DETERMINANTS OF THE MACHINING PROCESS IN THE STEEL INDUSTRY

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Abstract

Functioning of the quality management system plays only an indirect role in ensuring of a required product quality. Analysis and identification of the product quality determinants is essential for improvement of the steel products quality and its production processes implemented through corrective and preventive actions. Paper presents research findings on the quality determinants identified in the steel products manufacturing of the chosen Polish enterprise, what is the main research objective. Quality management tools were applied to identify and analyze main groups of factors affecting the final product quality. Crucial determinants of the steel product quality have been identified with using Ishikawa and Pareto-Lorenz diagram in order to solve quality problems that occur in the withdrawing rollers manufacturing process. Research methods applied in the paper allows elaborating corrective and preventive actions what is the main contribution of the research in the analyzed enterprise. Paper's conclusions present proposal of the steel product machining process improvement in order to reduce the risk of quality problems occurrence in the manufacturing process.

Keywords: Quality, machining process, steel industry, the withdrawing rollers

1. INTRODUCTION

Quality is understood as the fulfilment of the product specific requirements of the customer or users of the product. Quality management is directly related to the quality of products and activities. In the quality management decisions are related to management processes, resources and units having an importance in the product quality formation. Priority task is the continuous improvement of products and activities. The influence on the product quality in particular phases of the manufacturing processes is different and proceeds with different dynamics depending on the manufacturing process phase namely: pre-production, production and post-production. Quality in the production sphere is reflected in the quality of the production process and the product operation and the evaluation measure is the obtained number of usable effects (meeting of the customers' requirements), which is due to both the quality of standard model and the conformity of the product with the project [4]. The range and scope of the quality analysis in the production sphere includes: technological documentation, terms of products supply, quality testing of semi-finished products, quality testing of parts and assemblies, the product quality testing. They are used following quality assessment methods: individual assessment of the expert, statistical process control, testing of the quality capacity of machines and processes, traditional tools of quality management. Quality management is one of the issues that undoubtedly inspires metallurgical industry enterprises to introduce changes in the following areas: product manufacturing processes, organization, management and corporate culture [3].

The scientific goal of the presented study is to identify and analyze factors affecting the final quality of the withdrawing rollers obtained at the department of the mechanical machining in chosen Polish enterprise. The authors suggest, that the use of appropriate techniques and quality management tools will contribute to the final steel products quality and manufacturing process improvement. Analysis of quality determinants in the rollers machining process and introducing a corrective action allows the final product quality improvement.

1.1. Research object characteristics

The machining process is based on providing mechanical elements of any desired shape and the cylinder dimensions while covering of the necessary accuracy and smoothness. Cutting is the dominant type of processing in the steel industry therefore it has great importance in the production of the usable products and means of the production. The shape of the machined part and the precision of its execution are the result of interaction of the machine and the tools and bracket part in a suitable position in relation to the axis of the machine spindle. The cutting tool gives suitable specific shape of the work piece by removing excess material in the form of chips [2]. The withdrawing rollers intended for modern rolling mill must be processed in a very narrow tolerances and with a very smooth surface finish [7]. Certification bodies that certify steel products should meet the requirements specified in PN-EN 45011:2000 that include laboratories and departments of technical inspection in the steel industry enterprises [6].

The study used the production inspection results collected by the laboratory staff of the selected Polish steelworks in the department of mechanical machining, which has implemented a management system according to PN EN ISO 9001:2001, PN ISO 14001:2005 and the recognition of second UDT degree to perform chemical analyzes and magnetic - particle testing as well as recognition of the PRS (Polish Register of Shipping) to perform chemical analysis and metallurgical testing. The results of qualitative research are related to the period: 2013 - 2015. Analyzed enterprise employs 245 employees at two production units: the foundry department and machining department. It has modern technologies and equipment, and technical equipment that allows manufacturing of the castings weighing from 200 to 36.000 kg with the maximum diameter of 1300 mm and a maximum length of 7650 mm.

2. RESEARCH METHODOLOGY

Tools and techniques enables the quality problems solving in the organization. The effectiveness of the quality management tools depends on the staff knowledge, its experience in their application and the ability to interpret the results. They are instruments of monitoring and diagnostic of the design processes, the manufacturing, the inspection, the assembly and all other activities occurring in the product manufacturing [13].

Supervision of products that do not comply with the requirements of the analyzed company is conducted in accordance with the quality management system procedure. Detected nonconformity may concern: technological defect, inappropriate machines work. Identified nonconformity is given to the analysis that enables to prevent the nonconformity occurrence. Records are used to implement corrective and preventive actions to eliminate their causes and repetition of nonconformity occurrence [9]. The process of mechanical machining is performed at the department of mechanical machining according to customer requirements with the following procedure: machining of rollers, final control of the rollers, rollers marking, incompatible rollers handling, ultrasonic testing of the rollers, securing the cylinder from damage and packaging.

In the process of mechanical machining of rollers, the quality of its operation is a subject of the inspection at each stage of the production. The finished product in terms of the quality level should meet the requirements of national standards, international and technical procedures and technical instructions. The inspection at department of mechanical machining includes process controls and control of the finished product. It should, however, mention the feedstock inspection, because it has a big impact on the withdrawing rollers quality in the department of mechanical machining. Checking the feedstock begins even during melting and pouring of the feedstock. It consists of determining of the chemical composition of the metal, assessment of the surface or rolled billets [3, 7].

Visual inspection allows detection of defects with the unaided eye or using a magnifying glass. It should be noted, that the determination of the machining operations order is guided by the principle that it should allows the earliest possible detection of defects. During the machining the object of the precise inspection is the barrel surface. It allows identifying of defects such as: porosity, gas bubbles, micro, chipping of, non-metallic inclusions.

The scheduling of the identified causes of nonconformities is possible thanks to the Ishikawa diagram [1]. The diagram (**Figure 1**) is used to study the problems of different cross-sections and varying degrees of detail [5] by using the 5M method indicating the existence of the five groups of reasons of nonconformities occurrence in the manufacturing process [1]:

- manpower - skills, habits, job satisfaction, training, well-being;
- method - procedures, guidelines, responsibility, specifications, standards, rules, know-how and technology;
- machine - license, durability, modernity, efficiency, precision, safety and working conditions;
- material - Input materials, semi-finished, components, substitutes;
- management - organizational structure, organization of work, shift-working conditions.

Ishikawa diagram enables to identify dependences of a cause-and-effect relationship. To eliminate the quality problem, reasons responsible for its occurrence are searched. Ishikawa diagram is also used to analyze the problem areas on the basis of standards, as well as individual approach. Manufacturing of the product includes situations, when the product does not meet the set of requirements. There are usually cases of nonconformities, which cause the classification of certain product as a defect what result from different and multiple causes. It proves to be, however, that the majority of nonconformities are caused by a relatively small number of reasons. Taking into consideration principle of the rational action in the manufacturing process, the important thing is a proper identification of the causes that are responsible for the most important nonconformities [5]. Pareto-Lorenz diagram is based on the empirical regularity found that in nature, technology, human activity that assumes that 20-30% of the causes decides usually about 70-80% effects [4]. Pareto-Lorenz method (ABC method or 80-20 principle) is one of the techniques that determines the measures improving the manufacturing processes and the product quality by identifying the most important features (events, causes) affecting the quality [12]. Pareto-Lorenz diagram (**Figure 2**) is used to transmit a specific validity to factors causing the quality problem [10].

3. RESEARCH RESULTS AND DISCUSSION

The object of the qualitative analysis is the withdrawing roller formed in the department of mechanical machining. The main dimensions of the rollers are defined as the diameter and length of the roller's barrel. The length of the barrel is a constant dimension of the cylinder, while the diameter as the work is being undermined by regeneration (tumbling down, grinding) of used layers. The hardness of the rollers is determined by Shore 'A Vicersa HV test and HB Brinell test. The Shore's method is used to measure the hardness of pivots and the barrel [8, 11].

Static and dynamic loads determine the required bending strength, compression, torsion and impact strength. Surface pressure consist of requirements with regard to the hardness of the rollers surface. For the working surface there are applied materials which are pressure-resistant material, abrasion and temperature. The selection of optimum material depends on the following factors: the load transfer through the rolls, the metal surface pressure on the rollers, the desired surface smoothness of a the rolled product, the type and efficiency of the mill [9, 11].

In order to identify groups and causes of the nonconformities occurrence in the rollers manufacturing there was used Ishikawa diagram (**Figure 1**) with following groups of factors: people, machine, material, method, management.

The **Figure 1** indicates that greatest influence on the produced rollers have three groups of factors. The first is "the material" (30%) and the cause which has the greatest influence on the quality of the final rollers are bubbles that are formed on the barrel's surface. The other quality problems within material category are related with bubbles on the pivot or cracks on the barrels' surface. It is stated that mentioned problems result from problems with machinery modernity level and inadequate technology applying in the manufacturing process. Another important group is "the machine" (25%) and "the manpower" (25%), in which the most important is failure to comply with of dimensions and lack of motivation.

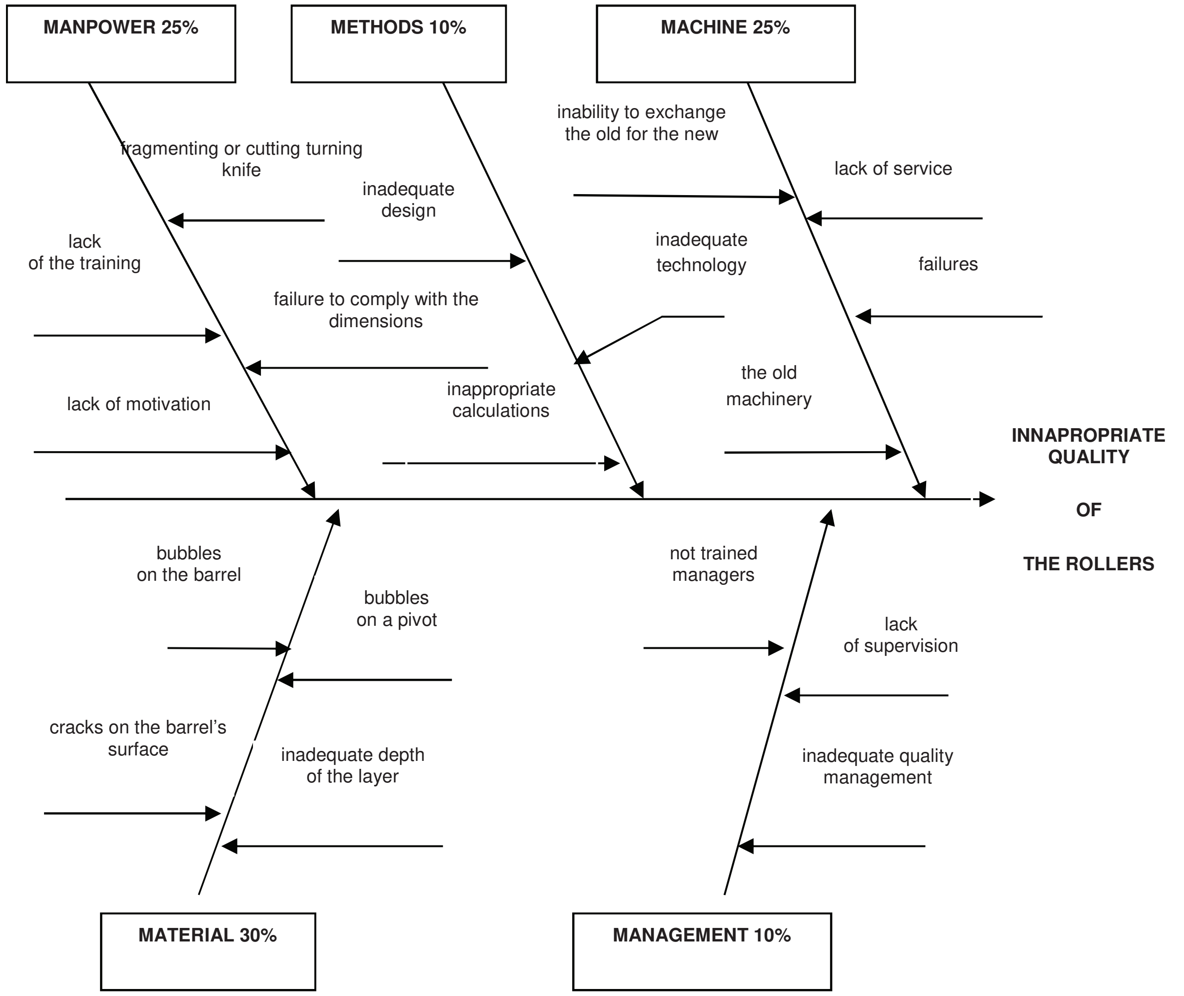

Figure 1 Ishikawa diagram for nonconformities analysis in the withdrawing rollers manufacturing

In order to identify the nonconformities structure in the rollers manufacturing process there was used Pareto-Lorenz diagram. This diagram is based on the principle 20/80 and it is one of the techniques used to determine the measures of the product quality characteristics improvement [10]. In Pareto-Lorenz analysis there are used three main groups of factors that have been identified in Ishikawa diagram. Nonconformities affecting the inadequate quality in the rollers manufacturing were ranked in order of its occurrence frequency in a given study period. **Table 1** presents the nonconformities structure prepared for the rollers manufacturing process analysis including nonconformities occurrence frequency, percentage, cumulative percentage and cumulative incidence.

Table 1 shows that among the 12 most common nonconformities are: bubbles on the barrel's surface, the old machinery, lack of motivation and failure to comply with the dimensions by the employees.

Table 1 The structure of the nonconformities identified in the withdrawing rollers manufacturing

Symbol	Nonconformity name	The frequency of occurrence	The percentage share [%]	The cumulative frequency [%]	The cumulative percentage share [%]
N1	Bubbles on the barrel's surface	23	23.46	23	23.46
N2	The old machinery	15	15.30	38	38.76
N3	Lack of motivation	12	12.25	50	51.01
N4	Failure to comply with the dimensions by the employee	11	11.2	61	62.23
N5	Cracks on the barrel's surface	9	9.2	70	71.43
N6	Bubbles on a pivot	7	7.14	77	78.57
N7	Inadequate depth of the hardened layer	5	5.10	82	83.67
N8	Lack of training	4	4.08	86	87.75
N9	Lack of service	4	4.08	90	91.83
N10	Failers	3	3.06	93	94.89
N11	Fragmenting or cutting knife turning	3	3.06	96	97.95
N12	Inability to replace the old machine to the new	2	2.05	98	100

On the basis of the data contained in **Table 1** there was prepared Pareto - Lorenz diagram (**Figure 2**).

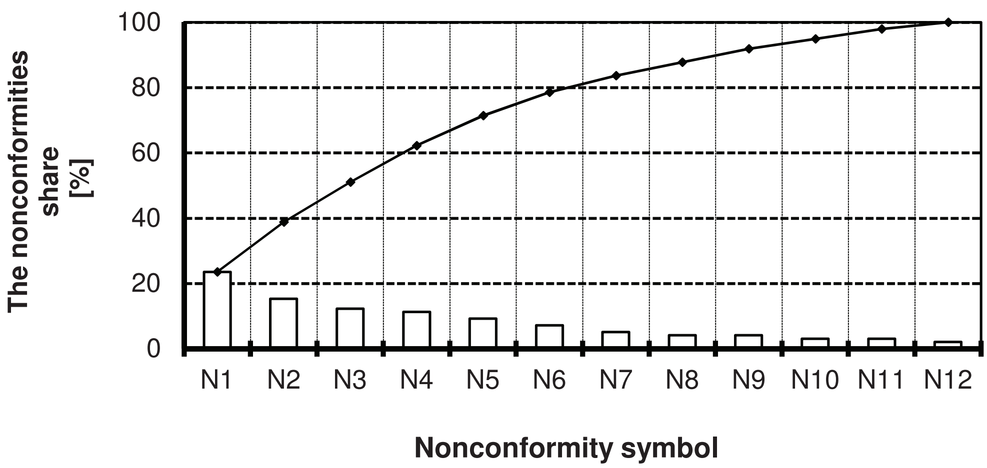

Figure 2 Pareto - Lorenz diagram for nonconformities occurring areas in the withdrawing rollers manufacturing

The analysis of Pareto - Lorenz (**Figure 2**) stated, that three nonconformity constitute 24.99% of the causes which are responsible for 51.01% of inadequate quality of rollers. The remaining 75.01% of the identified nonconformities is responsible for 48.98% effects resulting in the low level of the rollers quality that not meet customers and standards requirements.

4. CONCLUSION

Factors affecting the quality level of the withdrawing rollers have been identified and analyzed in the paper. The use of Ishikawa diagram allows identifying areas of emerging quality errors. Studies have shown that the inadequate quality of the analyzed rollers at department of mechanical machining is determined in the greatest level by the following factors: a material, a machine, manpower. The Pareto- Lorenz analysis used the three most important groups of factors resulting from Ishikawa diagram analysis, what enables to establish crucial nonconformities in the rollers manufacturing and indicate improvement areas.

As the result of the research findings analysis it was stated that there should be introduced improvement actions within the manufacturing process of rollers that allows rising the level of the product quality.

The company should pay attention to three crucial nonconformities since the research findings indicate them as the errors with the highest number of risk. Managers should analyze the nonconformities with the highest number of occurrence in the production process, what results from the production inspection realized by the laboratory staff. It is suggested, as the research findings analysis, that every employee of the analyzed steelworks should feel obliged to reveal observed nonconformities. If it is able to remove identified error, an employee should conduct a review and implement preventive measures. However, if the disclosed non-compliance is not able to remove, it should be notified to the supervisor. Managers are responsible for the removal of nonconformities. A study shows that an important role in the inadequate quality of the metallurgical rollers is played by a man with the motivation system.

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