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EXAMINATION OF THE WEAR OF NON-TUNGSTEN ELECTRO-SPARK COATINGS ON HIGH SPEED STEEL

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Abstract: Non-contact local electrospark deposition (LESD) are used in this work to study the wear and increase the wear resistance of products from high speed steel HS6-5-2 with coatings from TiC and TiN-based hard alloys electrodes at friction and cutting. The complex influence of the operating electric parameters for the LESD and the electrode materials on the contact processes and the wear of the layered samples and tools whit resulting coatings during cutting and abrasion friction were investigated. There has been an increase in wear resistance of the deposited samples and tools and the conditions under which the lowest wear can be obtained have been determined. Depending on the used processes parameters, the wear of the layered tools and specimens is 1.3 to 2.4 times lower than that of the uncoated. The values of the process parameters of the LESD modes in which the maximum durability of the coated products is reached are determined.
Keywords: elecro –spark deposition, coatings, non-tungsten electrode materials, wear resistance

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Introduction

A contemporary direction in the field of electro-spark deposition (ESD) is the production of coatings with increasingly high hardness and wear resistance. This is achieved by creating of new materials for the laminating electrodes and by improving of the equipment for layering. The contactless local electro-spark deposition LESD [1,2], allows obtaining coatings with high density, uniformity low surface roughness and a good repeatability of the quality characteristics. This ensures of LESD certain advantages over the classical electro-spark deposition with a vibrating electrode at all details and parts with high requirements on the quality of the work surface [3,4,5,6].

Along with its other tribo-applications as surface modification and application of wear-resistant coatings on friction metal surfaces, LESD creates prerequisites for the deposition of wear-resistant coatings, which can potentially improve the efficiency of cutting tools from high speed steels. For achieve an improved tool life, it is necessary to select an appropriate composition of electrode materials and process parameters for LESD of the tools. From practical and theoretical points of view [4,5,6,7], it is obvious that the further increase in the effect of LESD is related to obtaining coatings from harder and wear-resistant materials than WC-Co and, respectively, with better operational properties.

In this regard, the aim of this work is to investigate the complex influence of the composition of the hard alloy electrode materials based on TiC, TiN and TiCN and the parameters of the regimes for their deposition on the wear of the layered instruments and to determine the LESD processes parameters for obtaining of coatings with increased service properties and triboefect compared to those from WC-Co and WC-TiC-Co alloys.

Materials and methods

Apparatus for LESD

Contactless local electro-spark deposition (LESD) [1] is used in this work. Deposition is performed on machine type "Elfa541" [2] with single pulse energy up to 0.03J. The application of the coatings is carried out with cylindrical rotating electrode with a diameter of 1÷1.5mm, established in the laminating head. The performance of the deposition is 0.5÷0.6 mm/s. During the experiments the following primary adjustable parameters of the regime for LESD were used: Pulse current amplitude – I- to 16A; System voltage - 90V; Pulse duration - Ti= 8, 12 μs; Capacity – C=0.24, 0.68, 1 μF; Coefficient of filling of the pulses - τ = 0.1and 0.2, τ=Ti/T, where T=Ti+Tp is the period of the pulse, and Tp - pause between the pulses; 1/T=f - frequency of the pulses; Number of passages of the electrode - n=2.

Electrode materials

The present work uses non-tungsten solid alloys with soldering metals Ni, Cr, Mo and various technological additives such as Cu, Al_2O_3, B, etc., with the following designations and composition:

TNM10 – TiC + 10% Ni+Mo
TN10 – TiN + 10% Ni+Cr
KNT16 – TiCN + 16% Ni+Mo
TNM20 – TiN + 20% Ni + Cr
TC - TiC + 14% Ni, Mo, + 1% Cu, B, Al2O3
TN – TiN + 14% Ni,Cr,+ 1%Cu,B, Al2O3
TC-TN – TiC+TiN + 12% Ni,Mo + 1%Cu,B,Al2O3

Layering electrodes are obtained by electrically discharge cutting from monolithic plates, prepared by the methods of powder metallurgy.

Abrasion friction test

Tests of friction are carried out with a standard disk from carbide material on machine "Skoda-Savin" (Czech Republic) at a speed 675 min^{-1}, 9.8 N load, and testing time of 3 min. In one minute is measured wear of deposited patterns and curves are generated "Time-wear". Continuous cooling with 0.5% - solution of potassium dichromate in distilled water is used.

For substrate model plates of steel HS6-5-2 (1.3343) – (6%W, 5%Mo, 4.2% Cr, 1.8% V, 0.9% C) with hardness HRC 61-63 are used - with size 10x10x3 mm, and polished to a roughness Ra=0.63μm.

Cutting tests

The influence of the cutting time factor τ on the wear parameter (hi) is examined. At regular time intervals wear of tools along the front Kt and the width of the wear on the rear surface (the average width of the flank wear land) VB are measured and built curves "Time-wear“. The tool life is conventionally defined in terms of flank wear width. As per the accepted definition the tools life equals the times until flank wear reaches a value of 0.2 and 0.3 mm. The results obtained are statistical processed of 5 parallel trials.

Cutting tools were used - countersinks with diameter D=19 mm, and model cutting tools with square inserts from HSS type SPGN 120308 from high speed steel HS6-5-2 (1.3343) with hardness of HRC 61-63. The inserts are polished to a roughness Ra=0.63 μm. The inserts are attached in tool holder with section 25x25mm following geometrical parameters: front corner 5°, rear angle 6°, chief adjusting corner 75° and auxiliary adjusting angle 15°. Blanks are C45 steel (0.45% C) with a hardness of 210-220 HB. Used forced cooling with a 5% solution of boryol in water. The countersinks and are tested under production conditions. Processed material for countersinks is steel C50 (0.5% C) with a hardness of 250 HB. The coatings are deposit to the front surface of the major and minor cutting edges of the inserts in the form of line width 2.5-3mm. The experiments are carried out on a universal lathe trademark C10MB with stepless variation of speed.

Results and discussion

Three modes with medium and high pulse energy for machines ELFA were selected based on the results obtained from the studies of the coatings [8] for LESD of the samples for the friction and cutting tests. The values of the electrical parameters of LESD modes - current I, the capacity C, duty cycle τ, and the duration of the pulses Ti, as well as the parameters of the applied coatings - roughness Ra, a thickness δ, and microhardness HV are shown in Table 1.

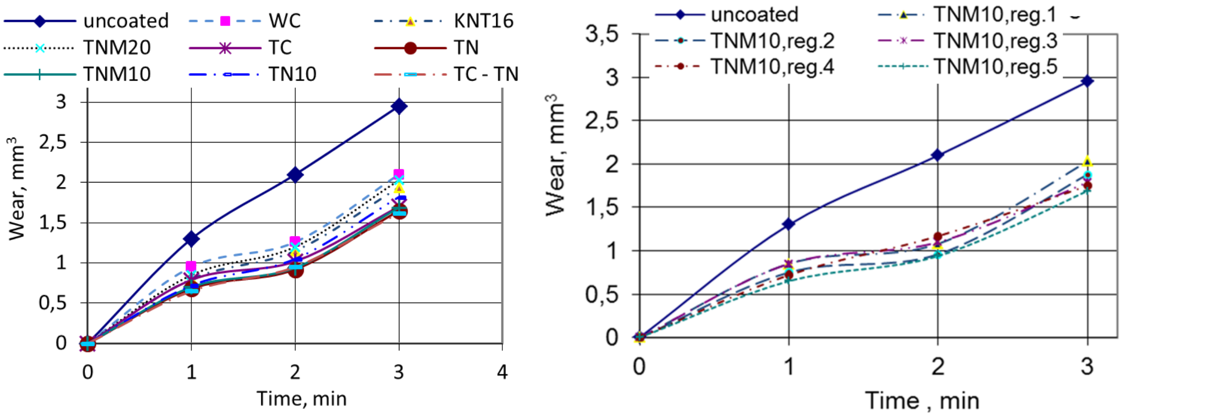
Table 1. Values of the parameters of the regime for LESD, and the resulting coatings

№	Electrode	I, A	C, µF	Ti, µs	τ	Ra, µm	δ, µm	HV, GPA
1	TNM20	14.4	0,24	12	0,1	1.08	4.35	11.79
2.	TNM20	16	0,68	8	0,1	1.19	5.66	12.53
3.	TNM20	14,4	1	12	0,1	1.33	6.1	13.45
1.	KNT16	14.4	0,24	12	0,1	1.04	4.9	12.76
2.	KNT16	16	0,68	8	0,1	1.18	5.3	11.84
3.	KNT16	14,4	1	12	0,1	1.28	5.78	13.79
1.	TN10	14.4	0,24	12	0,1	0.78	3.95	12.32
2.	TN10	16	0,68	8	0,1	1.03	4.95	11.39
3.	TN10	14,4	1	12	0,1	1.15	5.3	13.15
1.	TN	14.4	0,24	12	0,1	0.94	4.5	11.37
2.	TN	16	0,68	8	0,1	1.02	5.5	13.06
3.	TN	14,4	1	12	0,1	1.19	5. 7	13.81
1.	TNM10	14.4	0,24	12	0,1	0.82	3.9	11.80
2.	TNM10	16	0,68	8	0,1	0.97	4.9	12.89
3.	TNM10	14,4	1	12	0,1	1.09	5.5	13.55
1.	TC	14.4	0,24	12	0,1	1.19	4.6	11.59
2.	TC	16	0,68	8	0,1	1.07	5.12	12.19
3.	TC	14,4	1	12	0,1	1.19	5.7	13.72
1.	TC-TN	14.4	0,24	12	0,1	1.02	5.6	12.90
2.	TC-TN	16	0,68	8	0,1	1.05	5.5	13.50
3.	TC-TN	14,4	1	12	0,1	1.19	5.7	14.28

From the results obtained it is found that the lowest values of Ra and δ are obtained for the coatings deposited with the electrodes TNM10 and TN10, and the highest – at LESD with electrode TNM20, respectively, we can expect that they have the greatest coefficients of friction. It is obvious that the increase in the quantity of solder metals in the composition of the electrode leads to an increase of the roughness Ra and the thickness δ. There is a tendency to increase of the micro-hardness with an increase in pulse energy. At TiC, TiC-TiN and TiN electrodes, the HV values are lower than those obtained with an electrode THM10, which is probably due to the higher content of soldering metals in the composition of these electrodes. At the same time, the increase in the quantity of the binding materials in the direction TNM10 - TC-TNM20 leads to higher values of the roughness and thickness of the coatings - Table 1.

Comparative tests of friction

Graphics dependences for the change of volume of trace from wear when testing of the coated and uncoated samples in the time for tests of friction is given in Fig 1.



a) b)

Figure 1. Wear of specimens with coatings inflicted by electrodes based onTN and TiC: a) experimental curve of wear h=f (τ) at LESD in regime 5 (Table2); b) experimental curve of wear h=f (τ) at LESD in regimes 1- 5 (look in Table2).

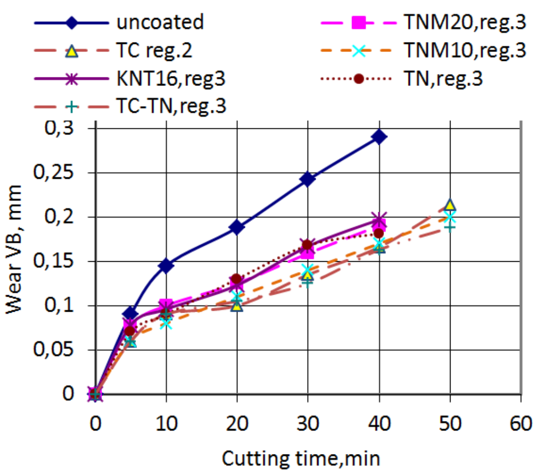
From the results it was established that at when criterion of wear is 1.5 mm3 the coated samples have 1.7-2.3 times longer durability than those of uncoated samples, and 1,2 times more than the deposited samples with electrode WC-Co -Fig.1a. At criterion of wear 2 mm3 the deposited samples have up to 1.8 times longer life than those of uncoated samples, and up to 1,2 times more than those of the deposited with electrode WC-Co samples. When comparing the influence of the electrode material on the wear is found that at LESD with electrode TiC-TiN the wear of the samples is small, but the differences are only up to 15-20%. The lowest wear is obtained in regime 5 – Fig.1b, Table2.The higher roughness of the coatings obtained under these regimes implies a decrease in wear resistance, but obviously this is offset by the greater thickness and concentration of the carbides in the layers as well as by the higher degree of dispersity and imbalance, i. e, the increase of the layering energy leads to an increase in the wear resistance of the coatings.

Table 2. Parameters of regimes for LESD and of coatings from electrode TNM10

Regime	I, A	C, µF	Ti, µs	Ra, µm	δ, µm	HV, GPA
1	12.8	0.47	8	0.85	3.5	11.9
2	14.4	0.68	8	0.95	4.2	12.8
3	14.4	0.68	12	1.04	4.5	13.5
4	11.2	1	12	1.1	4.9	13.8
5	14.4	1	12	1.16	5.4	13.3

Comparative tests of cutting tools

From the curves obtained (fig.2), it can be seen that the applied coatings reduce turning tool wear both on the front and the rear surfaces. The lowest wear has the inserts with coatings from TC-TN electrode. In criterion of wear VB=0.2mm, the wear of the layered with this electrode tools is up to more than 2.5 times lower than that of uncoated tools (Table3).



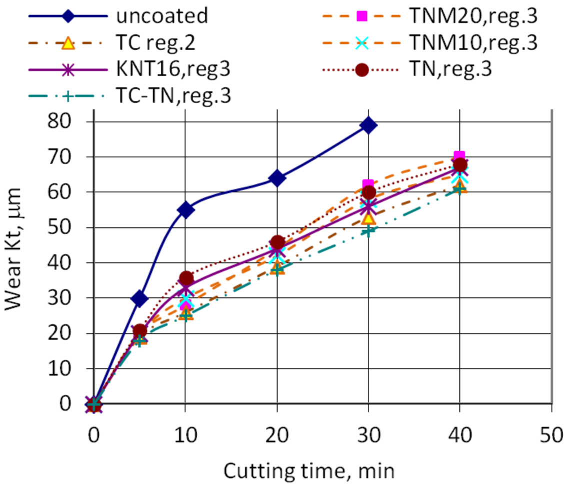


Figure 2. Wear of turning tools deposited with TiN and TiC based electrodes in cutting time: a) development of flank wear VB in time; b) development of Depth of crater Kt

Cutting speed V=30 m/min, feed f=0.37 mm/rpm, cutting depth 2mm, processed material – C45. Regimes for LESD coatings: reg.2–I=14.4A, C=0.68 µF, Ti=8 µs, τ=0.1, n=2 passes; reg.3–I=14.4A, C=1µF, Ti=12 µs, τ=0.1, n=2 passes;

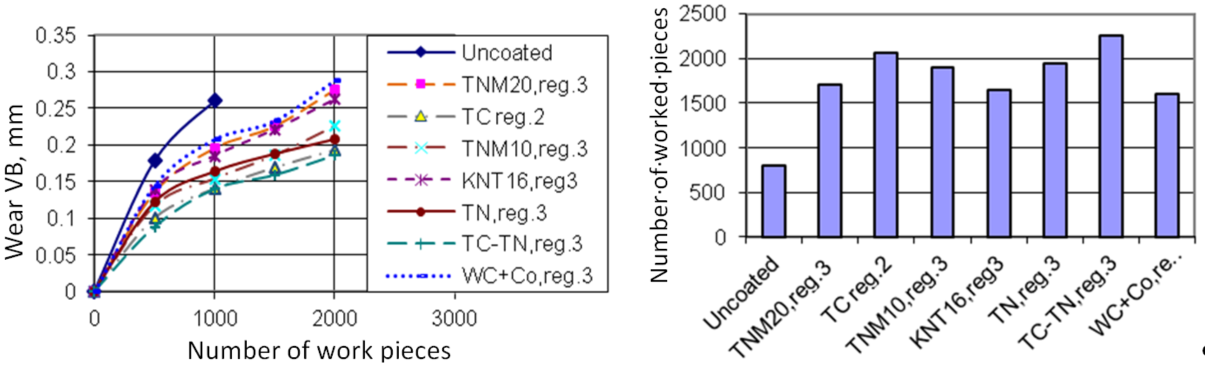
The values of depth of the crater Kt for LESD tools are up to 3 times lower than those of uncoated- Fig.2.b). The main reason for the reduced wear is higher diffusion resistance, hardness and chemical resistance of the TiC and TiN coatings. When comparing the influence of the type of the electrodes is established that the differences in the wear of the tools can reach to 25%.

Operational tests of countersinks (Fig.3), showed that their service life increased by more than twice as compared with non-reinforced ones.

Table 3. Durability of turning inserts at different criteria of wear

VB,mm	Tools life, min						
	Uncoated	LESD with TNM20	LESD with TC	LESD with TNM10	LESD with KNT16	LESD with TN	LESD with TC-TN
0.1	6.5	10	20	17	13	12	17
0.15	11	28	35	33	27	26	36
0.2	23	42	46	50	40	40	53

When cutting with a smaller thickness of the cut metal layer (countersinks), the effect of LESD at criteria of wear VB0.2mm with non-tungsten solid alloys is higher than that of turning (Figs 2,3).



a) b)

Figure 3. Durability of LESD counter sinks D=19 mm expressed by the number of parts made: ddevelopment of flank wear VB in time a); number of worked pieces b)

Cutting speed V=19,1m/min., feed f= 0,125 mm/rpm, cutting depth 0.25mm, processed material - St 0.50% C, HB250; Regimes for LESD: reg.2 – I=14.4A, C=0.68μF, Ti=8 μs, τ=0.1, n=2 passes; reg.3 – I=14.4A, C=1μF, Ti=12 μs, τ=0.1, n=2 passes;

It is can see that at all studied friction and cutting data the nature of wear of the LESD samples is similar to that of uncoated ones. The differences are in the lower values of the parameters characterizing the wear - Figs 1,2,3a). Wear of coated tools takes place in two stages. In the beginning coating is destroyed due to abrasion and delamination from the substrate. In the second phase, the layer of background material left without coverage keeps their working capacity for longer.

As can be seen from Table 3 and Fig. 1, 2 and 3.a) the effect of LESD differs according to the different wear criteria. At the beginning of the work the differences in tool life are smaller, and the differences in the durability of the tools coated with different electrodes are smaller too. With increasing of cutting time up to reach of criteria 0.1-0.15mm, the effect of LESD increases to maximum peak values - to more than 3 times increase in tool life. With a further increase in cutting time, the coatings gradual is wiped, and, as a result, the effect is reduced monotonically to 1.8-2.3 times at criteria 0.2mm, and then remains relatively constant. The highest values of the effect of LESD were observed in the second part of the curve of wear - after the initial smoothing of the friction surfaces.

When analyzing the influence of the electrode materials on the wear, it is found that the tools coated with TiC-TiN electrode have lowest wear - 15-25% lowers than that of tools coated with the other electrodes. Apparently, the combination of TiC and TiN in the composition of the electrode allowed to use the full advantages of each of the individual component and to receive higher wear resistance of the layered surfaces compared to that obtained with only TiC, TiN or with WC-Co electrodes. The tools deposited with electrodes with a smaller amount of solder metals show lower wear than those deposited with the electrodes TNM20 and KNT16, - the apparently higher content of soldering metals has a negative impact on the wear. However, the above conclusion is not valid for the TC-TN electrode, where wear is lowest.

The results obtained show that the influence of the electrode material is also related to the LESD mode. The increase of the pulse energy up to 0.02J as a result increases the durability of the coated surface. In the regime with higher energy, the wear of the tools is lower - Figs 2,3.

Coatings from non-tungsten electrodes reduce the wear intensity, slow down it over time, and can be successfully used to increase the durability of parts subjected to abrasive wear, as well as of cutting tools from high speed steel.

Conclusions

The influence the energy parameters of the mechanized LESD process on the abrasion wear and cutting wear of coatings obtained from electrodes based of TiC , TiN and TiCN on high speed steel was investigated. The wear of the coated tools decreases with increasing of energy of the LESD regimes. The conditions and processing parameters for LESD, at which has been obtained the lowest wear of coated steel have been determined.

The LESD coatings from TiC and TiN based alloys enhance the life of the tool bit. The increase in the durability of the investigated tools was more than 2.5 times than the uncoated and 1.2-1.5 times higher than when using the conventional WC-Co electrodes. They reduce the wear intensity, slow down its development over time, and can be effectively used to increase the durability of cutting tools from high speed steel.

It has been found the impact of different electrode materials on the wear of layered tools. The lowest wear showed the samples with coatings from electrodes based on TiC-TiN - to 1.5 times lower than that of the coated with tungsten carbide electrode specimens.

The established graphical dependencies can be used for development of technologies for hardening of parts and tools from high speed steels.

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