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Experimental-industrial development of the structural mix electrical steel smelt using ferrosilicon manganese instead of ferromanganese and ferrosilicon

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Abstract

The innovative smelt technology of structural electrical steel of various mixes (42CrMo4(U) 42CrMo4(U) and functional purpose using ferrosilicon manganese MnSi17 instead of ferromanganese of VMn78A, VMn88A types and ferrosilicon VSi65 is developed and introduced. Innovative technology reduces the long steel rejection on non-metallic inclusions, ultrasonic control and improves production efficiency.

Key words: *structural electrical steel, deoxidation, ferroalloys, ferromanganese, ferrosilicon, ferrosilicon manganese, long steel, recovery, economy*

In the mix of electrical steel, smelted in PLC "Dneprospetsstal", a large segment of long steel is presented by structural low- and intermediate-carbon steel types 42CrMo4, 42CrMo4(U), 20Cr, 20MoCr3, 20MnCr, S235J2G4 etc. Applied technological scheme of production includes the metal product smelt in electric arc furnace DSP-60, its partial deoxidation by the ferrosilicon VSi65 additives, subsequent metal alloyage by ferromanganese (types VMn78A, VMn88), steel processing on ladle furnace with the chemistry adjustment and steel degassing with the end deoxidation by aluminium and calcium silicon.

Though there are three steps of technological scheme of structural steel smelt with the separate application of ferromanganese and ferrosilicon, a certain amount of long steel is rejected on non-metallic inclusions and results of ultrasonic control at the final quality monitoring of metal.

The accumulated in PLC “Dneprospetsstal” experience of industrial production of electrical steel of bearing mix with application for the metal deoxidation and alloyage by ferrosilicon manganese MnSi17 (MnSi25) instead of ferromanganese and ferrosilicon [1, 2], was a premise for experimental and industrial development of smelt and secondary metallurgy of structural types. The complex in technological aspect steel types 42CrMo4 and 42CrMo4(U), which mainly differ in sulfur content (Table 1) were the object of experimental and industrial development of the structural electrical steel smelt technology.

Table 1 Constitutions of electrical steel types 42CrMo4 and 42CrMo4(U)

Name of technical specification	Type of steel	Mass fraction of elements, %							
		C	Si	Mn	Cr	Mo	S	Al	Ca
TS 4SS 006-2007	42CrMo4	0.38-0.41	0.10	0.7-0.9	0.9-1.0	0.15-0.20	≤0.01	0.020-0.035	not less than 0.002
TP № 309-08	42CrMo4 (U)	0.38-0.41	0.40	0.7-0.9	0.9-1.0	0.15-0.20	0.02-0.03	0.020-0.035	0.002
TS DSS 006-2007	42CrMo4	0.39-0.42	0.10	0.7-0.8	0.9-1.0	0.15-0.20	≤0.01	0.020-0.035	not less than 0.002
TP № 357-09	42CrMo4 (U)	0.39-0.42	0.30	0.7-0.8	0.9-1.0	0.15-0.0	0.020-0.030	0.020-0.035	0.002

Ferroalloys, which constitution is given in Table 2, are used in the structural steel smelt of the types given above on the functional and developed technologies for pre-deoxidation and alloyage of metal.

Table 2 Constitutions of ferroalloys, which are used in the structural electrical steel smelt on the functional (VMn78A, VMn88, Mn95, VSi65) and experimental (MnSi17) technologies

Type of ferroalloy	Standart	Mass fraction of component					
		Mn	C	Si	P		S
					A	Б	
			not more than				
VMn78A	DSTU3547-97	75-82	7.0	6.0	0.05	0.7	0.03
VMn88	DSTU3547-97	85-95	2.0	3.0	0.10	0.4	0.03
MnSi17	DSTU3548-97	65 not less	2.5	15-20	0.10	0.6	0.03
Mn95	GOST6008-90	95 not less	0.2	1.8	0.07	-	0.03
VSi65	DSTU4127-2002	0.5 not more	0.2	64-68	0.05	-	0.03

The criteria for the quality assessment of structural steel and the efficiency of smelt technology in electric arc furnace DSP-60 with the replacement of expensive ferroalloys VMn78A and VMn88 by ferrosilicon manganese MnSi17 were: the total rejection of long steel, including by the UT types of defects, scabs and flaws; the mill products pollution by nonmetallic inclusions; economical efficiency of steelmaking using ferrosilicon manganese MnSi17.

The ferrosilicon manganese use for steelmaking had a significant impact on the decrease of the long steel rejection by scabs and flaws (28%) and to a lesser extent on the rejection by UT (3.15%) (Table 3)

Table 3 Rejection of the long steel 42HM(U), smelted without- and with the use of ferrosilicon manganese MnSi17

Steelmaking technology	Nuber of smelts	Metal rejection by the types of defects, % rel.		
		Total	UT	scabs, flaws
Without the use of MnSi17	25	13.85	11.10	2.75
With the use of MnSi17	23	12.73	10.75	1.98
Reduction of metal rejection, %	-	8.10	3.15	28.0

The influence of ferromanganese replacement by ferrosilicon manganese with the reduced specific consumption of ferrosilicon on the pollution density of long steel by non-metallic inclusions as assessed by the standard ASTM E-45 (Method A) is analyzed on the smelt series of electrical steel of types 42CrMo4 and 42CrMo4(U).

It was found that the pollution density of rolled steel of 23 experimental smels by the type of sulfide inclusions A_{tn} (thin) decreased by 8.6% and by 15.78% by the type of A_{tck} (thick). The metal pollution density by the type of oxide inclusions B_{tn} and B_{tck} is almost unchanged. It should be noted that the experimental and industrial smelts were conducted primarily to determine the possibility of the production efficiency increase by the cost cut of ferroalloys. Therefore, further development of the steel deoxidation and alloyage modes is an independent issue.

The third priority factor of the ferrosilicon manganese application of the wide mix structural steel smelt is the economic efficiency of the ferrosilicon manganese use instead of ferromanganese VMn78A and VMn88 (silicothermic smelting method), applied on the basic technology.

It was found that the use of ferrosilicon manganese MnSi17 for steelmaking of types 20MoCr3, 16MnCr5, 20MnCr and 17MnSi instead of VMn78A or VMn88 and Mn95 (metal manganese) allowed to get economic benefits 75.24 UAH/t of metal yield. The steelsmelting of types with the use of MnSi17 allowed to get economic benefits for the steel 42CrMo4 on experimental smelts on average 54 UAH/t of metal yield and for the steel 42CrMo4(U) on average 148 UAH/t during the steelsmelting of types 42CrMo4 and 42CrMo4(U) with a normalized consumption of manganese ferroalloys of types VMn78A + VMn88 or just VMn88A. The data on specific consumption of all types of ferroalloys used in steelmaking of 42CrMo4 and 42CrMo4(U) on the functional and experimental technologies are presented as an example in Table 4.

Table 4 Comparative data on specific consumption of all types of ferroalloys in steelmaking of types 42CrMo4 42CrMo4-U on the functional and experimental technologies

Technology	Type of steel Smelt number	Types of ferroalloys						Share of MnSi17 in makeup of ferroalloys	Share of MnSi17 in cost of ferroalloys	Eeconomic benefits
		VMn78A	VMn88A	VSi45	VSi65	MnSi17	In total			
Functional	42CrMo4 V25005	4.9 69.35	4.64 176.13	4.54 29.53	3.16 40.16	-	27.44 315.17	-	-	-
Experimental		-	-	4.82 32.62	3.53 42.28	12.04 171.01	20.39 245.91	59.05	69.54	69.25

Functional	42CrMo4-U V25047	-	9.10 345.68	4.60 29.94	3.39 40.63	-	17.09 416.07	-	-	-
Experimental		-	-	4.85 32.85	5.17 81.92	14.20 201.59	24.22 296.36	58.62	68.02	120.23

Analysis of the data in Table 4 confirms that economic benefits increase 1.78 times more on the steelmaking of 40MnMo(U) is achieved due to the exclusion of the use of an expensive ferromanganese VMn88 of silicothermic production method and the use of ferrosilicon manganese MnSi17 produced by the more economical carbo-recovering process and therefore is cheaper in comparison with ferromanganese VMn88.

Data analysis of experimental and comparative steelmaking of 42CrMo4(U) showed that in most cases the actual specific consumption of silicon contained in applied ferroalloys for steelmaking on experimental technology exceeded the figures of functional technology by 5.8% (Table 5).

Table 5 Comparative data on the silicon content in the smelted steel 42CrMo4-U and the specific consumption of silicon on experimental and comparative technology

Type of steel	Technology	Silicon content in steel in accordance with GOST	Rate of silicon consumption (total), kg/t	Actual content Si, %	Actual silicon consumption, kg/t
42CrMo4(U)	functional	0.15-0.35	4.14	0.243	4.93
42CrMo4(U)	experimental		4.14	0.255	5.22

The specific consumption of the silicon (5.8%) contributed by ferrosilicon manganese and ferrosilicon is increased on the experimental steelmaking of 42CrMo4(U) and caused by its higher content in experimental metal (4.93%) in comparison with the steelmaking on functional technology, and also by unfinished modes of the ferroussilicon manganese and ferrosilicon addition in the metal at the steel deoxidation and alloyage.

Achieved in the work done the capitalization of knowledge on experimental and industrial development of the structural steel smelt can be increased at the further ferroalloys addition mode processing during the half-finished material metal processing in ladle furnace and the steel deoxidation in ladleman vacuum vessel.

Conclusions

1. Science-based technology of smelt and secondary treatment of grade composition structural steel with the replacement of ferromanganese VMn78A, VMn88 and ferrosilicium VSi65 by complex ferroalloy MnSi17 was developed and industrialized.

2. Steelmaking technology with the use of MnSi17 instead of VMn78A and VMn88A provides economic benefits for the steel of type 42CrMo4 amounting 69.26 UAH/t and for 49KHGM-U amounting 120.23 UAH/t of finished metal.

3. The actual consumption of the silicon entered by all types of ferroalloys in the experimental smelts in comparison with the norms (4.14 kg/t) increased by 5.88% due to a 4.93% more silicon content in the finished long products.

4. Appropriate changes and additions to the standing instructions on the smelt of structural mix steels, with the application of ferrosilicon manganese, for which the use of ferromanganese VMn88A is normalized, are made on the basis of the work done.

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