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ON POSSIBLE REASONS FOR DEFECTS IN LARGE BLANKS OF LOW-CARBON MANGANESE STEEL AT «YURMASH»

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Mechanical properties and microstructures of forged large blanks of low-carbon steel without necessary incoming ultrasound test have been studied. The examination was performed to find out the reasons for product defects. Abnormalities in structure and disagreement of metal plasticity with standard requirements are revealed. On the basis of the results obtained it is assumed that the reasons for the defects could be deviations from standard chemical composition and irregularities in hot forging.

Introduction

«Yurmash» metallurgical industry is one of the few in Russia which can produce forgings with mass up to 17,5 tons. From this point of view it is economically and technically attractive both for domestic and foreign consumers. However, this circumstance puts on high responsibility for the quality of production especially in new conditions of economical activity.

At the same time, by 2000, the situation at a factory is so that the in-plant defect at large finding manufacturing exceeds 7 %. Ingots more often crack at normalization and heating for hot forging or are not upset in the process of blacksmith redistribution. The most part of finished product is not undergone the required incoming ultrasound test (UST).

The external causes of such condition are stipulated by degradation of the enterprise raw material base and the internal ones – by high wearing of the equipment and significant expansion of a number of the produced steel grades. It is enough only to mention that at present, the plant melts not only domestic low- and medium-carbon steels but also some grades by German standards, specifically St52,3N [1].

The main way of these defects elimination is in strict observance of procedures discipline and timely science-based correction of production flow sheets. The latter is not possible without thorough comparative investigations of the structure and mechanical properties of waste and conditional blanks.

2. Materials and techniques of investigation

The crosscut template of steel St52,3N which was cut of the blank that had not been undergone the required UST was used as the material of the investigations. The diameter of the blank is 430 mm. The required chemical composition of the given steel is presented in Table 1. The place of template cutting was in the area of two broaching macro defects with the diameters of 5...8,5 and 8...10 mm, found out by UST at a depth of 210 and 200...230 mm, correspondingly. The template was undergone checking by the method of magnetic particle test before samples production for the mechanical and structural examinations that allowed detecting the crack parallel to the blank axis. The samples for the mechanical examination and metallographic investigations were cut of the template part that abutted straight to the crack. The structure of metal samples of conditional blank was investigated for comparison.

Table 1. *The standard required chemical composition of steel St52,3N, wt. %*

C	Mn	Al	P	S	Si, not more	Cr, not more	Mo, not more	Ni, not more
0,16...0,22	1,0...1,6	0,02...0,06	0,035	0,035	0,55	0,4	0,1	0,4

The uniaxial tension mechanical examinations were carried out at the universal testing machine Instron 1185. Strain rate was $1{,}67\cdot10^{-4}$ s^{-1} (1mm/min) at temperature 300 K. Flat samples with test portion sizes 100×10×3 mm were fabricated for tension by SS 1497-84. Longitudinal axis of the samples was normal to forging axis. Impact strength by SS 1524-2042 was determined at pendulum impact testing machine MK 30A with maximal impact energy 300 J at temperature 300 K with standard samples with U-stress concentrate.

Metallographic investigations were carried out at microscope Neophot-21. Mechanical buffing, mechanical polishing with diamond paste ASM 10/7 NVL, chemical etching in 4 % alcoholic solution HNO_3 were used at crosscut microsection manufacturing.

3. Results of the investigations and their analysis

According to the results of mechanical testing the type of deformative diagrams was analyzed and standard strength and plastic properties were determined. Only one of five tested samples on deformative curves (Fig. 1, Curve 1) had yield drop and plateau typical for low-carbon steel in normalize and annealed state. Therefore the conventional ($\sigma_{0,2}$) but not physical yield strength was calculated [2]. The typical loading diagram is presented in Fig. 1, Curve 2. The fact of a little nonstationary deformation in a collar may be noticed. The mechanical characteristics are presented in Table 2.

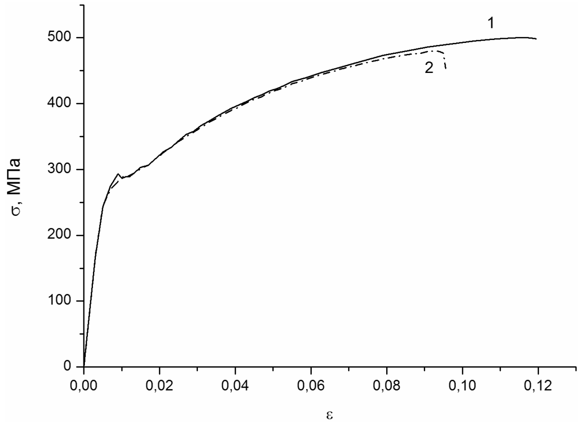


Fig. 1. *The diagram of steel St52,3N samples loading*

It follows from Table 2 that δ is rather higher than ε_{tot} so the process of deformation localization in the collar is of a great importance. Sample № 5 was fractured on the first mark near the tensile machine grip therefore δ and ψ were not determined and the data of this sample were ignored when calculating average strength properties.

Besides it is seen that if the strength parameters correspond to the maximum requirement level the plasticity is more than 40 % lower. In total correspondence with the type of deformative curve samples contraction in fracture collar ψ which did not exceed 20 % turned out to be very small. At the same time steel impact strength at temperature 300 K turned out to be at rather satisfactory level and formed 70 J/cm^2.

Table 2. *Mechanical characteristics of waste blank material*

	$\sigma_{0,2}$, MPa	σ_u, MPa	KCU, J/cm^2	ε_{tot}, %	δ, %	ψ, %
Sample 1	293	501	76	11,6	13	14
Sample 2	287	500	68	12,0	12,8	14
Sample 3	270	480	66	9,7	10,6	20
Sample 4	256	422,5	–	5,8	7,0	15
Sample 5	253	411	–	6,1	–	–
Average	270±18	463±45	70±5	9±2,9	10,8±2,7	15,7±2,8
TStandard requirements	≥275	450...630	≥50	–	≥17	–

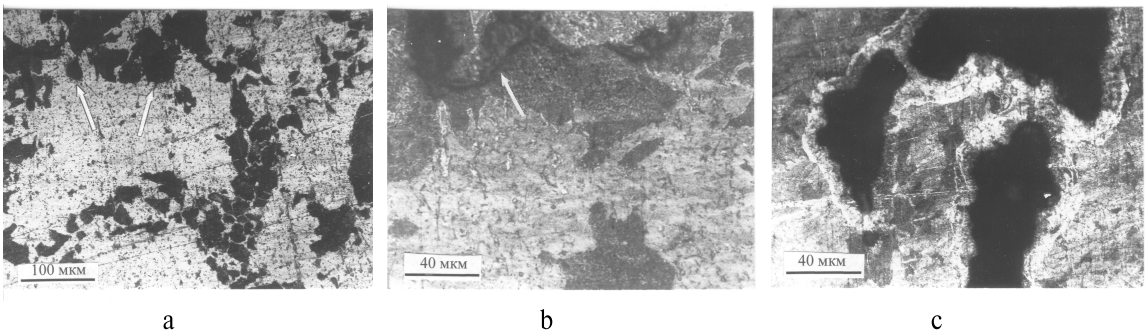
σ_u is the ultimate strength, ε_{tot} is the magnitude of a sample plastic deformation at breaking moment, calculated by the deformative curves, δ is the extension strain at breaking measured by conventional method at a base of 50 mm, KCU is the impact strength at temperature 300 K; ψ is the contraction

Fractures formed both at impact and quasi static tests turned out to be typical. According to the classification proposed in [3], they may be determined as heterogeneous-fibrous ones with tears. Separate areas of crystal chips are observed between the fibers. Fibers form the layers parallel to the forging axis. Such type of fracture appears owing to heterogeneity of the initial cast structure and insufficient degree of deformation at shaping [3].

Metallographic analysis allows revealing that the researched steel is ferrite-pearlite one with the following sizes of constituents: the diameter of pearlitic grains is 25...40 mkm and pearlitic colonies one is 10...15 mkm (Fig. 2, *a*). The fact that pearlitic colonies are settled in chains, evidently, along the boundaries of «old» austenitic grains seems to be significant (Fig. 2, *a, b*). Very coarse substructure of pearlitic colonies is noticed. In most cases pearlite represents the transition modification from laminar to grained. In those cases when pearlite structure is closer to the laminar one it turns out to be possible to measure interlamellar distance which exceeds 2 mkm.

Besides, pearilite content in steel is 25...30 % that corresponds to carbon concentration >0,25 wt. %, which exceeds appreciably the required one by standard (Table 1). Light polyhedral extractions of secondary phases are noticed in considerable quantities in ferrite grains (Fig. 2, *b*). Their sizes reach 0,5 mkm.

The second disadvantage of the researched samples is plenty of pores which sizes reach to 100 mkm. In a number of cases pores rise on the free surface of a blank. As a rule

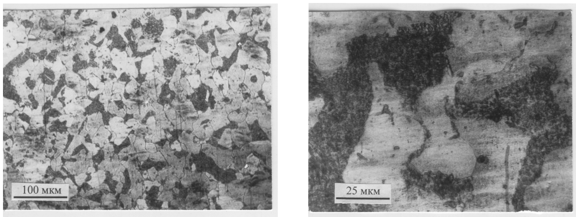


a b c

Fig. 2. *Microstructure of steel St52,3N of waste blank: a) general view of microstructure, pores are indicated with arrows; b) fine structure of pearlite colony, chain of pores is indicated with arrows; c) pores in pearlite colony*

they are mainly located in pearlitic colonies often forming a continuous chains (Fig. 2, *a*, *b*). Very large pores capture pearlitic colonies totally (Fig. 2, *c*). It is seen that ferrite grains surrounding them are weakly etched (Fig. 2, *c*). The peculiar aureole around a pore is formed where evidently alloy and carbon segregation is concentrated.

Let us emphasize that these peculiarities are distinguished more clearly when comparing with conditional metal sections (Fig. 3).



a b

Fig. 3. *Microstructure of steel St52,3N of conditional product: a) general view of microstructure; b) fine structure of pearlitic colony*

Structural element sizes in conditional material are the same as in the defective one but the pearlitic colonies are located stochastically and do not form the chains. Total pearlite is 20...25 % and corresponds to the grade chemical composition of steel (Table 1). Besides, the pearlitic colonies structure is more dispersed and its modification is close to the grained one (Fig. 3, *b*). There are relatively less extractions of secondary phases inside ferrite grains (Fig. 3).

4. Conclusion and summary

According to the data of mechanical tests and phractographic analysis steel St52,3N of the defective blank does not possess sufficient plasticity. The considerable areas of brittle failure are revealed on fractures. Such fractures appear at insufficient deformation degree at hot shaping.

Metal microstructure is not optimal. Pearlitic colonies morphology is coarsely dispersed, close to laminar. Pearlitic colonies are located in chains along the boundaries of «old» austenitic grains. As a rule pores are located in pearlitic colonies. A large number of secondary phase extractions is observed in ferrite grains solid. A part of pearlite relative to ferrite is higher than that which should be according to the standard chemical composition of steel. Hence it follows:

1. Carbon content in steel St52,3N of defective blanks was higher than permissible.
2. Steel contains a high proportion of large pores and secondary phase extractions in ferrite grains which may serve as the sources of thermal cracks.
3. According to the fractures state it may be concluded that deformation degree at hot forging was insufficient and cast metal was considerably heterogeneous in its chemical composition.
4. Electron microscopic investigations of metal deflected mode, nature of secondary phase extractions and ferrite grains fine structure and pearlite colonies are required for technological process correction.

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