not built frequently may require large amounts of material to remain in floor stock for long periods, preventing this material from being used in current production and resulting in older material lots being used after newer dated material has been consumed elsewhere.

ERP systems also have no concept that a part may be placed from a number of locations from single or multiple pieces of equipment as part of that setup or product optimisation. Nor does it have any concept of the number of parts on a reel of components. For example, the requirement for part A is 4500 but it is used from 2 feeder locations. ERP will ring-fence 4500 parts which for a part supplied on 5000 part reels will be 1 reel. This 1 reel will be picked but when delivered to the line the reel will either need to be split or another reel ordered. Either of these solutions add cost either from delay or additional manpower requirements.

In the past, scheduling of jobs would often group like products together to minimise costly changeovers, while this makes it easy for material scheduling it result in high levels of partial or completed stock (WIP). If order estimates are incorrect or a customer de-commits material is lost to WIP and unable to be used on product with actual demand. Kanbans attempt to minimise the overbuilding of product that has no requirements but introduce short and ever changing planning horizons which require to be reacted to dynamically.

Floor stock usage is also not subject to the other drivers such as using material 'First In First Out' (FIFO) or the using up partial reels which run out quicker than a full reel. So how can we minimise the amount of costly material in the void of floor stock while also minimising costly material shortages?

Methodology

To truly achieve SMT schedule management and shop floor material management all floor stock and line supply warehouse material needs to be managed real time. As attrition (feeder and nozzle errors) contributes to material consumption, we also need also be able to manage this efficiently. Minimising any material losses, or at the very least increasing their visibility allows stock levels to be adjusted more accurately.

Re-order solutions do exist to manage this loss by pulling material based on current floor and placement machine stock levels which compensate for attrition by just ordering more. However if applied in a common loading environment there is no visibility of unused material and re-orders or pulls anything that is low. This just moves the issue up the supply chain, either requiring costly buffer stock or causing stock outs later in the build schedule. Accepting these errors and their consequences also directly effects run rates and quality. Cycle recoveries for errors increase cycle time and the possibility of missing and misplaced parts reduces yield. Monitoring material real time in isolation is not sufficient without addressing attrition. Generally re-order/pull systems have no visibility of schedule and work on a minimal planning horizon. Highly accurate pull systems would need visibility of both the production schedule and common material to prevent over/under ordering. Pull systems also assume an infinite supply of on hand material is available when required, possible only by building in buffer stock to the requirement forecast.

In our customers factory, with a flexible Kanban driven schedule, 5 SMT production lines each averaging 6 changeovers per 8 hour shift, varying levels of common loading setup and the complication of consignment parts, a pull solution is just not a viable option. Ideally operations would load work orders to the line and they would only start jobs they knew they could finish.

To provide this 'What If' functionality the following would need to be known;

1. A snapshot of the current material on machines, off line feeders, floor and on-hand stock with its locations.
2. The current product being built and its current SMT Bill of Material (BOM).
3. The number of units still to be built of the current product.
4. The current SMT BOM and setup required to build the 'What if' product in question.
5. The material requirements of other lines already reserved.

The 'What If' can only be valid at that moment in time as material is constantly being consumed and reserved by other production lines. The forecast can only be valid if there is no material attrition, and material is not taken to satisfy other orders before it can be used or picked. Thus its implementation must be transparent to the scheduling process while integral to operations and equipment management.

However implemented correctly the 'What if' model has a number of advantages;

1. The only real fit for a Kanban driven or small batch environment.
2. Minimal interfacing with ERP/MRP.
3. Automatically takes into account multiple loading of single part numbers.
4. By its very nature it has the fall back option of changing batch requirements to fit the 'What if' rather than building until stock out. This allows dynamic management of batches to suit available material as well as not starting batches that cannot be satisfied.
5. Minimises floor stock by preventing material from being picked unless actually required. This is ideal when consignment stock is involved.
6. Makes it very easy to enforce FIFO and material quarantine.
7. Equally effective for kitting or common setup environments.
8. Applicable to both low and high volume manufacturing by treating high volume as multiple small batches which inherently improves traceability and order control/management.

Pre-implementation State.

The pre-implementation state is as follows. Material arrives on site and is receipted. A unique barcode 'licence plate' label is generated for each reel, tray and stick for later use during setup verification. Stored against this unique label are the part number, quantity, lot and date code. The reels are then 'Binned Away' to one of 3 carousel locations using random binning. Due to the use of random binning, like part numbers may be spread over several locations and could also comprise multiple batch or date codes across these locations. The 'Binned Away' process only records the number or components in each random location and not the number or identity of the reel, tray or stick.

Across 5 production lines there are 40 live feeder trolley locations on 15 machine with over 700 used locations. In addition to this there are more than 60 offline trolleys with over 1200 used locations. This totals almost 2000 loaded reels, trays and sticks of material with many locations having 2 reels due to splices. On average each line performs 6 changeovers per 8 hour shift and an average of 20 reels are replenished or spliced. Average changeover is performed within 5 minutes, where a changeover is classed as the time taken from the last PCB of Product A to the first PCB of Product B. This average includes changes that require trolley changes as well as loaded common material.

Material is replenished with a manual re-order system aided by the line level inventory monitoring of the setup management system. As currently loaded material locations get 'low' a pick request is manually generated, material picked and delivered to the line the request originated from. This material is then spliced to the 'low' reel, pending its depletion. Occasionally emergency picks are required when a location runs out before it is replenished. In this case the line is stopped until the location is reloaded or if no material is available the line run out. The next batch is then chosen based on the state of the Kanban levels in combination with the overall build schedule. It assumes sufficient ERP/MRP has material available based on currently scheduled orders. Consideration will also be given to the common setup currently on the machines and which order batches can be fulfilled without requiring a change of setup where possible. Ideally setup changes will be minimised by batching together orders that use the same setups.

Picking of material from the line feed carousels requires users to interrogate ERP/MRP to find which part is stored in which locations and which date/batches are located in each. They then should pick the reels with the oldest date/batch codes first to apply First in First out (FIFO).

Moisture sensitive material is retained in a humidity chamber whenever it is not being used and is not stored on line even as part of a common setup.

Due to material pull being triggered by a location being 'low', material is often picked and spliced even when there are sufficient parts remaining to complete the order batch currently being built. This part may or may not be used on the next order and it could be possible that the current setup itself is not required for next order, or possibly next 10 orders. This practice significantly increases material that is moved from the safety of 'on-hand' stock in the line feed carousels into the uncontrolled void of 'floor stock'. Review of material flow suggests 25% of this 'floor stock' could have remained 'on hand stock' by employing better triggers to pull material. 5% of this 'floor stock' is also 'consignment' stock which has now been paid for even though it is not required. Additionally where material is part of a common loading setup that is currently not required then inventory turns stagnate and FIFO rules are abandoned.

Part attrition contingency is reviewed regularly and updated within MRP/ERP if required and whilst this ensures safety stock is ordered to contend with the current levels, this process cannot cope with the constantly changing and dynamic target that is reality.

Subsequently the reality of 'floor stock' counts is rarely in agreement with that expected, and stock outs occur at somewhere between 'best in class' and 'industry average'.

Process Improvements.

For the purposes of this paper we will take it as read that we are able to monitor the component counts on each loaded machine location and off line feeders and trolleys using the setup management system already successfully implemented and operational.

We can also take it as read that we are already able to identify problematic feeders and nozzles and perform corrective actions to minimise part attrition using the process control management system already successfully implemented and operational.

Focussing then on the order selection and build, ideally in any scenario we want to prevent an order from being started if there is insufficient material available to complete the order. Depending on the implementation 'available' being just on line locations, on line and line feed locations or all on site locations. In this scenario we can to look at all locations in a logically structured order of; On Current Line, Off Line (Line Feed) and All Lines. We also need to review orders from a short list dictated by the status of Kanban levels, providing us with both what and how much to build. In reality it may not always be possible to complete any order and a fall-back position of 'how many can we build' is required.

To provide the required solution the system was initially configured as follows, the design is user configurable both in process steps and connectivity to external systems such as ERP/MRP systems. This ensures the ability of the system to grow with the user as they require and future proof changes within operations, business models and external connectivity.

1. Based on current Kanban levels jobs are passed to work order management.
2. Operators can then at any time 'Prepare a Work Order' by selecting one of the jobs loaded in work order management.
3. If that job can be built using the current loaded setup it is checked for sufficient material to complete the current job if there is already a job being built and then sufficient to complete the next job. If the job requires a setup that is currently of line, this off line setup is checked for sufficient material to complete the next job only.
4. Checks for sufficient material are performed feeder location by feeder location ensuring that where multiple loadings of a single part number are used, sufficient reels (or trays and sticks) are available not just sufficient parts.
5. If sufficient material is available the operator is informed and the job flagged as prepared.
6. If sufficient material is unavailable the operator will be warned how many units can be completed and a report highlighting the shortages generated. The operator then is offered the option to;
    a. modify the order to build the units that can be completed or
    b. return to select an alternate job.
    c. check off line (On-Hand) material storage for sufficient material.
7. If the operator chooses to check 'off line' all carousel locations are checked. All locations are then checked for the required material, and where available its unique licence plate reserved based on FIFO according to the materials batch or date code. Once reserved this material is removed from the material pool preventing it from being picked for another job on another line. Reserved material only returning to the pool should the job preparation be cancelled.
8. Reserved material is added to a pick list for that line. As required an operator or dedicated material picker is directed in turn to each location where the reserved material is located using the same hand held scanner used for machine replenishment. Where multiple licence plates exist at a location for parts with identical attributes the user can pick any licence plate as long as it is not reserved for another job or quarantined.
9. If sufficient material is available the operator is informed and the job flagged as 'picking' until all material is picked and delivered to the line when its status is changed to 'prepared'. Although any job can be selected at changeover the prepared job is initially offered.
10. If sufficient material is still unavailable the operator will be warned how many units can be completed and a report highlighting the shortages generated. The operator then is offered the option to;
    a. modify the order to build the units that can be completed or
    b. return to select an alternate job
    c. check other lines (floor stock) material storage for sufficient material.
11. If the operator chooses to check 'other lines' then ALL other line machine and trolley locations are checked for sufficient additional material. If additional material is available on other lines the operator is informed and a report generated but no material is reserved above that already located. Should the operator want to use material from other lines it needs to be unloaded and either moved to the required lines floor stock or retuned to the 'On-Hand' material pool and process run again.

Due to its dynamic nature the 'What If' can be ran at any time right up to selecting change over, allowing the operator to check or change the next job reservation. This not only ensures that should the next job requirement change this can be easily actioned but also provides a catch if material has been consumed that had not previously been accounted for.

In operation most 'what if's' require at least 1 reel of material to be picked from On-Hand stock. This would often be components supplied in small reel quantities or matrix tray parts that had been returned to the bake ovens after use on a previous job. Due to the common setups and preloaded trollies being available and included in the 'what if', Kanban orders can be almost 100% adhered to with minimum impact to line efficiency compared to time previously lost due to material shortage issues.

Picked material is delivered to one of 2 material loading trollies (one for each side of the line) ensuring all material is readily available to the operator as it is flagged low by the setup management system.

When prototype or new products are added to the schedule 'what if's' can either use a current setup, picking only the additional material required or effectively kit the job by picking all the material. In either case setup management driving the addition and removal of material as required.

With real time process control ensuring feeder and nozzle errors are kept at the minimum possible and the need to usually pick slightly more material than required due to reel sizes, the 'what if' estimates reflect reality in most cases. Only catastrophic feeder or nozzle failures on 1 off usage parts or product damage preventing previously committed batches being completed.

Conclusion

Using a 'what if' approach allows for a LEAN shop floor in what appears to be an almost impossible environment, while not only reducing the occurrence of stock outs to a new 'best in class' level, it directly improves both material and production metrics. On time delivery, throughput, direct material usage variance and OEE have all shown improvement and is expected to continue. Ensuring material can be monitored and transacted real time is no small task, material has to be uniquely identified from its birth at goods received until the reel, tray or stick is depleted. Material attrition must be managed not just measured. But where done correctly the results more than justify the journey required to get there.

By knowing a job cannot be completed or fulfilled before attempting to build, not only can the local losses of changeover and resource be eliminated but identification allows for advance reaction in both upstream and downstream segments of the supply chain.

Total 'Floor Stock' has initially been reduced by 20% with zero impact to the value stream. Ideally we would hope for further reductions as lower demand products are scheduled allowing infrequently used materials floor stock to be minimised. Stock remaining 'on hand' as long as possible improves visibility to MRP/ERP providing a true picture of actual demand and delays consignment material release until it is actually required. This visibly provides the opportunity for reductions in safety stock levels through better understanding of requirements and actual attrition levels. In combination these improvements ensure maximised stock turns and minimal depreciation of floor stock material.

Although shown here in a small volume, high mix environment, 'what if' is equally applicable in high volume, low mix by simply subdividing batches into smaller and easier to manage sizes. More importantly 'what if' removes most of the negatives of using common and pre-loaded setups allowing for more efficient utilisation of capital equipment while also managing inventory turns and minimising depreciation of material.

Summary

Dynamic Kanban driven SMT production can only be efficient if tools to manage a constantly changing planning horizon can be employed. Use of 'What if' enables this in the most practical, efficient and truly dynamic way. By allowing SMT production to operate in as close to 'build to order/Kanban' as is possible, without the need for costly high levels of safety stock and WIP, it provides the best solution to LEAN manufacturing practices with the minimal of effort.