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Improving the Non-Destructive Testing Process of the Outer Bearing Ring

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Abstract. The aim was to identify the unconformities in the product with the magnetic-powder method and extension of the analysis process about selected quality management techniques in order to identify the root of unconformities. The product subject to magnetic-powder testing was the outer ring of the four-point ball bearing. On the product, the cracks were identified, so in order to point to the root of unconformities, the techniques like Ishikawa diagram and the 5Why method were implemented. Analyses showed that the source of the cracks on the outer bearing ring was defective material from the supplier. The proposed process of using quality management techniques together with non-destructive testing can be used in any enterprise to detect the unconformities of the products and the reasons for their creation.

Introduction

Performing quality analysis of the products is a key stage in the product creation and improvement process. An important part of the quality analysis has non-destructive tests (NDT), which allow identifying the nonconformities of the product without its destructive [1]. It is very important in case of the mechanical products; which production is expensive. Although the NDT is effective in identifying nonconformities of the product, they don't indicate the root cause of nonconformities [2, 3]. So, improving the process of the NDT about the techniques which allow identifying the root of unconformities is a challenge for enterprises. A review of the literature on the subject indicates that the improving process of NDT research used other methods of research, simulations, and industrial robots [4-8] and moderated the substances, equipment, and test parameters used in NDT research [9-11]. Also, a few NDT methods in one research were used [12-14]. However, in this research, after detecting unconformities, no activities were performed to identify the source of the unconformities. Only focused on the effective identify the unconformities by NDT methods, but not a complex analysis of the problem. Therefore, it was purposeful to improve the non-destructive testing process by using quality management techniques in order to identify the source of unconformities. The problem lack of identifying the root of unconformities detected by NDT methods efforts was made in an enterprise located in south-eastern Poland.

In the enterprise, the unit control of the product with NDT methods (magnetic-powder and fluorescent) was made. In view of unit control of research after identifying the unconformities the additional analyses in order to identify the root of the problem were not made. This was due to the fear of time-consuming analyzes for a large number of different types of unit products. The results of NTD research showed repeated types of unconformities (including cracks), the

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number of which increased. However, in the enterprise, the quality analyses in terms of the type of unconformities not taken into account, because only the unit character of testing products was focused. Therefore, it was considered appropriate to extend the product analysis process by implementing quality management techniques for the types of unconformities identified. The aim was to identify the unconformities on the product with used the magnetic-powder method and extension of the analysis process about selected quality management techniques in order to identify the root of unconformities. The tested product was the outer ring of the four-point ball bearing. At the request of the client, the product was tested using the magnetic-powder method, after which the unconformities (cracks) were identified. In order to identify the root of cracks, the process of analysis of the product was expanded to the Ishikawa diagram and 5Why method. The main causes of the problem were selected by the Ishikawa diagram. These causes were analyzed by using the 5Why method and pointed out the root of the problem which was defective material from the supplier.

Material and Method

The outer ring of the four-point ball bearing was analyzed. Choice of product to analysis was conditioned by individual preferences of quality control manager, who claimed that earlier research made on these types of products showed different unconformities, mainly cracks. The outer ring of the four-point ball bearing was made from 418 alloy (i.e. 5616). It is a chrome-tungsten-nickel stainless steel alloy that is used for products subjected to heavy loads up to 649 °C. The outer ring of the four-point ball bearing as well as ball bearings in general is applicable in virtually every technical field, for example automotive, machinery, and light industry [15]. So, improving the NDT process on the basis of the outer bearing ring has considered important.

In the enterprise, the research was made with used NDT methods – fluorescent and magnetic-powder methods. The selection of methods for the tested products depended on individual customer requirements and the type of material. In the case of the analyzed product (outer bearing ring) the outer customer ordered to carry out analysis with the magnetic-powder method, which was adequate because this method has been applied to ferromagnetic products. This method has been applied to ferromagnetic material [16]. It consists in applying magnetic powder and inducing magnetic flux in material discontinuities [17]. The magnetic-powder method is considered the most sensitive, reliable, and efficient NDT method. In this method, color and fluorescent techniques are used. This method has been applied for example in the aviation, automotive, and foundry industries [18, 19].

The research was carried out with a MAG 50 magnetic flaw detector. This detector was powered by rectified 3-phase alternating current. The cleanliness of the product was checked (after washing operation and eventually magnetic residue). On the MAG 50 the destination of current flow and magnetic field force lines were set at 17 kJ. After fixing the product in the detector, the surface of the product was poured with magnetic suspension (Chemetall – MPI Diluent (HF)). Three magnetic pulses turned on (current 1600 A, time 0.5 s). The first and second magnetic pulses were turned on at a time when on the product the magnetic suspension was poured and the third without poured. These actions were repeated three times (every 120 s). Contact field value in magnetic time was measure and it was ≥ 2.4 kA/m. The product was demagnetized after inspection and the results recorded. On the outer bearing ring, the cracks were identified. Because, the root cause of the problem was not known, further analysis was made. In order to identify the potential causes of the problem, the Ishikawa diagram was prepared.

Techniques implemented in NDT process were Ishikawa diagram and *5Why* method. The choice these techniques to improving the process of NDT was conditioned their effectiveness in identifying the root of the problem. Added, these methods are simple in realization and not expensive. Application these methods in a sequence way allow finding the potential, main and root causes of the problem [2, 3, 20].

Ishikawa diagram is called a fishbone diagram or causes and effects diagram. Allows to graphic presentation the problem and causes which has influence on its uprising. The division of causes into categories helps in the analysis of the problem. Basic categories are rule 5M+E, i.e. method, machine, material, man, management and environment. Using this diagram to identify potential causes of the problem, among which the root causes can be selected [2, 21-23]. In the central part of the diagram, the problem (cracks) was noted. From main categories (5M+E) were selected: man, method, material, management and environment. Category like method was omitted, because it did not apply. To these categories the potential causes of cracks were noted. The main causes of the problem were selected and analyzed by *5Why* method.

The *5Why* method otherwise called *Why-Why* diagram has applies to identify the root of the problem. Analyzing the problem using the 5Why method is to ask the question "why?". The end of method is when the answer is exhausted and the source of the problem is found. The *5Why* method allows taking actions adequate to the root of problem in order to eliminate or minimalize the problem [3, 24]. It was started from the problem and main causes (pointed by Ishikawa diagram). The "Why?" question was asked sequentially until the root cause of the problem was identified. After identified the root cause of the problem (defective material from supplier) the improvement actions were proposed.

Results

After the magnetic-powder testing on the outer bearing ring the unconformities were identified (cracks), an example of which is shown in Fig. 1.

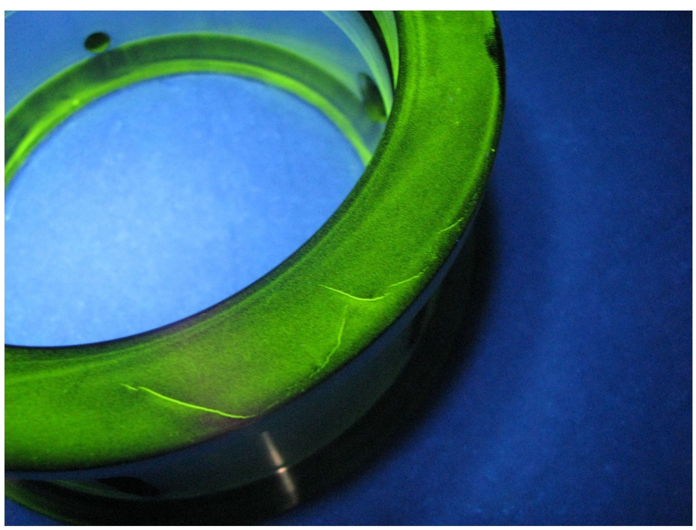

Fig. 1. *Cracks on the outer bearing ring.*

Next, in order to show the potential causes of the cracks problem on the outer bearing ring the Ishikawa diagram was prepared, which is shown in figure 2. The main causes of the problem were selected, i.e. defective material and lack of knowledge about material supplier. In order to identify the root cause of cracks the 5Why method was made, which is shown in figure 3. The root cause of the problem was defective material from the supplier. The improvement action was informed the customer about the root cause of the problem.

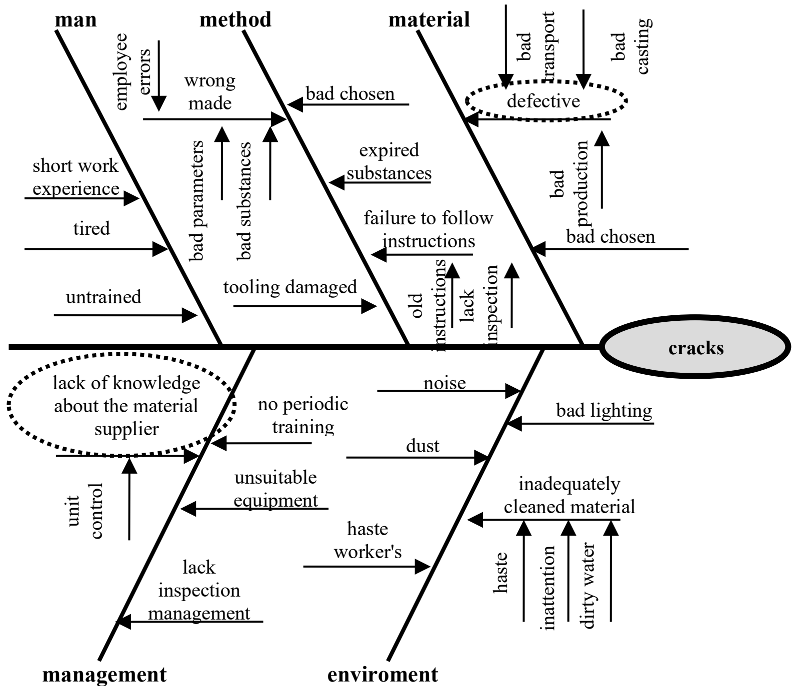

Fig. 2. The Ishikawa diagram for the cracks problem on the outer bearing ring.

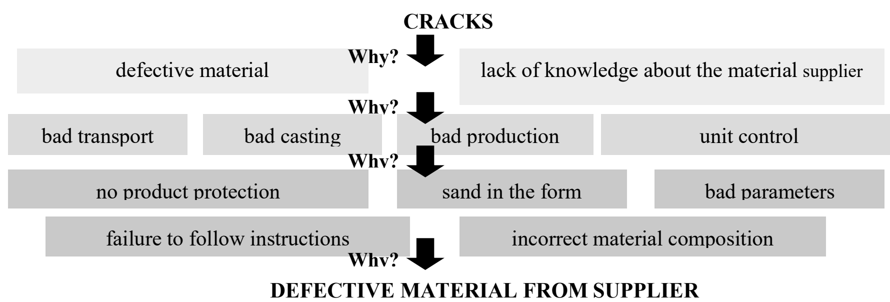

Fig. 3. The 5Why method for the cracks problem on the outer bearing ring.

Summary and Conclusion

Making the effective quality control of the product allows developing the product, enterprise and satisfaction of the customer. The desire to improve the process of NDT research has been demonstrated by an enterprise located in south-eastern Poland. In the enterprise the quality management techniques i.e. Ishikawa diagram and *5Why* method were implemented after NDT research. The aim was to identify the unconformities on the product with used the magnetic-powder method and extension of the analysis process about selected quality management techniques in order to identify the root of unconformities. The outer ring of the four-point ball bearing was analyzed. By the magnetic-powder method, the cracks on the product were identified. Expanding the process of NDT analyze the Ishikawa diagram was used, by which the main causes of the cracks were selected, i.e. defective material and lack of knowledge about the material supplier. Next, used the *5Why* method, which showed the root cause of unconformity i.e. defective material from the supplier. The proposed process of using quality management techniques together with non-destructive testing can be used in any enterprise to detect unconformities of the products and the reasons for their creation.

Non-destructive testing methods [25] are very important in many areas of research (special alloys [26], implants [27], tribological tests [28], welding [29] and biotechnology [30]) and industrial production (special coatings [31, 32], laser surface treatment [33, 34], machine regeneration [35], power hydraulics [36, 37], steel industry [38]), so the presented method may be inspiring for many recipients. Regardless, it is a development impulse both for the methods of experimental data analysis [39-41] and for the analysis of possible failure scenarios [42].

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