railway wheels, laser strengthening zones

Svetlana GUBENKO*, Yuriy PROIDAK
National Metallurgical Academy of Ukraine
Gagarin av., 4, Dnepropetrovsk-5, 49600, Ukraine
Alexander SHRAMKO
JSC “INTERPIPE – NTRP” Institute of Development,
Stoletova str., 21, Dnepropetrovsk-81, 49081, Ukraine
**Corresponding author*. E-mail: sgubenko@email.dp.ua

INVESTIGATION OF POSSIBILITY OF LOCAL LASER STRENGTHENING OF RAILWAY WHEELS

Summary. It was shown possibility and necessity of local laser strengthening of cove zone of railway wheels tread by coming out of bainite structure.

ИССЛЕДОВАНИЕ ВОЗМОЖНОСТИ ЛОКАЛЬНОГО ЛАЗЕРНОГО УПРОЧНЕНИЯ ЖЕЛЕЗНОДОРОЖНЫХ КОЛЕС

Резюме. Показана возможность и необходимость локального лазерного упрочнения зоны выкружки поверхности катания железнодорожных колес при получении вейнитной структуры.

1. INTRODUCTION

Problem of raising of reliability and service life of railway wheels is connected with working out of new design of wheels and new wheel steels, but also with possibility of using of new methods of tread strengthening. Railway wheels are exposed to heat treatment (quenching and tempering), but their wear resistance not always satisfactory. Moreover undercuts of crests during operation are the important problem. Therefore it is expediently the supplementary srtengthening action on the cove zone by laser treatment. The aim of this work was investigation of structural changes in wheel steel after laser treatment.

2. MATERIALS AND METHODS OF INVESTIGATION

Structure of worn-out tread of railway wheel in cove zone was researched. Investigation of laser treatment zones were conducted on wheel steel containing 0,59C 0,72Mn; 0,34Si; 0,025S; 0,012P; 0,14Cr; 0,15Ni; 0,20Cu. Preliminary heat treatment was carried out by following conditions: quenching temperature 800, 850, 900, 950^{0}C, cooling rate in water 10^{0}C/c (in accordance with cooling rate of wheel rims by railway wheels production), tempering temperature 400, 480, 520, 560, 600^{0}C with soaking time 2h. Laser treatment in condition of continuous radiation was carried out on installation LG-701 “Kardamon” with radiation power 600W, rate of laser beam 20, 15, 10 и 5 mm/s. Microstructure of laser strengthening zones was investigated by optical (Neophot-21) and electron

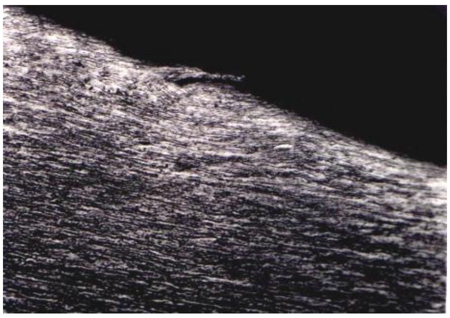
(Tesla) microscopes and also X-ray diffraction analysis. Hardness of laser strengthening zones was measured.

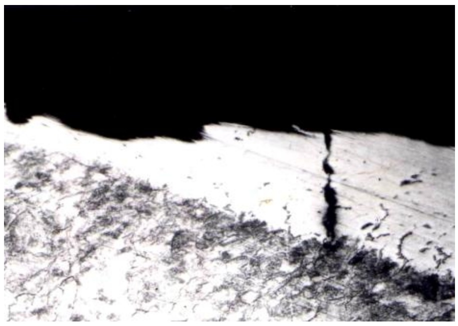
3. INVESTIGATION RESULTS AND DISCUSSION

Complex approach for wear mechanism of railway wheels tread is included not only investigation of structural changes in surface layers [1,2] and analysis of wear particles [4], but also working out effective methods of tread strengthening.

Macroanalysis of worn-out tread of railway wheel was shown that different areas of tread are worned in different ratio (Fig. 1a). Obviously cove zone is “weak place” owing to development of considerable contact stresses [1-3].

a





b c

Fig. 1. Macrostructure (a) and microstructure (b,c, x200) of railway wheel with worn-out tread
Рис. 1. Макроструктура (а) и микро (б,в, x200) колеса с изношенной поверхностью катания

Microstructure of wheel rim in cove zone of worn tread is area of deformed perlite and ferrite grains and also areas of “white layer” (Fig. 1b, c). Appearance of deformed zone is connected with bearing strain of metal by contact interaction wheel-rail. Plastic shears in thin surface layer passed in conditions of high pressure and cycling temperature. Character of microstructure of worn tread bears withness about heterogeneous deformation along section of wheel rim, that connected with heterogeneous disrtibution of contact stresses. It is known in cove zone these stresses are higher than in the middle of tread [3]. In cove zone the grains are significantly elongated and grinded, at the passage to tread degree of grains elongating is reduced and in the middle of tread it is less. Values of degree of grains elongating ε, depth of plastic shears zone h and dislocation density $\rho_{\perp}$ in different areas of worn tread are showed in Table 1.

Table 1

Values of degree of grains elongating *ε,* depth of plastic shears zone *h* and dislocation density $\rho_\perp$ in different areas of worn tread

ε, %		*h*, mcm		$\rho_\perp$, sм$^{-2}$	
Cove zone	Middle of tread	Cove zone	Middle of tread	Cove zone	Middle of tread
65...75	22...25	300	30	$9{,}22\cdot10^{11}$	$3{,}732\cdot10^{9}$

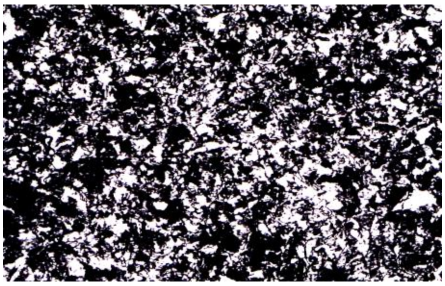
Analysis of worn tread of railway wheel shows the necessity for supplementary strengthening of cove zone of tread. Local laser treatment after ordinary heat treatment (quenching and tempering) or after turning down on a lathe of tread profile during operation
is proposed. It is necessary to investigate the influence of laser treatment on structural changes and hardness of wheel steel.

Microstructure of wheel steel after ordinary quenching was perlite with different dispersivity (Fig. 2a). After tempering at temperature 400, 480 and 520^{0}C the microstructure of wheel steel was the tempering troostite and dispersed carbides. After tempering at higher temperature the microstructure of wheel steel was tempering sorbite and carbides, but at temperature 600^{0}C the microstructure of wheel steel was coarser by all quenching temperatures. Microstructure of tempering wheel steel is heredited all principles coonecting with different quenching temperature [1]. At the all tempering temperatures microstructure of wheel steel after preliminary quenching from 950^{0}C is less dispersed by all the same conditions. Laser treatment of tempering wheel steel is the possibility of supplementary rise of service life.

Microstructure of laser treatment zone of wheel steel is dispersed martensite or bainite and also residual austenite and dispersed cementite (Fig. 2b, c). Character of principal structure is defined by rate of laser beam: at 20 mm/s when cooling rate of steel is maximum the martensite was formed, with the others conditions of laser treatment the bainite was formed. Parameters of laser treatment zone depend on temperatures of preliminary quenching and tempering and also the rate of laser beam. More dispersed microstructure of laser treatment wheel steel was formed at temperature of preliminary tempering 400, 480 and 520^{0}C (at all temperatures of preliminary ordinary quenching). Apparently, the effect of microstructure dispersion is observed by the rise of treatments quantity. Dispersivity of laser quenching microstructure of tempering wheel steel rose concerning preliminary quenching and tempering steel. But difference of degree of microstructure dispersivity existed before laser treatment in dependence on temperatures of preliminary quenching is stable after laser treatment.

The level of hardness on surface of specimen is defined by initial quenching and tempering microstructure of wheel steel at the same rate of laser beam (Table 2). At rise of temperature of preliminary tempering up to 600^{0}C hardness of laser quenching zone is decreased at all temperatures of preliminary quenching. Apparently, the influence of temperature of preliminary quenching on the hardness value of laser quenching zone is stable at all tempering temperatures. Level of laser quenching zone hardness is more when dispersivity of preliminary quenching and tempering wheel steel is higher.

Parameters of fine structure of wheel steel in laser action zone depends on regime of preliminary tempering which was leaded to reduce microstresses and dislocation density after tempering condition comparatively quenching condition of wheel steel (Tabl. 3).



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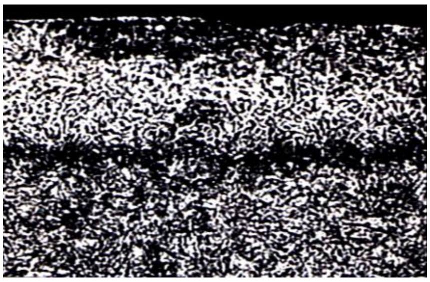

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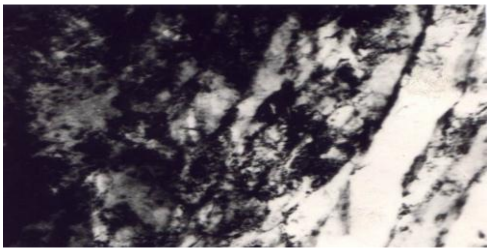


c

Fig. 2. Microstructure of wheel steel after ordinary quenching (a) and laser quenching (b,c); a,b - x500, c – x20000

Рис. 2. Микроструктура колесной стали после обычной закалки (а) и лазерной закалки (б,в); а,б – х500, в – х20000

Table 2

Hardness (x10, MPa) of laser quenching zone
at different preliminary quenching and tempeing temperatures

Tempering temperature,^{0}C	Quenching temperature, ^{0}C			
	800	850	900	950
400	460	440	420	410
480	440	440	410	400
520	430	415	390	400
560	425	400	390	380
600	390	380	370	370

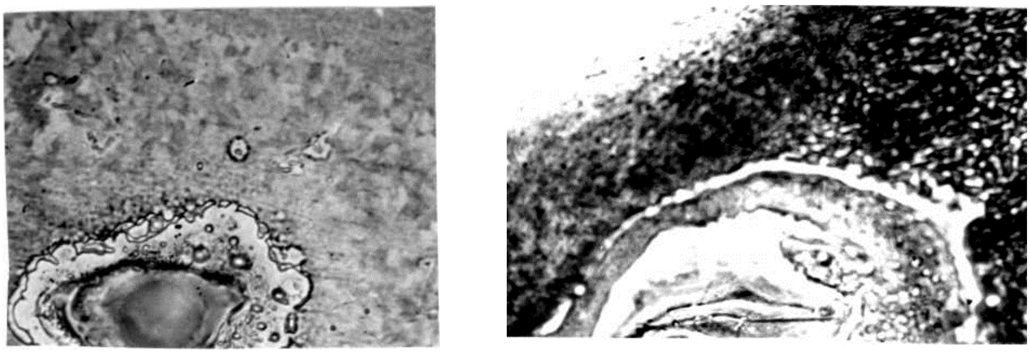
Nonmetallic inclusions being in wheel steel promote heterogeneous strengthening of wheel steel by laser treatment. Nonmetallic inclusions are melted or partialy dissolved in metal matrix and also are promoted formation of contact interaction zones in steel matrix (Fig. 3a, b).

In the results of alloying of local areas of steel matrix in the condition of abnormal mass transfer from internal sources (nonmetallic inclusions) liquational strengthening zones near inclusions are formed. These liquational zones have different type of composite structure: laminated type with cascade or “stain” distribution of chemical elements and microhardness, dispersal type with different hardened phases, and also combined type.

Table 3

Parameters of laser treatment zone of wheel steel

Temperature of quenching/ tempering, ^{0}C	Rate of laser beam, mm/min	Size of mosaic blocks, $x10^{5}$, sm		Microdistorsions $\Delta a/a$		Dislocation density, sm^{-2}	
		initial	after laser treatment	initial	after laser treatment	initial	after laser treatment
800/400	20		0,31		0,38	$4,7.10^{10}$	$6,3.10^{11}$
	15	1,82	0,31	0,34	0,37		$3,6.\ 10^{11}$
	10		0,34		0,36		$2,4.\ 10^{11}$
	5		0,33		0,36		$2,3.\ 10^{11}$
800/560	15	2,04	0,41	0,30	0,36	$2,1.10^{9}$	$1,8.10^{11}$
	5		0,48		0,34		$9,3.10^{10}$
850/400	15	1,91	0,36	0,32	0,38	$3,9.10^{10}$	$2,4.10^{11}$
	5		0,39		0,36		$2,3.10^{11}$
900/560	20		0,61		0,36	$1,9.10^{10}$	$2,9.10^{11}$
	15	2,12	0,78	0,30	0,36		$1,3.10^{11}$
	10		0,79		0,33		$9,8.10^{10}$
	5		0,84		0,32		$9,1.10^{10}$
950/560	5	2,46	1,39	0,28	0,31	$1,1.10^{10}$	$0,8.10^{11}$



a b

Fig. 3. Zones of local strengthening near non-metallic inclusions of oxide (a) and sulphide, (b) after laser treatment; x500

Рис. 3. Зоны локального упрочнения вблизи неметаллических включений оксида (а) и сульфида, (б) после лазерной обработки; x500

Analysis of laser beam rate influence on the parameters of laser treatment zone of tempering wheel steel allows when laser beam rate is increased the depth of laser strengthening zone is decreased at all regimes of preliminary tempering of wheel steel. And at all regimes of preliminary tempering of wheel steel the least deep laser strengthening zone was at temperature of preliminary quenching $950^{0}C$. At all temperatures of preliminary quenching the depth of laser strengthening zone at temperatures of preliminary tempering of wheel steel 400, 480 and $520^{0}C$ is approximately the same, is a little reduce at 560^0C and are significantly reduced at 600^0C that is defined by orientation and tense influence of the initial steel structure.

Thus, surface layer of wheel steel is strengthened with the result of considerable structure dispersion, rise of crystalline defects density, grinding of mosaic blocks and growth of crystal lattice microdistorsions by laser treatment. Change of laser beam rate is allowed to variate the level of wheel steel strengthening and depth of laser strengthening zone and also character of steel structure. Since martensite structure on tread is not assume the bainite structure of local place of cove after laser treatment is perspective. Hardness of bainite structure of wheel steel depends on conditions of laser treatment (370 – 460 HB). Initial microstructural condition of wheel steel is an essential influence on the microstructure of laser strengthening zone. Preliminary heat treatment is allowed to come out more homogeneous structure of laser strengthening zone and higher level of strengthening.

4. CONCLUSIONS

Investigation of structural changes in laser strengthening zones of wheel steel exposing to preliminary ordinary heat treatment shows the possibility of variation of character and parameters of microstructure of laser quenching. Regimes of preliminary heat and laser treatments are defined by laser strengthening effect of wheel steel. Local laser treatment of cove zone of tread coming out of bainite microstructure in the condition of continuous laser radiation is perspective for not only raising of reliability and service life of railway wheels, but also for fall of risk of crests undercut during operation. These results are interesting for not only working out additional method of cove zone of tread strengthening, but more also for possibility of structure and property reduction of railway wheels in the time of turning down on a lathe of tread profile during operation.

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