USE OF 18ФТ STEEL FOR PRODUCTION OF A400C (A500C) STEEL REINFORCEMENT AT LTD. "RUSTAVI STEEL"

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It was reported [1, 2] that production of reinforcing steel A500 C using high-temperature thermo-mechanical treatment (HTTMT) is complicated at Ltd. "Rustavi Steel".

Industrial experiments are carried out on 18ФТ steel developed by us and positive results are received according to which the finished product meets the A400 C steel reinforcement requirements. Required mechanical properties ($\sigma_y \geq 400\ N/mm^2$) are obtained in hot-rolled state without heat treatment. It allows to solve problems while rolling large diameter (N 25, 28, 32 mm) steel reinforcement. The same composition will promote the use of relatively safer modes when leveling properties along the full-length of the finished product while producing A500C, enabling to combine 8-12 t melting into 60-100 ton lots according to their chemical composition, followed by industry regulation, along with the substantial economic effect.

At the second stage uniform, weldable steel reinforcement will be produced without heat treatment - in hot-rolled state→ B500 W, with the yield strength $\sigma_y \geq 500N/mm^2$ according to ISO 9655/2 standard. For this purpose experiments will be carried out on steels developed by us (e.g. 13Г1С1ДФТ). The advantage will be given to the most corrosion resistant steel in ordinary concrete. Besides, the new phenomenon considerably simplifies solution of the problem.

According to the large-scale experimental data and the result analysis it is proved that the reinforcing steel durability should be taken into account in assessing the total specific destruction energy α_0^T (J/cm²), because the higher the α_0^T, the longer the durability - resistance.

Introduction

Production of A500C steel reinforcement from low-carbon steels (steel 3) using high-temperature thermomechanical treatment (HTTMT) is complicated at Ltd. "Rustavi Steel" rolling mill shop relating to the steel-smelting and metal forming processes.

1. Duplex process is necessary to be introduced in steel-smelting shop using ladle furnace, enabling to realize the full refining and selecting the chemical composition of steel (C = 0,17-0,22%, Si = 0,25-0,40%; Mn = 0,65-0,80%; Al = 0,020-0,030%; S ≤ 0,01%; P ≤ 0,01%; adding titanium and vanadium on microlevel - 18ФТ).

Degasser must be purchased for complete degassing of tapping steel.

It is necessary to upgrade the continuous caster of steel and use vibration while casting to increase productivity and improve billet macrostructure obtaining □ 120 mm product.

This enables us to get the highest quality product (□ 120 mm) which in case of necessity may be used for commercial purpose. In this aspect, 18ФТ steel composition has a number of advantages comparing with steel 3, revenue exceeds expenses (~ 10-40 USD).

2. "Hand-guided " refrigerating system will basically be allocated at the rolling mill shop for thermal treatment and a break from the end of rolling to the refrigerating systems (# 25, 28, 32 mm rolling is ended at the X th roll stand; # # 18, 20, 22 mm - XII pass; # 16 mm - XIV pass; # 12, 14 mm - without pause).

First, replacing current refrigerating systems with new, modern systems is very expensive; second, in all aspects it is advisable to produce uniform, weldable B500 W steel reinforcement for ordinary concrete with the yield strength $\sigma_y \geq 500N/mm^2$ without heat treatment - in hot-rolled state, according to ISO standard.

Breaks from the end of rolling to starting cooling promote development of metadynamic recrystallization that impacts negatively on the results of the heat treatment not infrequently bringing to naught the results of quenching – self tempering. Such adverse effects are frequent, when rolling large diameter (# 25, 28, 32mm) billets (attempts to obtain the needed results are unsuccessful; electricity and gas are spent; austenitic grain size and scale thickness are increased, etc.). Usually at this time use of ordinary rolling does not give the required results, added by the conventional inhomogeneities (deformation, temperature, etc.) along the full-length of rolled stock. A composition (18ФТ) was developed by us, accompanied by so-called "New Phenomenon", allowing to manage the process from crystallization to the finished product (the first stage of the problem[1]).

When rolling 18ФТ steel, A400C reinforcing steel properties are obtained for all profiles without heat treatment – in hot-rolled state being very important for large diameter (# # 25, 28, 32 mm) stock rolling. During heat treatment and use of relatively safer modes the same composition will promote leveling properties along the full-length of the finished product enabling to combine 8-12 t melting into 60-100 ton lots according to their chemical composition, followed by industry regulation, along with the substantial economic effect.

Besides, modernization of rolling schemes will positively affect the quality of the finished product.

For economic use of titanium and vanadium their modifying and microalloying limits must be revised, because former limits were adopted for open-hearth steel deoxidized with three elements (Si= 0,25-0,40%; Mn = 0,60-0,80%; Al = 0,020-0,030%) with the following sequence: right after steel tapping first required amount aluminum pigs were added and after certain pause - the other deoxidants (FeSi, FeMn) along with micro-additions (FeTi, FeV).

The present work contains the results and discussion of industrial experiments. The necessity of the measures to be carried out for improving quality and maintaining obtained results are proved. Otherwise, the task is solved including quality management.

Research Materials and Research Methods

Experimental melting was carried out according to the technological instructions [2]. Titanium (ferrotitanium, Ti = 70%) and vanadium (ferrovanadium, V = 80%) were used as micro-additions. Part of the billets from the test melting were rolled using current technological scheme - high - temperature thermomechanical treatment and part of them – without heat treatment, in hot-rolled state. This methodology has been used for studying #12, 14, 20, 32 mm steel reinforcement. Except conventional characteristics (tensile strength, yield strength, specific elongation, bending test results) it was calculated: S_k – actual destruction resistance, specific elongation with its components δ ($\delta_1 + \delta_2$), area reduction for necking with its components φ ($\varphi_1 + \varphi_2$), the total destruction energy - E_T, as well as the specific destruction energy without notch $-\alpha_0^T$. Using Neophot -21 metallographic microscope and a digital camera on the test meltings were investigated: microstructure by magnification × 100; × 400; × 800 × 2000; destruction relief by magnification × 10; × 50. Otherwise, micro - and fractografic analyses were conducted, micro - and macrohardness were measured. Experimental results are given in tables 1-4.

Discussion of experimental results

Change of mechanical properties of the experimental steels (18ФТ) in hot-rolled state and after high- temperature thermomechanical treatment (HTTMT) is given in Table 1.

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[1] At the second stage, using steels (e.g. 13ГСДФТ) developed by us, B500W steel reinforcement # 12-32 mm can be produced without heat treatment in hot-rolled state considering corrosion resistance in concrete.

Change of mechanical properties of experimental styeels (18ФТ) in hot-rolled state and after HTTMT

Table 1

Melting#, treatment, steel rein-forcing# / Mechanical properties	Actual destruction resistance S_k, N/mm^2	Yield strength σ_B, N/mm^2	Yield strength σ_y, N/mm^2	Specific elongation with its components $\delta(\delta_1+\delta_2)$, %	Area reduction for necking with its components $\varphi(\varphi_1+\varphi_2)$, %	Total destruction energy E_T, Nxm.	Specific destruction energy α_0^T, J/sm^2
1	2	3	4	5	6	7	8
Melting #3199, #20 Hot-rolled	722	590	414,5	30,5=23+7,5	26=19+7	11074	3527
Melting #3199, #20 After HTTMT	772	722	595	22=13,3+8,7	40=16+24	10649	3391
Melting #3882, #12 Hot-rolled	1201	616	484	28=18+10	56=45+11	2423	2144
	1162	617	492	27=17+10	57=46+11	2517	2228
Melting #3882, #12 After HTTMT	1369	758	692	20=11,3+8,7	53=39+14	1820	1611
	1018	760	707	24=11+13	52=34+18	2270	2009
Melting #3882, #14 Hot-rolled	1046	617	487	25=18+7	52=44+8	4122	2677
	1104	615	488	25=18+7	53=44+9	3679	2389
Melting #3882, #14 After HTTMT	1262	746	664	20=13+7	51=41+10	3470	2253
	1206	740	663	19=12+7	51=39+12	2989	1941
Melting #3882, #20 Hot-rolled	770	582	436	27,5=16+11,5	44=32+12	8432	2685
	776	581	442	31=18+13	44=32+12	9869	3143
Melting #3882, #20 After HTTMT	916	711	602	20=11+9	38=26+12	8239	2624
	919	711	608	22=12,5+9,5	40=37+13	7873	2507
Melting #3882, #32 Hot-rolled	676	602	489	21=14+7	24=18+6	25117	3124
	677	606	491	22=15+7	24=18+6	28902	3595
Melting #3882, #32 After HTTMT	779	736	682	15=8+7	17=10+7	25431	3163
	754	744	665	16=8+8	19=11+8	21913	2726

Comparison of specific destruction energies in hot-rolled state and after HTTMT is given in Table 2 .

Comparison of specific destruction energies in hot-rolled state and after HTTMT

Table 2

Melting #, Steel reinforcing diameter, mm / Specific destruction energy	Specific destruction energy in hot-rolled state α_0^T, J/sm^2	Specific destruction energy after HTTMT α_0^T, J/sm^2	$\Delta\alpha_0^T = {}^{h.r.}\alpha_0^T - {}^{h.t.}\alpha_0^T$, J/sm^2	$\Delta\alpha_0^T$ medium J/sm^2
#3199 #20 (Ti = 0,023%)	3527	3391	136=3527-3391	136
#3882 #12 (V = 0,08%)	2144	1611	533=2144-1611	376
	2228	2003	219=2228-2009	
#3882 #14 (V = 0,08%)	2677	2253	424=2677-2253	436
	2389	1941	448=2389-1941	
#3882 #20 (V = 0,08%)	2685	2507	178=2685-2507	349
	3143	2624	519=3143-2624	
#3882 #32 (V = 0,08%)	3124	2726	398=3124-2726	415
	3595	3163	432=3595-3163	

Comparison of the total destruction energies (calculation results) in hot-rolled state and after HTTMT is given in Table 3.

Comparison of specific destruction energies in hot-rolled state and after HTTMT (Calculation results *))

Table 3

Melting #, steel reinforcement diameter, mm, microalloying element / Specific destruction energy α_0^T, J/sm^2	Specific destruction energy in hot-rolled state α_0^T, J/sm^2	Specific destruction energy after HTTMT α_0^T, J/sm^2	Difference between specific destruction energies $\Delta\alpha_0^T = {}^{h.r.}\alpha_0^T - {}^{h.t.}\alpha_0^T$ J/sm^2	α_0^T medium J/sm^2
#3199 #20 (Ti = 0,023%)	2427	2105	322=2427-2105	322
#3882 #12 (V = 0,08%)	2831	2473	358=2831-2473	277
	2680	2484	196=2680-2484	
#3882 #14 (V = 0,08%)	2683	2486	197=2683-2486	143,5
	2786	2696	90=2786-2696	
#3882 #20 (V = 0,08%)	2322	2125	197=2322-2125	244
	2643	2352	291=2643-2352	
#3882 #32 (V = 0,08%)	2738	2455	283=2738-2455	309
	2878	2543	335=2878-2543	

*) $\alpha_0^T = 0{,}1 \cdot ((\sigma_y + S_k) / 2 \cdot \Delta l)$ J/cm^2 ; $\Delta l = \delta \cdot l_0$, mm

Distribution of hardness in core and edge layers in hot-rolled state and after HTTMT is given in Table 4.

Distribution of hardness ($HV_{p=100g}$ kgp/mm^2) in the core ande edge layers of the steel reinforcement in hot-rolled state and after HTTMT

Table 4

Melting #, steel reinforcing diameter, mm / Treatment hardness measuring area	Hot-rolled state (without heat treatment)			After high-temperature thermo-mechanocal treatment		
	core	edge	Δ	core	edge	Δ
#3882 #20	203	221	18	210	247	37
#3882 #14	186	213	27	243	310	67

In ordinary conditions, without heat treatment, difference between core and edge layers is observed (Table 4). In case of # 20 steel reinforcement $\Delta = 18 = 221\text{-}203$, but after HTTMT

$\Delta = 37 = 247\text{-}210$. In case of smaller diameter steel reinforcement (#14 mm) the effect is remained qualitatively, but quantitatively becomes stronger. Without heat treatment $\Delta = 27 = {=}213\text{-}186$, but after HTTMT $\Delta = 67 = 310\text{-}243$.

According to the data given in Tables 1-3 it is confirmed that by microalloying with titanium, as well as vanadium, in hot-rolled state (without heat treatment) required mechanical characteristics can be stably received for A400C. The results, according to which the total destruction energy of steel reinforcement is higher in hot-rolled state than after HTTMT, are also significant[2] (Table 2). A 100 ton computer testing machine automatically measures the total destruction energy (along with the other characteristics) and then total specific destruction energy (α_0^T) is easily calculated. The same characteristic has been calculated by classical method [$\alpha_0^T = 0{,}1 \cdot ((\sigma_y + S_k) / 2 \cdot \Delta l)$ J $/cm^2$, where $\Delta l = \delta \cdot l_0$, mm]. The results in tables 2 and 3 (experimental and calculated) coincided qualitatively.

Detailed discussion of experimental data showed that plasticity features, especially δ, δ_1; φ, φ_1 are higher without heat treatment than after HTTMT. Based on the experimental results ($\Delta\delta = \delta^{h.r} - \delta^{h.t}$; $\Delta\delta_1 = \delta_1^{h.r.} - \delta_1^{h.t}$.; $\Delta\varphi = \varphi^{h.r.} - \varphi^{h.t.}$; $\Delta\varphi_1 = \varphi_1^{h.r.} - \varphi_1^{h.t.}$) certain amount of plasticity is maintained in metal without heat treatment. Density of dislocations and other crystallographic defects $\rho < \rho_{critical}$. For gaining the level up to $\rho \geq 10^{12}$ cm^{-2} certain amount of energy is spent. If steel reinforcement in concrete is considered, its durability will be higher than that of thermomechanically treated. Therefore, according to ISO standard, the properties must be obtained without heat treatment – in hot–rolled state.

[2] Similar results are obtained by other authors, e.g. [3].

Relying on the obtained data, the new phenomenon will enable (using alloying by Ti and V at microlevel along with the atomic nitrogen) to gain $\sigma_y \geq 500\ N/mm^2$, considerably simplifying the task and making technological process cheaper.

According to the above, when assessing durability of reinforcing steel specific destruction energy must be considered. The higher the α_0^T, the longer is the lifetime of steel reinforcement. This effect will considerably be enhanced by the experimental data of impact strength [$a_{0.25}$ (a_n+ a_p)], embrittlement temperature threshold (T_{50}), cracking resistance (J_{IC}), etc.

Conclusion

1. **According to the results of industrial experiments, microalloying with titanium and vanadium without heat treatment results in obtaining required structure and mechanical properties for A400C;**
2. **It is shown that selection of 18ФТ composition simplifies production of A500C. Titanium and vanadium promote leveling mechanical properties along the full-length of the finished product after which relatively safer modes of HTTMT are conducted meeting the requirements for A500C;**
3. **Analyses of the data obtained on testing machine (100 ton computer unit) and the calculation results showed that the total destruction energy (as well as the total specific energy) of steel reinforcement in hot-rolled state is more than after HTTMT, that must be considered when assessing reinforcing steel durability. In this regard, it will be important to comply with the ISO requirements as soon as possible: production of uniform, weldable steel reinforcement (B500 W) with the yield strength $\sigma_y \geq 500N/mm^2$ without heat treatment - in hot-rolled state must be introduced.**

R E F E R E N C E S

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Acknowledgement:* *The authors thank Mr. David Vepkhvadze, Director Executive of Ltd. ”Rustavi Steel” Without His support this task would not be accomplished at this level.