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Plasma Modification of Structure of Replacement Operating Parts of Farm Vehicles

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Annotation

On the basis of own researches and the analysis of references it has been shown that for extension of an operational resource of heavy-duty high-wear parts in parameters of universality, availability and economic efficiency surface plasma tempering is rational. Without changing surface roughness parameters, such strengthening heat treatment easily is built in technology process of recovery of parts, is finishing operation. It is low-cost, rather productive and allows to improve effectively operational firmness of replacement parts of agricultural machines.

By comparison of results of the studied five options of thermal hardening of flat samples from steel 65G it has been proved that the best combination of high strength, plastic and viscous properties for heavy-duty replacement working parts of soil cutting machines is provided by plasma modification with tempering at 300 ^{0}C.

It is confirmed that at the superfast speed of heating taking place at plasma tempering, phase transformations are displaced in area of high temperatures and this thermally activated process strongly influences kinetics of emergence and growth of nuclei of a new phase. The ratio between the speed of origin of austenite and speed of their growth changes; in process of temperature increase process of origin of austenite happens quicker, than acceleration of their growth, and is observed the increasing quantitative advancing of speed of origin over growth rate. It leads to forming of fine-grained austenite which it turns high-disperse martensite with high strength characteristics.

Keywords: plasma, strengthening, quenching, tempering, normalization, steel, interchangeable parts, structure, soil cutting machines, martensite, ferrite, pearlite, abrasion resistance, hardness, toughness

Introduction

Soil cultivation is one of the most power - and material-intensive processes in agricultural production. Practice shows that it is the share of plowing, cultivation and a disking of the soil to 45-50% of a consumption of fuels and lubricants in agriculture, and annual consumption of *replacement* operating parts of tillers makes hundreds of millions dollars. Therefore decrease in operational expenses at soil cultivation and improvement of abrasive resistance of parts and nodes is the most important condition of decrease in cost of products of agro-industrial complex, improvement of its efficiency and competitiveness.

The perspective direction of decrease in operational expenses at soil cultivation and improvements of abrasive resistance is the strengthening heat treatment of a working surface of replacement parts the high-concentrated energy flow, namely, a plasma arch. The ultra small structures which are formed at superfast heating and cooling possess the high hardness (abrasive resistance), durability and resistance to destruction. It is especially important that today a bit different requirements which sense is reduced to obligation of a combination of high durability and hardness with a sufficient stock of plasticity and impact strength are imposed to durability of materials. It is caused by an urgent need of improvement of reliability and durability of soil-cultivating equipment. For modern conditions of soil cultivation it is necessary to provide durability of material of a product for 1500-1800 MPa. Impact strength has to correspond to values not less than 0,8-1,0 MJ/m^2. For decrease in intensity of abrasive wear it is necessary to provide the greatest possible hardness of a surface - 60-65 HRC. Such complex of durability, impact strength and hardness as it was noted, by traditional technology of heat treatment (quenching +tempering) are not provided.

From this point it follows that the problem of extension of an operational resource of replaceable details of PRM is very significant in economic and resource-saving aspects. Plasma training, being finishing operation, it is easily built in technological process of preparation and repair of details; it is low-cost, rather productive and lets to improve operational firmness of replaceable details effectively.

Material and technique of research

Replaceable details of working parts of farm vehicles traditionally make from ordinary or high carbon steels - St. 6, 65G, U8 etc.

In the real work disks of beet-harvesting combines from manganese steel 65G, were exposed to superficial plasma hardening. Their chemical composition and temperatures of critical points it is specified in Table 1 (GOST14959-99)

Table 1-the Chemical composition (%) of steels and temperature of critical points, ^{0}C

C	Mn	Si	P	S	Ni	Cu	Ac_1	Ac_3	Ar_1	Ar_3	M_n
0,63	0,1,12	0,35	0,031	0,029	0,25	0,19	721	745	620	720	270

Mechanical properties of the steel subjected to the strengthening heat treatment (quenching from temperature 800-820 0C in oil with the subsequent tempering at 340-380 0C, with air cooling) are provided in table 2.

Table 2 - Mechanical properties of steels

$\sigma_т$, *MPa*	$\sigma_в$, *MPa*	δ_5, *%*	Ψ, *%*	*KCU* *J/cm²*	HRC *mm*
1220	1470	5,0	38	69	49

Microscopic researches were conducted on an optical microscope of "Neophot" at scale x200 on the micro-section which are cut out in the cross direction from a segment with a condition of preservation of the strengthened layer. It was studied a microstructure, depth and quality of the strengthened surfaces.

Impact strength of KCV was defined on the standard samples with a V-shaped cut which are cut out from sheets 10 mm thick. The strengthened zone of 3,0 in depth 3,5 mm settled down on the top side of samples along a cut. Such design of samples let to imitate destructions of disks in use - origin of a crack in the strengthened zone and the subsequent its distribution to steel with initial structure. Tests for abrasive abrasive resistance were carried out by Brinell-Havort's technique with the specific pressure upon a sample 17,5 MPa.

As an abrasive corundum by granularity 0,2 … 0,5 mm is used. Plasma modification of flat samples 50x60x10 mm was carried out on one of flat sides with drawing the strengthened zones across to the direction of friction. The coefficient of abrasive resistance K_i was defined as the relation $\Delta P_{in.}/\Delta P_{upr}$, where $\Delta P_{in.}$ and ΔP_{upr} - losses in the mass of samples at friction within 0,5 hours respectively the initial and strengthened states.

The received results and their discussion

As it was noted, character and intensity of change of a form and the sizes of replaceable working parts of farm vehicles for its abrasive resistance substantially define an operational resource of replaceable details of soil cuttting machines and also level of power expenses and quality of the technology operations which are carried out in agricultural production. Operability of replaceable details of agricultural cars depends on hardness and abrasive resistance of its working surface, and also on external factors - properties of the processed abrasive environment (soil), its initial uniformity, influence of the changing initial weather conditions, influence of hostile environment (moisture, salts, etc.)

The most widespread method of their hardening is the volume strengthening heat treatment - quenching +tempering. Except abrasive resistance working bodies are often subject to influence of considerable dynamic loadings. Therefore tempering for the volume strengthening heat treatment usually is carried out so-so or highly temperature (300.... 600^0C) tempering to provide sufficient viscosity of steel. Temperature increase of tempering of the hardened steel leads to proportional decrease in its abrasive resistance. Therefore for the replaceable working details in the conditions of intensive shock and abrasive resistance, effectively saving high initial viscosity of the main metal and improvement of abrasive resistance of a working edge with methods of superficial hardening from which in relation to working bodies of agricultural machines are widespread: HFC hardening, a gas-flame or induction surfacingwith the high-alloyed materials (electrodes). Also superficial plasma and laser hardening is perspective to use.

Possibility of improvement of a complex of operational properties of steels, including carbon, by plasma modification of structure lets to recommend this way for hardening of soil-cultivating cars [1].

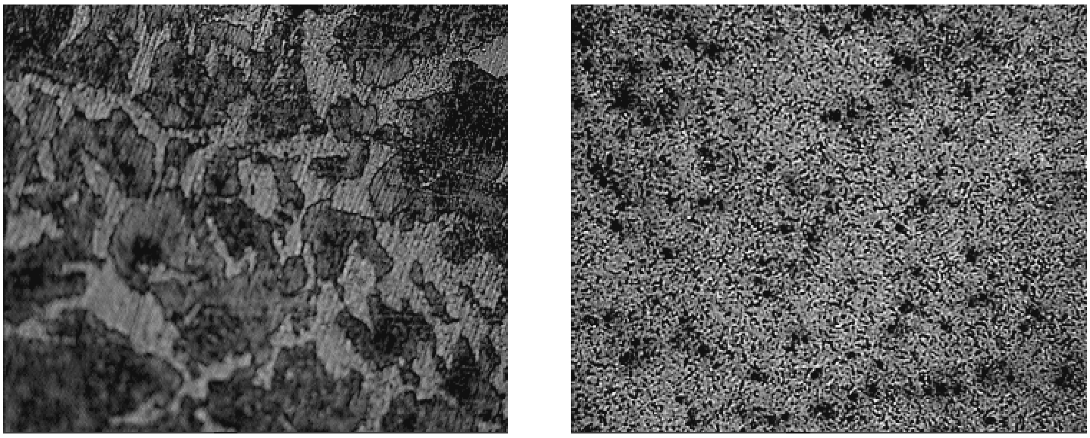
As an example of industrial applications by plasma modification of the structure of agricultural engineering enterprises can be, we've tested, the technology of plasma surface hardening drives beets harvester of low-alloy manganese steel 65G. Plasma modification performed without melting the surface superimposed reinforced annular zone at the periphery of cutting edge. Experiments show that the characteristics of phase and structural transformations in the plasma treatment of bulk samples of structural steels 65G are to change the kinetics of reactions. It is known that at superfast speed of heating during plasma hardening phase transformations are displaced in area of high temperatures that strongly influences kinetics of emergence and growth of nuclei of a new phase.

The relationship between the rate of nucleation and growth rate of embryos is changing with increasing grain temperature of a new phase (austenite) are generated faster than they rise. There is a growing quantitative advance rate of nucleation rate of growth. As a result, as the conversion $\alpha \rightarrow \gamma$ bias toward higher temperatures increasing role played by the nucleation and growth of nuclei is largely suppressed. This results in a fine-grained austenite, which turns into a finely structureless martensite.

By adjusting the amount of energy input, it is possible to create such conditions conversion $\alpha \rightarrow \gamma$, when the only possibility would be the initial phases of the transition process of origin. This opens the possibility of obtaining superfine austenite when the grain size will be commensurate with the size of the critical temperature achieved during the high-speed heating. It is used to improve the mechanical and service properties of steel after surface plasma hardening. In addition, it features hardening alloys during rapid heating due to the fact that the conversion $\alpha \rightarrow \gamma$ they are under nonequilibrium conditions in contrast to the traditional methods of thermal bonding with slow heating.

When there is no heating ultrafast shutter speed required for flow conversion $\alpha \rightarrow \gamma$, dissolution of carbides, followed by redistribution of carbon and alloying elements. Therefore austenite formed has different concentrations of dissolved carbon and alloying elements in contrast to the homogeneous distribution of the furnace by slowly heating [2, 3].

It should be noted that the sharpened cutting wedge drive has a small thickness, so to improve natural heat sink to a massive base metal during plasma hardening wheels are set at an angle of 45°. The rate of cooling of the cutting edge during plasma modification is high enough, that provides a bonded area in highly dispersed martensitic structure (Figure 1).



a) b)

Figure 1. The microstructure of the steel in the normalized 65G (a) and quenched state (b), x 200.

When optimization technology along with strengthening discs metallographic studies were conducted tests on toughness and abrasive resistance of the samples of steel 65G in the following structural conditions:

- Normalization (delivery status)
- Through hardened from 850°C in oil (basic technology)
- Through hardened and tempering at 300°C lasting 1 hour
- Plasma modification
- Modification of plasma and tempering at 300°C for an hour.

The results of the hardness measurements and tests are shown in Table 3.

Table 3 Performance properties of samples in different types of reinforcement

№ of item	Options for strengthening	Microstructure	Hardness, toughness, abrasive resistance		
			HV	KCV, J/cm^2	K_i
1	Normalization (initial state)	F+P	240…255	20,0	1,0
2	Through hardening	M_s	670…690	7,0	1,22
3	Through hardening + tempering	T+S	390…410	8,8	1,10
4	Plasma modification	M_b	850…870	9,6	1,65
5	Plasma modification + tempering	(T+S) в.д.	505…520	11,5	1,36

Note. F + R - ferrite-pearlite, M_s - martensite hardening, T + S - + troostite sorbitol, M_b - structureless martensite, (T + S) v.d. - Troostite + sorbitol finely dispersed.

As can be seen from Table 3 that the steel 65G in the normalized condition has ferrite-pearlite structure, the highest toughness and the lowest hardness and abrasive resistance. Plasma modification reduces toughness by 2 times and increase abrasive resistance by 65%. Through hardening reduces the toughness is almost 3 times and improves wear resistance by only 22%.

Sharp embrittlement of steel 65G after hardening due to the receipt of bulk big needle martensitic structure, which, despite a significant increase in hardness, does not contribute to a significant increase in abrasive wear resistance. More favorable combination of performance properties of steel 65G after plasma modification is related to the formation of a hardened zone finely martensitic structure with a hardness much higher than the level achieved in the hardening furnace. It is particularly important to note that while improving wear resistance is an increase in the viscosity (in comparison with a bulk quenching) - KSV plasma after modification of 30% higher than the bulk after hardening [4].

High hardness of space-hardened carbon steel served as the basis for recommendations on inappropriate increase in hardness over 60HRC (745NV) with considerable shock loads on the blade working replacement parts. However, the provision of local hardened layer and its joint loading during operation with plastic initial metal enables to depart from the recommendation.

For heavy-duty working replacement parts of soil cutting machines (for example, in a stony ground handling) a further increase in viscosity is achieved after application of plasma modification surround tempering. In this case, the hardness and abrasive resistance is significantly higher compared to the bulk hardening and subsequent tempering (Table 3).

Adjusting the shape and dimensions of the hardened zone by a heat treatment regimes lets to realize the effect of self-sharpening blade replacement parts in service, consisting in a selective nonuniform wear section of the blade, which preserves the shape and cutting properties.

Harder hardened layer wears less rapidly and therefore extends forwardly to form a cutting edge of the blade. In order to implement self-sharpening effect of the strengthening of the hardened layer must be at least 3 times the hardness of the base metal, which is achieved by plasma modification of 65G steel in the normalized condition [5].

Plasma modification disks may be either in a continuous mode (the perimeter of the cutting edge), and from applying discrete portions of predetermined dimensions and a predetermined pitch, which is beneficial to the disc and a soil treatment.

Innovative technology for plasma modification drives beet harvesters is characterized by high productivity - while strengthening one disc of 10 min., and the volume of heat treatment (quenching + tempering) - about 2 hours.

Conclusion

1. To extend the service life of heavy-duty wear-rational parameters of universality, accessibility and cost-effectiveness of a surface plasma hardening. Without changing the surface roughness, such hardening heat treatment can be easily integrated process of details, a finishing operation, low cost, adequate performance and can effectively increase their operational stability.
2. Comparison of the results of the five options investigated thermal strengthening of flat samples of steel 65G shows that the best combination of high strength, plastic and viscous properties of replacement parts for heavy duty working bodies of soil cutting machine provides plasma modification with tempering at 300^0C.
3. Rules of process of structure formation in the plasma quenching subject to the general laws of structure. With ultra-fast heating rates that occur within plasma quenching, phase transitions are shifted to higher temperatures and the thermally activated process greatly affects the kinetics of formation and growth of nuclei of a new phase.
4. The depth of the hardened structural zones in the plasma exposure depends on the parameters of heating and determined by the mechanism and kinetics of phase transformations in non-equilibrium states. The ratio between the rate of nucleation of austenite and their growth rate is changed; as the temperature of austenite nucleation process is faster than the acceleration of growth. This leads to the formation of fine austenite which is transformed martensite is finely divided with high strength characteristics.

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Түйін

Авторлардың өз зерттеулері және әдебиеттегі деректерді талдау негізінде ауыржүктелген, тезтозатын бөлшектердің эксплуатациялық ресурсын ұзартудың тиімді тәсілі болып плазмалық шынықтыру болатындығы көрсетілген. Себебі мұндай шынықтыру өзінің параметрлері жағынан универсалды, қолжетімді әрі экономикалық тиімді болып келеді.Мұндай беріктендіруші термиялық өңдеу бөлшектердің сыртқы қабатының кедір-бұдырларын өзгертпей оларды жөндеу мен қайтадан қалпына келтірудегі технологиялық үрдістерге жеңіл үйлестіріледі.Сонымен бірге үрдіс соңғы операция болып есептеледі, өнімділігі жеткілікті, аз шығынды және ауылшаруашылық машиналарының ауыстырылатын бөлшектерінің эксплуатациялық төзімділігін көтеруде өте тиімді. 65Г болатынан жасалған жазық үлгілерді термиялық беріктендірудің бес вариантының нәтижелерін салыстыра келе топырақкескіш машиналардың ауыржүктелген, тезтозатын бөлшектерінің беріктік, пластикалық және тұтқырлық қасиеттерінің ең жақсы үйлесімділігін қамтамасыз ететін плазмалық модификациядан кейінгі 300 ^{0}С босату болып есептеледі

Плазмалық шынықтыру кезінде болатын өте тез жылдамдықпен қыздыруда фазалық түрленулердің жоғарғы температураларға ығысатыны расталып, бұл өз кезегінде жаңа фазаның зародыштарыныұрықтарының пайда болу және өсуінің кинетикасына қатты әсер етеді. Өйткені бұл термиялық үдемелі үрдіс. Нәтижесінде аустенит бөлшектерінің пайда болуы мен өсуінің

қатынасы өзгереді: температура көтерілген сайын аустенит түйіршектерінің пайда болуы олардың өсуінен тезірек жүреді, яғни түйіршектердің пайда болу жылдамдығы олардың өсу жылдамдығынан үнемі артып отырады.Бұл үрдіс өте ұсақ түйіршікті аустениттің пайда болуына әкеліп, ол беріктігі жоғары өте ұсақ дисперсті мартенситке түрленеді.

Резюме

На основе собственных исследований и анализа литературных источников показано, что для продления эксплуатационного ресурса тяжелонагруженных быстроизнашивающихся деталей рациональным по параметрам универсальности, доступности и экономической эффективности является поверхностная плазменная закалка. Не изменяя параметров шероховатости поверхности, такая упрочняющая термообработка легко встраивается в технологический процесс восстановления деталей, является финишной операцией, малозатратна, достаточно производительна и позволяет эффективно увеличить эксплуатационную стойкость сменных деталей сельхозмашин.

Сравнением результатов исследованных пяти вариантов термического упрочнения плоских образцов из стали 65Г обосновано, что лучшее сочетание высоких прочностных, пластических и вязких свойств для тяжелонагруженных сменных деталей рабочих органов почворежущих машин обеспечивает плазменная модификация с отпуском при 300 ^{0}С.

Подтверждено, что при сверхбыстрых скоростях нагрева, имеющих место при плазменной закалке, фазовые превращения смещаются в область высоких температур и этот термически активируемый процесс сильно влияет на кинетику возникновения и роста зародышей новой фазы. Соотношение между скоростью зарождения аустенита и скоростью их роста меняется; по мере повышения температуры процесс зарождения аустенита происходит быстрее, чем ускорение их роста, наблюдается все большее количественное опережение скорости зарождения над скоростью роста. Это приводит к формированию мелкозернистого аустенита, который превращается в высокодисперсный мартенсит с высокими прочностными характеристиками.

Summary

On the basis of own researches and the analysis of references it has been shown that for extension of an operational resource of heavy-duty high-wear parts in parameters of universality, availability and economic efficiency surface plasma tempering is rational. Without changing surface roughness parameters, such strengthening heat treatment easily is built in technology process of recovery of parts, is finishing

operation. It is low-cost, rather productive and allows to improve effectively operational firmness of replacement parts of agricultural machines.
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