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IMPROVING THE QUALITY OF THE PRODUCT USING NON-DESTRUCTIVE TESTING AND SELECTED QUALITY MANAGEMENT INSTRUMENTS

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Abstract: Effective quality management of the product is an element that allows profit within the enterprise. Identifying unconformity and establishing their source enables quality. However, identifying unconformity is sometimes neglected. Such was evident in the analysis of the service-manufacturing enterprise located in Podkarpacie. In the enterprise, quality was assessed via non-destructive testing (via fluorescence), but decisions on sources of non-compliance were made without utilizing additional methods that allow source identification. Hence, the way of recognizing unconformity was not precise. Therefore, method sequence (Ishikawa diagram and 5Why method) approaches were proposed to enable this. The aim of this paper is to show the effectiveness of such approaches in identifying sources of unconformity. The subject of study was tubing that is used in aircraft engines. Via the applied analysis, the unconformity in production and the source cause was traced to material supplied from outside. The proposed method sequence approach can be used in other enterprises for quality analyses purposes.

Keywords: quality, incompatibility, penetration method, Ishikawa diagram, 5Why.

1. Introduction

The transport industry, and, in particular, the aeronautics industry is continuously applying new solutions in the area of material engineering and is constantly expanding the range of fabrication materials used. Hence, the wide range of materials used in aircraft technology, including composite materials and metal alloys (Deo, Starnes, Holzwarth, 2001), requires the adaptation of testing methods to the materials used and to the stage of control of the manufactured elements (Krysztofik, Manaj, 2011).

A model solution to the issue of assessing the condition of products is the application of non-destructive testing, the performance of which does not affect the condition of the controlled structure, and at the same time tests can be performed any number of times. This applies to production quality control practiced at the stage of components and parts manufacture and to operational tests carried out on aircraft during routine inspections or after emergency situations (Sikora, Chady, 2016; Onoszko, 2012). The non-destructive testing in aircraft technology is particularly important due to the low values of safety factors determined in the process of designing composite aircraft structures (Krysztofik, Manaj, 2011; Belzowski, Rechul, 2005; Mackiewicz, Góra, 2005). The application of non-destructive testing is mainly driven by safety considerations and the economic aspect of the occurrence of an unforeseen failure. These issues are an important aspect because the more responsible a supplier is, the more acute the effect of a supplied component failure (Zientek, 2016).

The problem that arose in a service-manufacturing enterprise localized on Podkarpacie was finding a way of identifying the source of product unconformity. In this enterprise, the fluorescent dye method was used as quality control check. Mainly, the concern practiced unit control. From this reason, after identifying the unconformity, decision about unconformity source was made on assumption, not science. The need to identify unconformity source still existed and therefore method sequence approaches such as Ishikawa diagram and 5Why method were proposed. These methods are complementary and applying them in sequence enables the tracing of unconformity sources.

The subject of study was tubing used in aircraft engine manufacture. In the enterprise, the unit control was practiced and data on nonconformity was not gathered. After application of method sequencing the source of unconformity was traced to the material supplied by an outside supplier.

2. Quality control

An important approach to quality identification and at the same time a key one, mainly in the field of industrial product supply, is the division of the notion of quality into three components: design quality, workmanship and operational quality. It must be underlined, however, that component specifications must be fulfilled at the same time in order for such items to be considered to be of quality (Gudanowska, 2010; Łunarski, 2012; Wolniak, Skotnicka-Zasadzień, 2010). At the stage of product realization (production process), the importance of quality assurance is gradually reduced and quality control becomes more important – including quality control and correction. At this stage, the design quality is transformed into the quality of workmanship in manufacturing processes. The aim of these activities is to achieve the highest possible degree of consistency between design quality and production quality (Dziudziak, Stoma, 2012). Therefore, component manufactories strive for effective practices that lead to continuous improvement of departmental operations and organizational culture. To this end, companies are currently implementing traditional Lean tools such as: Pareto-Lorenza charts, Ishikawa charts (cause and effect diagrams), as well as new tools such as matrix diagrams, 5xWhy and quality management methods (brainstorming) (Stadnicka, 2016).

Quality control is generally accepted as one of the first milestones in the development of a quality management concept. Its beginnings relate to the period of the second industrial revolution of the late nineteenth and early twentieth centuries, when the rapidly progressing productivity of work did not match the quality of the goods produced, and a significant amount of defective items were produced. These often had to be swiped out, which generated additional costs. In an attempt to limit this, the previously unknown position of controller was introduced in the industry. The task of this individual was to ensure that production factories produced goods of acceptable quality. Such quality control was a kind of quality assurance (Lisiecka, 2002; Drummond, 1998; Ahsen, 2008).

Currently, quality control is extremely important and is addressed in the organizational charts of company hierarchy (Bielski, Drozd, 2016). In accordance with the standard, quality control consists in examining the conformity of the performance of a specific product with the requirements set for it (PN-EN ISO 22000:2006 Food safety management system). The assumption of this type of control is to compare the tested characteristics or product size with appropriate standards (Karaszewski, 2005; Kolman, 2007; Łunarski, 2012; Urbaniak, 2004). Quality control is the result of the adopted principle that the final verifier of the product is the customer (Lisiecka, 2002; Zymonik, Hamrol, Grudowski, 2013).

In the broadest sense, quality control means that quality controllers try to detect product nonconformities, find their source and correct deviations from the desired condition. The task of quality control is to secure quality by preventing products that do not comply with specific requirements from being placed on the market or by increasing the chances that a product will be free from non-compliance at the time of putting it into service or through further stages of the manufacturing process (Kolman, 1998; Vogt, Kujawińska, 2013; Brzeziński, 2013).

3. Method

3.1. Non-destructive testing - penetration method

Quality control is of particular importance in aeronautical engineering, where a potential accident can lead to serious consequences, even disaster. In aviation, the penetration method is often used to verify the condition of products.

When a defect is present in a material, it can be made visible if a liquid penetrant is sucked into the disconformity if it exists in the form of a crack (Lovejoy, 1991; Lewińska-Romicka, 2001; Zientek, 2016).

The penetration test consists of several sequential operations. The first step is to prepare the surface to be tested by cleaning it with sand or brush. For more delicate surfaces, pressurized washers or steam are used. The next step is to apply the penetrant. If it is not possible to immerse the object in the penetrant, it is applied electrostatically or with a brush or by aerosol. When the liquid penetrates into the gaps of the workpiece, its excess should be removed and the surface should be dried. The test surface shall then be covered with the developer. This substance contrasts with the penetrant, which causes the disclosure of places and size of non-compliance. The irregular shapes thus made visible correspond to the discontinuities underneath (Borowiecka-Wilczyńska, 2007; Makowska, Kowalewski, 2015; Borowiecka, 1998; Ładecki, Knysak, 2018).

Depending on the type of penetration liquid used, three test techniques are distinguished. Color technology uses fluids to achieve high sensitivity. The resulting red image contrasts with the white background of the developer. Another technique uses a fluorescent penetrant, which is visible under the influence of UV rays. The third technique is a color-fluorescent technique, which combines two previous techniques. The obtained image is visible under visible light and UV radiation (Lewińska-Romicka, 2001; Fidali, Jamrozik, 2013).

3.2. Quality management tools - Ishikawa diagram, 5Why method

Effective improvement requires the use of numerous quality management tools and methods. The intent is aimed at reducing waste, improving competitiveness, as well as improving the processes carried out in the company (Wolniak, 2013).

The Ishikawa diagram is a graphical presentation of the analysis of the interrelationship of causes of a specific problem. The purpose of the diagram is to identify the causes of incurred or potential failures of projects. The causes can be identified in such areas as: management, man, method, machine, material and environment (Star, 2005; Sęp et. al., 2006). This tool is applied when there a complex problem is encountered and there are many potential causes of it. The following stages in the construction of the Ishikawa diagram can be distinguished: identification of the problem, initiation of work on the diagram, determination of the main groups of causes, specification of the diagram (Pacana, 2017; Hamrol, Mantura, 2008).

However, the Ishikawa diagram shows only the potential causes of the problem. In order to draw appropriate conclusions and identify the root cause of the problem, the diagram should be analyzed. A tool to facilitate this task is the 5Why analysis (Stadnicka, 2016).

5Why analysis is a simple method used to identify the root causes of the problem (Antosz et. al., 2015) in order to eliminate them and prevent the recurrence of the problem. Despite the simplicity of this method, it is sometimes incorrectly applied. The main mistake made during the analysis is the identification of causes that are beyond control. This can include weather or lack of financial resources (Stadnicka, 2016).

4. Material

Material AMS4439 is a proven magnesium casting alloy containing zinc, rare earth elements and zirconium (Table 1). This magnesium alloy of relatively medium strength and used in T5 conditions, is ideal for casting products of high integrity that are designed to operate at ambient temperatures or up to 300°F. In addition to the excellent casting specificity, AMS4439 alloy is also airtight and weldable (https://weldingwarehouseinc.com/products/magnesium-alloys/ze41/).

Table 1.
Chemical composition limits of AMS4439 material

Weight %	Zn	Rare Earth Total	Zr total	Mn	Cu	N	Other	MG
Magnesium Alloy AMS 4439	3.5-5.0	0.75-1.75	0.4-1.0	0.15 max	0.10 max	0.01 max	0.30 max	Balance

Source: https://www.aircraftmaterials.com/data/magnesium/ze41.html.

5. Results

After the product (tube) was analyzed via non-destructive testing (the fluorescent method), the unconformity was identified as being linear striations about size 3,2 mm (Figure 1).

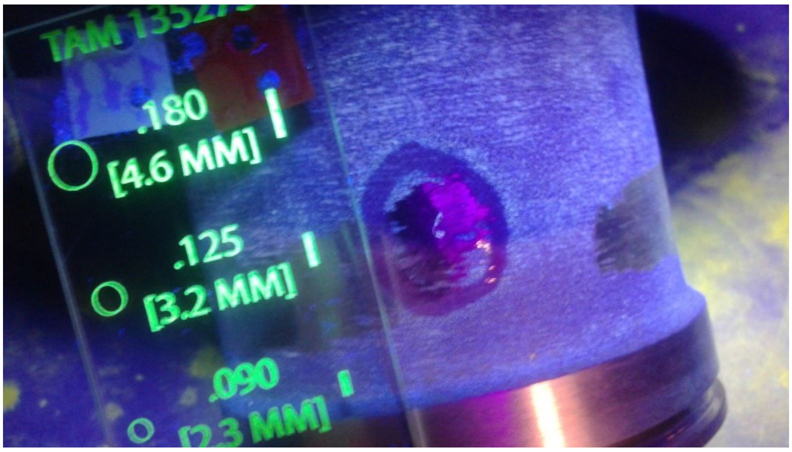

Figure 1. The unconformity (linear striation) in the supplied material.

In order to identify the source of the unconformity, Ishikawa diagram and 5Why method were applied sequentially. The working group to address the issue consisted of the quality control manager, a quality control employee, the employee performing the fluorescent test and the employee who accepts orders from suppliers. Via brainstorming, an analysis of the causes of linear striations on the tubing in question was made. By way of the Ishikawa diagram (Figure 2), the potential cause of the unconformity was identified. This was unconformity in production. In order to identify the source of the problem, the 5Why method was then applied (Figure 3). It was concluded that the source of the problem was unconformity of material from the product supplier, who, once informed, addressed the problem.

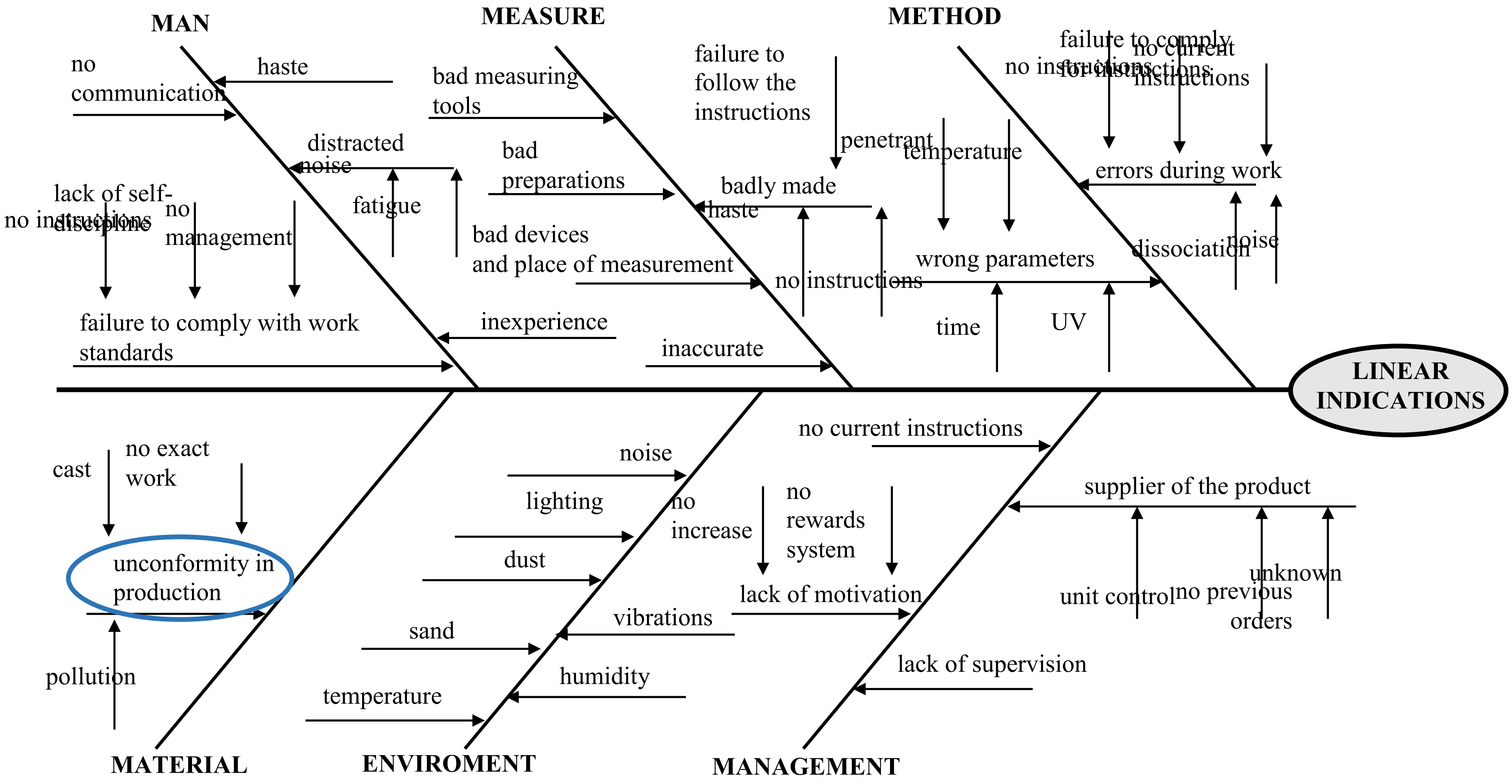

Figure 2. Application of Ishikawa diagram methodology for identifying reason of manufacturing defect.

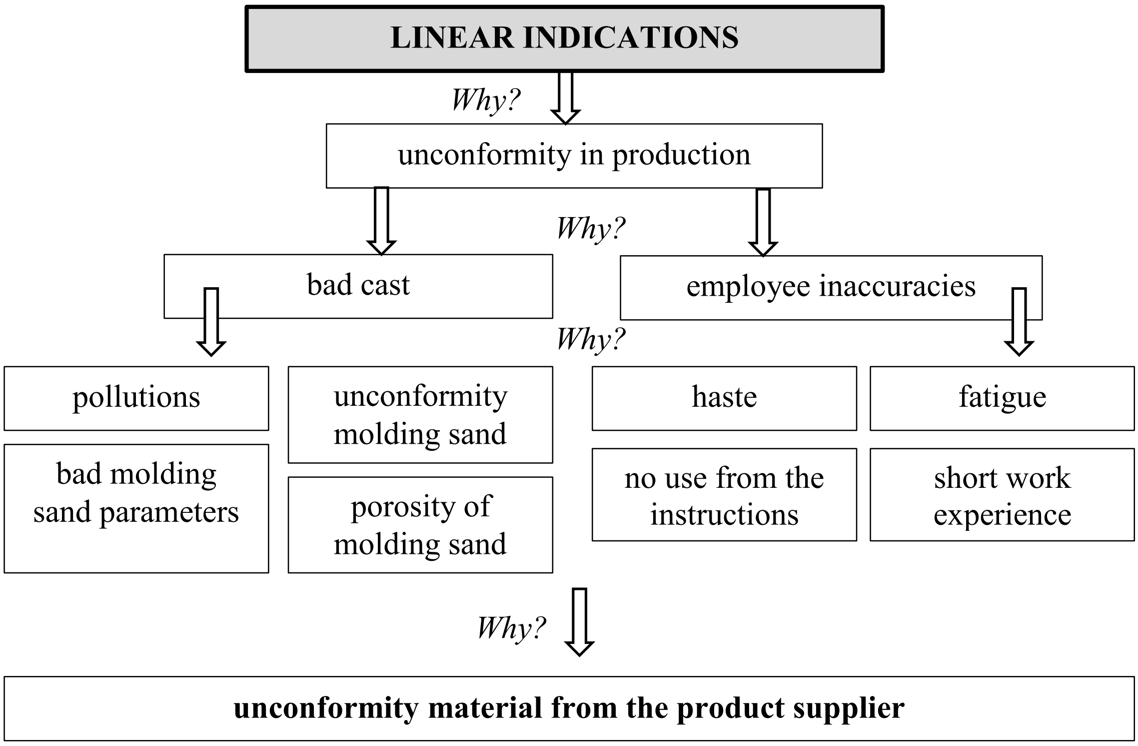

Figure 3. Application of 5Why methodology for identifying root cause of manufacturing defects.

6. Conclusion

It was concluded during the brainstorming session that quality control had to extend beyond applying the fluorescent method and removing defective material prior to use in assembly. The proposed sequence of methods (fluorescence method, Ishikawa diagram and 5 Why method) allowed:

- Identification of defect – striations about size 3,2 mm;
- Demonstration by means of the Ishikawa diagram, the potential causes, and selection of actual cause, i.e. unconformity in production;
- Identification via the 5Why method the source of the problem, which was the defective material from outside supplier.

In addressing the problem, the effectiveness of teamwork was shown, as the working group, appropriately composed, analyzed the problem using the proposed methods sequentially, and gained a solution. The proposed sequence that resolved the issue is a useful and effective way of analyzing the quality problem of products and can be readily applied within different enterprises.

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