LEAN MANUFACTURING AS A PREREQUISITE FOR MASS CUSTOMIZATION

Centre for Advanced Manufacturing Technologies, Wroclaw University of Technology,
Wybrzeże Wyspiańskiego 27
lucjan.kornicki@pwr.wroc.pl

Tomasz Koch,
Centre for Advanced Manufacturing Technologies, Wroclaw University of Technology,
Wybrzeże Wyspiańskiego 27
tomasz.koch@pwr.wroc.pl

ABSTRACT

Mass Customization (MC) is a concept of providing customers with goods which best suits their unique requirements and doing this with the high, close to mass production efficiency. This goal can be achieved only with most flexible production system which can quickly adapt to the changing market conditions. One of the solutions is to design Flexible Manufacturing Systems (FMS) which are of big interest within academic and industry worlds. FMS is highly automated and robotized production system which can produce different products with quick changeovers. But "different products" here means products within particular "range". Nowadays when products lifecycles are extremely short, we cannot rely only on machines, because they are quite inflexible. Most flexible production resources are people. They can adapt rapidly to changes in demand, changes in production patterns, changes in product being produced. Toyota understood this over 50 years ago and developed Toyota Production System (TPS), archetype of lean manufacturing, which rely on simple automation and multiskilled people to produce many different products in small batches and with high efficiency. TPS or lean came into being in repetitive production and prove its effectiveness. This paper aims at analyzing its usefulness in make to order/mass customization environment and providing guidelines for mass customization production system design.

KEYWORDS

Make to order production, lean manufacturing, production system design

1. INTRODUCTION

Manufacturing systems evolved along with technology development, changing market conditions and customer requirements. After WWII this evolution was different in US and Japan (Fig.1).

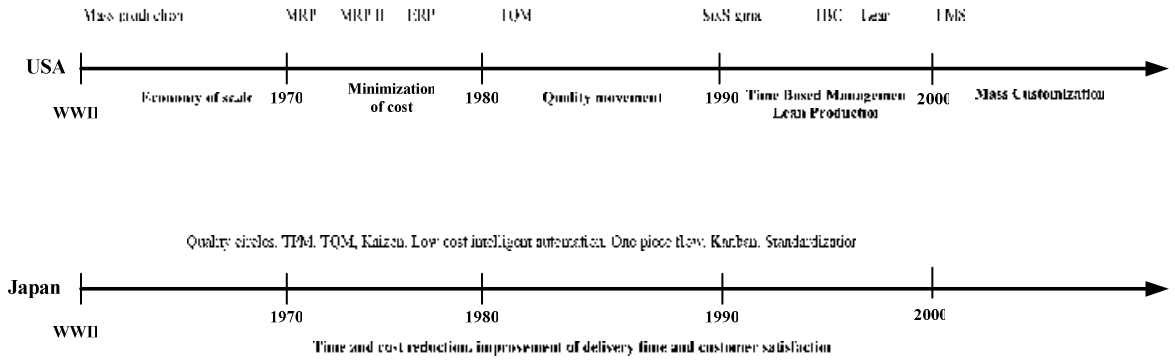

Figure 1. Evolution of production management concepts

US manufacturing initiated lots of new concept (e.g. MRP, SixSigma) to adapt to changing market conditions, while Japanese companies were faithful to one ultimate goal – provide customer with a

product of highest quality, with lowest cost and shortest delivery time. They of course use different tools and new technologies but never try to choose between quality (Q), cost (C) and delivery (D). These factors are always treated as unity (QCD). Market success of companies like Honda, Nissan or most referred Toyota prove legitimacy of such manufacturing strategy. Japanese manufacturing techniques are already known as lean manufacturing (LM) because, this system "*uses less of everything compared with mass production – half the human effort in the factory, half the manufacturing space, half the investment in tools, half the engineering hours, to develop a new product in half the time. Also it requires keeping far less than half the needed inventory on site [and] results in ... fewer defects...*" (Womack et al., 1991).
But opponents of LM point at some of its characteristic, which for them are weaknesses (Suri, 1998):

- LM was born in highly repetitive, high volume environment (automotive),
- Requires stable demand,
- Easiest to implement in high-volume, low-mix environments.

For adversaries of LM above features disqualify it as production management concept for the future because a pressure on producers to manufacture high mix of products with low volumes increases and demand is highly unstable. Lean is often mistakenly considered as not suitable for high-mix, low-volume manufacturing therefore mass customization is indicated as a panacea for ensuring choice to customers. However the most frequent cited author of papers on mass customization, B. Joseph Pine II stated *"customers […] do not want more choice. They want exactly what they want – when, where, and how they want it…"* (Pine II et al., 1995). This statement is exactly in line with lean approaches ultimate goal of producing the required items, at the required quality and in the required quantities, at the precise time they are required (Brown et. al., 1988). This paper will present lean manufacturing philosophy in the context of supporting market changes towards mass customization.

2. LEAN MANUFACTURING – CONCEPT, PRINCIPLES, IMPLEMENTATION METHODOLOGY

Lean Manufacturing is philosophy or approach rather than method. It uses many techniques and methods in order to achieve its imperative goal, which is elimination of all waste. The father of the Toyota Production System, Taichi Ohno distinguished seven main types of waste in manufacturing systems: overproduction, excess inventory, correcting defects or errors, unnecessary processing, unnecessary movement of material, excess motion and waiting. This list should be completed with the most dangerous waste: lost of creativity.

2.1 Five principles of Lean Manufacturing

In the book by Womack and Jones *Lean Thinking*, first launched in 1996, authors describe in detail principles of Lean Manufacturing. Womack and Jones summarise LM as five main principles (Womack, et all, 2001):

1. precisely specify **value** of specific product,
2. identify the **value stream** for each product,
3. make value **flow** without interruptions,
4. let the customer **pull** value from the producer, and
5. pursue **perfection**.

.

The value is starting point for Lean thinking. It can be defined only by customer, which can be both internal and external (final customer, next process or next firm in supply chain). Value must be specified for particular product (good, service or both at the same time), which satisfy the needs of particular customer, at the acceptable price in specific place and given time. It's necessary to correctly identify value stream (all the activities necessary to make a product, both value added and non-value added, along value stream from raw material to finished good) and create continuous flow of product, which is stimulated by customer who pulls goods from manufacturer. Enterprises should continuously strive for perfection. Continuous changes and process improvements are inherent part of Lean philosophy.

2.2 Implementation methodology

Implementation of Lean Manufacturing always begins with analysis of current situation and focusing on one product family, which is defined as "group of products which goes through the same process sequence performed by the same equipment"(Rother&Shook, 1999). Identifying product families is not always easy, especially when company product portfolio includes many types of goods (see point 2.1.1.).

2.2.1 What customers really want - X Company example of product grouping

Company X is a producer of brakes and ABS system elements. It manufactures wide range of product. Main processes are machining, painting and assembly. One of the assembly lines is dedicated to produce pneumatic actuators. A project was funded to optimize this line in respect of number of operators, lead time and production volume. A Pareto analysis was performed and result is shown on Fig.2.
There are 296 different types of products manufactured on the line. Less than 17% of all assemblies (50 types) make up over 80% of total volume. On the other side, 119 different types of products (40% of total variety) make up only 1% of total production volume. It is typical low-volume, high-mix production environment. In this situation the most important thing is proper scheduling and sequencing of production.

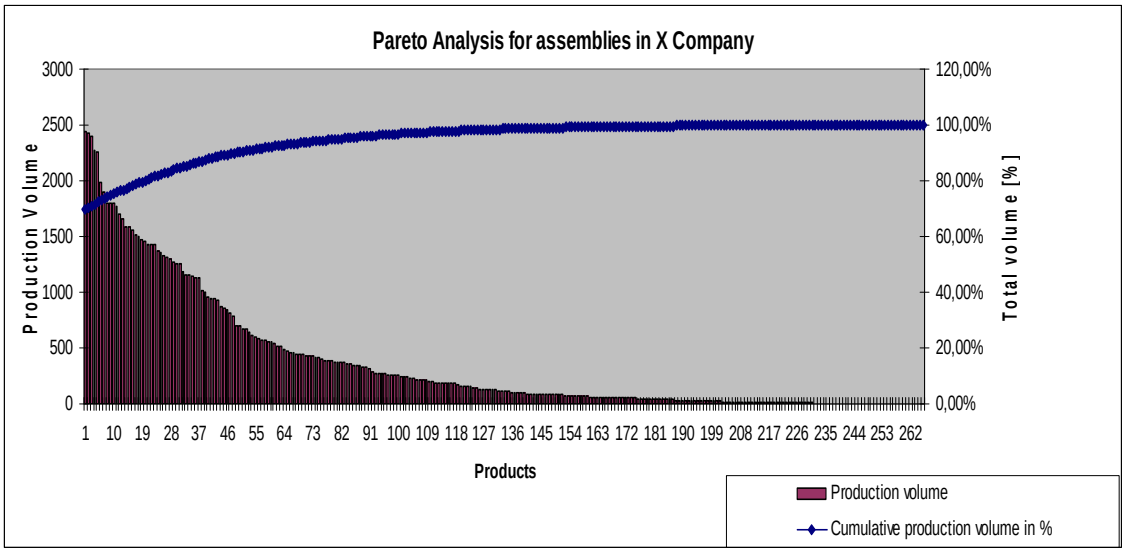

Figure 2. Pareto Chart for X Company Assemblies

As can be seen from the Fig. 2, the company has wide portfolio of assemblies but customers buy what they need so demand for some of existing products is volatile.
Products were split into 3 groups

- Runners – 50 types – 80% of volume
- Repeaters – 50 types – additional 14% of volume
- Strangers – 196 types – remaining 6 % of total volume

Demand for each group was known so takt time (time for completing one product determined based on demand and available work time- Fig. 3) was calculated in order to decide an product sequencing

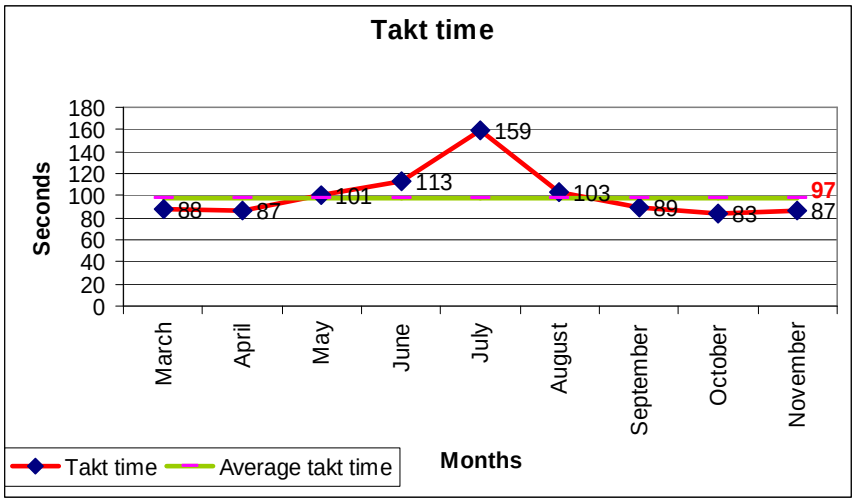

Figure 3. Takt time for the total volume of products.

2.2.2 Production strategy

After analyzing demand Company X had to choose production strategy for each group of product. Generally there is two main options: (1) make to stock or (2) make to order. There is also some hybrid strategies possible (e.g. assemble to order). For its 3 product groups Company X decided as follows:

1. Runners – make to stock based on Kanban
2. Repeaters – assemble to order (some amount of components/ parts have to be keep in stock)
3. Strangers – make to order.

Above strategy would work well only when assembly process would be flexible enough to produce high mix of products in very small batches with short lead time. In order to ensure this some of lean manufacturing tools was implemented.

2.2.2 Process improvement with lean tools

After analysis of current situation of the assembly line, some problems appeared:

- big containers of materials are waiting to be used
- most of the buffers are full with unfinished parts
- people continuously walk around the line and move between the stations
- regularly a group of people gathers around a machine that is not functioning correctly
- while some operators are working very hard others are just sitting and waiting for work to be completed somewhere else on the line
- there is no standardized work practices
- buffers stop continuous flow of products and break the direct connection between the consecutive stations
- each station is working for their buffer rather than for the next station (operators don't stop the work when buffer is full)

Table 1 presents areas of improvement and lean tools implemented to fix above problems. An implementation process lasted 6 months and some projects are still ongoing. Table 1 shows also some results already achieved.

Table 1. Lean tools for company X assembly line

Area of improvement		Lean tool implemented	Achievements
1	Assembly process Work distribution Process sequence	Standardized work Cell design Work balancing	Reduced labour 33%
2	Changeovers	SMED	Changeovers reduced by 60%
3	Layout	Cell design	Space reduction 40%
4	Machine reliability	Total Productive Maintenance	Machine breakdowns reduced by 70%
5	Material delivery	Timed delivery Parts presentation at the line	Line stoppages due to lack of components eliminated Improved ergonomics

Thanks to introducing the Lean Manufacturing concept and implementing lean tools, Company X assembly line began producing in small batches only when and what was needed without keeping much inventory. It reduced production lead time from 30 day to less than three. Reducing lead time was crucial for enabling Company X to produce "strangers" only to confirmed order (if the lead time would be longer, customer will not wait so company would have to keep extra inventory).

3. LEAN MANUFACTURING AND MASS CUSTOMIZATION

In the literature on lean manufacturing, there is more and more examples connected to mass customization and non repetitive operations. Proceedings of three congresses on Mass Customization include many papers describing use of lean tools in order to design production systems supporting customization of goods. Table 2 lists some of them.

Table 2. Description of lean tools in MC literature

Tool (s)	Author(s), *Title*	Event
Pull System	Jens R. Lopitzsch, Hans-Peter Wiendahl, *Push or pull? Mass customization by adaptive production control*	**MCPC2001**
Just in Time, Kanban	Tian-yuan XIAO, Gui-xiu QIAO, Jian-hua DONG, *Implementing Strategy and Key Technologies of Mass Customization in Automotive Manufacturing*	
DNA of Toyota Production System	Roach, G. M.; Cox, J. J.; Sorensen, C. D,, *Application of the Toyota Production System Principles to Mass Customized Product Engineering*	**MCPC2003**
Pacemaker, takt, standardization	Schwegmann, V.; Strube, G.; Willats, P.; Linck, J.; Boenigk, A. *Flexible Production and SC-Systems - Value through Effective Customization*	
One piece flow	Klock C. *Transforming Mass Production into Mass Customization – Understanding the Operational (system design) core principles*	**MCPC2005**

One of the most often referred examples of MC are configurators used by companies to involve customers into design process and let him decide on specification of product, which fulfill his needs best. It is characteristic, that most known configurators are offered by automobile companies, where Lean Manufacturing concept was born (Fig. 4).

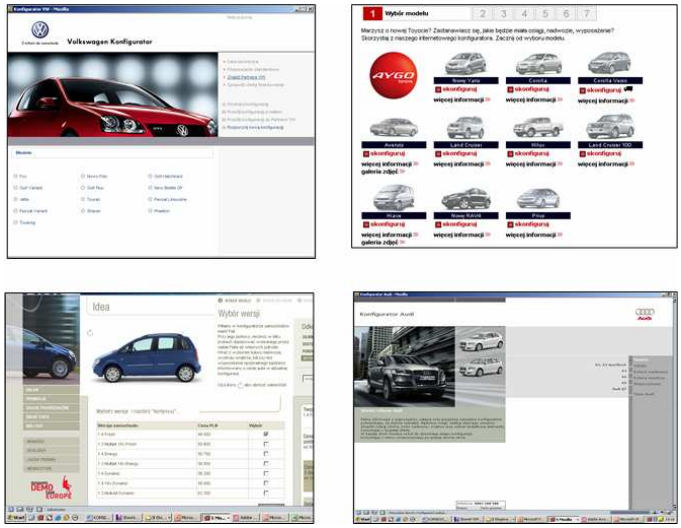

Figure 4. Examples of car configurators on the web

Customization is logical continuation of efforts undertaken to provide customer with right product in the right quantity in the right time. Lean practitioners already found a methodology for enabling mass customization in the lean production systems (Baudin, 2000):

1. analyze the structure of the demand
2. standardized components
3. make a catalog with a discrete set of sizes
4. postpone customization to the end of the process
5. identify a common process
6. maintain a database of past designs
7. design your custom manufacturing process
8. set up a simple production system.

Above strategies consist of set of techniques, which include creating product families and product cells, establishing simple material control mechanisms (e.g. Kanban, FIFO), standardizing components and modularizing products which all are strongly in line with lean production philosophy.

4. CONCLUSIONS

Lean manufacturing and mass customization seemed to be relatives in term of perceiving meeting customer requirements as their ultimate goal. Achieving this goal is a big challenge in terms of matching production process, its technology and resources up with the market demands. Lean Manufacturing can provide tools and strategy to set up flexible production system, which will be able to manufacture goods that customer really wants.

ACKNOWLEDGEMENTS

Preparation of this paper is supported within the grant no. 4 T07D 007 29 of Polish Ministry of Education and Science within the project aiming at developing methodology for successful implementation of Lean Manufacturing in job shop companies.

REFERENCES

Baudin M. (2000), *Eight Stretegies for Mass Customization*, MMTI, Palo Alto, CA

Brown J., Harven J., Shivnan J. (1988), *Production Management Systems*, Addison-Wesley Publishing Company, Inc., Wokingham, England

Pine II B.J., Peppers D., Rogers M. (1995), *Do You Want to Keep Your Customer Forewer?*, Harvard Business Review, March-April, pp. 103- 114

Rother M, Shook J.(1999), *Learning to See. Value Stream Mapping to Create Value and Eliminate Muda*, The Lean Enterprise Institute, Brooklin, MA

Suri R. (1998), Quick Response Manufacturing. A Companywide Approach to Reducing Lead Times, Productivity Press, Portland, Oregon

Womack, J., Jones D., Roos D.(1991), *The Machine That Changed The World: The Story of Lean Production*, Reprint edition, HarperCollins,

Womack, James P. and Daniel T. Jones (2001), *Odchudzanie firm. Eliminacja marnotrawstwa kluczem do sukcesu*, Warszawa, CIM,