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QUALITY MANAGEMENT OF ALUMINUM PISTONS WITH THE USE OF QUALITY CONTROL POINTS

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Abstract:
The publication analyses the way of managing and improving the quality of the production process of aluminum pistons for internal combustion engines. The aim of the article is to propose a method of analysis of the effectiveness of individual control methods used in the process of controlling the aluminium piston. Thanks to the location of a control point with the highest share of product non-compliance detection in the production process, it is possible to reduce quality control points by less effective points, which will contribute to lower costs or shorten the time of production processes. In view of the increasing demands on the efficiency of the checkpoints for components in internal combustion engines, the issue is important and topical.

Key words: *aluminum piston, non-destructive testing, production process, quality control point, quality management*

INTRODUCTION

Currently, quality control plays a very important role in modern enterprises and is one of the factors creating the principles of organisation and functioning of enterprises [14, 21]. According to the standard, quality control consists in testing the conformity of a specific product with the requirements set for it [3, 19]. The assumption of this type of control is to compare the checked features or size of the product with the corresponding sizes or features of the control apparatus [1, 2, 7, 23]. Quality control is the result of the principle that the final verifier of the product is the customer [8, 9].

In the broadest sense, quality control means that quality inspectors shall attempt to identify non-conformity of the product, the causes of non-conformity and to correct deviations from the desired condition. The purpose of quality control is to safeguard quality by preventing the customers of products that do not comply with the specified requirements or to increase the chances that the product will be free from non-conformity when it is put into service or further stages of the production process [10, 11, 16].

The aim of the article is it propose and method of analyzing the effectiveness of particular methods of quality control used in the production process of aluminium piston. After identifying checkpoints about the top stair of the detection of the disagreement in products reducing the number of checkpoints of the quality by not very effective points is possible. These activities will contribute it the reduction of costs and shortening the time of the production process. The proposed method is and useful and universal way of analysing the effectiveness of quality ctrl points, which can ugh practiced in different companies.

CONCEPT OF CHECKPOINTS

Checkpoint can be defined as a place located in the technological process, where in order to guarantee the correct course of production (in the context of product quality) it is necessary to avoid any product inconsistencies arising in a given place. In the case of non-compliance at a specific control point, the defect may result in a critical non-compliance that will affect the final quality of the product. It is important to monitor the process and related feedback, therefore, when defining the location of control points in a manufacturing company it is important to pay attention to the location of such points in the subsequent stages of the technological process. A situation where the control point is only at the exit of the finished product should be avoided, since in such a situation it will constitute the acceptance control and serves only to determine the conformity or non-compliance with technical standards of the finished products. In contrast to the final acceptance control, single control points of the technological process allow to draw attention to subsequent production processes in order to eliminate and prevent the occurrence of irregularities in the future. In addition, the identification of non-compliance immediately after the technological operation in which it arose results in separating the product from the further processing process and protecting the company from incurring unnecessary costs (further processing of incompatible product) [13, 15, 16, 17, 25, 26].

In each of the designated control points it is possible to apply quality control with a division into two types of data: numerical data or alternative data, therefore it can be stated that each quality control is a numerical control (assessment of product properties takes place on the basis of measurable characteristics) or an alternative control (assessment of properties takes place on the basis of non-measurable characteristics (or measurable, but not measured), by comparison with a standard, and then a two-stage assessment, e. g. "compliant product", "non-compliant product" or multivalent) [12, 20, 15]. A common functional quality measurement that can be used to monitor the product at almost any control point is the number of non-conformities per unit. This parameter is calculated as a ratio of the number of discrepancies to the total number of products manufactured or the number of controlled products [18, 24]. In order to reduce the value of this indicator, qualitative methods should be applied in order to solve problems arising in the production process. It is important that employees and management are aware of and oriented towards solving problems and correcting errors that may occur in internal processes, and in particular to eliminate their causes. [4, 5, 17, 22].

METHODOLOGY OF RESEARCH

The example analysed concerns the production process of a mass-produced product. The company produces pistons for internal combustion engines. During the realization of the order, at each stage of the production process, the product ordered by the customer is constantly checked for compliance with technical parameters, clearly defined in the technical documentation. The control of the process is carried out in accordance with an established control plan, which specifies in detail the scope of each control, specification of regulations and standards (on the basis of which the control should be carried out), name of the measuring instrument, acceptable deviation limits, as well as the position at which the control should be carried out and the scope of competence of the employees carrying out the control.

Depending on the stage in the production process at which the control point is determined, different testing methods and tools are used. These methods can be divided into the following groups [6]:

- X-ray examination (X-ray) – allows to detect systolic porosity, internal blemishes, discontinuity of piston material.
- Visual inspection (VT) – surface tests. The following are checked during the test: material discontinuities of the whole piston surface, discontinuities of mechanical treatment (injuries, cracks) on the whole piston surface, appearance of the piston surface after phosphating, appearance and distribution of the graphite surface, chips in the ring ducts, width of the insert above and below the canal, permeability of the cooling channel, marking of compatible pistons.
- Ultrasonic testing (UT) – allows to detect faulty adhesion of elements inside the piston structure (alphin inserts).
- Dimensional inspection – allows you to check, among others: compression dimension from the upper edge of the hole, diameter and perpendicularity of the pin hole, depth of the chamber from the hole axis, spacing of securing grooves, as well as the diameter of the binder.
- Eddy current (ET) testing – allows to identify the presence of material defects on the surface of the piston combustion chamber, as well as on the surface of the bolt hole.
- Penetration testing (PT) – allows to detect surface discontinuities.

SUBJECT MATTER

The subject of the research was a piston intended for diesel engine – diesel engine, used in passenger cars. The subject of research is shown in Figure 1. Pistons are produced in one of the plants in the south of Poland.

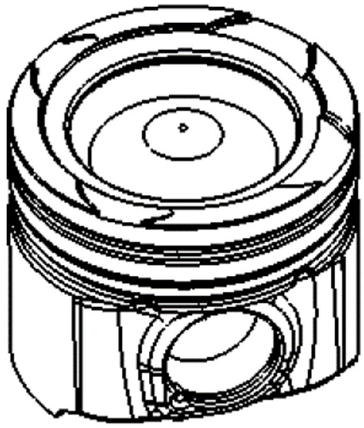

Fig. 1 Subject of the tests – diesel piston model
Source: [6].

RESULTS OF RESEARCH

In order to analyze the relation between the frequency of inspections during the detection of piston inconsistencies and the share of detected inconsistencies in the first step, the analysis of detected inconsistencies of aluminium pistons in the period of 2 quarters was carried out. The result of the analysis of product nonconformities together with the division of specified nonconformities, taking into account the frequency of occurrence of up to 3 groups: A – critical, B – important, C – less important and identification of quality control methods, type: P – measurement and X-ray – X-ray examination, UT – ultrasonic examination, VT – visual inspection, ET – eddy current testing, PT – penetration testing and KL – numerical inspection and KA – alternative inspection used to detect them, are presented in Table 1.

Based on the data from Table 1, a Pareto-Lorenz diagram was developed (Fig. 2) in order to identify the so-called critical incompatibilities (from group "A") in terms of frequency of their occurrence.

Table 1

Types and number of inconsistencies of piston casting during the period considered

Lp.	Name of non-conformity f the product (NW)	Percentage share (UP)	Cumulative value (WS)	Group NW	KJ method Detection NW P; RTG; VT; ET; PT; C; KP; KW	KL; KA
N1	Presence of radii on piston casing in canals stress	36.6%	36.6%	A	RTG	KA
N2	Presence of oxides in the piston casing area	22.9%	59.5%	A	RTG	KA
N3	Material discontinuity in the piston combustion chamber	10.5%	70.0%	A	ET	KA
N4	Inappropriate combination of alpha-numeric inserts	6.4%	76.4%	A	UT	KA
N5	Graphotated surface covered with craters (orange peel effect';)	5.0%	81.5%	B	VT	KA
N6	Graphite stains	4.1%	85.6%	B	VT	KA
N7	Seepage on the annular part after anodising	4.1%	89.7%	B	VT	KA
N8	Linear material separation	2.7%	92.4%	B	VT	KA
N9	Non-continuous material in the bolt hole	2.3%	94.7%	B	PT	KA
N10	Incompatibility of bolt hole dimensions	1.8%	96.6%	C	P	KL
N11	Material discontinuities in the area of the cast iron insert connection with the piston material	1.4%	97.9%	C	PT	KA
N12	Inadequate pocket depth	1.1%	99.1%	C	P	KL
N13	Presence of systolic cavities	0.9%	100.0%	C	RTG	KA

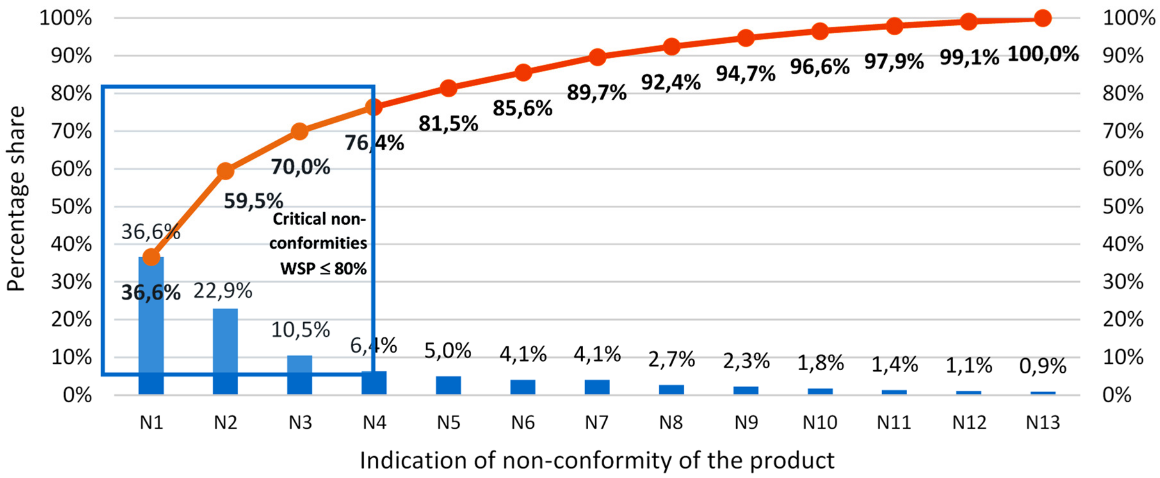

Fig. 2 Pareto-Lorenz diagram for incompatibility of aluminium pistons

Critical incompatibilities of aluminium pistons of group ”A”, are 4 incompatibilities with the 13 specified, i. e. presence of radishes on the piston casing in the canals stress (N1), presence of oxides in the piston casing area (N2), material discontinuity in the piston combustion chamber (N3) and discontinuities in the area of the cast iron insert connection with the piston material (N4). They account for 76.4% of the quality problems identified. All nonconformities from group “A”, are detected with the use of non-destructive testing (X-ray, eddy current, penetration testing).

DISCUSSION

The results of the research of the occurrence of control methods in the aspect of quality in the detection of non-conformity of the product and the share of detected non-conformity with these methods are presented in Table 2.

Table 2

Analysis of the relation between the share of control and detected non-conformity of the product

Quality control method (symbol)	Application of quality control upon detection of product non-conformity	Detection of product non-conformity by quality control method
P	15.38%	2.97%
RTG	23.08%	60.41%
VT	30.77%	16.02%
ET	7.69%	10.53%
PT	23.08%	10.07%
Total	100.00%	100.00%
KL	15.38%	2.97%
KA	84.62%	97.03%
Total	**100.00%**	**100.00%**

The results of the relation analysis (Table 2) were illustrated by means of a matrix chart (Fig. 3). The area of the graph has been divided into quarters showing the relationship between the application of a specific control method for the detection of non-conformity and the share of detected non-conformity of the product analysed by a certain quality control method (Fig. 3). Visual (visual) inspection was the most frequent method of quality control (4 out of 13 cases; 30.77%), while the method detecting the most discrepancies was X-ray examination (60.41%).

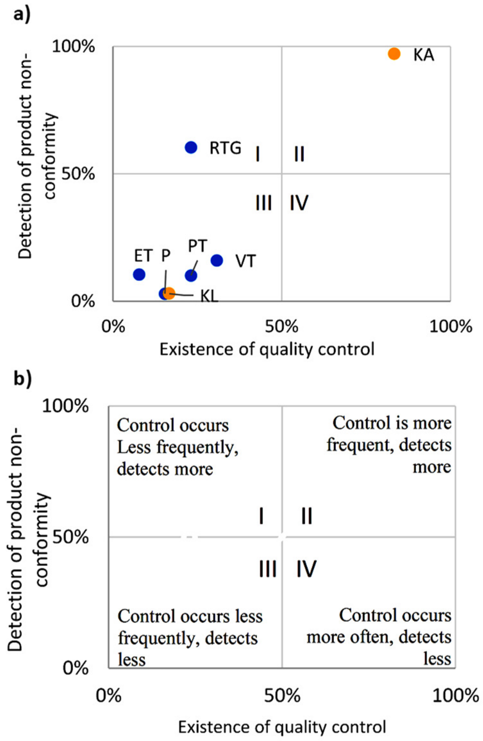

Fig. 3 Matrix diagram showing the relation between the share of quality control methods and the share of detected discrepancies a) result of analysis, b) overview diagram

A numerical check took part in 15.38% of cases of non-compliance and detected 2.97% of all non-compliances analysed. The alternative control was used to detect 84.62% of cases of non-compliance and 97.03% of non-compliance.

– The conducted analyses of product quality control allowed to divide the quality control methods of product non-compliance detection into the following groups:
– I – methods with a relatively low share of product non-compliance detection and a relatively high significance of non-compliance: X-ray inspection;
– II – methods with a relatively high proportion of product non-compliance detection and a relatively high proportion of non-compliance: alternative control (KA).
– III – methods with a relatively low share of non-compliance detection and relatively low significance of non-compliance: measurement (P), ultrasonic (UT), eddy current (ET), penetration (PT), visual inspection (VT), numerical inspection (KL);
– IV – methods with a relatively high proportion of non-compliance detection and a relatively low proportion of non-compliance: none of the control methods.

A number of percentages of detected aluminium piston non-conformity by quality control methods are shown in Formula 1:

$$RTG > VT > ET > PT > P \quad (1)$$

According to formula (1), the highest number of discrepancies (60.41%) is detected at the quality control point where the X-ray examination takes place. A significant number of detected non-conformities of the product may be caused by a low level of castings quality (the first production process of the product).

In the analyzed company, the important criteria that influence the creation of the ranking concerning the effectiveness of applied methods in control points (formula 1) include: accuracy of the survey, time of the survey, level of expected savings and flexibility of the method.

CONCLUSION

The paper presents the results of the analysis of relations between the share of quality control methods, i. e. measurement, X-ray, ultrasonic, eddy current, penetration, visual inspection, numerical inspection and alternative inspection, occurring in the process of detecting the incompatibility of the tested workpiece – aluminium piston, and the share of incompatibilities detected, at control points, by specific control methods.

The presented concept of quality analysis does not only refer to the causes of non-compliance and their elimination, but also to the monitoring of the effectiveness of control points in manufacturing companies. This approach makes it possible to identify control methods that detect non-conformities of relatively high significance. By locating the highest percentage of detection of a specific control method when detecting product inconsistency in the production process, it is possible to reduce quality control points by less effective points. Methods with the lowest rate of detection of non-conformity of a product may be transformed from 100% inspection of products to sampling alternative method, which will allow to reduce costs while maintaining a comparable level of detection of non-conformity of products and shorten the production process of the product.

To sum up, it is worth stressing that we should still strive to ensure that all the works carried out are carried out correctly the first time. This will avoid or minimize the costs associated with the need for a significant number of quality control points, error correction, remachining or even deletion of parts.

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