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Effect of Qualitative Characteristics of High-Carbon Rolled Wire on Properties of Rope Wire

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Comparative analysis of qualitative characteristics for high-carbon steel 70 (1.1231according to DIN) rolled wire produced by OJSC "Moldova Steel Works" under Specifications of Ukraine 27.1-4-519-2002 and by company Lucchini Piombino (Italy) under Specification 6034-2 corresponding to EN 10016 was performed. We have developed the production technique of rope wire with diameter 2.20 mm by drawing with no heat treatment (patenting). Effect of qualitative characteristics of high-carbon steel 70 rolled wire on final properties of rope wire and its compliance with European requirements was determined.

Keywords: ROLLED WIRE, CHEMICAL COMPOSITION, STRUCTURE, MECHANICAL PROPERTIES, FERRITE, PERLITE

Introduction

Severization of requirements to quality of high-carbon rolled wire, which is a basic raw material for manufacture of rope wire and ropes, causes development and implementation of new highly effective production processes. Considering consequences of the world financial crisis accompanied with output recession in metallurgy, and also increasing competence on distribution areas of metal products, new technologies of rope wire manufacture are more and more in demand. They have no hardening (patenting) and smaller cost price of manufacture. It is obvious that rope wire quality directly depends on quality of initial raw material – high-carbon rolled wire.

Methodology

In this conjunction, we have conducted comparative analysis of finished rope wire properties produced by Orel Plant JSC "Severstal-metiz" from high-carbon steel 70 (1.1231according to DIN) rolled wire with nominal diameter 5.50 mm produced by JSC "Moldova Steel Works" and company Lucchini Piombino (Lucchini).

Results and Discussion

Qualitative characteristics of high-carbon steel 70 rolled wire produced by Moldova Steel Works (Specifications of Ukraine 27.1-4-519-2002) and by Lucchini (Specification 6034-2) are given in **Tables 1, 2**.

Table 1. Requirements to chemical composition of steel 70 according to various normative documents

No.*	Chemical composition, % not more								
	C	Mn	Si	P	S	Cr	Ni	Cu	B
1	0.68-0.72	0.30-0.60	0.15-0.25	0.017	0.017	0.10	0.15	0.20	0.0025
2	0.68-0.72	0.30-0.60	0.15-0.25	0.025	0.020	0.15	0.15	0.07	-

* 1 – rolled wire produced by Moldova Steel Works under Specifications of Ukraine 27.1-4-519-2002
2 – rolled wire produced by Lucchini under Specification 6034-2

Table 2. Requirements to mechanical properties, microstructure, decarburized layer and nonmetallic inclusions of steel 70 according to various normative documents

No.*	Mechanical properties		
	Ultimate tensile strength, N/mm^2, not more	Contraction Ψ, % not less	Elongation δ, % not less
1	1140	30	9
2	1000-1100	30	-
	Microstructure**	Decarburized layer, %	Nonmetallic inclusions, not more, grade
1	P (1-st grade) ≥ 70 %	2.5	3.0
2	P or F+P	1.5	3.0

* see note for Table 1
** P – perlite; F – ferrite

It follows from **Table 1** that requirements to chemical composition of steel 70 rolled wire under Specifications of Ukraine 27.1-4-51-2002 are identical to those under Specification 6034-2, except for insignificant difference in content of P, S, Cr and Cu.

Results of incoming inspection of quality characteristics of high-carbon steel 70 rolled wire at Orel Plant are given in **Tables 3-5.**

Table 3. Results of incoming inspection of high-carbon steel 70 rolled wire chemical composition

No.*	Chemical composition, %							
	C	Mn	Si	P	S	Cr	Ni	Cu
1	0.72	0.55	0.20	0.011	0.080	0.05	0.09	0.18
2	0.71	0.45	0.23	0.010	0.007	0.02	0.019	0.05

*see note for Table 1

It follows from **Tables 3-5** that qualitative characteristics of steel 70 produced by Moldova Steel Works and Lucchini under various standardized documents correspond to regulated indexes and differ insignificantly. Microstructure analysis (**Table 5**) showed that maximum amount of sorbitie-like perlite of 1st grade and minimum amount of structurally free ferrite are in the rolled wire produced by Moldova Steel Works.

For comparative processing at Orel Plant, high-carbon rolled wire produced by Moldova Steel Works (100.0 t) and by Lucchini (100.0 t) was manufactured. The conventional (base) production technique of rope wire with diameter 2.20 mm is carried out as follows:

6.50 mm SP, D → 4.20-5.40 mm P, D → 2.10-2.40 mm → RL,

where SP – surface preparation; D – drawing; P – patenting; RL – rope lay.

Table 4. Results of incoming inspection of steel 70 rolled wire mechanical properties

No.*	Mechanical properties		
	Ultimate tensile strength, σ_{UTS}, N/mm^2	Contraction Ψ, %	Elongation δ, %
1	1019-1088	39-48	10-13
2	960-1019	36-43	11-14

* see note for Table 1

Table 5. Results of analysis of microstructure and decarburized layer depth at incoming inspection of steel 70 rolled wire

No.*	Amount of sorbite-like perlite of 1st grade, %	Amount of structurally free ferrite, %
1	> 70	1-2
2	> 50	5-8
No.*	Decarburized layer, %	Nonmetallic inclusions
1	0.8	2nd grade
2	1.0	1st grade

* see note for Table 1

Considering the experience of high-carbon steel grades processing, in particular, cord steel 80 rolled wire under reduced flow diagram [1], the experimental flow diagram of processing of high-

carbon steel 70 rolled wire with diameter 5.5 mm was suggested:

5.50 SP D → 2.10-2.40 mm → RL

Wire rod drawing was carried out on drawing mill of 2500/7 type in seven passes as follows:

5.50 → 5.10 → 4.50 →3.90 →3.30 →2.80 →2.40 →2.20 mm

When producing rope wire with diameter 2.20 mm, total reduction (Q_Σ) and overall elongation (μ_Σ) are:

$$Q_\Sigma \frac{d_0^2 - d_\kappa^2}{d_0^2} = \frac{5.5^2 - 2.2^2}{5.5^2} = 0.84 \quad (0.84\%)$$

$$\mu_\Sigma = \frac{1}{1 - Q_\Sigma} = \frac{1}{1 - 0.84} = \frac{1}{0.16} = 6.25$$

Rope wire quality characteristics were tested according to GOST 10446 and GOST 1545. Test results are given in **Table 6.**

It follows from **Table 6** that rope wire produced from steel 70 rolled wire always corresponds to GOST 7372-79 only if it is produced from rolled wire by Moldova Steel Works. Minimum value of ultimate tensile strength of wire rod produced by Lucchini is 1670 N/mm^2, which is less than standard value – 1700 N/mm^2.

Table 6. Results of mechanical tests of steel 70 spring wire with diameter 2.20 mm

No.*	Mechanical characteristics**		
	Ultimate tensile strength, σ_{UTS}, N/mm^2	Torsion value	Bend value (90°)
1	1770-1870	31-37	21-24
	1845	34	22
2	1670-1860	25-38	16-21
	1765	32	18

* see note for Table 1;
** numerator – minimum and maximum values, respectively; denominator – average

Larger value of torsions and bends typical for rolled wire produced by Moldova Steel Works can be logically explained as follows. Electric steel produced by Moldova Steel Works contains boron as microalloying addition. As standard Gibbs energy change for compounds BN, Fe_2B and B_4C is determined by inequality $\Delta G^0_{BN} < \Delta G^0_{Fe2B} < \Delta G^0_{B4C} \Delta 0$ at 900-1200°C, boron contacts nitrogen first, further interacts with ferrum and then with carbon [2].

In boron microalloyed steel 70, the relative microstrain of ferrite lattice ($\Delta a/a$) is less than in the same steel without boron. As a result, boron microaddition improves accommodative fitting of ferrite and cementite lattices in perlite of steel 70, therefore the total level of relative microstrain and density of dislocations in ferrite decreases after both two-phase cooling and patenting of rolled wire [3].

Consequently, high-carbon boron-containing steel rolled wire, which has smaller density of dislocations in ferrite as compared to rolled wire without boron, also has smaller density of dislocations than a wire made of analogous steel without boron after cold deformation by drawing. This conclusion is fair provided that drawing of rolled wire made of steel with boron and without boron is carried out with equal amount of reduction. At the subsequent test for alternating strain, rolled wire produced by Moldova Steel Works has a larger limit in increase of density of dislocations to critical level (before metal fracture), that is why number of torsions and bends of rolled wire produced by Moldova Steel Works exceeds number of torsions and bends of rolled wire produced by Lucchini respectively.

As known [4], wire wrapping test gives a clearer concept of wire plastic properties than torsional tests. So it is possible to conclude that steel 70 rolled wire produced by Moldova Steel Works has higher ductility than similar rolled wire produced by Lucchini. This feature is related to the low consumption index and yield ratio: Moldova Steel Works – 98.2%; Lucchini – 78%.

Conclusions

High-carbon rolled wire produced by Moldova Steel Works is more preferable as compared to similar rolled wire produced by Lucchini for manufacture of rope wire with diameter 2.20 mm by direct drawing (without intermediate patenting) providing conformity of its quality parameters to requirements of GOST 7372-79 and low consumption index.

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Влияние качественных характеристик высокоуглеродистой катанки на свойства канатной проволоки

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Проведен сопоставительный анализ качественных характеристик сокоуглеродистой катанки из стали марки 70, произведенной по ТУ У 27.1-4-519-2002 Молдавским металлургическим заводом и спецификации 6034-2, соответствующей EN 10016, компанией Lucchini Piombino (Италия). Разработана технология производства канатной проволоки диаметром 2,20 мм прямым волочением с исключением термообработки – патентирования. Установлено влияние качественных характеристик высокоуглеродистой катанки из стали марки 70 на конечный комплекс свойств канатной проволоки и ее соответствие европейским требованиям.