УДК 620.197

P. B.Kubrak, PhD (Chemistry), senior lecturer (BSTU);
V. V. Zhylinskiy, PhD (Chemistry), senior lecturer (BSTU);
V. V.Chayevskiy, PhD (Physics and Mathematics), assistant professor (BSTU)

PRECIPITATION OF ABRASION RESISTRANT FE-NI ALLOY COATINGS FROM SULFATE ELECTROLYTES

The abrasion resistant Fe-Ni alloys were precipitated on the surface of the blades of woodworking tools by electroplating from sulfate electrolyte. The elemental composition and surface morphology of the coatings were studied by energy dispersion X-ray microanalysis and transmission electron microscopy. The microhardness of obtained coating of Fe-Ni alloy has reached 400 HV that is 2 times greater than the microhardness of the substrate. It had been found that coating of Fe-Ni alloy on knife-edge of woodworking tools reduces the wear by 50% or more compared with the uncoated blades.

Introduction. Today iron coatings and coating with iron alloys are widely used in mechanical engineering [1]. Traditionally these coatings are precipitated from chloride electrolytes on the surface of parts to give special properties to their surface layer (magnetic, anti-friction) [1, 2]. One of the trends in the development of ironingis the precipitation of Fe-Ni alloys from sulfate electrolytes [3]. The alloys obtained are quite abrasion resistant and can be used as a replacement for chromium coatings [3].

The application of such coatings to the cutting edge of woodworking tools for increasing their lifetime is of great interest. It should be noted that in the Republic of Belarus only imported woodcutting tools which are often made of hard-alloymetals, high-speed steel [4–6] are used for machining, which brings about additional expenses for maintenance of woodworking equipment. The principal trend towards broadening the range of machined wood-based materials and intensification of industrial equipment operation is observed in the Republic. It makes the task of increasing the abrasion resistance of the used woodworking tools, relevant and technically and economically feasible

Thus, the work involved was aimed at preparing resistant Fe-Ni alloy coatings from sulfate electrolytes and the study of the modified tool lifetime while cutting laminated chipboard (Spending), depending on the elemental composition of the coatings.

Main part. Electroplating of Fe-Ni alloys was applied to the prepared surface of a woodworking double-edge Steel20 knife from sulfuric acid electrolyte [2] containing (g/dm^3): $NiSO_4 \cdot 7H_2O$ – 100, $FeSO_4 \cdot 7H_2O$ – 50, H_3BO_3– 30, 1,4-butindiol – 1–3, at a temperature of 40–50°C and pH = 2.5. A compound from the group of alkyl ethylene diamine tetraacetic acids is used as a ligand. The thickness of coating on blades did not exceed 10 microns. The microhardness of Fe-Ni alloy coating was determined using control steel-20 samples by means of a PMT-3 microhardness tester according to the Vickers method at a load of 50g and coating thickness of 20 microns. The elemental coating composition and its morphology was examined by using a scanning electron microscope JSM-5610 LV with a chemical analysis system EDX JED-2201 JEOL (Japan). Laboratory tests for efficient knife blade life of an interlocking side mill 21 mm in diameter when cutting 25 mm thick laminated chipboard with a double-sided finish of surfaces was carried out using a machining center ROVER-B 4.35 (Italy) in the following modes: the number of knives on the mill – 2; mill rotation speed – 15,000 min^{-1}; feed speed – 1 m/min; oversize - 1.0 mm/run; cutting length – 1200 p. m. The cutting failure criterion of the cutter is an appearance of chipped plate finish.

When carrying out investigations it has been established that the current efficiency of a Fe-Ni alloy coating reaches 30% of maximum values in the current density domain from 6.5 to 8.0 A/dm^2 (Fig. 1, Curve 1).

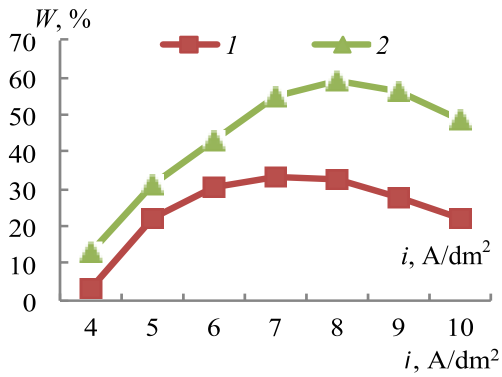


Fig. 1. The relation of the current efficiency ofthe Fe-Ni coating to the current density:
1 – electrolyte without ligand;
2 – electrolyte with ligand

At higher current densities the deterioration of the cake quality is likely observed due to the appearance of diffusion limitations.

Injecting ligands into an electrolyte leads to an increase in the current efficiency of an alloy up to 60% (Fig. 1, Curve 2).

The microhardness of the obtained Fe-Ni alloy coatings reaches 400 HV, which is twice as large as that of annealed Steel 20.

Using an electron probe microanalysis (EDX) it has been established that a Fe-Ni coating contains up to 3 wt. % of Ni and more than 92-94 wt. % of Fe (Table 1). The presence of carbon in the coating is likely due to the introduction of organic electrolyte constituents. Oxygen found in the near-surface coating layer in minute amounts (up to 1.0 wt.%) is indicative of the passivation behavior.

Table 1

The elemental Fe-Ni coating composition

Current density A/dm^2	Component mass fraction, %		
	Fe	Ni	C
10	94.0	3.2	≈2.0
7.5	92.5	3.8	–

Studies have shown that the volumetric wear of the cutting edge of a knife blade,whether it is coated (electroplated) or not,has the same non-uniform distribution bylength (Fig. 2).

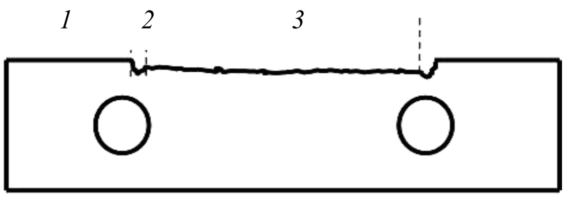


Fig. 2. The layout view of the volumetric wear distribution by length ofthe edge of the knife blade

There are three areas: Area 1 from the edge of a knife blade to the knife attachment point (almost no wear), Area 2 of less than 1 mm long opposite to the knife attachment points with maximum wear per unit length of the blade edge, Area 3 of the basic wear which is less than in Area 2, but the length of this area is 25–26 mm.

A SEM micrograph of the worn edge of the knife blade without a coating in the area of the basic wear (Fig. 3) confirms the literature data on thermal wear of cutting metal surfaces of a tool when they drag on wood due to high temperatures in thin surface layers of the knife blades [4].

The analysis of micrographs of the worn edge surface of the coated knife blade after cutting chipboard has shown that while operating the cutting tool there is mechanical stripping of Fe-Ni coating only from cutting edges (Fig. 4, *a*). A coating applied to the surface of a blade which is not involved in cutting remains without visible damages, chips does not peel off due to heating (Fig. 4, *a*).

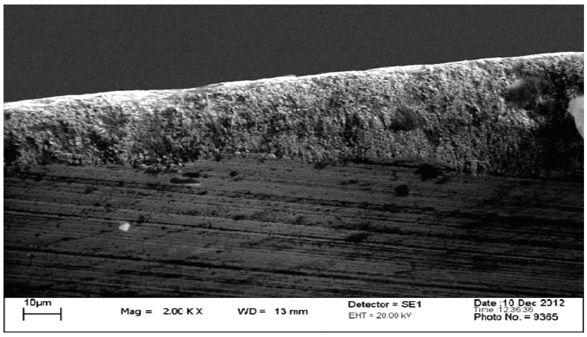
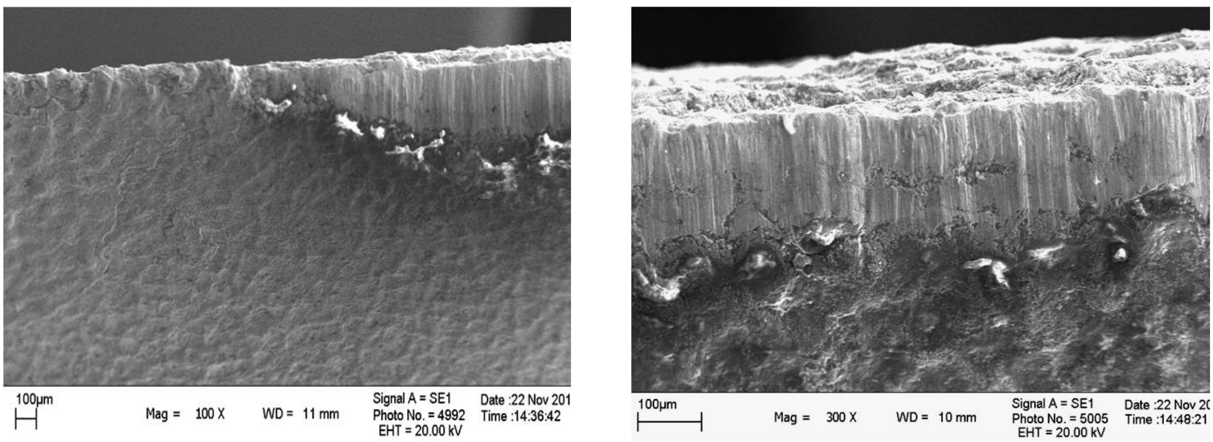


Fig. 3. The photomicrography of the edge of the knife bladewithout coatingsin the area ofbasic wearafter cutting laminated chipboard

The wear-out area (Fig. 4, *b*) is marked by the severe coating damage on the cutting edge of the knife and steel base wear-out.

Studies carried out by using an EDX method (Table 2) have shown an increase in the number of introduced carbon up to 33 at. % when a coating wears off that is possibly due to the mechanical introduction of oxidation products of wood into the coating because of active heating under cutting.



maginification ×100

a

maginification ×300

b

Fig. 4. SEM micrograph of the knife blade with Fe-Ni coating after cutting chipboard: *a* – edge of the knife blade after cutting chipboard; *b* – area of severe coating damage

When cutting wood there is a loss of strength properties of cutting edges of coated knives, which may be due to the deterioration of alloy adhesion to the base coat because of an increase in temperature on the knife-chipboard border.

Table 2

The EDX results ofthe worn-outsurface of the Fe-Ni coated knife blade

Component	Concentration, at. %
C	33.3 ± 6.1
Fe	64.8 ± 9.6
Ni	1.9 ± 0.6

The test for knife blade life has shown that the presence of a Fe-Ni alloy coating on a knife blade helps reduce the wear-out rate by 50% or more as compared with untreated blades.

Conclusion. Thus, the electrodeposited Fe-Ni alloy coatings on double-sided stainless (Steel20) blades deliver an increase in cutting power life by 50% or more under treating of chipboard materials. The microhardness of the obtained coatings has reached 400 HV, which is twice as large as that of the base coat. It has been established that injecting ligands into stannous sulfate electrolyte for applying Fe-Ni alloy intensifies the coating sedimentation process,and it also increases the current efficiency of the alloy.

References

1. Эпштейн А. А., Фрейдлин А. С. Восстановление деталей машин холодным гальваническим железнением. Киев: Техника, 1981. С. 63–64.

2. Петров Ю. Н. Электролитическое электроосаждение железа. Кишинев: Штиинца, 1990. 356 с.

3. Функциональные покрытия на основе сплавов железа / С. С. Попова [и др.] // Гальванотехника и обработка поверхности. 2001. Т. 9, № 1. С. 34–39.

4. Кузнецов А. М., Янюшкин А. С. Износостойкость твердосплавного инструмента при обработке ДСтП // Технология машиностроения. 2008. № 11. С. 29–31.

5. Гришкевич А. А., Чаевский В. В. Влияние ионно-плазменных покрытий на износостойкость стальных резцов при резании древесины на фрезерно-брусующих станках // Труды БГТУ. Сер II, Лесная и деревообраб. пром-сть. 2010. Вып. XVIII. С. 348–351.

6. Ульянов А. А. Оптимизация свойств поверхностных слоев инструментальных сталей для повышения износостойкости дереворежущих инструментов: автореф. дис. … канд. техн. наук: 05.02.01 / Брянская гос. инженер.-технол. академия. Брянск, 2001. 151 с.

Received 07.03.2014