THE INFLUENCE OF LEAN MANUFACTURING TOOLS ON THE PRODUCT QUALITY IN THE CASTING PROCESS - CASE STUDY

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Abstract

Nowadays, most of production industries (also casting industry) strive to implement properly functioning organizational structures, the activities of which must ensure the increased level and quality of manufactured elements while eliminating unnecessary wastefulness - generated during the manufacturing process. The implementation of tools comprising Lean Manufacturing methodology and the application of many qualitative methods make it possible to create properly functioning technical-organizational structure aimed at avoiding defects, or if they occur - to identify them quickly.

The article presents the impact of selected production system tools organized according to the principles complied with Lean Manufacturing concept (LM) on the product's quality of the enterprise specializing in casting production. The article characterizes basic and often applied Lean tools which, as an effect, contribute to the improvement of the quality of the manufactured products.

Keywords: Lean Manufacturing, quality, casting defects

1. INTRODUCTION

The universality of Lean Manufacturing tools makes it possible to implement them in production enterprises which stem from different sectors of industry. The necessity to minimize costs generated by the production process due to the increase in the competition level and market demands hinders the functioning of the enterprise not having complex technical-organizational structure on the basis of LM philosophy. Due to a dynamic development of metal industry as well as applied techniques and methods supporting production organization, most of production plants have integrated systems enabling identification and elimination of wastes due to the manufacturing process. In most cases the application of methods comprising Lean concept develops the production process itself and makes it possible to limit technological problems. On the basis of executed research it is possible to identify defects in manufactured products, and then propose organizational-technological adjustments having an impact on the course and quality of the manufacturing process. The article proposes the implementation of various methods comprising Lean Manufacturing aimed at improving quality of engine piston casts. The selection of a given method depends on the type of identified problem and the level of its impact on the manufacturing process [1].

2. THE CHARACTERISTICS OF THE SELECTED LEAN MANUFACTURING TOOLS AND THEIR IMPACT ON THE PRODUCTION PROCESS

Methodology allowing standardization of activities complied with Lean concept is relatively simple and enables acquisition of assumed goals provided that all theoretical assumptions which define the functioning of a given method are met. The time necessary to acquire the appropriate structural-organizational level depends on the type of executed production works as well as the complexity and the scope of their implementation. Regardless of the type of introduced organizational activities complied with LM; the assumed result of their application is

the elimination of wastefulness as well as standardization and control of the specified manufacturing processes.

The basic principles defining Lean Manufacturing methodology and the mode of operation of selected LM tools may cover the following phenomena which are directly connected with the functioning of the production process [2]: wastefulness elimination, inventory and inter-operational stocks reduction, correction and standardization of the new procedures in the case of wrong organizational-technological approach, constant development, creation of the production environment which hinders the occurrence of the mistake, application of early warning system, constant improvement of the quality of finished product and its components, elimination of mistakes, high level of operational and technological reliability as well as minimization of conversion time for devices and technological machines.

The most frequently applied tools of Lean Manufacturing concept are [2, 3]:

- Kaizen - the method of constant improvement of the production process and organizational systems which is divided into stages, based on the analysis of selected activities concerning defined areas of activity of the production enterprise [2, 4, 5].
- 5S - constant process allowing arrangement of the work environment through the implementation of 5 stages of activities (sort, set in order, shine, standardize, sustain) the application of which makes it possible to achieve order and improve the level of safety. In most cases, this method is applied as a type of supporting tool in the identification of mistakes and defects which occur in the selected workplaces [6].
- SMED (Single Minute Exchange or Die) - the method aimed at shortening the time for the implementation of machines conversion by the application of standardized organizational activities which minimize the number of necessary operations to execute the conversion.
- TPM (Total Productive Maintenance) - TPM is defined as a continuous process of servicing machinery and equipment implemented within the entire enterprise by all operators and maintenance technicians. TPM focuses on maximizing the efficiency of the machinery by applying actions to prevent accidents during the whole period of application. Thanks to implementation of TPM every machine in the manufacturing process is capable of performing tasks, as there are no disruptions in the production process. The key role is played by the activities executed by the operators under Autonomous Maintenance [7].
- VSM (Value Stream Mapping) - the method of production process mapping which presents the flow of materials and information in the course of the process. On the basis of executed map of the process, it is possible to verify the production capabilities of the enterprise and identify risks which theoretically result in stoppages and delays in analyzed manufacturing process. This tool suggests the application of adequate solutions in terms of Lean in order to remove wastes and improve activities.

The results of the implementation of selected LM methodology tools depend on the level of organization of the production process and applied manufacturing technology. The proper adaptation of standardized rules which improve the functioning of defined areas in the enterprise aims at identifying and eliminating defects and restrictions which negatively affect the parameters of the production process.

The identification of defects and risks along with identification of causes of their creation is the key function implemented under activities of LM methodology. The proper identification and specification of the level of intensity of defects and causes of their occurrence is the basis to plan organizational and technological changes aimed at eliminating. The necessity to execute activities connected with the identification of defects and their elimination is defined by well-known Pareto analysis, known also as (pattern) 80/20 rule - which states that roughly 80 % of the effects come from 20 % of the causes (**Figure 1**) [8, 9].

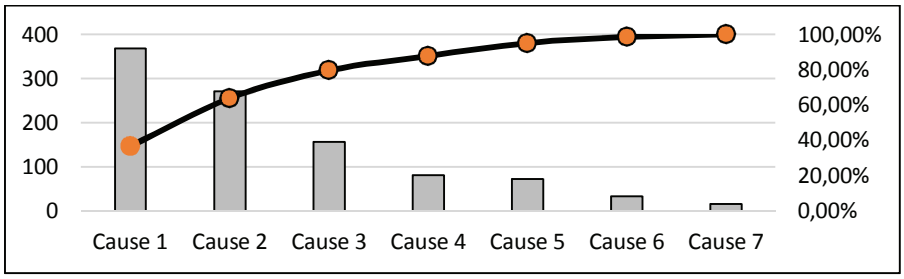

Figure 1 Pareto chart

The decrease of the percentage level of causes for defects and difficulties in the manufacturing process will influence on the decrease of the level of effects which negatively affect the course of the production process, at the same time, decreasing the number of defects in the finished product and improving the level of the organization of the manufacturing process. Therefore, for the enterprise and the process it is necessary to identify defects (wastes) and then undertake necessary activities in order to acquire the product of high quality, for which the client will pay (according to Lean concept).

3. THE IDENTIFICATION AND ELIMINATION OF DEFECTS IN ENGINE PISTON CASTS WITH THE APPLICATION OF LEAN MANUFACTURING TOOLS

Casting production process covers the large number of technological operations, the proper execution of which guarantees the acquisition of the product characterized by the level of quality accepted by the client, meeting the specified criteria (e.g. resistance). The basic parameters taking into account in the casting process cover, among others: pouring temperature of liquid alloy, material from which the model is made and its density, construction of the gating system and the connection area of the model with liquid alloy [10].

The complexity of casting process and the possibility for small margin of error in the estimation of relevant parameters of castings makes that this process is subject to the high risk of defects, the occurrence of which hinders further execution of production works. The basic defects which occur in the course of the casting process include [11,12]:

- Defects of the shape of casting - short run castings, mechanical damages, bumps, pockets, beaker, warping
- Breaks in casting structure (discontinuity) - cold cracking, hot cracking, inter-granular cracking, rupture,
- Defects of the surface of the casting - roughness, scabs, punctures, scars, folds, bonds, flexures,
- Internal defects - shrinkage cavities, scabs, porosities, swells, cold drops, external metals, sorts, coarseness.

It is assumed that under commercial casting production - depending, among others, on: the casting material, level of complexity, applied technology and the size of batch - the percentage share of defects in relation to the total number of manufactured elements constitute approx. 2-5 % [13]. The occurrence of defects causes the increased production costs, while assuming the production of 10000 tones of casting made of cast iron. Reduction of the number of defects from 5 % to 3.5 % may result in the increase in production capacity of the company by approx. 150 tones of properly made cast (meeting quality standards) which directly accounts for the increase of savings of the production plant reaching approx. PLN 450 000 [13].

The analysis covered basic causes of defects in engine piston casts made of Al-Si alloy and then defects reduction capacities with the application of standardized tools of Lean Manufacturing methodology were identified (**Table 1**). The basic types of defects occurring in these types of casting cover: scabs, metal and non-metal parts, inappropriate diameter of piston casts as well as casting cavities and porosities (**Figure 2**).

Figure 2 The example of defects created in the casting process [1]

On the basis of the observation of the technological process the most important causes of defects in engine piston casts were identified (**Table 1**). The selection of the most important causes was executed on the basis of the attribution of categories as those which have the greatest impact on the problem. Then, they were divided in terms of assumed criteria (machine, man, method, material, management - according to 5S principle). The next stage defines the possibilities to eliminate these causes through the application of selected LM tools, (**Table 1**) on the basis of [1].

Table 1 The elimination of casting defects with the application of selected LM tools

Criterion	Cause	5S	Kaizen	TPM	SMED	VSM
Machinery park	Limited capacity of machinery	■	■	■	■	
	Heating failure			■		
	Lack of machinery maintenance		■	■		
	Lack of identified technological parameters			■		
	Inadequate casting mould change				■	
Production employees	Inadequate organizational solutions	■	■			■
	Lack of the application of production improving methods	■	■			
	Negligence and haste	■	■			
	Monotony of work		■			
Production methods	Outdated production methods	■	■	■	■	■
	Lack of the organizational solutions in the process	■	■	■	■	■
	Delays in the execution of operations	■	■	■	■	■
Applied material	Inadequate storage of materials	■	■			
	Pollution of input material	■				
	Lack of innovative technology		■			
Management	Lack of supervision over the implementation of the process					■
	Lack of accurate quality control					■
	Disorder in the production hall	■				

Following the analysis and covering of appropriate criteria (which cause casting defects) with causes of their occurrence - it was proposed to implement LM tools which may contribute to the elimination of the frequency of their occurrence. The most useful tool is Kaizen (proposed in 11 cases). It is a tool which enables improvement of simple activities and solves problems occurring in the production hall. The next suggested method is 5S (proposed in 10 cases) which may solve many organizational problems occurring in the production position. Both tools are simple in implementation, involve employees and enterprises want to apply them when solving problems. Kaizen and 5S were proposed during almost all of proposed causes which prove their universal nature and the possibility to improve the quality in the process. TPM and SMED were proposed during elimination of causes connected directly with Machinery Park and work methods (influence the

improvement of capacity of machinery through the preventive actions and standardize the execution of actions in order to implement the process, which as a result contributes to the quality of the product. It is not simple to implement - it requires extensive involvement of employees and time. VSM tool, proposed in 3 cases, enables the identification of the source of a given cause through the analysis of the whole process. Its advantage is visualization of the flow of materials in the process and the possibility to identify wastes which may negatively affect the quality of products.

4. CONCLUSION

The existence of casting defects is not only a technological problem. The cause of defects may also be organizational problems resulting from the lack of the application of methods, tools and techniques in terms of quality management and Lean Manufacturing concept. The most useful, effective and applied by the enterprises are: 5S, Kaizen, SMED and 5Why technique which reflects the increase of the quality of products and improvement of the production process. The effectiveness of activities connected with introduction of solutions from Lean is proved by many enterprises from automotive, metallurgy and other industries - LM concept underlies World Class Manufacturing [14]. The proposed Lean tools for the elimination of causes of defects may be applied to: collect and analyze data, identify causes of defects, create new solutions and assess the effectiveness of activities. The implementation of these tools is not always possible mostly due to the lack of involvement of employees and lack of understanding. Since 80 % of the effects come from 20 % of the causes resulting from their influence, the analyzed enterprise should start work on the implementation of suggested solutions which will influence the increased quality of the product.

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