

**CHEMICAL ELEMENTS DISTRIBUTION INVESTIGATION
IN THE DEPOSITED HIGH-TEMPERATURE STEEL
BY PEARLITIC ELECTRODES LAYER**

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INTRODUCTION

When selecting materials for metal constructions and machines, they try to ensure different technical requirements (strength, rigidity, reliability, endurance and so on) and economic (minimum price, minimum weight, cheap treatment and others) requirements [9-11]. Some of these requirements contradict each other.

Frequently different parts of the same construction will work with different temperatures and conditions of oxidation. For the work carried out under such conditions different degrees of pearlitic and austenitic strength class steels. Therefore many contemporary constructions are manufactured from the parts, which are made from different steels and are welded together.

The necessary condition for the welded compound formation for the majority of the welding processes of is smelting the edges to be welded and shaping of weld or pillar from the melted base metal, or partially due to the deposited and melted metal. For the conditions for manual arched facing or penetration welding of austenitic they became 20-30% bigger than pearlitic. Therefore the composition of this weld layer with the adequate accuracy can be calculated with the collaboration in it of the share melted basic and deposited electrode metal [1].

Technological and structural strength of welded joints is ensured when in different layers of the weld and heat-affected zone there are no brittle and low-strength sections. In connection with the selection of welding base materials of different steels it is necessary to estimate structure and properties of different layer weld. This preliminary estimation can be made with the aid of the structural diagram (for example Sheffler's) [1-10].

When welding different alloying steels, the presence of crystallization layers in one structural class does not usually influence the properties of the welding connection and it is possible not to consider them. When welding different structural class (pearlitic and austenitic) steels the formation of welded compound is connected with the conditions for the cocrystallization of metals with the different structural grates (α and γ - phase). In this case the interlayer in the dilution zone of the deformed structural grates mated between themselves is formed. The greatest degree of structural instability appears when the insignificant width of the crystallization layers of variable composition [1].

In the limits of a change in the composition of the zone of crystallization layers the structure and their properties can considerably be changed. Thus, in the dilution zone of pearlitic steel with the austenitic the section of crystallization layer with content of Cr = 3-12% and Ni = 2-7% has a structure of the high-alloyed martensite and is brittle. The width of brittle martensite layers depends on the reserve of austenitic weld material. Also with the welding influence on the structure and the properties of layer renders the diffusion redistribution of elements on the dividing line of different metals. To the greatest degree the layers indicated are connected with the migration of carbon. Usually carbon migrates of the less alloyed metal in that more alloyed. The intensity of the development of layers is reduced with the decrease in the low-alloy steel of carbon content [1-7]. When different began necessarily to weld under the assembly conditions, junction of more alloy steel under the shop conditions are preliminarily melted by less alloy steel. It is later, for welding the construction under the assembly conditions, it is possible to use electrodes intended for welding less alloy steel.

EXPERIMENTAL RESEARCH

Authors investigated the distribution of the alloying elements (Mn, Si, Cr, Ni) in deposited to high-temperature (strength) steel 20X23H18 ГОСТ 5632-72 (X20CrNi23-18 EN 10027-1) in a manual arched manner (111 EN 24063) by pearlitic electrodes УОИИ-13/45 ГОСТ 9467-75 (EN 499- E462B5H10) metal. Electrodes УОИИ-13/45 have a base coating and a core from the wire СВ-08А. Facing was manufactured into three layers. After the facing of each layer the surface of metal was decontaminated with small grinding machine. After the end of facings plates were prepared for the investigation of chemical composition according to the diagram, that is represented in figure 1. The surface of metal was ground on the machine tool. After the removal of the layer of weld metal was determined its chemical composition by tool Spectro LAB 05 3N 45/263. Last layer was separated together with the base metal into the depth by 0.8 mm. Therefore Table 1 it shows with the minus sign. In addition to this of the weld metal the templates were cut out and micro-sections were made. The obtained structure was investigated by the optical microscope LEICA MEF 4M. Also the weld metal mechanically failed and the obtained surface was investigated by the scanning microscope XL 30 ESEM, PHILIPS.

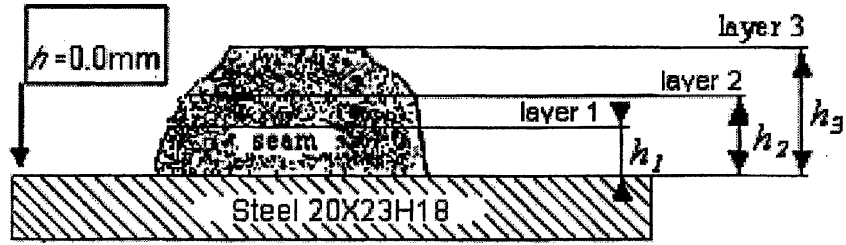


Fig.1 Chemical composition of the weld metal study schematics [5]
RESULTS AND THEIR ANALYSIS

Table 1

Chemical composition of base metal and weld material, %

Material	h_n , mm	C	Mn	Si	Cr	Ni	Fe
Steel 20X23H18	-	0.084	1.61	0.366	23.62	17.18	56.60
Wire CB-08A	-	0.08	0.57	0.23	0.30	0.30	98.42
Welded metal	- 0.8	0.069	0.95	0.22	11.87	9.51	77.04
1 layer	0.8	0.058	0.81	0.23	6.30	5.35	86.99
1 layer	2.5	0.52	0.49	0.12	1.91	2.31	94.95
2 layer	4.7	0.053	0.41	0.09	0.88	1.42	96.99
3 layer	7.0	0.051	0.44	0.10	0.12	0.30	98.84

Chemical composition of the weld metal can be approximately determined by the formula:

$$C_w = C_f + (P/100)^n (C_p - C_f), \quad (1)$$

where C_w is the quantity of an element in n-th-layer in a deposited metal; C_f is the quantity of an element in the base metal, %; C_p is the quantity of an element in the addition (electrode) metal, %; p is melting degree, $p = [A/(A + B)] \cdot 100\%$; A is sectional area of the welded metal; B is the fusion zone area of the base metal;

n is the number of layers. The results of calculating the coefficient p are presented in Table 2.

Table 2

Calculation of the welding degree

n	A, mm^2	B, mm^2	$p, \%$
1	42	35	55
2	68	35	66
3	90	35	72

Calculations of the elements Mn, Si, Cr and Ni in metal seam quantity were performed and they were compared with those, obtained during the experiment:

$$C_1(\text{Mn})=1,61+(55/100)^1(0,57-1,61)=1,038 ;$$

$$C_2(\text{Mn})=1,038+(66/100)^2(0,57-1,038)=0,834 ;$$

$$C_3(\text{Mn})=0,834+(72/100)^3(0,57-0,834)=0,735 ;$$

Si, Cr, Ni quantities in the weld metal were calculated. Results obtained in analogous way are presented in Table 3.

Table3

Calculated quantity of elements in the weld metal, %.

Layer, n	Mn	Si	Cr	Ni
1	1,038	0,291	10,794	7,896
2	0,834	0,264	6,223	4,587
3	0,735	0,251	4,012	2,987

According to the tables 1 and 3 data the graphic dependences of distribution Mn, Si, Cr and Ni in the weld metal were built. Since the first layer was ground 3 times (last layer together with the base metal at the depth of 0.8 mm from the surface of measurement), that we will obtain 3 real values of chemical elements in the first layer. Tables 1 and 3 present obtained data graphically in Fig. 2-5.

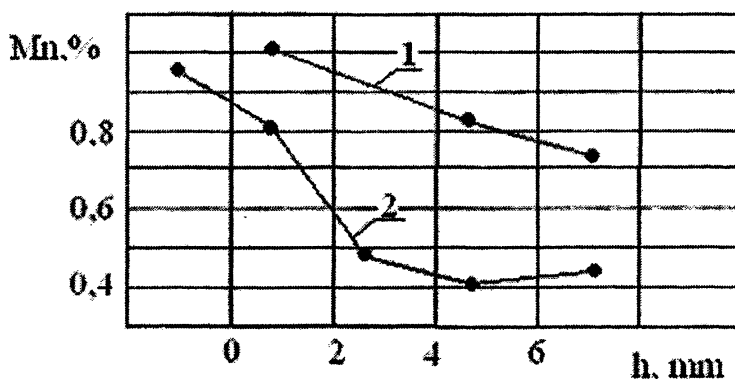


Fig.2. Distribution of manganese in the metal of seams:
 1- the calculated quantity of Mn;
 2- the real quantity of Mn in the weld material

As can be seen from second figure, a calculated quantity of manganese in the weld metal is more, than that established is experimental. This can be explained that, in the calculations there was not considered the activity of manganese in the metallurgical processes. It is established, that only in the first layer a quantity of manganese is close to the calculated.

In figure 3 there is presented the distribution of silicon in the weld metal. The

calculated quantity of silicon only in the first layer is close to the established experimentally. Subsequently its quantity is decreased and is stabilized with $Si=0,1\%$. This can be explained that, that silicon is the most active element in the metallurgical processes with the welding.

Figure 4 represents the distribution of chromium in the weld metal. Real quantity of chromium only in the lower part of the first layer - about 12%. Subsequently a quantity of chromium sharply is decreased. A calculated quantity of chromium is close only in the first layer; subsequently its quantity is decreased, but as it is not rapid as in the reality. Chromium is passive in the metallurgical processes and barely he burns down.

Theoretically, 12% Cr can be only in the third layer. This can be explained by the fact that Cr is passive in metallurgical processes and it nearly does not burn down.

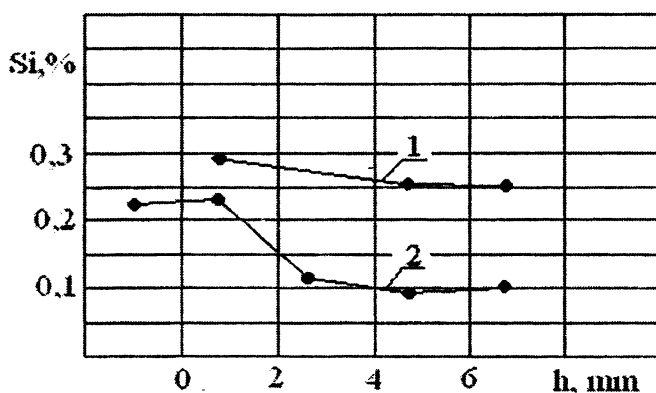


Fig.3. Distribution of silicon in the weld material: 1- the calculated quantity of Si; 2- the real quantity of Si in the weld metal

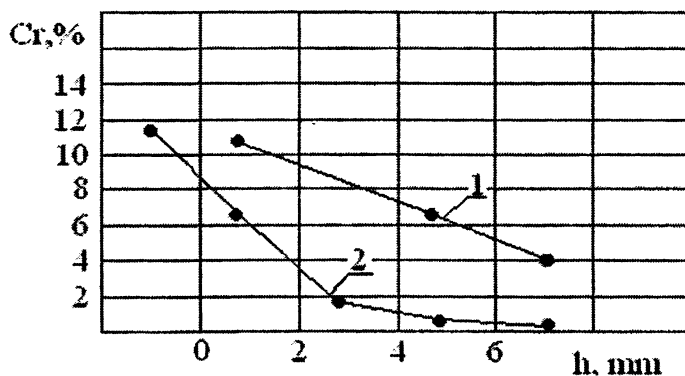


Fig.4. Distribution of chromium in the seam of the metal: 1- the calculated quantity of Cr; 2- the real quantity of Cr in the weld metal

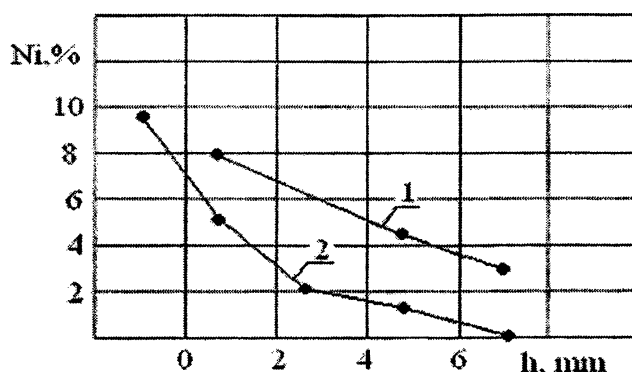


Fig.5. Distribution of nickel in the weld metal:

1- the calculated quantity of Ni; 2- the real quantity of Ni in the weld metal

Figure 5 presents nickel distribution in the weld metal. The real quantity of nickel in the lower part of the first layer only composes 9.5%, which makes it possible to obtain the austenitic weld structure. Subsequently a quantity of nickel sharply is decreased. A calculated quantity of nickel only in the first layer is close to the real. In other layers a quantity of nickel is decreased, but so not sharply, as in the reality. Nickel, also, like chromium, it is passive in the metallurgical processes, therefore it barely burns down.

Generalizing, it is possible to say, that the quantity of alloying element in the weld metal depends on its quantity in electrode metal and its activity in the metallurgical processes.

The structure of a welded metal can be determined using Sheffler diagram taking average values of Ni and Cr.

$$Ni_{eq} = of \%Ni + 30 \times \%C + 0.5 \times \%Mn. \quad (2)$$

$$Cr_{eq} = of \%Cr + \%Mo + 1.5 \times \%Si + 0.5 \times \%Nb. \quad (3)$$

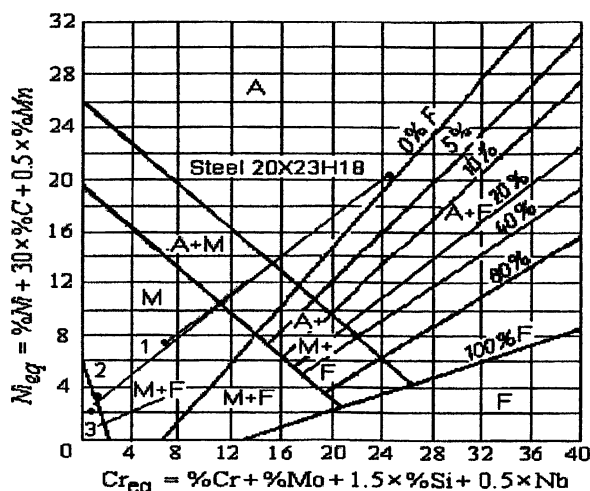


Fig. 6. Structures of welded seams on Sheffler diagram at welding steel 20X23H18 by electrodes УОНИ-13/45 [4, 5]:
1 – first seam layer 2 – second seam layer; 3 – third seam layer

Using Sheffler diagram for the determination of the composition phase of the weld in the case of welding carbon steel with an austenitic one, we can see that the structure contains 90 % of an austenite and 10 % of ferrite. The martensite in this case is entirely excluded. Therefore it may be expected that the formation of cracks in the weld metal is nearly impossible when the weld is formed by welding different metals using austenitic electrodes. By the way, in practice during the welding of austenitic steel with carbon steel in the weld metal and also in the fusion zone, cracks sometimes appear.

Steel 20X23H18 has: $Cr_{eq} = 24.17\%$, $Ni_{eq} = 20.51\%$, $Cr_{eq}/Ni_{eq} = 1.18$, $Cr_{eq} + Ni_{eq} = 44.68\% > 30\%$. The structure of steel is austenitic.

By pearlitic electrodes we will obtain with the facing to steel 20X23H18:

1 layer - $Cr_{eq} = 6.65\%$, $Ni_{eq} = 7.5\%$, $Cr_{eq} + Ni_{eq} = 14.15\% < 30\%$, $Cr_{eq}/Ni_{eq} = 0.89$.

We obtain the martensite weld structure. It can be seen from Sheffler diagram.

2 layer - $Cr_{eq} = 1.02\%$, $Ni_{eq} = 3.21\%$, $Cr_{eq} + Ni_{eq} = 4.23\% < 30\%$, $Cr_{eq}/Ni_{eq} = 0.32$. The structure of the weld is martensite, according to the Shefflers martensite-ferrite diagram.

3 layer - $Cr_{eq} = 0.27\%$, $Ni_{eq} = 2.05\%$, $Cr_{eq} + Ni_{eq} = 2.32\% < 30\%$, $Cr_{eq}/Ni_{eq} = 0.13$.

The structure of weld metal is martensite-ferrite.

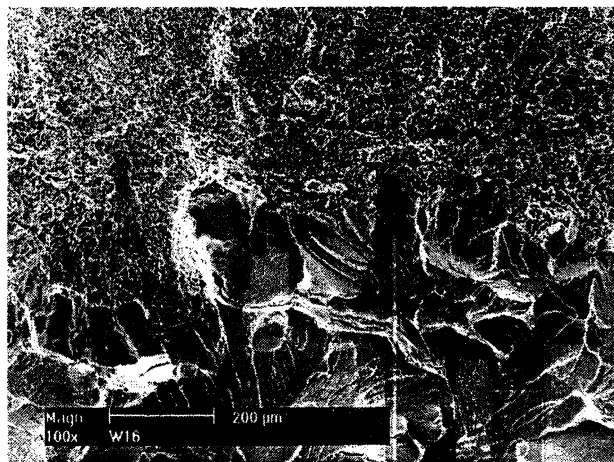


Fig.7. Fracturegram of the zone of the destruction of dilution zone: above - base metal, below - deposited

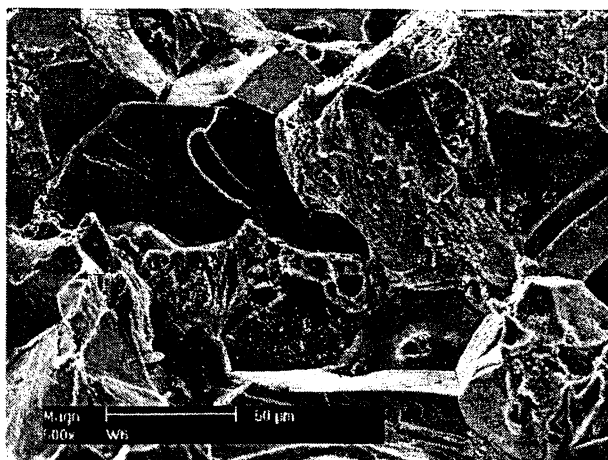


Fig.8. Fracturegram of the destruction of 1 layers:
brittle-ductile form of fracture

Dilution zone microstructures are represented in figures fracturegram (fig. 7 - 9) the destruction of weld metal. They confirm, that the destruction of the first layer has intermediate (brittle-ductile) nature more frequently. The destruction of the second and third layer has brittle nature, which confirms the martensite structure of weld metal.

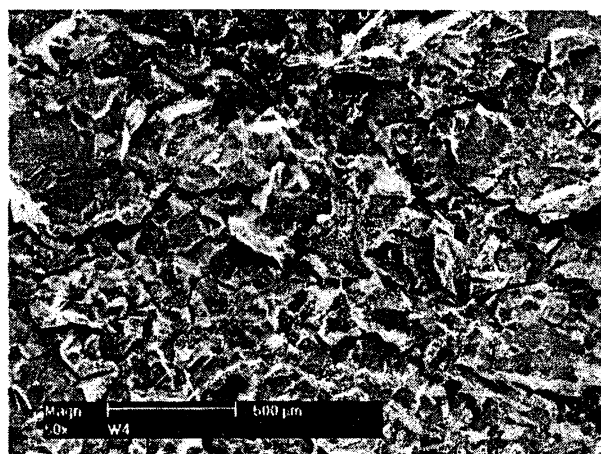


Fig. 9. Fracturegram of the destruction of 2 layers:
brittle form of fracture

CONCLUSIONS

1. Calculations are carried out and Mn distribution is determined, Si, Cr, Ni with the facing by the pearlitic electrodes YOHI-13/45 to high-temperature (strength) steel 20X23H18. It is established, that beginning only from the third layer the chemical composition of weld metal is close to the composition of electrode metal. 2. The fracturegrams of weld metal show their brittle form of fracture and possibility of crack formation with the structural design made of different classes steels.

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THE BEST CUTTING METHOD FOR METALS

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INTRODUCTION

Plasma cutting can improve productivity and lower cutting costs. By 95%