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A Review On Lean Manufacturing to Aerospace Industry

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ABSTRACT : Lean manufacturing provides a new management approach for many small and medium size manufactures. Improvement results can be dramatic in terms of quality, cycle times, and customer responsiveness. It is more than a set of tools and techniques and has been widely adopted by many production companies. It is a culture in which all employees continuously look for ways to improve processes. Simply lean, is a systematic method for the elimination of waste within a manufacturing process. Lean also takes into account waste created through overburden and unevenness in workloads. The core idea is to maximize customer value while minimizing waste. Simply, lean means creating more value for customers with fewer resources. The advantage of this concept is, it strives to eliminate non-value-added or wasteful resources, including material, space, tooling, and labour. It applies such principles as waste minimization, flexibility, and responsiveness to change; these are supported by efforts to optimize the flow of material and information and to achieve superior quality in order to eliminate scrap and rework. Though lean manufacturing was originally developed for the automotive industry, aerospace manufacturing companies have found that these principles can also be applied in this high-precision industry to create dramatic improvements in the efficiency of production.Our aim is to identify the bottlenecks in the production line of a reputed manufacturing industry. The main objective is to provide a background on lean manufacturing, present on overview of manufacturing wastes and introduce the tools and techniques that are used to transform a company into a high performing lean enterprise.

Keywords : Lean manufacturing, Aerospace Industry, Lean Production Cycle, Lean leadership, Quality maintainence, Kaizen, Implementation model etc.

I. INTRODUCTION :

In times of decreasing orders, increasing overhead costs and fewer customers, lean manufacturing techniques may allow the aerospace defense industry to remain healthy and profitable while offering the United States an avenue to maintain a more viable national industrial base. In the first section of this paper I will present and contrast the principles of mass production, originated and employed extensively in the United States during this century, and the principles of lean manufacturing developed and implemented in the Japanese automotive industry after World War Two.' Mass production principles were initially used to produce automobiles, although ultimately the methods extended the world over, and affected the processes used to manufacture millions of different items. The methodology of lean manufacturing differs significantly from that of mass production, and in the closing decades of the twentieth century lean manufacturing has produced dramatic successes in terms of volume, quality and customer satisfaction. The lessons of the automobile industry have not been lost on aerospace defense companies that, because of massive cuts in the United States defense budget, arc struggling in an intensely competitive market. The automobile industry has shown lean manufacturing techniques can substancially reduce costs, cut development time, and produce a better product that more precisely mects customer needs. Those companies that have successfully implemented lean production, primarily owned or managed by the Japanese, have done well in a very competitive market, while those that have retained traditional mass production methods have had a difficult time competing. Increased quality, flexibility, and affordability arc potential benefits of lean manufacturing techniques that could have a vital impact on the aerospace defense industry. Yet, the aerospace defense industry is only now beginning to fully implement these new techniques. In the second section of this paper I will compare the automotive and aerospace defence industries, and analyze the app!icability of lean manufacturing to aircraft production. The benefits of Iean manufacturing were first quantified in a study accomplished under the auspices of the International Motor Vehicle Program (IMVP),2 as described in The Machine that Changed the World.' In an effort to use those lessons. the Aeronautical Systems Center (ASC) in Air Force Material Command is exploring ways to implement lean manufacturing in the aerospace defense industry as a way to obtain better weapon systems at lower costs. The first step is a study similar to IMVP called the Lean Aircraft Initiative (LAI). I will briefly describe the LAI, which will serve as an introduction to a leading-edge example of lean manufacturing in the aerospace defense industry today. The F-22 Engineering and Manufacturing Development (EMD) Program will probably be the largest and most costly aircraft acquisition program of the decade.

As a way to hold down program costs, government and contractor managers have structured the entire program around lean manufacturing principles. I will describe the F-22 lean manufacturing plan, explain how program managers will measure progress toward achieving true lean manufacturing, describe the success already achieved early in EMD and sonic of the problems encountered, and finally I will project some of the difficulties the F-22 program may encounter in coming years. The potential benefits of lean manufacturing have also been recognized by European defense companies who .i.. now wrestling with many of the same problems, often to a much greater degree, faced by their American counterparts. In the final section of this paper I will describe European efforts to implement lean manufacturing.

II. LEAN CONCEPT

Lean principles are the mechanism for process improvement developed by Womack and Jones based on the original work done by Ohno of the Toyota Motor Corporation to optimize production by eliminating waste. Toyota settled on an effective strategy based on: Kanban-based pull production, eliminate waste, faith in the value and importance of quality, continuous improvement, belief in the value and utilization of human resources, reducing setup time for machines, integration of suppliers and material acquisition and efficient, cellular layouts with balanced material flow. It has four defining characteristics: waste awareness, continuous quality assurance, just in time and level production. During the 1980s, the Institute of the Automobile at MIT did a comprehensive study of manufacturing processes in the automobile industry. This project and the concepts developed within the context of this initiative were documented in the book "The Machine that Changed the World. One of the major ideas was developed as part of this work was called Lean Production. Koskela discussed the concepts of Lean Production in a report generated at Stanford University in which he coined the term "Lean Construction." In the early 1990s, the aerospace company which is the focus of this study initiated a lean approach to production using Kawasaki Production System. Boeing introduced Lean Manufacturing in 1997. It succeeded to construct moving assembly line in 1999 at Long Beach Plant by building 100-seat 717 aircraft. Boeing 747 final assembly line introduced moving line technology in 2001. The results presented highly optimized production flows and processes, reducing cost and flow time from the traditionally 24 days to the targeted possible 18 days [8]. Lockheed Martin applied lean techniques to the F-16, F-22 and C-130J in 1999. Lean implementation is therefore focused on getting the right things to the right place at the right time in the right quantity to achieve perfect work flow, while minimizing waste and being flexible and able to change. Apply the Lean Production can eliminate the waste of production operations and business processes. Remove the redundant operations and processes to reduce the cost and increase profit . The lean concept not only can apply in the production process of aerospace industry, but also in the business process. Especially for aerospace manufacturing suppliers, they have to reduce their cost to increase their competitiveness.

III. LEAN CYCLE

The concept of lean production is continuous improvement. It is a long-tern journey and efforts. The lean cycle combine and link the Plan-Do-Check-Action (PDCA) cycle, show as Fig. 1.

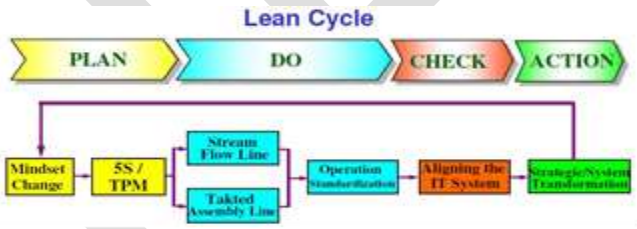

Fig. 1. Lean production cycle.

A. Plan Aspect

1) Mindset change

The company awareness and mindset change are the most important for the lean implement. There are many different functional groups in aerospace manufacturing suppliers, including design engineering, production engineering, production control, parts fabrication and component assembly…etc. Those functional groups should change their mindset and stereotype to remove interface barrier within the organization. All departments align the same goal and target to achieve the overall benefit of enterprise.

The key issues of mindset change describe as follow:

- Top management commitment is the key successful factor for improvement activities. All improvement ideas need the support from management to become activities and obtain benefits.
- Leader Lead Lean (3L) is the current concept for lean improvement. Due to the management level has more resources, authorization, information, and judgment ability, the management level lead the lean improve can get quick and more results.
- 7 wastes include defects, overproduction, transportation, waiting, inventory, motion, and processing.
- 7 ways are the methodologies to inspire and encourage creativity to generate multiple solutions to meet a customer needs.

2) 5S/TPM

Manpower and machine/facility are the key elements for the shop floor of aerospace manufacturing suppliers. The 5S can ensure the employee disciplines and accountability. The TPM can secure the machine availability and utility. Those two factors can support the steady and smooth production in the shop floor.

The key issues of 5S/TPM describe as follow:

- Visual management: include supermarket, Kanban system, and color code control. These tools help the first line supervisor and manager to find the bottleneck and critical area for improvement.
- Machine availability and utility/Overall equipment efficient (OEE).
- Tracking and evaluation mechanism
- Autonomous Maintenance
- Focused Improvement
- Education and Training
- Planned Maintenance
- Quality Maintenance
- Early Management and Initial Flow Control
- Safety and Pollution Control
- Administrative and Office TPM

The example of TPM for machine maintenance concept shows in Fig. 2. The original concept was starting repair after machine breakdown. The current concept is operators do the fundamental maintenance of their own machines; observe the vibration and the noise of the spindle in daily operation. Also measure the dimension/key characteristics from the production parts. Once they found any error or abnormal message, then response to maintenance department for repairing. Also the maintenance engineer monitors the spindle life, machine accuracy. And prepare the key spare parts of machines. Thus, it help to reduce the machine down time, and increase the machine availability and utility.

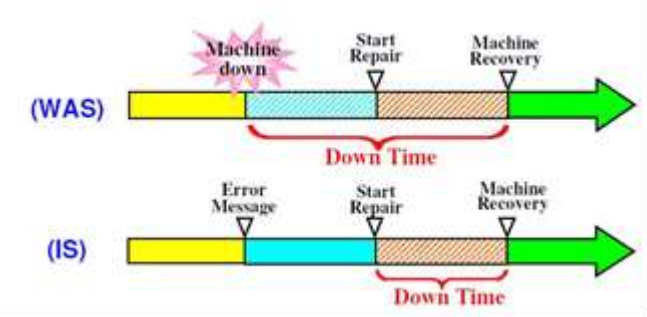

Fig. 2. The TPM for machine maintenance concept.

B. Do aspect

1) Stream flow line/ takted assembly line

The main products of aerospace manufacturing suppliers are detail parts and component assembly. The machine/facility of parts fabrication line should follow the process sequence to construct the stream flow line. The rhythm and assembly progress should base on the requirement of production rate and takt time to arrange the number of manpower and assembly jig.The concept of paced production line shows as Figure 3. The warehouse setup the supermarket to release the raw material (plate, metal sheet, tube and composites preprag) to part fabrication, include machine, sheet metal, tubing and composite shop uniformly and sequentially. These flow line of parts fabrication shop pull and produce the raw material into required dimension, contour and function, and then flow to surface treatment for coating and painting. These parts go to kitting center and ready to supply the kitting board to assembly line follow the production rate and takt time. The assembly activities include drill, rivet, and seal. Design a moving line to combine and link those operations together.

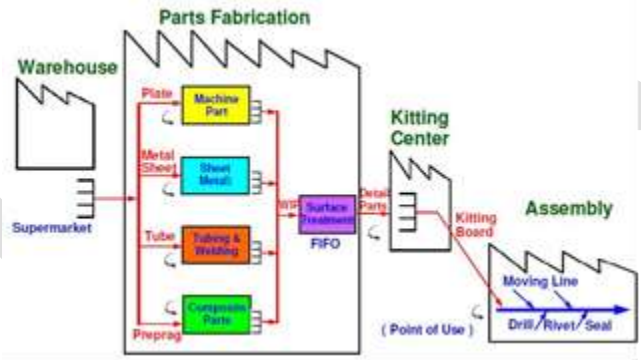

Fig. 3. The concept of paced production line.

- The key issues of stream flow line/ takted assembly line describe as follow:
- Work load leveling helps to construct a steady and stable production line.
- One piece flow in part fabrication line.
- One kit flow in assembly line.
- Facility/equipment layout should follow the work and process sequence.
- Synchronize production flow
- The multi-skill employee keeps the flow line flexible to overcome production fluctuation.
- Abnormal warning: Utilize the equipment, such as Andon, to warn the abnormal or line stop issues. Quick identify and fix the trouble of production.
- Automation
- Error detection and proofing

2) Operation standardization

It is important to standardize the process/operation after improvement/lean activities. Thus, the improve result can be kept and embedded into the system. The aerospace manufacturing suppliers have to consider those improvement ideas how to apply to another/wider fields to enlarge the improve benefit.

The key issues of operation standardization describe as follow:

- 4M (man, machine, material, and method) determine the quality of processes and products. If we can find the better/right process or production parameters of 4M and firm fix those combinations, then we can obtain the reliable products.
- Process capacity
- Standard work combination table
- Visual aid and work instruction can help the operator manufacturing complicated parts in an efficient way.

C. Check Aspect

1) Aligning the IT system

The production cost control is critical to evaluation the gain or loose of different program. The working-hour collection of each ship-set aircraft number will be monitored and compared with the value come from learning curve.Once the working-hour of process or machine was improved by lean activities, the improve results (standard working-hour, lead time, transportation, space, downtime…etc.) should revise in IT system.Also the lean implement office will monitor the long-tern implement trends to ensure the lean activities have been follow-up and flow down.

The key issues of Aligning the IT System describe as follow:

- Production control information system
- Key performance indicators (KPIs)
- Update the schedule parameters: include lead time, working hour.
- Shop floor control information
- Visibility

The concept of production scheduling system shows as Fig. 4. The system will compare the demand and supply and come out the feasible detail schedule of each detail parts and end item. schedule parameters (include lead time, working hour…etc.) will input into the production scheduling system after verification. So the IT system can reflect and keep the current and latest competence.

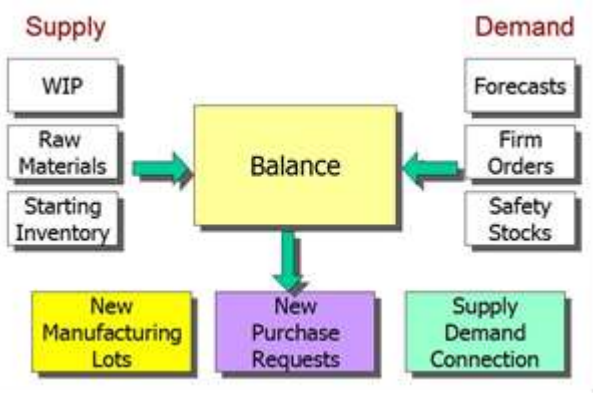

Fig. 4. The Concept of Production Scheduling System.

D. Action Aspect

1) Strategic / system transformation

After the team work of lean activities, the work definition, process, interface of each functional group will be changed. The process flow/layout may change after value stream mapping and shop floor simulation. The management philosophy may change after the

team brain storming and several times simulation. So after the lean cycle, management should consider the Strategic / System Transformation:

The key issues of Strategic / System Transformation describe as follow:

- Organization and functional group integration to reduce the interface and barrier.
- Personnel training: include on-job-training and multiple skill training.

The example of lean improvement for machined part assembly shows in Fig. 5. The production control prepares the work-in-process in the kitting cart base on the demand of next process/customer. The multiple-skill operator picks the part up, seal, press, and put into the oven for curing through 7 ways analysis and simulation. The transportation distance, working space, manpower and the production lead time can be reduced.

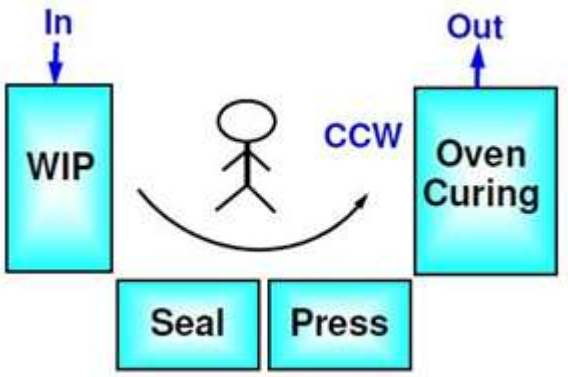

Fig. 5. The Improve of machined part assembly.

IV. IMPLEMENTATION MODEL

The Lean Implement Model includes four categories (human resources, machine, method, and process). Through the continuous lean cycle, the scope/level of lean topics and environment will become wider/higher than before. The Lean Implement Model shows as Fig. 6.

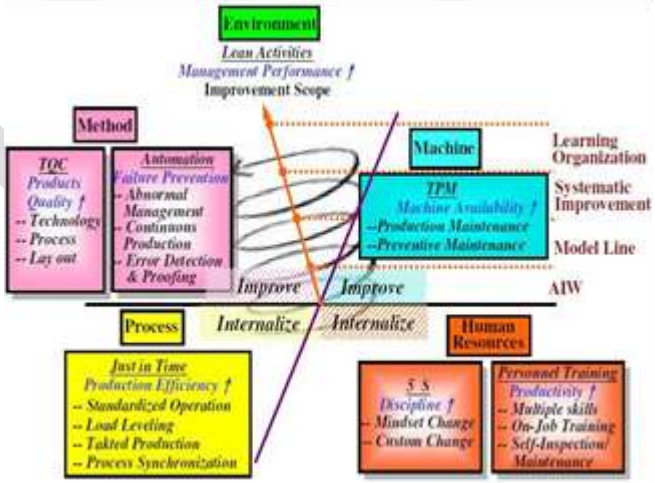

Fig. 6. The Lean implement model.

A. Human Resources

The domain of human resource is the fundamental and initial for lean concept implement. The 5S and personnel training are two major factors.

1) 5S

5S is an internalize process during Lean Production implement. The goal of 5S implement is to strength the employee discipline and enterprise culture through organizational awareness and involvement.

The detail items include:

- Mindset change
- Habitual behavior change.

2) Personnel training

Personnel training is an internalize process during Lean Production implement. The goal of Personnel training is to strength the employee productivity and accountability through training.

The detail items include:

- Multiple skills
- On-Job Training
- Self-Inspection/ Self-Maintenance

B. Machine

The domain of machine plays the main role of production shop floor. The TPM is the major responsibility for the daily operation of machine operator and first line supervisor.

1) TPM

TPM is an improvement process during Lean Production implement. The goal of TPM implement is to strength the machine utility and availability.

The detail items include:

- Production Maintenance
- Preventive Maintenance

C. Method

The domain of method is critical for the quality and cost for the end product. The TQC and automation are two major approaches.

1) TQC

TQC is an improvement process during Lean Production implement. The goal of TQC implement is to strength the products quality and reliability.

The detail items include:

- Technology innovation.
- Process planning.
- Lay out planning.

If the concept of ”Design for Manufacturing” was apply in design and planning stage, it will get more benefit from downstream improvement.

2) Automation

Automation is an improvement process during Lean Production implement. The goal of Automation is to strength the failure prevention.

The detail items include:

- Abnormal Management
- Continuous Production
- Error Detection and Proofing

D. Process

The domain of process influences the results and performance of management. The Just-in-time concept should apply in production line.

1) JIT

JIT is an internalize process during Lean Production implement. The goal of JIT implement is to strength the production efficiency and performance.

The detail items include:

Standardized Operation

- Load Leveling
- Takted Production
- Process Synchronization

E. Environment

The development of lean implement will request by prime aircraft manufacturing company. They will coach and evaluate the lean implement about their component and want to reduce the purchase price after cost down.

1) Lean activities

The Lean activity is a step-by-step and spiral upgrade process during Lean Production implement. The goal of Lean activity implement is to strength the management performance of enterprise.

- The detail improvement scopes include:
- AIW (Accelerate Improvement Workshop)
- Model line
- Systematic improvement
- Learning organization

The lean production implement is a long-tern journey and efforts. Through the top management commitment and companywide involvement, the resources can be aligned and focused. The ultimate goal of Lean Production Implement is try to construct the learning organization and achieve the continuous improvement. Thus, the aerospace manufacturing suppliers can increase their competence in the competitive market.

V. LEAN LEADERSHIP

The role of the leaders within the organization is the fundamental element of sustaining the progress of lean thinking. Experienced kaizen members at Toyota, for example, often bring up the concepts of Senpai, Kohai, and Sensei, because they strongly feel that transferring of Toyota culture down and across Toyota can only happen when more experienced Toyota Sensei continuously coach and guide the less experienced lean champions.One of the dislocative effects of lean is in the area of key performance indicators (KPI). The KPIs by which a plant/facility are judged will often be driving behaviour, because the KPIs themselves assume a particular approach to the work being done. This can be an issue where, for example a truly lean, Fixed Repeating Schedule (FRS) and JIT approach is adopted, because these KPIs will no longer reflect performance, as the assumptions on which they are based become invalid. It is a key leadership challenge to manage the impact of this KPI chaos within the organization.Similarly, commonly used accounting systems developed to support mass production are no longer appropriate for companies pursuing lean. Lean accounting provides truly lean approaches to business management and financial reporting.After formulating the guiding principles of its lean manufacturing approach in the Toyota Production System (TPS), Toyota formalized in 2001 the basis of its lean management: the key managerial values and attitudes needed to sustain continuous improvement in the long run. These core management principles are articulated around the twin pillars of Continuous Improvement (relentless elimination of waste) and Respect for People (engagement in long term relationships based on continuous improvement and mutual trust).This formalization stems from problem solving. As Toyota expanded beyond its home base for the past 20 years, it hit the same problems in getting TPS properly applied that other western companies have had in copying TPS. Like any other problem, it has been working on trying a series of countermeasures to solve this particular concern. These countermeasures have focused on culture: how people behave, which is the most difficult challenge of all. Without the proper behavioral principles and values, TPS can be totally misapplied and fail to deliver results. As with TPS, the values had originally been passed down in a master-disciple manner, from boss to subordinate, without any written statement on the way. Just as with TPS, it was internally argued that formalizing the values would stifle them and lead to further misunderstanding. However, as Toyota veterans eventually wrote down the basic principles of TPS, Toyota set to put the Toyota Way into writing to educate new joiners.

Continuous Improvement breaks down into three basic principles:

- **Challenge** : Having a long term vision of the challenges one needs to face to realize one's ambition (what we need to learn rather than what we want to do and then having the spirit to face that challenge). To do so, we have to challenge ourselves every day to see if we are achieving our goals.
- **Kaizen**: Good enough never is, no process can ever be thought perfect, so operations must be improved continuously, striving for innovation and evolution.
- **Genchi Genbutsu**: Going to the source to see the facts for oneself and make the right decisions, create consensus, and make sure goals are attained at the best possible speed.

Respect For People is less known outside of Toyota, and essentially involves two defining principles:

- **Respect**: Taking every stakeholders' problems seriously, and making every effort to build mutual trust. Taking responsibility for other people reaching their objectives.
- **Teamwork**: This is about developing individuals through team problem-solving. The idea is to develop and engage people through their contribution to team performance. Shop floor teams, the whole site as team, and team Toyota at the outset.

VI. LEAN GOALS AND STRATEGY

The espoused goals of lean manufacturing systems differ between various authors. While some maintain an internal focus, e.g. to increase profit for the organization, others claim that improvements should be done for the sake of the customer.

Some commonly mentioned goals are:

- **Improve quality**: To stay competitive in today's marketplace, a company must understand its customers' wants and needs and design processes to meet their expectations and requirements.
- **Eliminate waste**: Waste is any activity that consumes time, resources, or space but does not add any value to the product or service. See Types of waste, above.
- **Reduce time**: Reducing the time it takes to finish an activity from start to finish is one of the most effective ways to eliminate waste and lower costs.
- **Reduce total costs**: To minimize cost, a company must produce only to customer demand. Overproduction increases a company's inventory costs because of storage needs.

The strategic elements of lean can be quite complex, and comprise multiple elements. Four different notions of lean have been identified:

1. Lean as a fixed state or goal (being lean)
2. Lean as a continuous change process (becoming lean)
3. Lean as a set of tools or methods (doing lean/toolbox lean)
4. Lean as a philosophy (lean thinking)

VII. CONCLUSION

This study integrates the lean concepts and summaries the Lean Cycle for lean implement and practice, and also develops the Lean Production Implement Model to strengthen the competitiveness of the manufacturing suppliers in the aerospace market. The conclusion describe as follows:

The lean concept not only can apply in the production process of aerospace industry, but also in the business process. Especially for aerospace manufacturing suppliers, they have to reduce their cost to increase their competitiveness.

The concept of lean production is continuous improvement. It is a long-tern journey and efforts. The lean cycle combine and link the Plan-Do-Check-Action cycle.

The Lean Implement Model includes four categories (human resources, machine, method, and process). Through the continuous lean cycle, the scope/level of lean topics and environment will become wider/higher than before.

The Lean activity is a step-by-step and spiral upgrade process. The goal of Lean activity implement is to strength the management performance of enterprise.

Through the top management commitment and companywide involvement, the resources can be aligned and focused. The ultimate goal of lean production implement is construct the learning organization and achieve the continuous improvement. Thus, the aerospace manufacturing suppliers can increase their competence in the competitive market.

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