NON DESTRUCTIVE TESTING OF ALNICO ALLOYS

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Abstract

In this article, the non-destructive testing of alnico alloys was carried out by various methods. Paper provides and researches about non-destructive testing (NDT) methods. The research was divided into surface and volumetric test material. The paper covers the review on the capabilities of NDT applications such as visual testing (VT), penetrate testing (PT), ultrasonic testing (UT), radiographic testing (RT) with respect to advantages and disadvantages of these methods.

Keywords: Non-destructive testing, alnico alloys, visual testing, penetrate testing, ultrasonic testing

1. INTRODUCTION

Recent decades have resulted in an intensive increase in diagnostic tests of both electrical and mechanical elements of machines. For this reason, there has been a development of methods of obtaining information from diagnostic tests in order to assess the technical condition of the device and on this basis to enable actions to be taken to increase its durability, reliability and efficiency. There are many methods for evaluating materials, fabricated layers [1-3], joints [4,5], components, castings [6], etc. Mainly there are two types of testing: destructive and non-destructive. Non-destructive testing (NDT) are methods to evaluate material integrity for surface or internal flaws without interfering in any way with the destruction of the material or its suitability for service [7]. There are varieties of methods to evaluate materials and components as per their state of application [8].

NDT plays an important role not only in the quality control of the finished product but also during various stage of manufacturing. A better understanding of advantages and limitation of each NDT method is essential in ensuring the success of the evaluation. Understanding only one method may not guarantee the success in solving the problem [9]. In many cases, the approach to finding a defect requires more than use of a single NDT test method. The advantages and limitations of individual NDT methods are presented in **Table 1.**

Table 1 Commonly used NDT techniques [10]

Technique	Capabilities	Limitation
Visual Inspection	Macroscopic surface flaws	Small flaws are difficult to detect, no subsurface flaws
Radiography	Subsurface flaws	Smallest defect detectable is 2% of the thickness; radiation protection. No subsurface flaws not for porous materials
Dye penetrates	Surface flaws	No subsurface flaws not for porous materials
Ultrasonic	Subsurface flaws	Material must be good conductor of sound.

2. MATERIALS AND RESEARCH METHOD

AlNiCo 400 was selected for the tests. The chemical composition is presented in **Table 2**.

Table 2 Chemical composition of the AlNiCo (wt%)

Element	Al	Ti	Fe	Co	Ni	Cu
Average	17.90	0.91	35.16	26.19	15.29	4.56

The samples were subjected to surface and volumetric non-destructive testing. First, they were tested using the VT method. Visual test inspection is probably the most widely used among all the NDT [11,12]. It is simple, easy to apply, quickly carried out, and usually low in cost. Even though a component is to be inspected using other NDT methods, a good visual inspection should be carried out first [13]. VT involves observing a component with the naked eye to evaluate the presence of surface discontinuities. VT can be assisted with optical instruments such as magnifying glasses, boroscopes, mirrors, and other computer equipment for remote viewing. If a component can be viewed, visual testing is the first method of testing in an NDT examination [14].

In the next step penetration tests (PT) were carried out. PT method is based on use of capillary properties of liquids (namely, on capillary penetration of special indicator liquids inside defects) [15-17]. This method reveals defects by forming an indication pattern on the surface of tested items. These patterns have high optical (luminance and color) contrast and width exceeding width of the defect opening. When performing testing a special wetting liquid (penetrating liquid, penetrant) is applied on the surface of the tested item. By impact of capillary forces this liquid fill cavity of surface defects and then it is removed from the tested area. Defects are detected already by applying a developer to the surface of the tested area. The developer absorbs penetrant remaining in cavities of defects. As a result of this process, there is either a red indication pattern appears on the developer's white background.

After surface studies, volumetric studies were carried out. First ultrasonic tests (UT) were carried out. Ultrasonic testing uses high-frequency sound energy to perform examinations and take measurements [18-20]. In most common UT applications, very short ultrasonic pulse-waves with center frequencies ranging from 0.1-15 MHz, and occasionally up to 50 MHz, are transmitted into materials to detect internal flaws or to characterize materials. A common example is ultrasonic thickness measurement, which tests the thickness of the test object, for example, to monitor pipework corrosion. Ultrasonic testing can inspect for dimensional measurements, thickness, material characterization, flaw detection, and more.

The phased array (PA) technique is an extension of the classic ultrasound tests, which is mainly aimed at increasing the speed of testing and facilitating the interpretation of indications. The key role in this ultrasound testing technique is played by the speed and accuracy of the defectoscope software, which must display a much larger amount of information compared to classic tests. In the PA technique, the head is divided into elementary heads, separately stimulated to vibrate, which generate the beam in a manner selected by the operator, thanks to which it is possible to form an ultrasound beam of the desired shape, refraction angle and focusing. With the help of the triggering control of the elementary heads, it is also possible to perform several scans with one head. Thanks to such methods of beam control, the image obtained is similar in appearance to medical imaging or radiographic images.

Finally, the sample was radiographic testing (RT). RT is an extremely popular non-destructive testing inspection technique, thanks to its versatility in detecting a wide range of defects on multiple materials, and its ability to produce a permanent record of each inspection. Radiographic Testing consists of passing a beam of ionizing rays (X-rays or gamma rays) through a part to recover the image on a radiographic film which, after development, will provide a negative image of the part examined. The variation of ionizing radiation density on the exposed film exposes the defects. This method is widely used in industry, because the radiographic film generates a test document that can be archived. Radiographic testing also allows measurement of the wall thickness of most materials. This method is used to measure losses of thickness by corrosion and erosion. The presence of insulation does not limit the inspection in any way.

3. RESULTS

Visual test (VT)

Figures 1 and **2** show surface defects captured on an optical microscope at appropriate magnifications.

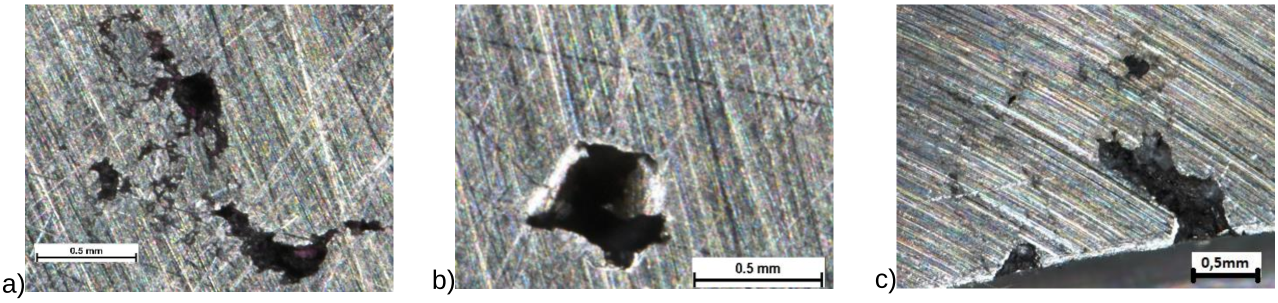

Figure 1 The surface with the discontinuity found

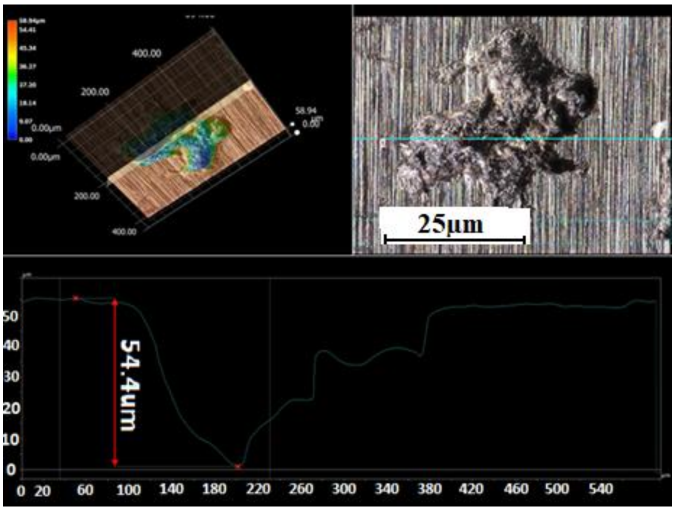

Figure 2 An exemplary view of the surface pore with a 3D view and a height section

Penetration tests (PT)

Figure 3 shows the samples (diameter 50 mm) with the developer applied, development time about 15 minutes. Dynamics of observation of indications from the moment of drying out every 3 minutes. **Figure 3c** shows the tested detail after penetration tests, visible red markings on the surface.

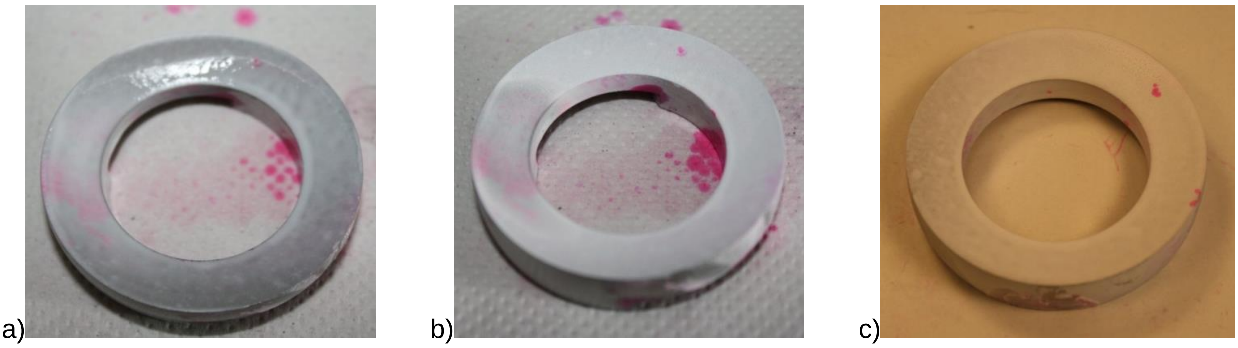

Figure 3 Photograph of samples after the application of the developer, a) immediately after the application, b) while the developer is drying - revealing discontinuities on the surface in the form of a pink color indication, c) sample after the development process is completed - two indications on the surface are visible

Ultrasonic tests (UT)

The calibration of the device on a sample with a thickness of 11 mm is presented in **Figure 4a**. The material discontinuity during the test with the MSEB-4 double probe, occurring in the tested element with a thickness of 11 mm, was recorded at a depth of 5.16 mm (see **Figure 4b)**.

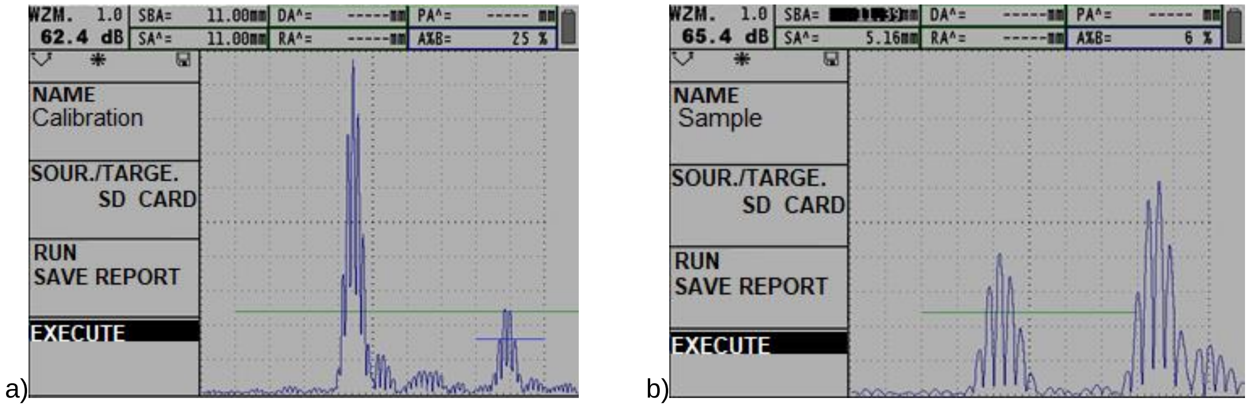

Figure 4 a) Device calibration results, b) Sample test report using the MSEB-4 probe

Examples of material discontinuities that were located in the tested material are presented in **Figure 5**. The test was carried out using the Phased Array method.

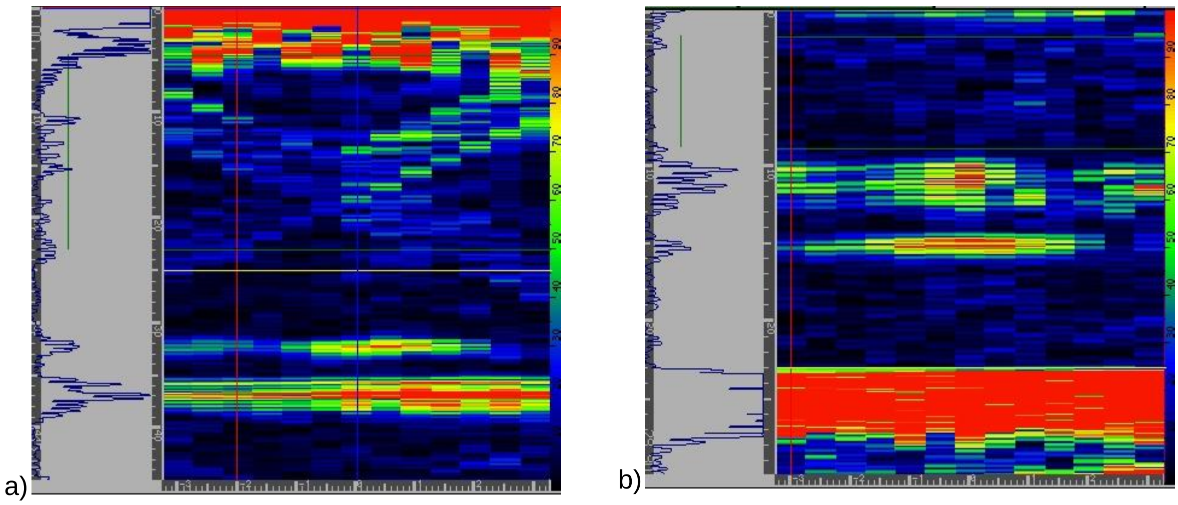

Figure 5 Sample test reports using the Phased Array probe

4. CONCLUSION

The armed eye examinations, i.e. macroscopic and microscopic examinations, allow the identification of details containing surface imperfections that were not selected during visual examinations with the naked eye. It should be emphasized that the use of devices that increase the imaging, e.g. a magnifier or a microscope, increase the accuracy and allow the indication of details that do not meet the quality requirements of the surfaces of the analyzed details.

Penetrant testing requires adequate penetration and development time, a total of about 30 minutes, but we can 100% say that they detect material discontinuities that come out to the test surface and are easy to interpret.

The results of the ultrasonic tests with the MSEB-4 transducer give satisfactory results. There are large drops in the echo and the appearance of peaks before the echo of the day, which gives information about the indication of discontinuities. When using the Phased Array probe, the same indications are visible as with the previous two probes, but you can see a number of smaller indications at different depths of deposition.

The undoubted advantage of ultrasound tests is the immediate obtaining of results. The disadvantage of these tests is the need to train personnel in the calibration of the device, sample searching and interpretation of test results, which must be performed on an ongoing basis. The test specimens must be pre-sewn so that the UT probe face adheres well to the test object.

Radiographic examinations give satisfactory results, but it requires the use of appropriate equipment and time when creating and developing an image on the film.

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