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FOREIGN TECHNOLOGY DIVISION

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by

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А а	*А а*	A, a	Р р	*Р р*	R, r
Б б	*Б б*	B, b	С с	*С с*	S, s
В в	*В в*	V, v	Т т	*Т т*	T, t
Г г	*Г г*	G, g	У у	*У у*	U, u
Д д	*Д д*	D, d	Ф ф	*Ф ф*	F, f
Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
Ж ж	*Ж ж*	Zh, zh	Ц ц	*Ц ц*	Ts, ts
З з	*З з*	Z, z	Ч ч	*Ч ч*	Ch, ch
И и	*И и*	I, i	Ш ш	*Ш ш*	Sh, sh
Й й	*Й й*	Y, y	Щ щ	*Щ щ*	Shch, shch
К к	*К к*	K, k	Ъ ъ	*Ъ ъ*	"
Л л	*Л л*	L, l	Ы ы	*Ы ы*	Y, y
М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

* ye initially, after vowels, and after ъ, ь; e elsewhere. When written as ё in Russian, transliterate as yё or ё. The use of diacritical marks is preferred, but such marks may be omitted when expediency dictates.

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Ye. A. Sagalevich, Ya. M. Potak, and V. V. Sachkov (VIAM)*

Alloying of martensite stainless steels with a number of ferrite forming elements in order to increase the corrosion resistance and heat resistance very frequently results in the formation in the basic martensite structure of a second phase – δ-ferrite.

In spite of the fact that in many martensite stainless steels δ-ferrite will be formed, in the literature very little light has been shed on this problem.

This work has as its aim to investigate the effect of different quantities of δ-ferrite on the properties of low-carbon martensite stainless steels.

The investigation was conducted on chromium-nickel-aluminum steels smelted in an induction furnace. The varying quantity δ-ferrite was attained by means of the change in content of nickel (Table 1).

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*[Translator's Note: VIAM = All-Union Scientific Research Institute of Aviation Materials].

Table 1. Chemical composition and content of δ-ferrite in the investigated steels.

No. of melt	Content of elements, %								Quantity of δ-ferrite, %				
	C	Cr	Ni	Al	Si	Mn	S	P	in cast test	in deformed bar after quenching from a temperature, °C			
										1000	1050	1100	1220
1	0,079	13,36	None	1,01	0,60	0,5	0,012	0,0064	88	73	73	83	86
2	0,075	13,28	2,54	1,03	0,59	0,5	0,0102	0,0066	49	23	23	38	46
3	0,078	13,44	4,93	1,04	0,59	0,5	0,012	0,0062	3	0	St.	1	2
4	0,065	13,46	7,13	1,03	0,57	0,52	0,012	0,0066	1	0	0	St.	1

Note: Quantity of δ-ferrite was measured by the metallographic, linear method [1].

Figure 1 shows the effect of the temperature of heating under quenching on the dimensions of grains of austenite and ferrite, and also the effect of δ-ferrite on the dimension of a grain of austenite in the cast and deformed states after different temperatures of quenching. It was determined that the more ferrite a steel contains, the bigger the dimension of grain of ferrite in both the cast, and in the hot-deformed states at all temperatures of quenching to 1220°C. In the cast steel the dimension of the austenitic grain acquires a minimum in that case, when the ferrite content is very low or very high (steels 1 and 4).

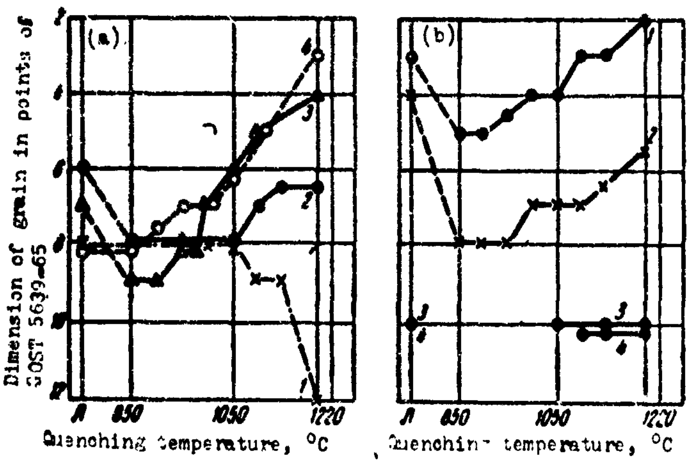

Fig. 1. Change in dimension of a grain of austenite (a) and ferrite (b) depending upon the temperature of quenching in hot-rolled steels with a different content of δ-ferrite. The steel is shown by numbers (see Table 1): Л - cast state.

For hot-deformed steel it was shown that the presence of δ-ferrite in the structure sharply retards the growth of grains of austenite with an increase in quenching temperature. In steel 1 even a considerable decrease in dimension of the grains of austenite at a high temperature of quenching is revealed which is connected, apparently, with the fact that with an increase in temperature of heating the intense increase in quantity of the ferrite phase, and also the growth of the dimension of ferrite grains occurred due to a decrease in the quantity of austenite and the dimension of its grains.

The mechanical properties of steels were investigated in two states: after quenching from the minimum temperature sufficient for dissolution of the carbides (for steels 1, 2, and 4, these temperatures were 1100, 1050, and 1000°C), and after double quenching from 1100°C + quenching from the temperature of precipitation of carbides at 900°C; cooling in water. Tempering in all cases was done at 300°C during 1 h with cooling in air. At such low tempering, aging does not occur.

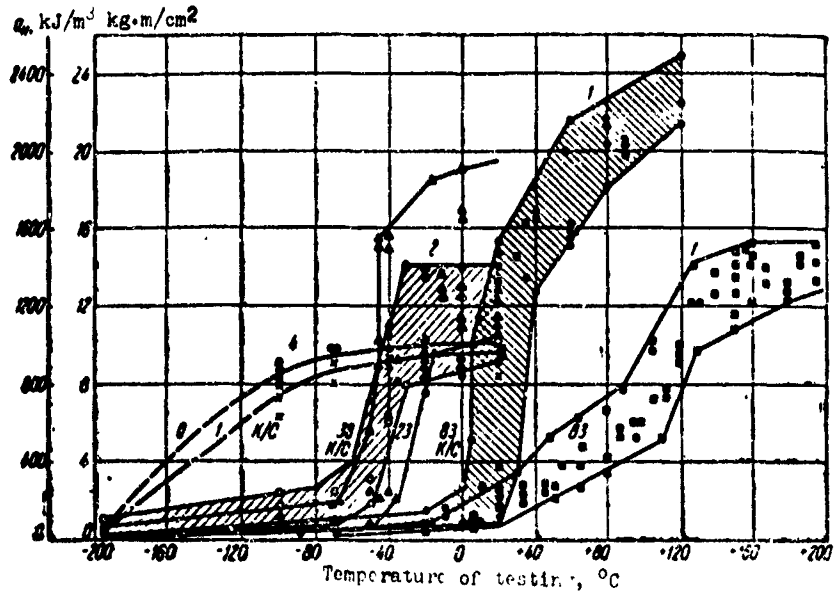

Fig. 2. Effect of δ-ferrite on the change of impact toughness depending on the temperature of the test (figure 1, 2, 4 - numbers of steel; figure for curves - quantity of δ-ferrite, %; k/c - structure with a carbide grid).

It was determined that the effect of 23% δ-ferrite on the standard mechanical properties in a longitudinal direction at room temperature hardly shows at all.

Delta-ferrite sharply increases the tendency of steel towards brittle rupture. One may see this most distinctly during the comparison of temperatures of cold brittleness (Figs. 2 and 3).

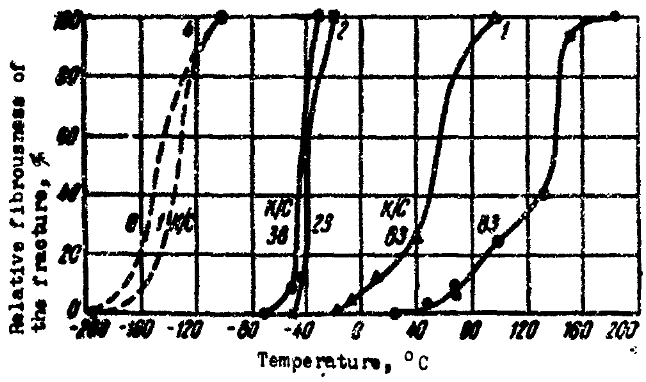

Fig. 3. Effect of δ-ferrite on the change of content of fibrous components in the fracture of impact samples depending upon the temperature of testing (designation is the same as in Fig. 2).

Curves of the change of the impact toughness with a decrease in temperature of testing of steels with δ-ferrite have a sharply expressed step character. One of the main causes of an increase in temperature of cold brittleness of steels containing δ-ferrite is the low resistance to breakaway of the ferrite itself [2]. However, apparently, there is significance in the fact that according to the increase in quantity of δ-ferrite the microhardness of martensite is increased as a result of the increase in the content of carbon in austenite (Fig. 4). It is very interesting to note that in low-carbon steel when a considerable content of δ-ferrite, the hardness of martensite approaches the hardness of tool steel. Quenching from the temperature of formation of carbides leads to a decrease in the content of carbon in martensite and, consequently, to lowering of temperature of cold brittleness steel containing δ-ferrite (see Fig. 3).

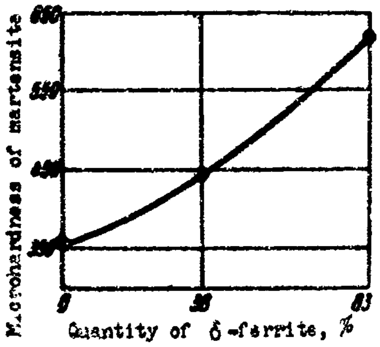

Fig. 4. The effect of the quantity of δ-ferrite on the microhardness of martensite after quenching from 1100°C in water.

The presence of δ-ferrite in the structure of martensite steel considerably lowers the work in development of a crack [3]. The negative effect of δ-ferrite with a decrease in temperature of testing to -70°C is especially strengthened (Fig. 5).

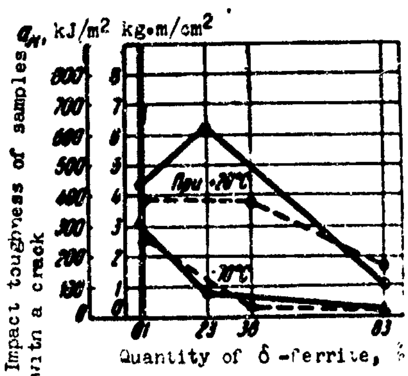

Fig. 5. Impact toughness of samples with a crack: solid line - structure without a carbide lattice; dotted line - carbide lattice lacking.

As espected, the influence of δ-ferrite was sharper on the properties in a direction perpendicular to the fiber of steel (Fig. 6), and especially on the properties of steel in the third direction, i.e., in the direction with respect to thickness, perpendicular to the plate or disk (Table 2).

The strength of ring samples during the test for collapse with a content of 23% δ-ferrite in the steel is reduced by one-half (Fig. 6).

Fractures of the Menazhe samples cut in a third direction, for all steels with δ-ferrite are brittle, with distinctly visible spangles. Brittle rupture of samples occurred on the plates of δ-ferrite.

Table 2. Effect of δ-ferrite on the properties of martensite steel in the third direction (with respect to thickness of a plate, 20 mm).

Structural state	No. of melt	Content of δ-ferrite, %	σ_b MN/m²	σ_b kg/mm²	δ, %	ψ, %	a_n without carbide lattice kJ/m²	a_n without carbide lattice kg·m/cm²	a_n with carbide lattice kJ/m²	a_n with carbide lattice kg·m/cm²
Martensite + δ-ferrite	1	83	730 720 690 715 715	73 72 69 71,5 71,5	14,4 1,25 1,25 12,6 9,7	28,6 6,35 19,1 25,4 25,6	50 63 75 63 75	0,5 0,63 0,75 0,63 0,75	50 87 226 63 63	0,5 1,87 2,26 0,63 0,63
Martensite + δ-ferrite	2	23	1015 1080 1110 1100 1160	101,5 108 111 110 116	3,75 8,2 1,[illegible] 9,7 7,5	9,6 47 23,5 41,7 45,4	30 60 40 30 50	0,3 0,6 0,4 0,3 0,5	88 75 75 75 63	0,88 0,75 0,75 0,75 0,63
Martensite	4	0	1260 1300 1280 1320	126 130 128 132	18,9 16,5 18,8 18,4	58 50,8 59 50,8	625 475 590 425	6,25 4,75 5,9 4,25	460 425 660 450	4,6 4,25 6,6 4,5

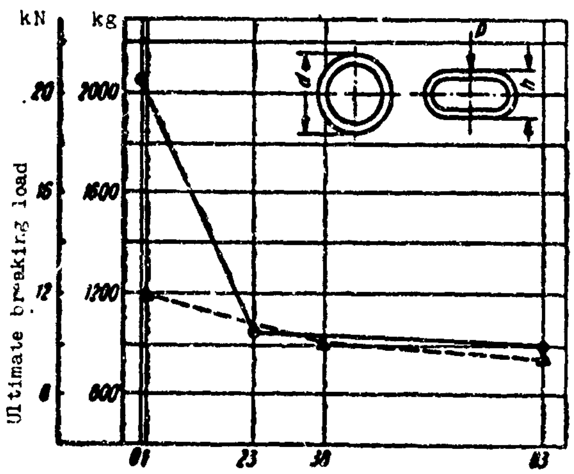

Fig. 6. The effect of the quantity of δ-ferrite on maximum breaking load of rings during testing for collapse (designation the same as that in Fig. 5).

The catastrophic decrease in viscosity and plasticity of the samples in the third direction of steels with δ-ferrite indicates that with the concentration of stresses a lowering of strength will also occur. With testing of samples of steels containing δ-ferrite, a considerable scattering of plasticity is revealed.

Conclusion

1. The formation of structurally free δ-ferrite in martensite stainless steel substantially worsens its mechanical properties. During testing along the fiber the value of impact toughness decreases especially at low temperatures of testing; temperature of cold brittleness is increased considerably and work of the propagation of a crack decreases. Delta-ferrite renders a sharply negative effect on the mechanical properties of steel during testing across the fiber and especially in the third direction (with respect to thickness of plate).

2. The case of brittleness of martensite steel with the appearance of δ-ferrite is the low resistance of ferrite to brittle rupture, and also, apparently, the increase in hardness and decrease in viscosity of martensite as a result of the increase in content of carbon in martensite due to its redistribution between austenite and δ-ferrite.

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13. ABSTRACT
The formation of structurally free delta-ferrite in martensitic stainless steel greatly impairs its mechanical properties. Tests along the fiber showed lower notch toughness values, particularly at low testing temperatures; the cold-brittleness considerably increased while the work of crack propagation decreased in tests across the fiber and, particularly in the third direction (over the thickness of the plate), delta-ferrite was found to have a drastically negative effect on the mechanical properties. The brittleness of martensitic steel with the appearance of delta-ferrite is caused by the low resistance of ferrite to brittle failure, and apparently, the increase in martensite ductility due to the increase in carbon content in the martensite following its redistribution between the austenite and the delta-ferrite. Orig. art. has: 6 figures, 2 tables, and 3 bibliographic entries. (AT9005644)

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