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Development of the Technology for Manufacturing Welded Scraper Conveyor Pans from High-Strength Steel

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Investigation purpose is to prevent formation of cracks for manufacturing welded pans. The mechanical properties and hardness of pan sides in hot-rolled condition, after normalization and tempering are investigated. The heat-treatment furnaces and equipment are used for definition of chemical composition, mechanical properties and structure of sides. It was shown that technology including side tempering, side heating before welding and pan tempering after welding guarantees missing of cracks. Investigation results can be used for manufacturing welded goods from high-strength steels.

Keywords: PAN, SIDE, TECHNOLOGY, WELD, CRACK, NORMALIZATION, TEMPERING, HARDNESS, MECHANICAL PROPERTIES, STRUCTURE

Introduction

In the coal mining industry for the delivery of coal from production faces chain scraper conveyors are used, which are assembled from separate sections (pans), joined together with special locks. Pan is a welded construction consisting of two side walls (sides) made from the profile sidewall pan and bottom made of sheet metal. To the ends of side walls are welded parts of lock joints, and in the intermediate part - bracket with holes for mounting various attachments. Transportation of coal mass at the bottom of the pan is carried out with special scrapers fixed to the traction chains.

During the operation pans are exposed to intensive abrasion traction chains, scrapers, material transported and experience considerable stress from exposure to coal combine. All this makes high demands on the coal conveyor pans for strength and durability.

Currently the sidewall profile pans are made of low alloy high strength steel 25ХГ2СРФ with hardness within the 241-321 HB in hot rolled condition and structure, comprising upper bainite, which provides high durability; the bottom of the pans is of sheet metal (steel grade 25ХГСР) which in heat treated condition has hardness 255-321 HB: locks and plates are made of steel grade 35 by hot stamping.

It should be noted that in some cases there is the formation of microcracks in the zone of the weld and heat affected zone in the manufacture of welded pans and pans brittle fracture in the process of operation.

Results and Discussion

Text In the process of production of welded pans there are significant stresses that can lead to the formation of both hot and cold cracking. To reduce stress and reduce the possibility of hot cracking it is recommended to preheat the welded products. Prevention of formation of cold cracks contributes to improving the plastic properties of the base metal, slow cooling after welding (preventing the formation of hardening structures and preventing the occurrence of residual stresses) and the final tempering to reduce the level of residual stresses.

The ability of steel to weld is characterized by carbon equivalent (Ce), which can be determined by the formula (1)

$$Ce = C+Mn/6+Si/24+Cr/5+V/14+Ni/10+Mo/4, \quad (1)$$

where C, Mn, Si, Cr, V, Ni and Mo –mass fractions, respectively, of carbon, manganese, silicon, chromium, vanadium, nickel and molybdenum in steel (%).

The value of carbon equivalent of steel 25ХГ2СРФ is within 0.56-0.73, steel 25ХГСР - within 0.45-0.61; and steel 35 - in the range 0.41-0.62, while steel carbon equivalent of more than 0.45 are of limited weldability [1]. Because of the steels used to make pans, steel 25ХГ2СРФ has a maximum value of carbon equivalent, by welding the steel imposed more stringent requirements.

The main reasons for the formation of cracks in welded pans with sides of steel 25ХГ2СРФ are low plastic properties and impact strength specific to hot rolled steel to weld with the structure of upper bainite, and a high level of internal stresses in welded pans. To prevent this it is required to improve the plastic properties of hot metal before welding, reduce the stress introduced by welding, and the level of stress after welding.

Investigation of mechanical properties and structure was carried out on the sidewall profiles of pans with minimum and maximum cross-section (type СП190 and 255Д) from the steel 25ХГ2СРФ (**Table 1**) according to TS 27.1-26524137-1355:2007 production of PJSC " Azovstal. "It should be noted that in accordance with the specifications profiles are supplied in hot rolled (СП190) and tempered (255Д) states.

Table 1. Chemical composition of profiles of the pan sidewall

Profile	Mass concentration of chemical elements, %					
	C	Mn	Si	Cr	V	B
СП 190	0.22	1.66	0.70	0.54	0.085	0.004
255Д	0.24	1.68	0.72	0.59	0.081	0.004
Acc. to TS	0.21-0.26	1.50-1.80	0.50-0.80	0.45-0.75	0.06-0.12	0.002-0.005

Analysis showed the mechanical properties of profiles (**Table 2**) showed that the profile 255Д supplied to the released state, has significantly higher values of elongation (3% abs.) and percentage reduction (by 10-13% abs.) compared with non-tempered profile of СП190. It should be noted that the overall low level of impact strength of profiles impact strength of the more massive profile 255Д was ~ 10 J/cm^2 less than the profile of СП190.

Table 2. The properties of profiles of the pan sidewall in the initial state

Profile	Yield point, N/mm²	Tensile strength, N/mm²	Relative elongation, %	Relative reduction, %	Impact elasticity, KCU, J/cm^2	Hardness, HB (limits)
СП 190	721–729	1014–1021	16–17	27–29	35–44	302–321
255 Д	740–753	1010–1020	19.5–20	37–42	23–31	285–293
Acc. to TS *	≥ 580	≥ 780	≥ 9	≥ 32	–	241–321
* – for the profiles in the tempered state						

To develop the optimal technology of preliminary heat treatment of pans sidewalls we studied the effect on their property as tempering in the temperature range 300-650 ° C, and the normalization at 880-900 ° C with an exposure of 40-60 min and subsequent tempering in the temperature range 300-650 ° C. Holding during tempering was 2 h, cooling after tempering was carried out on the air. Mechanical properties of heat-treated sidewalls are shown in **Table 3** and **4**.

Analysis of the dependence of the properties of hot metal from the annealing temperature showed that for the sidewalls of type СП190 tempering in the temperature range 300-350 ° C practically does not change the hardness and tensile strength slightly increases the yield point and impact strength (KCU), promotes the values of elongation and the relative reduction, while the elongation at the level of 16-18%, and the magnitude percentage reduction is at the level of 41-52%. Further increase in annealing temperature leads to a decrease in hardness, yield strength and tensile strength, virtually no effect on elongation and slightly increases the relative narrowing. It should

Table 3. Mechanical properties of heat-treated sidewalls of type СП190

Condition before tempering	Tempering temperature, °C	Yield point, N/mm²	Tensile strength, N/mm²	Relative elongation %	Relative reduction, %	Impact elasticity, KCU, J/cm²	Hardness, HB (limits)
Initial hot-rolled	–	721–729	1014–1021	16–17	27–29	35–44	302–321
	300	800–818	1004–1004	17–18	41–44	44–45	285–321
	350	827–839	1007–1011	16–16	46–52	54–60	302–331
	400	821–824	976–996	15–16	46–49	33–33	302–331
	450	753–772	965–968	16–17	48–52	31–31	302–321
	500	736–753	933–947	15–16	46–51	31–46	285–302
	550	724–735	893–895	17–17	48–50	51–53	269–293
	600	732–744	872–878	17–18	53–53	50–51	285–293
	650	691–691	811–811	19–19	57–57	40–59	255–269
Normalized	–	647–725	1042–1081	19–20	34–39	44–45	302–321
	300	810–822	1018–1032	16–17	48–53	80–84	302–331
	350	783-838	975–1025	17–17	50–51	55–63	302–341
	400	794–813	979–993	17–17	51–56	26–31	302–341
	450	693–744	979–979	16–17	49–51	24–31	302–321
	500	713–719	943–961	17.5–17.5	48–48	31–48	269–277
	550	699–701	861–874	18.5–20	52–54	39–44	269–285
	600	621–687	775–810	17.5–18.5	56–58	69–71	241–269
	650	570–691	713–732	19.5–21.5	64–66	91–95	241–255

be noted that the temperature range 400-500 ° C for steel 25ХГ2СРФ is an interval of temper brittleness, as evidenced by the reduction of 1.5-2 times the values of toughness.

Tempering of sidewalls of type 255Д in the temperature range 500-650 ° C practically does not change the values of mechanical properties, but the toughness values are significantly lower than for sidewalls of type СП190.

For sidewalls of type СП190 mechanical properties after normalization with the release of almost identical properties of hot-rolled sidewalls after tempering, whereas for sidewalls profile of type 255Д the application of normalization has led to a decrease in strength characteristics, it does not change the values of elongation and contraction, but it helped to improve the impact strength.

Thus, the optimal combination of strength and plastic properties and impact strength for the sidewalls of type СП190 is provided after tempering in the temperature range 300-350 ° C, whereas for more massive sidewalls of type 255Д the desired set of properties is provided after normalization and tempering in the temperature range 300 -350 ° C.

Before welding, the products from a limited welding high-alloy steel must be heated. In general, the recommended temperature of heating lies within 100-350 ° C and is adjusted depending on the carbon equivalent steel. For sidewalls of

Table 4. Mechanical properties of heat-treated sidewalls of type 255Д

Condition before tempering	Tempering temperature, °C	Yield point, N/mm²	Tensile strength, N/mm²	Relative elongation %	Relative reduction, %	Impact elasticity, KCU, J/cm²	Hardness, HB (limits)
Acc. to TS , not less than		580	780	9	32	–	241-321
Initial hot-rolled	–	740–753	1010–1020	19.5–20	37–42	23–31	285–293
	500	723–726	925–950	16–17	47–50	14–19	269–285
	550	735–742	905–905	16–16	50–50	15–24	269–285
	600	758–769	895–895	16–18.5	49–51	8–10	269
	650	727–738	845–854	16–18	57–57	11–35	255–269
Normalized	–	701–707	1075–1095	18.5–18.5	34–34	35–36	255–311
	300	775–794	1040–1050	16–16.5	42–43	65–66	293–302
	350	621–799	870–1010	14.5–19.5	47–52	55–56	293–321
	400	698–824	960–1010	16.5–16.5	49–49	20–25	255–269
	450	514–747	833–979	16.5–17	49–49	54–56	241–277
	500	656–750	869–936	17.5–18	50–51	60–71	241–269
	550	557–684	770–848	15.5–21	51–55	55–110	229–269
	600	595–676	773–823	17.5–18.5	48–55	60–85	229–255
	650	544–622	711–765	19–21	56–59	84–105	207–235

steel grade 25ХГ2СРФ heating temperature (Th) in accordance with [2] can be determined by the formula (2)

$$Th = 350\ °C\ \text{x}\ (Ce - 0{,}25)^{0{,}5}. \qquad (2)$$

Analysis of the chemical composition of the of the pan sidewall profiles of the steel 25ХГ2СРФ made in 2004-2007 showed that the actual value of the quantity of carbon equivalent ranged from 0.60-0.69, while the value of carbon equivalent to the chemical composition of the technical conditions are in the range 0.56-0.73. Design temperature of heating steel 25ХГ2СРФ with minimum and maximum possible content of alloying elements is respectively 195 and 243 ° C. Practically heating temperature should be between 200-230 ° C.

It was established experimentally that the cooked side walls of the pans with steel 25ХГ2СРФ should be no later than 20-30 min after the end of the welding loaded into heated furnace for tempering at 500-520 ° C with holding at least 3 hours.

According to the developed technology, including pre-tempering of type СП190 sidewalls made of steel grade 25ХГ2СРФ, heated of pans sidewalls before welding to a temperature of 200 ° C, welding and dispensing of pans sidewalls after welding, made an experimental batch of pans sidewalls. It is established that the developed technology of pans sidewalls with sides of steel 25ХГ2СРФ guarantees no cracks in the zone of the welded joint and heat affected zone.

Conclusions

The technology of production of welded pans of coal scraper conveyors with sidewalls of high-strength low-alloy steel 25ХГ2СРФ , the bottoms of the steel 25ХГСР, as well as locks and bars of steel grade 35, providing pre-tempering of sidewalls , heating of the collected pans prior to welding and tempering of welded pans. The developed technology ensures the absence of cracks in the zone of the welded joint and heat affected zone.

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Разработка технологии изготовления сварных деталей скребковых конвейеров из высокопрочной стали

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Цель исследований – предотвращение образования трещин при изготовлении сварных рештаков. Исследовали механические свойства и твердость боковин рештаков в горячекатаном состоянии, после нормализации и отпуска. Использовали термические печи и оборудование для определения химического состава, механических свойств и структуры боковин. Показано, что технология, включающая отпуск боковин, подогрев их перед сваркой и отпуск рештаков после сварки гарантирует отсутствие трещин. Результаты исследований могут быть применены при изготовлении сварных изделий из высокопрочных сталей.