Metallographic research into the quality of X15N27T3MR-VD steel wire (EP700-VD)

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Abstract. The purpose of this paper is to report on the results of metallographic research into the quality of X15N27T3MR-VD steel wire (EP700-VD). The reason for the research was an oxidized zone with intergranular cracking which had been detected on the surface of the wire. To remove the defects, a variety of chemical methods were applied to the surface. As the research shows, after the chemical treatment methods such as winding springs, blowing them with corundum, etching in a mixture of HNO₃ and HF, and electropolishing were applied to the surface, the defects were removed completely.

Type of steel X15H27T3MR-VD (EP700-VD) is used for the manufacture of the assembly components in aerospace industry and special equipment. This type of steel is recognized as a high alloy providing resistance to corrosion and heat.

To produce springs, hard wire with a diameter of 2.6 mm, 2.8 mm and 4.5 mm made of steel EP700-VD according to the State Standard (GOST) 14-1-3098-81 is widely used. However, the quality of the surface of the wire, having defects in the form of cracking, fails to meet the requirements introduced by the State Standard 14-1-3098-81 for spring production due to drawbacks in technologies and equipment used at JSC "MZ Elektrostal".

The results of metallographic research into the wire surface confirmed this problem. After being increased 25 times in length ≈200 mm on the surface of 2/3 of the circumference, a grid of cracks was evident by an unaided eye. Microscopic examination on the surface of the wire revealed an oxidized zone with a thickness of 0.016 - 0.060 mm, with intergranular cracking, in some places the upper layer peeled away completely (Fig.1). These defects exceed the tolerance for diameter (0.03 mm) table №2 the State Standard 2771-81, and in terms of the quality of the surface, the wire also does not meet the requirements introduced by the State Standard in paragraph 2.3 of TU14-1-3098-81.

Additional research on the surface of the wire after the surface treatment operations in the manufacture of springs, that is, aging at a temperature of 700 ° C, blowing with corundum and electropolishing, showed that surface defects are not completely removed. On the surface of the wire there are remnants of the oxidized layer with a depth of up to 0.046 mm, alternating with recesses from the blowing depth of up to 0.03 mm (Fig. 2).

To remove the surface defects completely, some chemical methods were applied to the surface. The results of metallographic research are given in table 1.

The best results were obtained after blowing with electrocorundum, etching in a mixture of HNO₃ acids 140-160 g/l and HF 40-60 g/l for 20 minutes, and electropolishing allowing to smooth irregularities.

Similar results were obtained on the wire samples of 2.8 mm and 4.5 mm made of EP700-VD steel.
Figure 1. Defects on the surface of wire Ø2.6mm made of steel EP700-VD:
a), b) - a general view of the surface of the wire;
c), d) microstructure of the upper layer.

Figure 2. Microstructure of the upper layer of wire Ø2.6mm made of steel EP700-VD after aging,
blowing with corundum and electropolishing.

Table 1. Results of metallographic research into the quality of the surface of the wire made of steel
EP700-VD after various chemical processing options.

| Type of treatment                                           | Microstructure test results                                                                 | Microstructure | Increase |
|-------------------------------------------------------------|--------------------------------------------------------------------------------------------|----------------|----------|
| Etching in a mixture of HNO3 and HF for 20 min              | Roughness in the form of grooves with a depth of 10-15µm. Increased grain etchability in the modified upper layer to a depth of 131 microns. | x100           |          |
| Electrocorundum blowing + etching in a mixture of HNO3 and HF for 20 min. Roughness in the form of grooves with a depth of 15-20 µm | x200 |  |
Electrocorundum blowing + etching in a mixture of HNO₃ and HF for 20 min + electropolishing for 4 min, current density 15 A / dm².
Roughness in the form of grooves with a depth of 5-10 µm

Due to the difficulties in removing surface defects in the coil of the original wire, as well as taking into account the partial removal of the modified layer while passing through the die plate before winding and in the process of winding, etching was applied to the springs after winding, but before heat treatment. As a result, after winding the springs, blowing with corundum, etching in a mixture of HNO₃ and HF for 20 minutes, and electropolishing, the surface defects are removed completely. Investigation of the wire surface after winding springs, blowing with corundum, etching in a mixture of HNO₃ and HF for 20 minutes and electropolishing (without blowing with corundum before electropolishing) also showed that surface defects are completely removed. The results of metallographic research are given in table 2 [3].

**Table 2.** Results of metallographic research into the quality of the surface of springs made of EP700-VD steel after two chemical treatment options

| Type of treatment                                                                 | Microstructure test results                                                                 | Increase |
|-----------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------|----------|
| Winding of the spring + electrocorundum blowing + etching in a mixture of HNO₃ and HF for 20 min + electropolishing for 4 min, current density 15 A / dm². No surface defects are visible. | ![Microstructure image](image.png) x100 | ![Microstructure image](image.png) x200 |

Thus, the best results in complete removal of defects and improvements in technological manufacturability are obtained by winding springs, blowing them with corundum and etching in a mixture of HNO₃ and HF for 20 minutes, prior to heat treatment, with further necessary treatments followed, according to technical requirements, i.e. aging, blowing with corundum and electropolishing.

The mechanical characteristics of the spring meet the requirements of the design documentation.

**References**

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