RESEARCH ON NITRIDING OF SHOE SEWING MACHINE NEEDLES USING ELECTRON BEAM IN VACUUM ENVIRONMENT

Abdullayev Lazizbek Abdulazizovich

Namangan davlat universiteti

Annotation. *In the article the results of studies of the influence of gas pressure and displacement potential on the process of electron beam nitriding of titanium in the vacuum pressure region are presented. The results of measurements are presented and a correlation is revealed between the mass-charge composition of the beam plasma and the parameters and characteristics of the nitrided surface.*

Key words: *vacuum, plasma cathode, electron sources, electron beams, plasma nitriding, steel, carbon, nitrogen, hardness, processing.*

Аннотация. *В статье представлены результаты исследований влияния давления газа и потенциала смещения на процесс электронно-лучевого азотирования титана в области вакуумного давления. Приведены результаты измерений и выявлена корреляция между массово-зарядовым составом плазмы пучка и параметрами и характеристиками азотируемой поверхности.*

Ключевые слова: *вакуум, плазменный катод, источники электронов, электронные пучки, плазменное азотирование, сталь, углерод, азот, твердость, обработка.*

Introduction: Sewing needles are made of specially hardened needle wire, the material for which is high-quality U9A steel. After heat treatment, the needle should have a hardness of HRC 54-60. The surface smoothness of the needle should not be lower than 10.

Nitriding of metals is a method of improving the performance properties of structural materials. There are three main types of nitriding: gas nitriding [1], liquid nitriding in salt solutions [2] and plasma nitriding [3].

Among these types of nitriding, plasma nitriding is distinguished by a short technological process time, no environmental pollution, low gas and energy consumption [4], which leads to the widespread use of plasma nitriding to improve hardness, corrosion resistance and reduce surface friction. [5].

Research and its methodology: The pressure of the argon-nitrogen mixture and the accelerating voltage of the beam were 0.1-1 Pa and one hundred volts, respectively. It was also possible to achieve strengthening of the surface layers of the samples, which was primarily due to the presence of atomic nitrogen near the workpiece, since the technological mode of nitriding is carried out at electron beam voltages at maximum dissociation of nitrogen molecules under electron influence (60-140 eV).

The use of vacuum sources for nitriding products has significant advantages - the ability to independently regulate the current, radiation energy and gas pressure allows you to provide the necessary temperature conditions of the nitrided product and create a dense plasma without the use of additional devices, [6].

Thus, the purpose of this work was to study the possibility of nitriding steel in the electron beam plasma of a vacuum electron source during direct irradiation of a steel sample with an electron beam, as well as to characterize the formed modified surface layer. Studies were carried out on the mass-charge composition of the beam plasma ions, tribological properties, microhardness, X-ray diffraction and elemental analysis of the nitrided surface.

Since the hardening of the steel surface is associated with the presence of nitrogen atoms near the processed sample, studies were conducted on the mass-charge composition of the beam plasma ions to find the optimal parameters of the electron beam during nitriding. The study of the mass-charge composition of the plasma ions was carried out using a modernized RGA-100 quadrupole residual atmosphere analyzer near the area of subsequent placement of the nitrided sample.

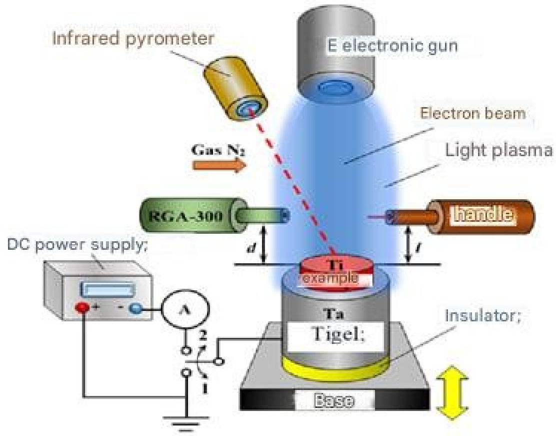

Figure 1 – Experimental scheme:

Sample. As a sample, we used 4 mm thick U9A steel, from which an element of 10×10 mm was cut. The side of the sample exposed to the electron beam was polished using abrasive paper and then wiped with ethyl alcohol before being placed in a vacuum chamber. The sample was placed on a tantalum crucible and a continuous electron beam with an energy of 4-9 kV, a current of 100 mA and a length of 20-25 mm was generated by a vacuum plasma source based on a hollow cathode discharge. The generated electron beam falls on the titanium sample and is used to heat it. [7].

Using an RGA300 turbomolecular pump with a pumping speed of 300 l/s, the air inside the working chamber was sucked in to a pressure of 0.03 Pa, after which nitrogen was pumped into the chamber to the required working gas pressure of 1–7 Pa. However, in this experiment, to ensure sufficient temperature for nitriding, the accelerating voltage was increased to 6 kV and the sample temperature reached 900 ˚C.

The elemental composition of the nitriding layer was determined using scanning electron spectrometry (Figure 3).

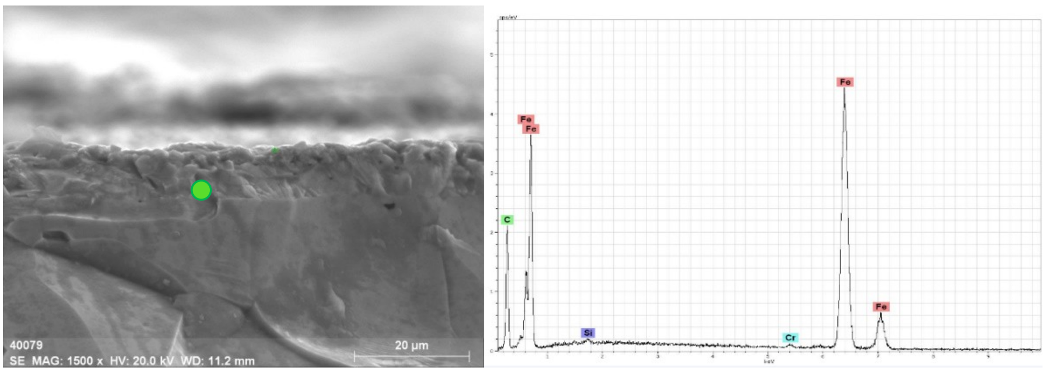

Figure 2 - Auger spectroscopy results.

The main elements are steel and nitrogen, but oxygen and a small amount of carbon are also present, but the sum of the concentrations of the last two elements does not exceed 6.2 wt.%. The small amount of oxygen and carbon in the nitrided layer is associated with their content in the layer near the surface of the steel, such an amount does not lead to the destruction of the nitrogen layers. When the duration of the nitriding process was 75 minutes, the thickness of the nitrided layer was approximately 8 μm.

At the same time, a small amount of oxide phase corresponding to Fe3 was detected (Figure 3). From the small percentage of oxide phases it follows that the oxide layer has a small thickness and occupies an insignificant volume fraction of the volume of the studied sample and is associated with its presence on the original surface. The data of X-ray diffraction analysis fully confirm the data of the scanning electron microscope.

These indicators allow to increase the service life of steel nitrided by electron beams in a medium vacuum environment. It is noteworthy that the hardness of the nitrided layer increased almost 3 times compared to the initial surface (Fig. 3).

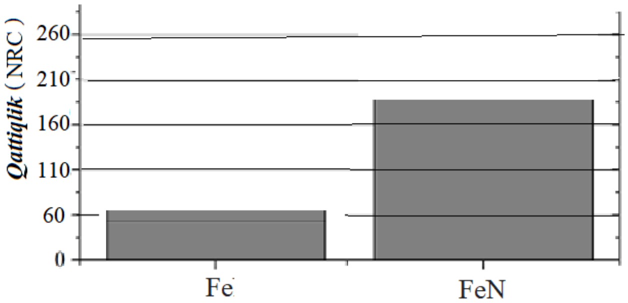

Fig. 3 - Hardness of the initial and nitrided sample.

Conclusion

It was shown that it is possible to nitride steel in an electron beam plasma with direct irradiation of electron beams from a vacuum electron source. The light spectra of the nitrided layer sample indicate that it contains the main amount of steel and nitrogen, with small traces of carbon and oxygen.

The study of the hardness and tribological properties of the surface layers showed a low friction coefficient compared to steel and a several-fold increase in the resistance and hardness of the nitrided layer. The results obtained indicate the advantage of using vacuum sources for nitriding products based on beam-plasma.

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