SELECTION OF MODERN INSTRUMENTAL METHODS OF TESTING MATERIALS IN THE AVIATION INDUSTRY, Part II

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Abstract

Modern instrumental methods used to determine the composition, microstructure and surface structure should respond to increasingly complex problems material testing requirements, in order to meet the increasingly strict technical conditions of receiving and using materials, and therefore the delivery of the finished product. In the aviation industry, with regard to the chemical composition of materials, the requirements have been extended to a significantly larger number of parameters: to "impurities", to trace elements, to micro alloying components, to local, as well as to structural and phase analysis. In this sense, requirements such as: accuracy of determination; determination of low concentrations (traces); duration of the analysis; simultaneous determination of a number of elements under the same experimental conditions; microanalysis (below 1 micron), i.e. testing at small locations are inviolable.

Keywords: *Modern instrumental methods; metallographic examination; XRF analysis*

1. INTRODUCTION

Parts of aircraft engines are exposed to various harmful effects during the exploitation process, such as the effect of the atmosphere, aggressive media, high operating temperatures and the like. Under the influence of these factors, corrosion occurs, which must be prevented. For this purpose, metal coatings are applied, which are applied to the base material chemically or electrochemically. Protective coatings increase resistance to corrosion, wear and abrasion, modify the physical and mechanical characteristics of material surfaces, increasing the quality of the treated surface of the protected object (B. Arsenović et.al. 2019). Also, metal galvanic coatings are applied for the purpose of regenerating damaged parts, improving electrical conductivity at contact points, preparing the surface for painting, etc. (B. Arsenović et al. 2021).

Modern instrumental methods used to determine the chemical composition of materials, microstructure and surface structure should respond to the increasingly complex requirements of material testing. In the aviation industry, with regard to the chemical composition of materials, the requirements have been extended to a significantly larger number of parameters, to "impurities", to trace elements, to microalloying components, to local, as well as to structural and phase analysis. In addition to these requirements, additional requirements were imposed in terms of: accuracy of determination; determination of low concentrations (traces), duration of analysis, simultaneous determination of a large number of elements under the same experimental conditions, microanalysis (examination at small locations) and others. And if we are talking about modern instrumental methods, one thing is absolutely certain that there is no method or instrument that can satisfy all the stated requirements, the application of several different instruments that work on different physico-chemical principles is needed.

In the paper of the given title (Part II), a brief description of the most common modern instrumental methods (with test results) used in the aviation industry is given (Z. Ristić et al., 2022).

2. SELECTION OF MODERN INSTRUMENTAL TESTING METHODS

For the complex identification of the structure and composition of materials, four basic groups of instrumental methods are known: general physical-chemical methods; electrochemical; optical-chemical and spectrochemical and thermometric methods.

Appropriate equipment is used for laboratory testing of the basic mechanical properties of materials, such as for testing materials for tension, pressure or bending, and various types of testers are used. The mechanical properties of the material are, like all other properties, a consequence of the microstructural state of the material, which is obtained by processing the material of a certain composition with a certain technological procedure (ISO 18203, 2016).

By choosing the material and the appropriate technological procedure, the target structural state of the material is achieved, which gives the desired properties.

2.1. Metallographic testing of materials

To observe the microstructure of steel, knowledge of **metallography** is required, which deals with the investigation of the structure of metals and alloys using light (metallographic) and electron microscopes. The **macrostructure** is visible with the naked eye or with low magnification, and the **microstructure** requires the help of a microscope. Sample preparation for metallographic analysis includes:

- cutting the sample,
- sample grinding,
- inserting small samples into the resin (pressing the clips),
- fine sanding,
- polishing, degreasing,
- etching of the sample surface,
- sample washing i
- drying.

The task of the **metallographic examination of the material is** to determine the properties and behavior of the alloy under given load conditions for a certain chemical composition from the total macro- and micro-structure, if possible, and to indicate the most favorable structure for a certain processing process or area of application of the metal. In addition to certain limitations, today it is no longer possible to imagine modern tests of metals and alloys without metallographic tests.

Figure 1 shows a metallographic microscope in the material/product testing laboratory at "ORAO" A.D. Bijeljina. On the presented example of metallographic testing on high-pressure turbine blades and test tubes (coating - PACK process - aluminization; heat treatment) (BAS EN ISO 1463, 2004), the quality of the coating application process was determined (Z. Karać et al, 2022).

Measurement of the hardness of the coating on the spatula and test tubes, Figure 2 (preparation of pressed sections, Figure 3; 5 measuring points; Vickers HV 0.2 method) was determined with the "Karl Frank" type "38 536" microhardness tester; No. 19951- "ORAO" A.D. (BAS EN ISO 6507-1, 2018). The results of coating hardness measurements are shown in Table 1, while Table 2 shows the results of coating thickness measurements on the high-pressure turbine blade.

Figure 1. *Metallographic microscope "Carl Zeiss" type "Neophot 21" Nº22984 - "ORAO" AD. Bijeljina*

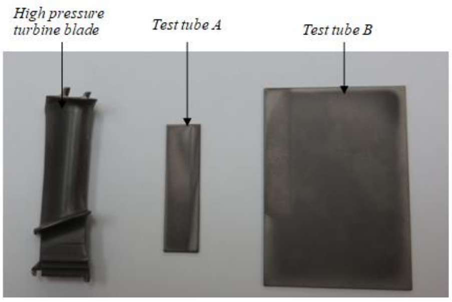

Figure 2. *Layout of the high-pressure turbine blade and test tubes A and B*

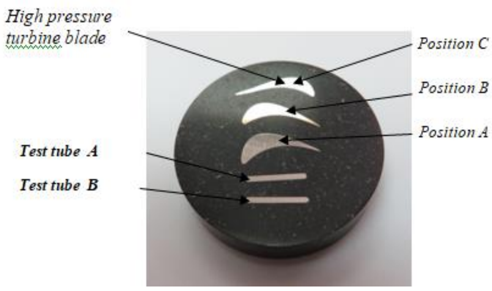

Figure 3. *The appearance of the pressed pieces of the spatula and test tubes*

Table 1. *Results of hardness measurement of HV 0.2 on the high-pressure turbine blade and test tube*

Ordinal number of measurement	***HARDNESS HV 0.2***		
	Position A	*Position B*	*Position C*
1.	*672*	*631(*)*	*658*
2.	*701*	*658*	*733(*)*
3.	*701*	*686*	*686*
4.	*686*	*658*	*701*
5.	*717*	*672*	*644*
Mean value	***695***	***661***	***684***

** - measurements above the requirements of the standard*

After etching the interface between the blade and the test tube with Kolling's reagent, the entire surface was observed on a metallographic microscope at a magnification of 400X. On all observed surfaces, the existence of a ***coating and a diffuse layer was confirmed.*** The appearance of the coating on the blade body is shown in Figure 4. The coating is spread evenly, has a uniform thickness (BAS EN ISO 1463, 2004), the surface of the coating is slightly uneven, wavy.

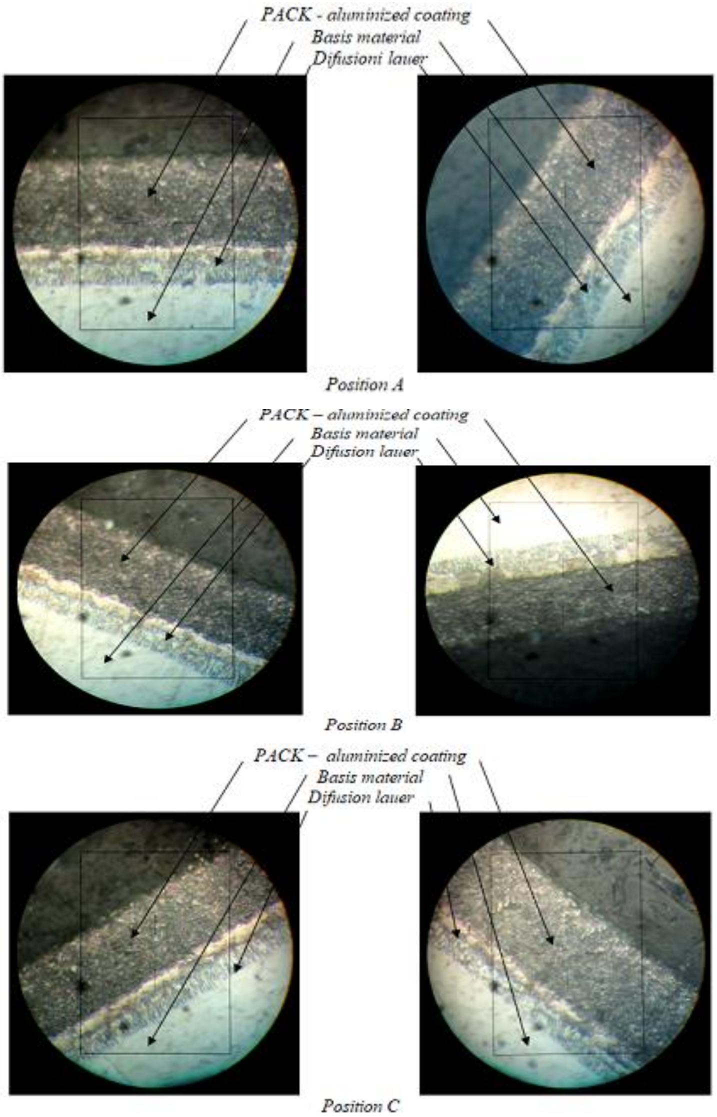

Figure 4. *Appearance of the coating on the high pressure turbine blade (Magnification 400X)*

Table 2. *Results of coating thickness measurement on the high-pressure turbine blade*

Position	***Coating thickness (mm)***				
	Place of measurement				
	1	*2*	*3*	*4*	*5*
a	*0.028*	*0.038*	*0.028*	*0.022*	*0.022*
b	*0.025*	*0.030*	*0.026*	*0.022*	*0.025*
c	*0.027*	*0.035*	*0.022*	*0.025*	*0.025*

The thickness of the diffusion layer is: position a: 0.011 mm; position b: from 0.009 mm to 0.012 mm and position c: 0.012 mm.

The appearance of the coating on test tubes A and B is shown in Figure 5.

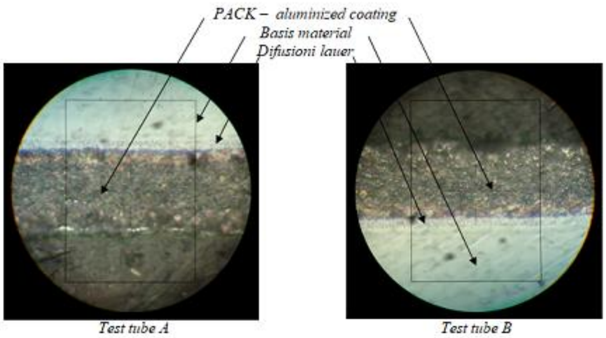

Figure 5. *The appearance of the coating on the test tubes (Magnification 400X)*

The results of measuring the thickness of the coating on the test tubes are shown in table 3.

Table 3. *Results of coating thickness measurements on test tubes vetama*

Tube	*Sektion (area)*	***Coating thickness (mm)***		
		Place of measurement		
		1	*2*	*3*
A	*1*	*0.024*	*0.025*	*0.021*
B	*1*	*0.028*	*0.025*	*0.027*
	2	*0.025*	*0.023*	*0.022*

The thickness of the diffusion layer is: test tube A, surface 1: from 0.006 mm to 0.009 mm; tube B, surface 1: 0.006 mm, tube B, surface 2: 0.006 mm.

2.2. X-ray fluorescence spectrometry, XRF

X-ray fluorescence spectrometry, XRF, is a method based on the excitation of the atoms of the examined sample with X-ray radiation. Given that the emission of fluorescent radiation from the examined material is characteristic of its elemental composition, the obtained information gives a qualitative and quantitative picture of the elemental composition of the sample. XRF is a non-destructive, fast, universal and relatively simple analytical method for multi-element analysis of samples (Z. Ristić et.al., 2022). This very powerful analytical technique for determining almost all elements of the periodic table present in a sample, ensures detection limits at the sub-ppm level, also, it can easily and simultaneously measure concentrations up to 100%. Figure 6 shows a **portable handheld XRF analyzer** with accompanying equipment.

Legend:

1. Device X-Met 8000 Expert
2. Slot for optional radiation shield light
3.Plate for optional backplate
4. Battery charger
5. Power supply and adapters
6. Batteries (2pcs)
7. Optional radiation shield
8. USB cable
9. Strap slot
10. Bright stan

Figure 6. *Appearance of portable handheld analyzer X-MET 8000 Alloy Expert "HITACHI"; N° 804280 "ORAO" A.D. Bijeljina*

Table 4 shows the chemical composition of the material DTD 200A (DTD 200A, 2022) (5 rods Ø 10mm) obtained using an XRF-analyzer, Figure 6. The composition of C and S has not been determined.

Table 4. *Chemical composition of material DTD 200A*

Element	***Chemical composition % (m/m)***					*Material requirement, max DTD200A*
	1	*2*	*3*	*4*	*5*	
C	-	-	-	-	-	*0.30*
Si	*0.21*	*0.18*	*0.17*	*0.36*	*0.47*	*0.50*
Mn	*0.96*	*1.00*	*1.08*	*1.06*	*1.05*	*2.00*
S	-	-	-	-	-	*0.02*
Cu	*31.47*	*31.27*	*31.05*	*31.06*	*31.15*	*34.00*
Co	*0.01*	*0.02*	*0.01*	*0.01*	*0.01*	*2.00*
Fe	*1.05*	*1.06*	*1.06*	*1.10*	*1.06*	*2.50*
Ni	***Rest***					

According to the results of the chemical composition test (Z. Karać et al., H-73/22; 2022), five samples of DTD 200A material bars were confirmed to match the chemical composition of DTD 200A material.

CONCLUSION

According to the choice and representation of modern instrumental methods, as well as their suitable combination, primarily metallographic examination of materials with XRF analysis, as a very powerful analytical technique for determining almost all elements of the periodic table present in the sample, (as well as a number of other techniques) the company "Orao" AD For the last decade, Bijeljina has been fully characterizing materials used for R/D, as well as finished R/D in the aviation industry.

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