

FORMATION OF STRUCTURE AND PROPERTIES DURING THE THERMAL TREATMENT OF POWDER STEELS WITH DIFFERENT CARBON-CONTAINING COMPONENTS

The effect that thermal treatment has on the formation of the structure of hotstamped powder carbon steels with different carbon containing components (CCCs) is determined. Processes of thermal treatment such as quenching, tempering, and annealing are investigated. The inheritance of the initial structure was observed at all steps of thermal treatment.

Improving the physical–mechanical properties of powder steels can be achieved not only by changing their composition and production practice, but also by directional thermal treatment (TT). The results of TT are affected by factors both inherent to cast steels and specific ones caused by the characteristic properties of the initial materials used and technologies for their processing. The possibility of applying different types of TT is based on the fact that each powder particle is compact metal in which the same transformations take place as in large volumes of metal during heating and cooling. However, the features of the thermodynamic state of powder metal do not allow us completely evaluate its structural changes using the regularities observed for compact cast steels.

The specifics of the formation of the structure and properties of hotdeformed powder steels obtained from a charge with different carbon-containing components (CCCs) is related to the features of phase transformations and to the character of structures arising under their effect. These phenomena can proceed both directly in the course of cooling the samples after hot stamping (HS) (then they are similar to hightemperature thermomechanical treatment (HTMT)) and during the TT of the materials already cooled after HS. In this work, the effect of a cooling rate after hot stamping on the structure formation of powder steels was determined. Water, oil, or air was used as a cooling medium. In the first case, the effect of the HTMT is achieved with a simultaneous increase in the strength and plasticity of samples containing all types of CCCs and any amount of carbon (Tables 1, 2). As should be expected, the highest properties are characteristic of the steels of eutectoid composition, which were obtained with the application of artificial special lowash carbon (ASLC) and hightemperature pitch (HP).

Table 1

PROPERTIES OF POWDER STEELS COOLED AFTER HS IN VARIOUS MEDIA

CCC type in the charge	Carbon content in steel,%	Cooling medium					
		Air			* Water		
		σ_B , MPa	δ ,%	HRC** (HRB)	σ_B , MPa	δ ,%	HRC** (HRB)
PL	0,5	515	19	20	$\frac{750}{1,46}$	$\frac{29}{1,53}$	$\frac{25}{1,25}$
	0,8	755	16,5	18	$\frac{900}{1,20}$	$\frac{19}{1,15}$	$\frac{34}{1,89}$
	1,2	1320	5	33	$\frac{1125}{0,85}$	$\frac{16}{3,2}$	$\frac{34}{1,03}$
ASLC	0,5	775	22	20	$\frac{925}{1,19}$	$\frac{37}{1,68}$	$\frac{(185)}{1,13}$
	0,8	975	10	22	$\frac{1275}{1,31}$	$\frac{26}{2,6}$	$\frac{28}{1,27}$
	1,2	1510	8	38	$\frac{1800}{1,19}$	$\frac{18}{2,3}$	$\frac{38}{1}$
HP	0,5	750	22	22	$\frac{1525}{2,03}$	$\frac{31}{1,41}$	$\frac{31}{1,41}$
	0,8	1125	17	25	$\frac{1850}{1,64}$	$\frac{22}{1,29}$	$\frac{43}{1,72}$
	1,2	2004	13	44	$\frac{2220}{1,11}$	$\frac{15}{1,15}$	$\frac{55}{1,25}$

The denominator represents the ratio of the values of the parameter during cooling in water and in air.

Steel samples after HS were heated at a rate of 5–6 K/min to a temperature of 850–875°C; held for 15–20 min; and cooled V_{cool} at a rate of 450–500 (in

water), 100–150 (in oil), and 30–45 (in air) K/s. The mechanical properties of steels that contain pencil lead (PL) and ASLC within the charge are improved as V_{cool} rises (like in cast steels), remaining much higher in the second case. An increase in the cooling rate of

the samples doped with pyrocarbon (PC) from 150 to 450 K/s has almost no effect on their properties, which allows us to use oil as a cooling liquid. Cooling in air

did not allow us to obtain a structure characteristic of hardened steel in any of the cases (Table 2).

Table 2

EFFECT THAT THE COOLING RATE DURING TT HAS ON THE STRUCTURAL FORMATION OF DIFFERENT REGIONS AND PROPERTIES OF HOTSTAMPING SAMPLES OF STEEL 80P FOR DIFFERENT CCCS IN THE CHARGE

Cooling medium %/s	Condition		CCC type in the charge					
			PL		ASLC		HP	
			face;	center	face;	center	face;	center
Water 450-500	Structure		M+A+B	M+A+T	M+A	M+A+T	M+A	M+A
	properties	HRC	35	29	42	33	50	38
		σ_B , MPa	1575		1800		2075	
Batter, 100-150	Structure		M+A+B	M+A+C	M+A+T	M+A+C	M+A	M+A
	properties	HRC	27	20	35	33	35	33
		σ_B , MPa	1125		1500		1750	
Air, 30-45	Structure		T+P+C	T+P+F	P+F+A	P+F	B+P+C	P+F
	properties	HRB	89	86	92	88	95	90
		σ_B , MPa	800		1075		1325	

The structure of the samples obtained from the charge containing PL after hot stamping consists of Large lamellar pearlite; upon heating, it transforms into large grain austenite. The tendency of PC to segregate causes the formation of austenite with a different carbon saturation of grains, which results in an intensified growth of martensite crystals during quenching. The coherence of austenite and martensite in ASLC-containing and HP-containing steels is violated because of the appearance of dislocations at the interface of these phases during martensite transformation, and the rapid growth of martensite grains is stopped.

The martensite structure with inclusions of residual austenite and bainite is observed on the surface

of samples of the eutectoid composition, which were obtained from the PL-containing charge, after annealing in water. Most martensite needles have a rough surface, which is caused by the precipitation of fine carbide particles of the Fe₃C type. In its core, bainite is absent, but an increased amount of fine pearlite appears. The fracture has a brittle transcrystalline river character. Residual graphite inclusions are the centers of cracking. Quenching microcracks were observed in large acicular martensite; they intersect martensite plates or are located in the places of joint with cementite inclusions (Fig. 1). The occurrence of cracks indicates significant quenching stresses.

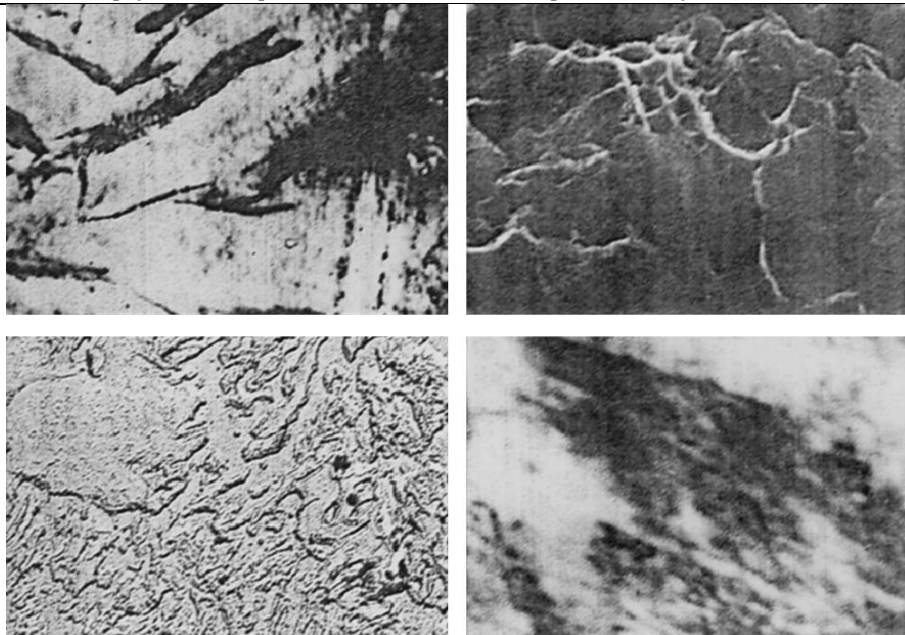


Fig. 1. Microstructure of PL-containing powder steel after quenching in water. (a) Martensite with carbide precipitations ($\times 1000$), (b) fractography of the fracture ($\times 3000$), (c) coal replica with a fine perlite structure ($\times 5800$), and (d) fine structure and carbide precipitates ($\times 105$).

The surface and core of the HP-containing samples after quenching in water have a martensite structure with austenite inclusions; no microcracks were found. Fine martensite needles of different etching abilities and single carbide particles are mainly

found, destruction proceeds along the martensite plate, and the fracture is brittle and stony (Fig. 2). It is characterized by pits that are divided into honeycombs; consequently, the pit surface is formed during destruction along the fine dispersed subinterfaces.

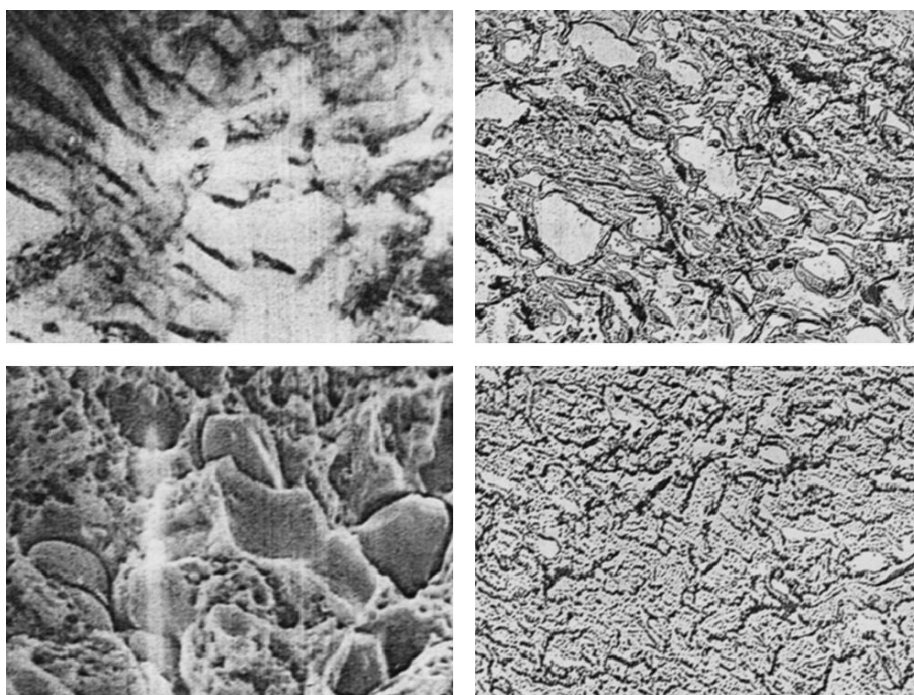


Fig. 2. Microstructure of PL-containing powder steel after quenching in water. (a) Fine foil with twins of martensite needles ($\times 19000$), (b) coal replica with globules of residual austenite ($\times 7200$), (c) fractography of the fracture ($\times 1500$), and (d) coal replica ($\times 5200$).

In the case of the ASLC-containing samples quenched in water, we observed spear-shaped large martensite needles which were formed in the initial period of transformation and fine needles formed during the following cooling. A significant amount of

residual austenite was also found, and it increased as the quenching temperature increases. The destruction is interparticle and brittle; the fracture is stony. During the investigation of fine foils obtained from the samples after HS and TT (followed by cooling in water and

containing PC in the charge), large packets of martensite crystals were found. Their apparent section in the foil plane has a uniaxial shape. In the case of the present treatment, they completely inherit the substructure of initial austenite. We can see on a replica that the sizes of twin martensite needles are significant. These samples are characterized by brittle destruction. The shape of cementite grains changes during annealing in all cases, which is related to the repacking of iron atoms during the phase transformation. Because cementite has a larger specific volume than ferrite, the generation of vacancies, the rate of which increases under the influence of deformation, as well as the presence of carbon is necessary for repacking.

The fact of a simultaneous increase in strength and plasticity during annealing of the materials seems interesting. This can be explained by the healing of defects arising in the course of the hot recompacting of moldings, the improvement of the quality of fusing on the thus formed contact surfaces, and the decrease in the softening action of pores due to their healing and spheroidization. It is noteworthy that, as the annealing duration increases, the properties of steels with all CCCs improve and the ranking of the carbon-containing components, which is discovered at other steps of obtaining and treating hotdeformed steels, remains (namely, HP-ASLC-PC-PL). This indicates that the positive qualities of unconventional CCCs are also inherited at this technological step.

CONCLUSIONS

The HTMT effect is achieved during the accelerated cooling of hotdeformed powder steels obtained from charges containing different CCCs. This is related to the austenite structure formed upon heating and characterized by fineness, which is inherited by high quality fine needle martensite. In the course of the thermal treatment of powder steel, the martensite structure is formed only during cooling in water. With the use of oil for these goals, such a structure is revealed only for PC-containing and HP-containing steels. No quenching structure arose after cooling in air.

The characteristics of CCCs affect the formation of the structure and properties of steels during tempering, which manifests itself in the inheritance of their features laid at all previous technological steps. Therefore, the properties of ASLC-containing and HP-containing steels tempered at all temperatures improved with respect to the PL-containing materials.

Diffusion annealing of the ASLC-containing and HP-containing samples, which are characterized by the homogeneity and fineness of the structure, leads only to the additional refinement of perlite. Therefore, we can either not perform this operation at all, or we can restrict ourselves to holding for 30 min at 1100°C.

Only prolonged annealing for 2 h at $t_0 = 1100^\circ\text{C}$ was favorable for the formation of a structure with separate regions of granular perlite for PL-containing samples. A homogeneous structure requires an even longer time for annealing.

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ИССЛЕДОВАНИЕ ФОНОВОГО УРОВНЯ ХИМИЧЕСКИХ ЭЛЕМЕНТОВ В ПРИРОДНЫХ ВОДАХ В ПРИАРАЛЬЕ

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Аннотация. В статье рассматриваются вопросы исследования фонового уровня химических элементов в природных водах в Приаралье. Показано, что обогащение вод р. Амударья идет в соответствии с загрязнением их состава коллекторно-дренажными, техническими и сбросными водами в русло реки.

Annotation. In the article the questions of research of base-line level of chemical elements are examined in natural waters in Priaralie. It is shown that enriching of waters Amudarya in accordance with contamination of their composition collector-drainage, technical and upcast waters in the river-bed of the river.

Ключевые слова: Приаралье, природные воды, элементный анализ, загрязнение.

Keywords: Priaralie, natural waters, element analysis, contamination.

Исследование качества природных вод (поверхностных, подземных, питьевых, поливных вод и т.д.) и связанные с водой процессы заболачивания, засоления и загрязнения плодородных почв тяжелыми металлами, агрохимикатами, их влияние на здоровье населения относятся к первостепенным задачам, которые

ждут своего решения для региона Южного Приаралья.

В условиях экологического кризиса в регионе Приаралья характер, количество и содержание химических элементов изменяются в пространстве и во времени, а также и во взаимосвязи с отдельными компонентами природной среды (почвы, растения, воды, воздух и т.д.).