Improving the Non-Destructive Test by initiating the Quality Management Techniques on an Example of the Turbine Nozzle Outlet

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Abstract. The NDT methods are an effective way to make a quality analysis of the product, mainly in the case of the aviation industry. However, although these studies effectively identify unconformities, they do not indicate the source of their occurrence. The aim was to analyze the quality of the product (turbine nozzle outlet) using the fluorescent method and identify the root of the unconformity by using the quality management technique sequence. The Ishikawa diagram and the 5Why method were the techniques used in the study and the turbine nozzle outlet made from 410 steel was its subject. The product using the fluorescent method was analyzed, after which the unconformity was identified (porosity cluster). By using the Ishikawa diagram, the potential causes were identified, from which two main causes were selected (molding sand and errors during production). The 5Why method was used, by means of which the root cause was identified - it was a faulty material form a supplier. On the example of the fluorescent method, it was shown that using the non-destructive test (NDT) in a sequential way with quality management techniques (Ishikawa diagram and 5Why method) allows for making a complex quality analysis of the product and identifying the root of eventual unconformity. The proposed technique sequence (fluorescent method, Ishikawa diagram and 5Why method) can be applied to analyze other products and other unconformities in production and service enterprises.

Introduction

Creating the quality of products required by the customer initiates the need for comprehensive qualitative analyses [1, 2]. It is very important in the case of the production and aviation industry, in which using the non-destructive test (NDT) is the main way to identify unconformities. These tests allow for identifying the unconformity without destroying the product [3]. One of the NDT methods is the penetration method, which includes the fluorescent method (FPI). This method applies mainly to aviation products [4]. Also, with the FPI method the tests were performed on the analyzed product (turbine nozzle outlet). A literature review of the selected literature positions shows that the fluorescent method was used in testing the quality of a product surface [5, 6] and detecting nonconformities that are the basis for further analysis [7]. Its efficiency was improved by using additional machines, substances [8] and was compared with other methods [9]. It was concluded that the area of NDT practice with quality management techniques, in order to identify the root of pointed unconformity is not sufficiently discussed. Therefore, it was important to show that using the NDT method in a sequential way (on the example of the fluorescent method) with quality management techniques (Ishikawa diagram and 5Why method) allows for making a complex quality analysis of a product and identifying the root of eventual unconformity. Improvement of the NDT process is very important in the case of developing enterprises because, for these enterprises, it is not enough only to identify the unconformity, but they also need to identify their root. The proposition of the improvement of the NDT process on the fluorescent method in an enterprise localized in south-eastern Poland was made. In the enterprise, the non-destructive test was used, i.e. magnetic-powder and fluorescent method. After identifying the unconformity, the root cause of creation was not analyzed. In order to increase the effectiveness of the product analysis, application of the NDT with the Ishikawa diagram and the 5Why was proposed. The aim was to analyze the quality of the product (turbine nozzle outlet) using the fluorescent method and identify the root of the unconformity by using the quality management technique sequence. These techniques were the Ishikawa diagram and the 5Why method. By means of the fluorescent method, the unconformity (porosity cluster) was identified. By means of the Ishikawa diagram, the potential causes were identified, from which two main causes were selected, i.e. molding sand and errors during production. In the last step of the analysis, the 5Why method was used, by means of which the root cause was identified (it was the faulty material from the supplier). It was shown that using the NDT method in a sequential way (on the example of the fluorescent method) with quality management techniques (Ishikawa diagram and 5Why method) allows for making a complex quality analysis of the product and identifying the root of eventual unconformity.

In general, combining NDT methods with root cause analysis can be a very useful procedure also in other industrial areas, including mechanics [10, 11], hydraulics of working machines [12], heat flows [13], as well as diagnostics of modified surfaces [14, 15], including plasma-sprayed coatings [16] or electro-spark deposition ESD combined with laser machining [17, 18]. This approach may also be useful in the biotechnology industry [19, 20], where the cause-effect relationships of the processes are very complicated due to numerous feedbacks and the occurring circular processes. The inference scheme resulting from this approach should be taken into account in related data analyzes, e.g. stereological [21, 22] and statistical [23, 24].

Material

The turbine nozzle outlet, used in the aviation industry, was the subject of the research. The choice of object for the analysis was determined by the type of unconformity that was identified on the product by the fluorescence method (cluster of porosity). In the enterprise, a large number of these types of unconformity (porosity cluster) existed. That is why it was decided that it is preferred to make the analysis of this type of problem. The turbine nozzle outlet was made from 410 steel. It is a martensitic chrome stainless steel resistant to corrosion [25, 26]. Martensitic steels are used to manufacture structural elements [25, 27]. They are characterized by excellent mechanical properties and good corrosion resistance. Selected properties of 410 steel are shown in the subject of the literature [25, 27, 28].

Method

Product testing (turbine nozzle outlet) was carried out using the fluorescence method (FPI), due to the requirements of the customer who commissioned the product analysis using this method and the material from which the product was made. The fluorescent method allows for identifying the unconformity, in turn, the technique sequence i.e. the Ishikawa diagram and the 5Why method allow for pointing the root of unconformity. Therefore, it is effective to make the quality analysis of the product (identify the unconformity and root of the unconformity) by the connection of the NDT methods with quality management techniques [29-31]. The fluorescent method is one of penetrant tests. In FPI, a penetrant has colorant, whose indicators can be identified by ultraviolet radiation. To make this possible, it is necessary to darken the test stand [29, 32]. The methodology of conducting fluorescence research was presented in the literature [29]. By using the FPI method, the unconformity was identified (porosity cluster), and in order to identify the root of this unconformity the sequence of the Ishikawa diagram and 5Why method were used. The Ishikawa diagram (fishbone diagram) is a technique, by means of which it is possible to analyze the problem, and next point the potential causes and select the main causes [2, 33, 34]. For the analysis of the problem with the cluster of porosity on the turbine nozzle outlet, the problem was noted in the main part of the Ishikawa diagram. The main categories of Ishikawa (5M+E), which applied to this problem, were selected for its analysis. They were the following: man, method, material, machine, management and environment [1, 29-31]. To each of the categories, the intermediate causes were noted, from which the main causes were selected. Next, the analysis of the problem using the 5Why method was made. The 5Why (Why-Why method) is an effective way to identify the root cause of the problem. In the first step, the problem (porosity cluster) and the main causes of the problem were pointed. Next, the „Why?" question was made in a sequential way. The end of analysis was at the moment when the answer pointed that it was possible to make the improvement action, adequate to the problem [1, 2, 29, 31, 35]. After identifying the source of the problem, improvement actions were proposed.

Results

The quality of the turbine nozzle outlet was analyzed using a fluorescent method. After the analysis, the unconformity was identified (porosity cluster), which is shown in Fig. 1.

Fig. 1. The cluster of porosity on the turbine nozzle outlet.

The problem (porosity cluster on the turbine nozzle outlet) was analyzed using the Ishikawa diagram, which is shown in Fig. 2. From the potential causes shown in the criteria (5M+E), two causes were selected, i.e. molding sand and errors during production. In order to identify the root of the problem, the next analysis was made using the 5Why method shown in Fig. 3. It was concluded that the root cause of the porosity cluster on the turbine nozzle outlet was the faulty material from the supplier. The improvement actions, which were made in order to eliminate or minimalize the cause of the problem (porosity cluster) are to inform the customer about the root cause.

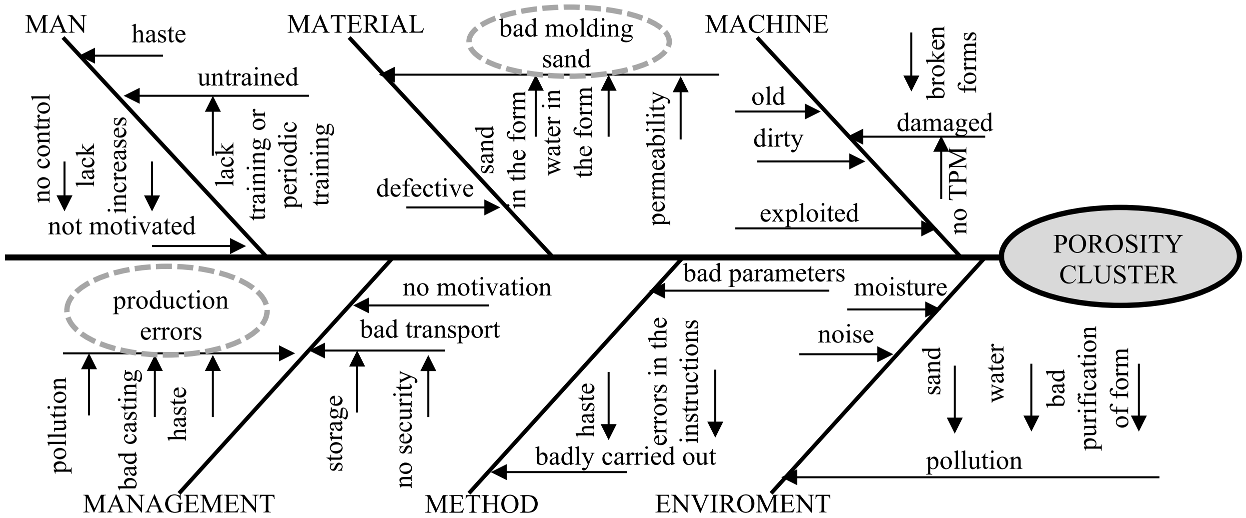

Fig. 2. The Ishikawa diagram for the porosity cluster on the turibne nozzle outlet.

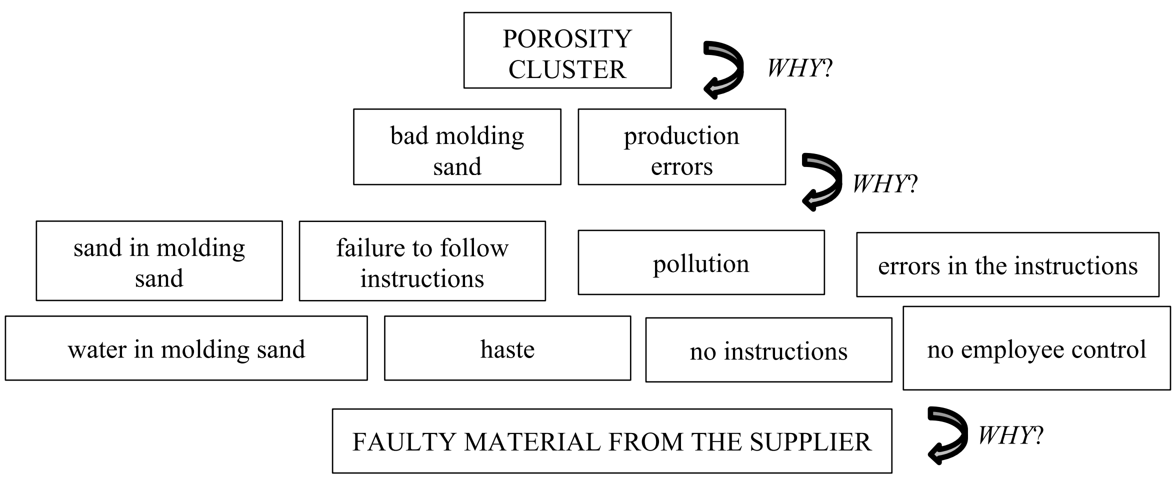

Fig. 3. The 5Why method for the porosity cluster on the turbine nozzle outlet.

Summary

The NDT methods are an effective way to make a quality analysis of the product, mainly in the case of the aviation industry. However, although these studies effectively identify unconformities, they do not indicate the source of their occurrence. Therefore, it is purposeful to improve the non-destructive testing process by initiating quality management techniques. This was done in a production and service enterprise located in south-eastern Poland. The aim was to analyze the quality of the product (turbine nozzle outlet) using the fluorescent method and identify the root of the unconformity by using the quality management technique sequence. These techniques were the Ishikawa diagram and the 5Why method which, when used in a sequential way, allow for making an effective analysis whose results show the root cause of the problem. A turbine nozzle outlet made from 410 steel was the subject of the study. The problem (porosity cluster) was identified using the FPI method. By using the Ishikawa diagram, the potential causes of the problem were identified, i.e. bad molding sand and production errors. By using the 5Why method the root cause of the problem was identified – faulty material from the supplier. The improvement actions, which were made in order to eliminate or minimalize the cause of the problem (porosity cluster) are to inform the customer about the root cause. It was shown that using the NDT in a sequential way (on the example of the fluorescent method) with quality management techniques (Ishikawa diagram and 5Why method) allows for making a complex quality analysis of the product and identifying the root of eventual unconformity. The proposed technique sequence (fluorescent method, Ishikawa diagram and 5Why method) can be applied to analyze other products and other unconformities in production and service enterprises.

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