С.Сейфуллин атындағы Қазақ агротехникалық университетінің

ҒЫЛЫМ ЖАРШЫСЫ

(пәнаралық)

ВЕСТНИК НАУКИ

Казахского агротехнического университета им. С. Сейфуллина

(междисциплинарный)

№ 4(103)

Нұр-Сұлтан 2019

УДК 621.791.755

INFLUENCE OF COOLING RATE ON THE CHARACTERISTICS OF THE STRENGTHENED LAYER AT PLASMA HARDENING DURING WHOLE-ROLLED WHEEL

Sarsembaeva T.E.[1], doctoral candidate phD
Bogomolov A.V.[2], Ph.D.
Kanaev A.T.[1], Doctor of Technical Sciences, Professor
Topolyansky P.A.[3], Ph.D., Associate Professor
[1]Kazakh Agrotechnical University. S.Seifullin, Zhenis Avenue, 62, Nur-Sultan, 010011, Kazakhstan, tolkyn_adil@mail.ru
[2]Pavlodar University named after S. Toraigyrov, 64 Lomova street, Pavlodar, 140000, Kazakhstan, bogomolov71@mail.ru
[3]St. Petersburg Polytechnic University named after Peter the Great, 29, Polytechnic St. Petersburg, 195251, Russia, topoljansky@mail.ru

Annotation

The experiments showed the effect of hardening modes on the width of hardened tracks. With an increase in the plasma arc velocity by a factor of 4, the track width decreases by ~ 30%, and an increase in current by a factor of 2 leads to a proportional increase in the track width. The effect of the cooling rate on the characteristics of the hardened layer during plasma quenching is studied. It was shown that the cooling rates at temperatures corresponding to the austenitic region (not less than 750 0C) and the decomposition temperatures of austenite with the formation of perlite (700-500 0C) significantly exceed not only the critical quenching rate, but also the cooling rate during volume quenching in water or oil. As the temperature decreases and it reaches the martensitic transformation region, the cooling rate slows down. This helps to prevent the formation of internal quenching stresses arising from the temperature gradient. The experimental hardening of a solid-rolled railway wheel at the UDGZ-200 installation shows that in the range of practical operating modes, the surface layer of the wheel is hardened, which confirms the calculated conclusion about the optional supply of coolant (water) to the hardened surface during plasma hardening. The experimental hardening of a solid-rolled railway wheel at the UDGZ-200 unit in the range of practical operating modes provides hardening of the surface layer of the wheel, which confirms the calculated conclusion about the optional supply of coolant (water) to the hardened surface during plasma hardening.

Keywords: Surface hardening, solid-rolled wheel, plasma arc (jet), heating, cooling rate, UDGZ-200 installation, experimental hardening, hardening heat treatment, hardened product, martensitic transformation.

Introduction

The surface layers of widely used structural materials used in various fields of production are gradually destroyed during operation under the influence of a natural and aggressive environment, as well as technological load. The destruction of the surface layer occurs due to shock-abrasive wear, contact friction, corrosion and other technological factors.

The problem of wear and corrosion leads to a significant overspending of metal structural materials used in industrial production. The development of technology for wear and chemical resistance of the surface of materials exposed to aggressive environments and mechanical stress will allow more efficient use of structural materials in industrial production. Layers of nitrides, carbides, carbonitrides, etc., created on the surface of metals and alloys, have special protective properties with respect to the action of various aggressive media [1,2].

Another feature of the processes of wear and fracture of the surface layer is that during wear there is a continuous superimposition of cycles of plastic deformation and fracture, when the next cycle follows the ablation of wear products. Such a dynamic nature of the process also provides for the dynamic nature of structural changes in the surface layer. These sharp changes in the fine structure and structure of the surface layer with the external environment and the formation of wear products in this case lead to a high concentration of stresses with a complex pattern of their interaction in the surface metal layer. As a result of the influence of these factors, the fine structure and structure of the surface layer can turn out to be completely different in the process of wear than the initial structure and the structure of the metal in volume [3, 4].

In this article, the task is to improve the surface properties of structural materials on the basis of an economical, and at the same time the most effective method - surface plasma treatment. The use of plasma hardening allows you to directly process the working surface, to improve the physical and mechanical properties and corrosion resistance of the material. The advantages of this method include the versatility of processing, the cheapness of hardening technology. Moreover, the undoubted advantage of surface plasma treatment is the complete absence of harmful emissions into the environment. Plasma hardening does not use toxic substances, flammable and explosive gases, which ensures environmental cleanliness and processing safety.

The main effect of plasma exposure on a material is thermal exposure. In this case, the samples instantly heat up to a high temperature, up to the melting and evaporation temperatures. The exposure time is usually tens of microseconds, which provides a high power density. After the end of pulse heating, the surface temperature drops sharply due to heat diffusion into the interior of the sample. Due to thermal and shock effects, the depth of plasma exposure can reach 200 μm in the depth of the sample.

Thus, the plasma treatment is characterized by the simultaneous occurrence of nonequilibrium processes of melting, diffusion, and phase transformations in the surface layer of the material [5, 6].

At high loads and high train speeds, the thin surface layers of the metal heat up to temperatures exceeding the critical points (Ac1, Ac3) and subsequent accelerated cooling may form solid, at the same time brittle, martensite, which leads to cracking of the surface layers of the wheel rim.

These objective data indicate that increasing the wear resistance of the rolling surface (wheel flange and rim) of wheel sets is an urgent problem in railway transport. In recent years, innovative plasma technologies have been actively used to solve this urgent problem. The attractiveness and prospects of plasma hardening technology are due to the universality of its parameters, availability, environmental friendliness and economic efficiency of use. At the same time, without changing the general chemical composition of the material and its physical and mechanical properties in the inner layers, such processing easily fits into the technological process of repairing wheels, it is not expensive, quite productive and being a finishing operation, it can effectively increase the operational stability and service life of locomotive wheel sets and wagons. .

At the UDGZ-200 manual plasma hardening unit, the effects of the cooling rate on the characteristics of the hardened layer under various conditions of surface plasma hardening were studied. The use of the UDGZ-200 manual plasma hardening unit in this work is justified by the fact that it has certain advantages over automated plasma hardening units, which do not require large capital expenditures for the acquisition of expensive mechanisms in the form of a support for moving the plasmatron over the surface of the machined parts, robots for manipulation during operation, automatic machines, etc. The technology of hardening heat treatment by hardening consists in heating steel above e critical temperatures (Ac1 or Ac3) followed by rapid cooling. As you know, rapid cooling in the practice of traditional heat treatment is provided by placing a heated part in a cooling liquid (water, oil, mixtures of salts and alkalis, etc.) or by supplying liquid to the heated surface of the hardened product (spray cooling). In plasma hardening, a part or plasmatron moves along the processing surface at a speed that provides a critical hardening rate, i.e. the minimum cooling rate at which the high-temperature phase (austenite) turns into martensite without decomposing into a ferrite-cementite mixture. Depending on the speed of movement of the part (plasmatron), the heating can be with micro-fusion or without micro-fusion of damage to the surface of the part. In the case of reflow, one should not allow gross damage to the surface of the hardened part, which, as a rule, is accompanied by the formation of drops of molten metal. Such non-forced cooling, which provides quenching with heat removal to cold areas of the hardened part without supplying coolant to the heated surface, is widely used to increase the wear resistance of such large and massive products as heavy machine tool spindles, solid-rolled railway wheels, rolling rolls, etc. [1, 11].

Materials and methods of research

In this article, in accordance with the theory of N. Rykalin [2,3] the cooling rate when heating a large (massive) body is investigated, such as a single-rolled wagon wheel, under the conditions used in the UDGZ-200 manual plasma hardening unit. Using the formula ω = q/ 2π λ ν t2, the cooling rates were calculated at a point on the axis of motion of a powerful point heat source 1 s after its passage through a heat source. The power of the plasma arc is proportional to the current strength and the voltage drop across it. The hardening voltage is not regulated. The remaining plasma treatment parameters are selected in the ranges typical for the UDGZ-200 installation. The plasma arc power q = IU, while the voltage is constant, equal to 30 V (U = const), the current strength varies in the range of 50-250 A, the thermal conductivity of the steel is constant, equal to 47 W / (m 0C), the speed of arc movement varies in range 5-40 m / h, constant time (t = const), equal to 1 s. The exact values of the calculation values are presented in table 1.

Table 1 - Dependence of the cooling rate on the speed of movement of the plasma arc (hardening rate) at various values of current

Ser. No.	ν, m/h	ν, m/s	ω,^{0}C/c at I, A				
			50	100	150	200	250
1	5	0,0014	3631.96	7263.92	10895.88	14527.85	18159.81
2	10	0,0028	1815.98	3631.96	5447.94	7263.93	9079.91
3	20	0,0055	924.21	1848.43	2772.64	3696.86	4621.07
4	30	0,0083	612.24	1224.49	1836.73	2448.99	3061.22
5	40	0,0111	457.88	915.75	1373.63	1831.50	2289.38

As can be seen from the table, the numerical values of the cooling rate (18159.81-612.240 C/s) for all current values from 50 to 250 A exceed the critical quenching rate in water, which according to [4] is ~ 5000 C/s. The exception is the cooling rate (less than 500 ^{0}C/s) at a current of a plasma arc of 50 A and a speed of its movement of 0.0111 m/s, which is equal, according to the calculation, to 457.880 S/s. Thus, we can conclude that, when high-temperature plasma-jet high-speed heating of massive parts is heated in almost the entire selected processing range of the part, the critical cooling rate required for plasma quenching is ensured by the strength of the arc current and the speed of movement of the part. Note that medium carbon structural steels are hardened even at significantly lower cooling rates.

The effect of simultaneously varying the cooling time and the thermal conductivity of steel on the change in the cooling rate during plasma quenching calls scientific and practical interest. The cooling rates were calculated with the value of the thermal conductivity of carbon structural steel (~ 47 W / (m^{0}C) [5]. It is natural to assume that the value of the cooling rate affects the final structural state of the steel. Small values of the cooling rate (with a longer time) correspond to a high temperature range, in which austenite decomposes (more than 550 ^{0}C), and cooling rates at shorter times correspond to low temperatures, when martensitic transformation occurs, i.e. steel has already acquired akalennuyu martensitic structure.

The calculation was performed with the following initial data. The thermal conductivity of steel (~ 47 W / (m^{0}C), current strength I (150 A) and arc voltage U (30V) are constant, arc power q = IU = const (4500VT), the arc travel speed is also constant and is 20 m / h, the time from the start of heating ranged from 2 s to 16 s.The calculation was carried out according to the above formula, the results are shown in table 2.

Table 2 - the dependence of the cooling rate on time

Ser.No.	t, c	2	4	6	8	10	12	14	16
1	ω, ^{0}C/c	694.44	173.61	77.16	43.42	27.78	19.29	14.17	10.85

As can be seen from the presented calculation data, as the plasma arc moves away from the considered point, the cooling rate substantially slows down. This indicates that immediately after the start of cooling, the temperature rapidly decreases and there is not enough time for austenite decomposition by the diffusion pearlite mechanism with the formation of soft structures (ferrite-cementite mixture), therefore supercooled austenite quickly reaches the region of martensitic transformation and its decomposition occurs by the diffusion-free martensitic mechanism with the formation of a solid martensite structure [6, 7, 12].

In order to specify at what temperature and, correspondingly, time, a transition is made from the diffusion-free martensitic transformation (rapid cooling) to the not so fast diffusion pearlite transformation, a calculation is made for a typical quenching mode. The time range is limited to 6 s., since the most significant slowdown of the cooling rate occurs in it.

Initial data for calculation: temperature for heating T = q / 2π λ ν t; coefficient of thermal conductivity of steel (~ 47 W / (m^{0}C), current strength - I (150 A) and arc voltage - U (30 V), arc power q = IU = const (4500 VT), arc movement speed is also constant and is 20 m / h, the time from the beginning of heating ranged from 1 s to 6 s. The calculation results are shown in table 3.

Table 3 - the dependence of the temperature on time during hardening

Ser. No.	t, c	1	2	3	4	5	6
1	T, ^{0}C	2777,78	1388,89	925,93	694,44	555,56	462,96

The main results of research

According to the data in Table 3, a significant slowdown in the cooling rate after 4 and 6 s occurs at temperatures of 694.44 and 462.960 C, i.e. in the interval immediately preceding the interval of martensitic transformation of medium-carbon steels (400-200 ^{0}C). This confirms the above calculations, which show that during plasma hardening, the cooling rates are high (for current 150 A and part speed 5m / h 10895.880C), to prevent decomposition of supercooled austenite by the pearlite mechanism with the formation of soft perlite structures (ferrite cementitious mixture). From table 3 it can be concluded that is important for practice, that in the interval of martensitic transformation the cooling rates decrease. This helps prevent quenching cracks due to temperature gradients. This method of quenching, which consists in rapid cooling to temperatures of 400-500^{0}C, then delayed cooling, is used in the practice of hardening heat treatment and is known as quenching in two environments. First, the part is immersed in water and after a short exposure in water is transferred to oil. Therefore, this method of quenching is called quenching through water into oil.

Rapid cooling in water prevents pearlite transformation, and subsequent delayed cooling in oil reduces quenching stresses in the martensitic range. As practice shows, here the most crucial moment is exposure to water, the duration of which is set for each particular product. Both overexposure and underexposure can lead to marriage. Partial or complete decomposition of austenite occurs during underexposure in water and underestimates hardness, while overexposure produces strong hardening stresses that can lead to warping and cracking. Despite these drawbacks, quenching through water into oil is widely used in the manufacture of carbon steel cutting tools. It is known that carbon steels have low hardenability and therefore a cutting tool from it cannot be quenched in oil [8, 13, 14].

In plasma hardening, the width of the hardened tracks in one pass of the plasmatron is of practical importance, since it determines the productivity of the process. Therefore, it is of interest to predict the width of hardened tracks according to the calculation scheme used in this work. The width of the hardened tracks at a temperature of 750 ° C was calculated. This temperature is taken as the minimum temperature necessary for complete austenization of steel, i.e. the temperature of the hardenability of the steel during subsequent rapid cooling.

$$2l = \sqrt{\ } 8q/\pi\ \nu\ cp\ \Delta Tl,$$

where 2l is the width of the heating zone up to 750 0C;
cp is the heat capacity of steel equal to 4.8 J/(cm3K);
current strength varies I = varia, equal to 100, 150 and 200 A;
arc voltage U = const (30B);
plasma arc velocity ν = varia (10, 20, 30, 40 m / h);
temperature increment is constant.

The calculation results are given in table. 4 and in fig. 4 show that in the studied range of processing modes, the width of the hardened track varies between 13.8 and 39.1 mm.

Table 4 - Dependence of the width of the hardened (hardened) track on the current strength during plasma hardening.

Ser.No.	v, m/h	v, см/s	2l см, at I, A		
			100	150	200
1	10	0,278	2.76	3.39	3.91
2	20	0,556	1.95	2.39	2.76
3	30	0,833	1.59	1.95	2.26
4	40	1,111	1.38	1.69	1.95

Below are the results of a study of the surface hardening of a solid-rolled railway wheel made of steel grade 2 according to GOST 10791-2011. The chemical composition of grade 2 steel for railway wheels:%, C-0.64; Mn-0.58; Si 0.34; P-0.008; S-0.020; V-0.025; Ni-0.043.

A solid-rolled railway wheel is considered as a semi-infinite body, considering that when hardening single strips, heating the wheel does not affect the quality of hardening.

To ensure the necessary speed of rotation of the wheelset during plasma hardening, a rotation mechanism was designed and manufactured, equipped with a special gear motor that allows you to change the rotation speed. A strip of the ridge and wheel rim is subjected to plasma hardening. The hardening zone begins at a distance of 5-8 mm from the top of the ridge. The tracks were tempered at different speeds and at different currents. After quenching, the hardness was measured using a MET-U1 portable ultrasonic hardness tester [9, 10]. The results of the study are shown in table 5.

Table 5 - Dependence of hardened track width and Rockwell hardness on current strength and hardening rate

Ser.No.	I, A	v har, m/h	Track width, mm	Hardness HRC, (hardness MET-У1)
1	100	10	9	62
		25	7	61
		40	6	61
2	150	10	11	60
		25	9	61
		40	7	59
3	200	10	15	63
		25	13	63
		40	10	64

The hardness of the hardened tracks is practically independent of the current strength and the speed of movement of the plasma arc. This is due to the fact that the cooling rates during plasma quenching significantly exceed the critical quenching rate. Note that a slight increase in hardness from 61 to 64 HRC with an increase in current strength from 100 to 150 A cannot be explained only from the standpoint of cooling conditions. With a certain degree of simplification, this can be explained by an increase in the residence time of the heated metal in the austenitic state, and, as a consequence, a more complete dissolution of alloying elements in it, contributing to an increase in the martensite hardness [15, 16, 17].

The experiments also show the effect of hardening modes on the width of hardened tracks. As can be seen from table 5, with an increase in the speed of movement of the plasma arc by 4 times, the width of the track decreases by ~ 30%, and an increase in current strength by 2 times leads to a proportional increase in the width of the track. The best agreement between the calculated and experimental values of the width of the hardened track was obtained at high speeds of movement of the plasma arc relative to the workpiece. This is because the design scheme assumes a fast-moving heat source.

Discussion of the data

In the work, the calculation method investigated the effect of the cooling rate on the characteristics of the hardened layer during plasma hardening. It was shown that the cooling rates at temperatures corresponding to the austenitic region (not less than 750 ° C) and the decomposition temperatures of austenite with the formation of perlite (700-500 ° C) significantly exceed not only the critical quenching rate, but also the cooling rate during bulk quenching in water or oil. As the temperature decreases and it reaches the martensitic transformation region, the cooling rate slows down. This is of great practical importance, as it favors the prevention of the formation of internal quenching stresses arising due to the temperature gradient. The experimental hardening of a solid-rolled railway wheel at the UDGZ-200 installation shows that in the range of practical operating modes, the surface layer of the wheel is hardened, which confirms the calculated conclusion about the optional supply of coolant (water) to the hardened surface during plasma hardening. It is shown that the experimental hardening of a solid-rolled railway wheel at the UDGZ-200 unit in the range of practical operating modes provides hardening of the surface layer of the wheel, which confirms the calculated conclusion about the optional supply of coolant (water) to the hardened surface during plasma hardening.

Conclusion

The results of the studies showed that the cooling rate at temperatures corresponding to the austenitic region (not less than 750 ^{0}C) and the decomposition temperatures of austenite with the formation of perlite (700-500 ^{0}C) significantly exceed not only the critical quenching rate, but also the cooling rate during volume quenching in water or oil. This ensures hardening of the workpiece without the use of concomitant cooling at the UDGZ-200 plasma hardening unit.

As the temperature decreased and it reached the martensitic transformation region, a slowdown in the cooling rate was observed. This is of great practical importance, as it favors the prevention of the formation of internal quenching stresses arising due to the temperature gradient. In the technology of heat treatment of parts to obtain such an effect, a method of quenching through water into oil is used. In surface plasma treatment, such a quenching method is present naturally, which makes it technologically attractive.

In turn, the experimental hardening of a solid-rolled railway wheel at the UDGZ-200 unit (plasma hardening unit) showed that in the range of practical operating modes the surface layer of the wheel is hardened, which confirms the calculated conclusion about the optional supply of coolant (water) to the hardened surface during plasma hardening . This fact is of great practical importance, since the organization of work on a technological site without supplying water to the hardened product and subsequent assembly is much simpler.

The calculated and experimental values of the width of the hardened track for surface plasma hardening at high speeds of movement of the plasma arc (hardening speed) are obtained, which is explained by the calculation for the case of rapid movement of the plasma arc (jet) relative to the part.

References

1 Bogdanov V.M., Zaxarov S.M. Sovremennye problemy sistemy koleso-rels. Zheleznye dorogi mira, - 2014. №1. p. 57- 62.

2 Bogdanov V.M., Zaxarov S.M. IX Vsemirnyj kongress po skorostnomu zheleznodorozhnomu dvizheniyu, Tokio, - 2015 // Zheleznodorozhnyj transport, 2016. № 4. p. 20-23.

3 Kanayev A., Nekushev S., Jusin V. Increasing the wear resistance of wheelset flange susingthe plasma ticquenching. viii international congress machines, technologies, materials 2011. Varna, Bulgaria, 2011. p.103-105.

4 Korotkov V.A., Ananev S.P., Shur V.V. i dr. Issledovanie vliyaniya skorosti oxlazhdeniya na kachestvo poverxnostnogo sloya pri plazmennoj zakalke. -Nizhnij Tagil: Svarochnoe proizvodstvo,

2012. № 3. p.23- 27.

5 Xarris U., Zaxarov S., Landgren D. I dr. Obobshhenie peredovogo opyta tyazhelovesnogo dvizheniya: Voprosy vzaimodejstviya kolesa i relsa / perevod s angl. - M.: Intekst, 2002. - p. 416 .

6 Semechkin A.E. Zheleznodorozhnyj transport na sovremennom etape. Zadachi i puti ix resheniya. sb. nauch. trudov oao «Vniizht» - M.: Intekst, 2008. – 288 p.

7 Nechaev V.P., Ryazancev A.A. Issledovanie, razrabotka, obosnovanie vozmozhnostej povysheniya nadezhnosti raboty krupnomodulnyx shesteren putem plazmennogo uprochneniya ix poverxnostej. Progresivni texnologii i sistemi mashinobuduvannya. vip.1, 2 (43), 2012. p. 227-232.

8 Petrovyx V.A., Ivanova T.V., Nalabordin D.G. Ocenka iznosa grebnej celnokatanyx koles gruzovyx vagonov po rezultatam dorozhnogo eksperimenta. Vagony i vagonnoe xozyajstvo. - M .: RPK «Rrast», 2015. № 2. p. 45-47.

9 Goldshtejn M.I., litvinov V.S., Bronfin B.M. Metallofizika vysokoprochnyx splavov. - M.: Metallurgiya, 1995. 312 p.

10 Tuftyaev A.S., Mordynskij V.B., Zhelobcev E.A. Ocenka iznosostojkosti vysokouglerodistyx stalej v usloviyax suxogo treniya i abrazivnogo iznashivaniya. -M.: Stal, 2015. № 10. p.55-60.

11 Rykalin N.N., Nikolaev A.V., Kulagin I.D. Teplovoj potok v telo, vzaimodejstvuyushhee s plazmennoj struej / tvt, 1965. № 6. p.25-27.

12 Rykalin N.N. Raschety teplovyx processov pri svarke. – M.: Mashgiz, 1951, 296 p.

13 Filinov S.A., Firger I.V. Spravochnik termista. - M.: Mashinostroenie, 1969, 320 p.

14 X. Kuxling. Spravochnik po fizike. - M.: Mir, 1982, 520 p.

15 Laxtin yu.m. metallovedenie i termicheskaya obrabotka metallov. - m.: Metallurgiya, 1984, 360 p.

16 Materialovedenie B.N. Arzamasova, - M.: Mashinostroenie, 1986, 384 p.

17 Novikov I.I. Teoriya termicheskoj obrabotki metallov. - M.: Metallurgiya, 1986, 480 p.

ПЛАЗМАЛЫҚ БЕРІКТЕНДІРУ КЕЗІНДЕГІ ТҰТАС ИЛЕМДЕНГЕН ДОҢҒАЛАҚТЫҢ БЕРІКТЕНДІРІЛГЕН ҚАБАТЫНЫҢ СИПАТТАМАСЫНА САЛҚЫНДАТУ ЖЫЛДАМДЫҒЫНЫҢ ӘСЕРІН ЗЕРТТЕУ

Сарсембаева Т.Е .[1], phD докторанты
Богомолов А.В.[2], т.ғ.к.
Канаев А.Т.[1], т.ғ.д., профессор
Тополянский П.А.[3], т,ғ.к., доцент
[1]С.Сейфуллин атындағы Қазақ агротехникалық университеті, Жеңіс даңғ. 62
қ. Нұр-Сұлтан, 010011, Қазақстан, tolkyn_adil@mail.ru
[2]С.Торайғыров атындағы мемлекеттік Павлодар университеті, к. Ломова 64
қ.Павлодар, 140000, Қазақстан, bogomolov71@mail.ru
[3]Данқты Петр атындағы Санкт-Петербург
политехникалық университеті, Политехническая к., 29
Санкт-Петербург қ.,195251, Ресей, topoljansky@mail.ru

Түйін

Тәжірибелер нәтижесінде беріктендіру режимдерінің беріктендірілген жолдардың еніне әсерін көрсетті. Плазмалық доға жылдамдығының 4 факторға артуымен жолдың ені ~ 30% төмендейді, ал токтың 2 есе артуы жол енінің пропорционалды өсуіне әкеледі. Салқындату жылдамдығының плазмалық беріктендіру кезіндегі қатайтылған қабат сипаттамаларына әсері зерттелген. Аустениттік аймаққа сәйкес келетін температурада салқындату жылдамдығы (7500С-тан кем емес) және перлиттің пайда болуымен аустениттің ыдырау температурасы (700-5000С) критикалық тоқтау жылдамдығынан ғана емес, сонымен бірге суда немесе майда көлемді сөндіру кезінде салқындату жылдамдығынан да асып түсетіні көрсетілген. Температура төмендеп, ол мартенситтік трансформация аймағына жеткенде салқындату жылдамдығы баяулайды. Бұл температуралық градиенттен туындайтын ішкі жану кернеулерінің алдын алуға көмектеседі.

УДГЗ-200 қондырғысындағы қатты домалақ теміржол доңғалағының тәжірибелік беріктенуі практикалық жұмыс режимдерінің ауқымында доңғалақтың беткі қабаты қатайтылғанын көрсетеді, бұл плазмалық беріктендіру кезінде қатайтылған бетке салқындатқыштың (судың) қосымша берілуі туралы есептік қорытындыны растайды. Плазмалық шынықтыруға арналған УДГЗ-200 құрылғысында жүргізілген эксперимент көрсеткендей, тұтастай илемденген теміржол доңғалақтарының жұмыс беттерін беріктендіруде қолданылатын кестелердің практикалық интервалында плазмалық шынықтыру үшін өңделетін сыртқы бетті су немесе судің ертіндісін қолдану арқылы жүргізу (есептеулер растағандай) міндетті емесетігін дәлелдеп растайды.

Кілттік сөздер: Беттік шынықтыру, тұтастай илемденген доңғалақ, плазмалық доға (жалын), қыздыру, салқындату жылдамдығы, УДГЗ-200 құрылғысы, тәжірибелік шынықтыру, беріктендіретін термиялық өңдеу, шынықтырылған бұйым, мартенситке ауысу.

ИССЛЕДОВАНИЕ ВЛИЯНИЯ СКОРОСТИ ОХЛАЖДЕНИЯ НА ХАРАКТЕРИСТИКИ КОЛЕСА УПРОЧНЕННОГО СЛОЯ ПРИ ПЛАЗМЕННОЙ ЗАКАЛКЕ

Сарсембаева Т.Е .[1], докторант phD
Богомолов А.В.[2], к.т.н.
Канаев А.Т .[1], д.т.н., профессор
Тополянский П.А.[3], к.т.н., доцент
[1]Казахский агротехнический университет им. С.Сейфуллина, проспект Жеңіс, 62 г.Нур-Султан, 010011, Казахстан, tolkyn_adil@mail.ru
[2] Павлодарский университет им.С.Торайгырова, улица Ломова 64 г.Павлодар, 140000, Казахстан, bogomolov71@mail.ru
[3]Санкт-Петербургский политехнический университет им. Петра Великого, ул.Политехническая, 29, г.Санкт-Петербург,195251, Россия, topoljansky@mail.ru

Резюме

Эксперименты показывают влияние режимов закалки на ширину закаленных дорожек. При увеличении скорости перемещения плазменной дуги в 4 раза ширина дорожки уменьшается на ~30 %, а увеличение силы тока в 2 раза приводит к пропорциональному увеличению ширины дорожки. Исследовано влияние скорости охлаждения на характеристики упрочненного слоя при плазменной закалке. Показано, что скорости охлаждения при температурах, соответствующих аустенитной области (не менее 750 ^{0}С) и температур распада аустенита с образованием перлита (700-500 ^{0}С) существенно превосходят не только критическую скорость закалки, но и скорости охлаждения при объемной закалке в воду или масло. По мере снижения температуры и достижения ею области мартенситного превращения скорость охлаждения замедляется. Это благоприятствует предупреждению образования внутренних закалочных напряжений, возникающих из-за градиента температур. Экспериментальная закалка цельнокатаного железнодорожного колеса на установке УДГЗ-200 показывает, что в диапазоне практических режимов работы обеспечивается закалка поверхностного слоя колеса, что подтверждает расчетный вывод о необязательной подаче охлаждающей жидкости (воды) на закаливаемую поверхность при плазменной закалке. Показано, что экспериментальная закалка цельнокатаного железнодорожного колеса на установке УДГЗ-200 в диапазоне практических режимов работы обеспечивает закалку поверхностного слоя колеса, что подтверждает расчетный вывод о необязательной подаче охлаждающей жидкости (воды) на закаливаемую поверхность при плазменной закалке.

Ключевые слова: Поверхностное упрочнение, цельнокатаное колесо, плазменная струя, нагревание, скорость охлаждения, установка УДГЗ-200, практическая закалка, термическая обработка, закаленная деталь, мартенситное превращение.