METHODS AND TOOLS OF LEAN MANUFACTURING AND THEIR APPLICABILITY IN METALLURGY

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Abstract

The goal of this article is to describe and analyze specific methods and tools of lean manufacturing and their applicability in metallurgical industry. These methods are described: Kaizen, Value Stream Management, Lean Workplace, Lean Layout, Standardization, Management of Bottlenecks, TPM, 5S and Visualization, Poka Yoke, Kanban etc. For every method is discuss suitability of its application in specific process in metallurgical industry. Lean manufacturing (and its methods and tools) was originally established in the automotive industry, i.e. in mechanical engineering. It is understood that the usefulness of some methods and tools has increased in processes or parts of processes, including those involving the human factor (e.g. Poka Yoke, 5S, Visualization etc.). On the other hand, some methods are valid regardless of the level of involvement of human factor and type of industry (e.g. Value Stream Management, Lean Layout, Management of Bottlenecks etc.), however, it is necessary to adapt them the sectoral specifics. Typical examples of wasting in metalworking processes are described including appropriate methods of lean manufacturing.

Keywords: Lean manufacturing, Kaizen, lean layout, TPM, metalworking processes

1. INTRODUCTION

The current competitive environment forces companies (in any industry) to be competitive in especially in two areas (1) products and services must be offered to customers in the highest quality and simultaneously (2) at the lowest possible price. Pressure is generated to companies in the form of cost reduction, fast delivery of products and services and providing of the highest quality of production. The concept of Henry Ford from the beginning of the last century, based on the mass production of the uniform product, is inadequate nowadays, as overcapacity over supply has long been outdated. The high competitiveness of Japanese companies after the Second World War was triggered by a new concept that improves Ford's manufacturing system and builds on the importance of employee as a core business article. Today, the author of this approach (Toyota) is the most well-known high-efficiency operating system, and its lean methods based on waste elimination find use in various areas. It is no coincidence that all revolutionary changes in production have arisen in automotive. Pressure triggered by market needs (in the Ford's case by a high demand, and Toyota's case by pressure on costs and quality) very often begins in the automotive industry.

The concept of lean manufacturing is typically for engineering, especially in the above-mentioned automotive industry as a leader in this field. However, the concept of lean manufacturing is now transformed into other sectors as lean administration or lean software. The metallurgical industry, characterized by high investment costs, a long return on investment, low flexibility in changing the structure of production has often neglected this approach, because the implementation of lean manufacturing under these conditions is more difficult. However, the implementation of the idea of lean production and partial methods is possible, for example, in the case of blast furnaces or heavy metallurgy, as mentioned below. The goal of this article is to describe and analyze specific methods and tools of lean manufacturing and their applicability in metallurgical industry.

2. PHILOSOPHY OF LEAN MANUFACTURING

The essence of lean production and lean thinking is creating greater value while using a smaller amount of human effort, time, place or equipment. We can therefore say that lean is generally a philosophy of improvement, by eliminating waste [1], where the improvement is in the form of small and continuous improvement, so-called *kaizens*. Elimination of waste (*muda*) is the essence of *lean manufacturing*, but cannot be ignored crucial human factor as many companies do [2].

2.1. TPS and Kaizen

Although *Toyota Production System* (TPS) is often perceived as a set of methods, it is more about philosophy and thinking. TPS is depicted as a house that stands on two key pillars: *just-in-time* and *jidoka*. *Just-in-time* can be characterized as a system of supplying components that are needed to the place where they are needed and at the moment they are requested, thereby maximizing the reduction of insurance stocks. *Jidoka* consists of controls to ensure that the defective piece is not allowed to the next workplace, thereby eliminating waste. In particular, the metallurgical industry is characterized by a high level of waste due to technological aspects of production (e.g. cooling process causes the inner and surface pressure). In TPS, all employees are at the same time controllers on which they are relied on and given full confidence [3]. The foundations of the house are philosophy, visual management, stability and standardization of processes and heijunka (as a principle of balanced production). Liker [4] divides elements of the house into four groups (4P): People & Partners, Philosophy, Process, and Problem solving.

Kaizen philosophy is broader than just the elimination of waste (*muda*). Kaizen can be seen as progressive philosophy of continuous improvement. Masaaki Imai (father of this philosophy) defined Kaizen as *„ongoing improvement involving everyone-top management, managers and workers“* [5]. The philosophy of smaller incremental changes often stands in opposition to the strategy of innovation and reengineering, which promote mainly western companies. The essence of metallurgy (the manufacturing process is mainly based on heavy machinery) leads to dramatic changes being often impossible, so the Kaizen philosophy should have a place in the management of these companies.

Benefits of *Lean Manufacturing* (TPS) and *Kaizen* are indisputable. For example, Melton [6] states in his research that the implemented *Lean* or *Kaizen* philosophy reduces the time between accepting the order and accepting the finished product or service on average by 25 % or eliminating inventories by 30 %. Womack a Jones [7] talk about a fourfold increase in productivity.

2.2. Methods of Lean Manufacturing

Value Stream Management could be described as a manager's focus on value while disposing of waste. It is the *„process of lean implementation to link the metrics and reporting required by managers with the people and tools needed to achieve the expected results*“ [7]. In connection with this term is necessary to mention *Value Stream Mapping*; see more [8].

Lean Layout could realize *Lean Workplace* (it means workplaces with limited wasting. Lean Layout is based on principles: (1) detailed analysis of a set of validated tools is required; (2) the workplace is organized by those working in it; and (3) the production system of the company and individual workplaces are designed and improved in a comprehensive way (with using other methods - SMED, Visualization, Kanban etc.).

Standardization. Standards do not only concern processes, activities, methods, procedures, measurements or work, as well as corporate rules, policies, behaviors, and conventions at all on which corporate culture builds. Perfect standardization incorporates improvements to the sorting, straightening and cleaning system, including preventive measures. The importance of standards is in reducing deviations, increased security, simplifying communication processes, visualize and respond to difficulties and problems, aid for education, strengthening working ethics, clear definition of workflows [9].

Management of Bottlenecks. Bottlenecks can exist in all types of manufacturing processes, including the job process, batch process, line process, and continuous process. An effective approach is: (1) Identifying Bottlenecks (variability in the workloads will again likely create floating bottlenecks, especially if most processes involve multiple operations, and often their capacities are not identical. (2) Relieving Bottlenecks and (3) Product Mix Decisions.

Total Productive Maintenance (TPM) is a system of maintaining and improving the integrity of production and quality systems through the machines, equipment, processes, and employees. The pillars of TPM are mostly focused on proactive and preventive techniques for improving equipment reliability: (1) Focused improvement; (2) Autonomous maintenance; (3) Planned maintenance; (4) Quality maintenance; (5) Cost deployment; (6) Early equipment management; (7) Training and education; and (8) Safety health environment [10].

5S is a method that uses a list of five Japanese words: sort (*seiri*), set in order (*seiton*), shine (*seiso*), standardize (*seiketsu*), and sustain (*shitsuke*). It describes how to organize a workspace for efficiency and effectiveness by identifying and storing the items used, maintaining the area and items, and sustaining the new order. It is connective with *Visualization*, see more e.g. [11].

Poka-yoke is a Japanese term that means “inadvertent error prevention”. A poka-yoke is any mechanism that helps an equipment operator avoid (*yokeru*) mistakes (*poka*). Poka-yoke is able eliminate product defects by preventing; correcting; or drawing attention to human errors as they occur, more see [12].

Kanban is a method for managing work, which balances demands for work with the available capacity for new work. Work items are visualized to give participants a view of progress and process, from task definition to customer delivery; more see e.g. [13].

2.3. The types of wasting and methods for its elimination

Taiichi Ohno originally involved seven types of wasting [14], now eighth type is included to the classification [1], or other types are being discussed in [15].

The main approaches for elimination every types of wasting are:

1) *Unnecessary transport* as moving products that are not actually required to perform the processing. The useful method is Lean Layout, Lean Workplace and Kanban, with connection with 5S, Visualisation and Management of Bottleneck.

2) *High inventory* of components, work in process, and finished product. The appropriate methods are Value Stream Management, Just-in-Time, Kanban and Management of Bottleneck.

3) *Motion* equipment or walking people more than is required to perform the processing. An important means of eliminating this type of waste is the method 5S respected Lean Layout and Lean Workplace.

4) *Waiting* for the next production step, interruptions of production during shift change. It is advisable to use the pull system and prevent failures and defects by using the Total Productive Maintenance. Management of Bottlenecks and Kanban are appropriate too.

5) *Overproduction*. The effective methods to prevent these problems are in the case of casting using of SMED method; during planning using the pull system as part; and to prevent failures TPM.

6) *Over processing* as a result from poor tool or product design creating activity. There is necessary use Value Stream Management.

7) *Defects*. The protection is Total Productive Maintenance and Poka-yoke.

8) Manufacturing goods or services that *do not meet customer demand or specifications*. There is necessary use Value Stream Management and Value Stream Mapping for calculation value added and non-value added activities.

3. SECONDARY RESEARCH IN METALLURGICAL AREA AND ITS CONCLUSION

The Ohno´s seven waste are modern methods how to define basic waste's principles. Aspects of modification for metallurgical processes are very general. Searching for balance between innovations and financing in the metallurgical processes are going across the elimination of the Ohno seven waste [16]. Four areas in metallurgy industry are identified (Technological and technical basis of metallurgical processes; Material and energy demandingness; Large production batches and volume processed in a single cycle; High demandingness for organization and operational planning and control) and authors connect type of wasting with these areas.

Metallurgical processes are unfriendly to the environment around. Whole process is beginning by mining when is necessary to receive the raw material. These processes are very unfriendly to environmental exactly by the opencast mining. In metallurgy, we are able these not pleasure processes partly eliminated. Focusing on the types of waste and trying them to eliminate is proof the environmental around us [17].

The simplification of these methods (which small and medium companies use) is successful approach for elimination of waste. Simplified methods help to these enterprises for faster and successful implementation of lean methods and faster financial return [18].

4. TYPICAL EXAMPLES OF WASTING IN METALWORKING PROCESSES

This part follows and develops four areas defined in [16], more in chapter 3. The typical areas of wasting (No 1 - 8 above) are in these metalworking processes:

Casting:

- (1), (3) Long distances between the workplaces (storage - furnace - casting machine - intermediate storage);
- (2), (5), (7) Consumption of surplus material in silo for pressure casting machines;
- (3) Long distances between machines operated by one person;
- (4) Time for replacing the ingot during production change;
- (6) The wear of the ingot leads to more waste;
- (7) Technological burdens in production and inner and surface pressures during cooling;
- (8) Disposable materials (protective elements).

Forging:

- (1), (3) Long distances between the workplaces (storage - furnace) including additives;
- (2), (5) The molten material cannot be returned to the warehouse;
- (4) There is no material in stock; poorly planned continuity of casting;
- (5) Prevention from defects;
- (6) Poor estimate when filling the furnace;
- (7) Another alloy is produced by the wrong substance ratio.

Rolling:

- (1), (3) Long distances between the workplaces (storage - furnace - rolling machine - intermediate storage);
- (2), (5) Large stock of pre-prepared material;
- (4) Rolling machine is bottleneck;
- (6), (7) Wear of the cylinders, there is a greater load on machining;
- (7) Inner and surface pressures;
- (8) Disposable materials (protective elements) during cooling.

Laser Cladding:

- (1), (3) Long distances between the workplaces (storage - laser - intermediate storage) for product or material;
- (4) Software switching;
- (6), (7) Wear of the cylinders, there is a greater load on machining;
- (7) Surface pressures, consistency of the applied layer;
- (8) Internal control protocols.

Extrusion:

- (1), (3) Long distances between the workplaces (storage - extruder - intermediate storage);
- (5) Prevention from defects;
- (6) Machine tool wear, additional machining required;
- (7) Machine tool wear, if machining is larger, cannot be reversed;
- (8) Demanding administration.

Sintering:

- (1), (3) Long distances between the workplaces (storage - furnace - crushing machine - intermediate storage);
- (4) Crushing machine is a bottleneck;
- (5) Prevention from defects;
- (7) Inner and surface pressures during cooling;
- (8) Higher consumption of binding substance.

Machining:

- (1), (3) Long distances between the workplaces (storage - machine shop - intermediate storage);
- (3) Long distances between CNC machines;
- (5) (Sometimes) prevention from defects;
- (7) Cutting machine/tool wear, bad material/product placement;
- (8) Demanding administration.

Fabrication:

- (1), (3) Long distances between the workplaces (storage - machines - intermediate storage);
- (2), (4) It depends on technology;
- (3) Long distances between machines;
- (5) (Sometimes) prevention from defects;
- (7) Machine/tool wear; and (8) demanding administration.

Forming:

- (1), (3) Long distances between the workplaces (storage - furnace - forming machines - intermediate storage);
- (2), (4) It depends on technology;
- (3) No chance for new layout after installation equipment and machines
- (5) Prevention from defects; inner and surface pressures during cooling;
- (7) Machine/tool wear.

To eliminate waste, use the tools described in chapter 2. Of course, it is necessary to adapt the methods to the technological process.

5. CONCLUSION

The philosophy of lean manufacturing and lean methods today belongs to standard operational management tools. Although the cradle of these methods is automotive, these methods find their place also in metallurgy. Metallurgy is characterized by long production cycles; high investment costs; a long payback period; and a relatively high production defects. Radical changes are almost impossible due to this. The principle of continuous improvement (philosophy lean and kaizen) is a solution. Appropriate approaches to metallurgy include mainly: (1) before construction a new plant Value Stream Management and simulation of production process with a goal to find Bottlenecks of this process; (2) Standardization, Poka-Yoke, 5S, Visualization and Kanban for developing Lean Layout and Lean Workplace; (3) Poka-Yoke, Standardization and Total Productive Maintenance for reduction of defects.

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