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# Influence of Covering Components of Welding Electrodes on Chemical Composition and Mechanical Properties of Fused Metal

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The influence of composition of welding electrodes covering chemical composition and mechanical characteristics of a fused metal is investigated in the article. Welding electrodes with the different content of components, included in covering of welding electrodes, were made to perform test and research. The content of a covering changed at the expense of the basic component - chalkstone. The analysis of a chemical composition of a fused metal and mechanical characteristics of a weld metal has allowed to establish the influence of different components, included in covering of welding electrodes, on the quality of a weld metal and welding electrodes.

*Keywords*: welding electrodes, chemical composition, mechanical properties of fused metals.

## 1. INTRODUCTION

The welding is one of technological processes of metal constructions manufacture. The quality of welding materials has an important value for quality of welding constructions. The uniformity of structure and technological strength are demanded to a weld metal. The metal obtained as a result of an electrode fusion in welding conditions, should not have considerable pores and slag inserts and have enough high resistance to formation of hot and cooling cracks in welded joints.

The greatest part of coverings of welding electrodes is composed of slag-forming components. The slag, obtained as a result of welding, basically is formed from slag-forming components, though it is impossible to eliminate change of the composition of slag as a result of its updating by oxides and other chemical compounds (sulphides, nitrides and etc.), which get from a metal component coverage, metal of an electrode or base metal [1 – 3].

Usually deoxidizers and alloying components enter into coverings. They enter into coverings as metal materials - of ferroalloys, which have necessary chemical elements (ferromanganese, ferrosilicon, ferrotitanium, ferrochrome etc.), or as almost pure metals (aluminium powder, metal manganese etc.).

Recently a ferrous powder was applied to a covering of electrodes with the purpose to increase welding productivity and improvement of electrodes technical characteristics [4].

Some metal materials, especially deoxidizers, largely transfer in slag and are also slag-forming [5].

The chemical composition of fused metal depends on a chemical composition of wire and used covering components.

When alloying metal of a weld, first of all it is necessary to investigate affinity of alloying elements to oxygen. According to the increasing affinity to oxygen elements most frequently met in steel can be arranged in the following line:

$$Cu \rightarrow Ni \rightarrow Co \rightarrow Fe \rightarrow W \rightarrow Mo \rightarrow Cr \rightarrow$$
$$\rightarrow Mn \rightarrow V \rightarrow Si \rightarrow Ti \rightarrow Zr \rightarrow Al.$$

The elements located to the left of iron, during welding are practically assimilated completely by a welding pool. The tungsten and molybdenum located near to iron on the right are also almost fully assimilated by a welding pool. All other elements are oxidized and the more actively, than further to the right they are from iron.

Alloying additions can be contained both in metal and in a covering of an electrode. The weld metal can alloy and the basic metal but only when welding of alloyed steels and alloys is made and full penetration of the basic metal is provided enough [6 – 8].

Concentration of alloying elements in fused metal depends on their content in a metal rod, content of components in covering composition, concentration of alloying element in that component, coefficient of covering weight, and coefficients of alloying element transition from a covering and wire to metal. Coefficients of alloying elements transition of a covering and wire differ.

The coefficient of transition shows physical and chemical properties of element, intensity of element evaporation, sputtering and other technological phenomena. In practice orientation experimental average values of element transition coefficients are used. These values can be used only when conditions of a weld metal alloying and experiments are identical [5 – 10].

## 2. OBJECT OF RESEARCH

Electrodes have been made for testing and research (the increased productivity of surfacing) with the basic covering and diameter 4 mm. The following components enter into a covering of electrodes: limestone, rutile, fluorite, quartz sand – basically slag-forming components, organic materials – to increase plasticity and improve covering surface, an iron powder – to increase surfacing productivity, and ferromanganese, ferrosilicium, a nickel powder – components for deoxidation of a weld metal alloying.

Electrodes with the different content of metal components (content changed due to the basic component

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of electrodes covering – limestone) have been tested. The contents of other components in a covering of electrodes did not change. Contents deoxidating and alloying substances of the tested electrodes are given in the Table 1.

**Table 1.** Composition of a covering used in the research

| № a sample of electrode | Composition of a covering, % of weight | | |
|---|---|---|---|
| | Ferromanganese | Ferrosilicium | A nickel powder |
| 1 | 2.0 | 5.0 | 0.1 |
| 2 | 5.0 | 5.0 | 0.1 |
| 3 | 10.0 | 2.0 | 0.1 |
| 4 | 10.0 | 5.0 | 0.1 |
| 5 | 6.0 | 5.0 | 0.1 |
| 6 | 6.0 | 5.0 | 0.2 |
| 7 | 6.0 | 5.0 | 0.5 |
| 8 | 6.0 | 5.0 | 1.0 |
| 9 | 6.0 | 5.0 | 2.0 |
| 10 | 6.0 | 5.0 | 5.0 |

For manufacture of electrodes the welding wire Sv-08A was used.

## 3. TECHNIQUE OF RESEARCH

### 3.1. The analysis of a fused metal chemical composition

8 layers of metal were surfaced on a metal plate. Between surfacing welding of layers, metal was cooled in water. The top layer of a fused metal was deleted and the working surface was ground.

The tests of wire (Table 2) and fused metals were analysed by means of spectrum analyzer BELEC-compact-lab-N.

### 3.2. Mechanical properties of a weld metal

As the basic feature of electrodes with a base covering – high impact strength of a weld metal at the normal and lowered temperatures, and other mechanical properties considerably do not differ from mechanical properties of other types of electrodes it is important to define dependence between a chemical compound and impact strength of a weld metal.

Rectangular samples, with the sizes 10×10×55 mm and cut of V form, were applied to define impact strength in accordance with GOST 9454. The tests of impact strength were carried out on Sharpi method by pendulum MK-30A. The cooling of samples was carried out in the environment of the alcohol, which was cooled by liquid nitrogen. Initial energy of a pendulum is equal $E_1$ = 305.8 J.

Impact strength $KCV$ (J/cm$^2$) was calculated by formula:

$$KCV = KC / S = (E_1 - E_2) \cdot 9.81 / S . \quad (1)$$

The area of fragile failure (%) was calculated as a ratio of the fragile failure area in a fracture of a sample to the initial area ($S$) of cross section of a sample near the cut.

## 4. EXPERIMENTAL RESULTS AND DISCUSSIONS

The chemical composition of a fused metal is presented in Table 3.

The contents of silicon and manganese raise in fused metal when the content of ferrosilicium in a covering is increased (Fig. 1). It is related with deoxidation of metal. The main part of silicon deoxidizes metal. When metal is completely deoxidized and the content of ferrosilicium is increased silicon alloys a fused metal. At the insufficient content of ferrosilicium the metal is deoxidized by a ferromanganese. It also influences the concentration of manganese in fused metal (Fig. 2).

**Table 3.** The chemical composition of fused metal, % of weight

| № a sample | C | Si | Mn | P | S | Ni | Ti |
|---|---|---|---|---|---|---|---|
| 1 | 0.06 | 0.16 | 0.35 | 0.022 | 0.019 | 0.14 | 0.003 |
| 2 | 0.06 | 0.26 | 1.06 | 0.023 | 0.018 | 0.15 | 0.006 |
| 3 | 0.08 | 0.05 | 1.40 | 0.021 | 0.018 | 0.11 | 0.001 |
| 4 | 0.08 | 0.35 | 1.96 | 0.027 | 0.017 | 0.14 | 0.006 |
| 5 | 0.08 | 0.27 | 1.24 | 0.017 | 0.020 | 0.09 | 0.005 |
| 6 | 0.05 | 0.26 | 1.20 | 0.023 | 0.017 | 0.18 | 0.005 |
| 7 | 0.05 | 0.27 | 1.22 | 0.024 | 0.017 | 0.30 | 0.007 |
| 8 | 0.05 | 0.24 | 1.20 | 0.025 | 0.019 | 0.55 | 0.004 |
| 9 | 0.08 | 0.31 | 1.46 | 0.018 | 0.019 | 0.98 | 0.009 |
| 10 | 0.07 | 0.37 | 1.41 | 0.024 | 0.019 | 2.47 | 0.008 |

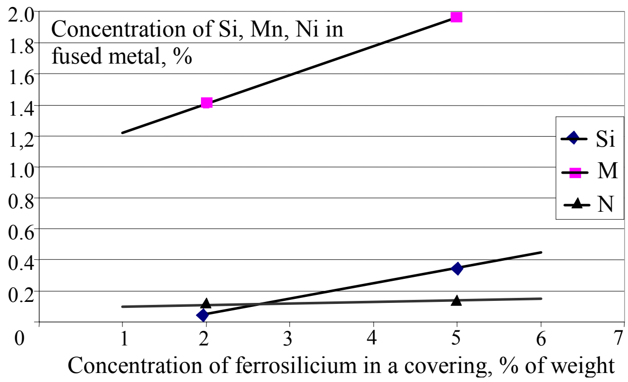


**Fig. 1.** The dependence of Si, Mn and Ni concentration in fused metal on concentration of ferrosilicium in a covering, when FeMn = 10 % and Ni = 0.1 %

**Table 2.** The chemical composition of wire metal, % of weight

| | C | Mn | P | S | Cu | Al | Cr | Ni |
|---|---|---|---|---|---|---|---|---|
| Range | 0.09 – 0.10 | 0.40 – 0.46 | 0.007 – 0.013 | 0.011 – 0.022 | 0.02 – 0.03 | 0.001 – 0.010 | 0.01 – 0.02 | 0.01 – 0.02 |
| Average value | 0.10 | 0.44 | 0.009 | 0.017 | 0.02 | 0.003 | 0.01 | 0.01 |

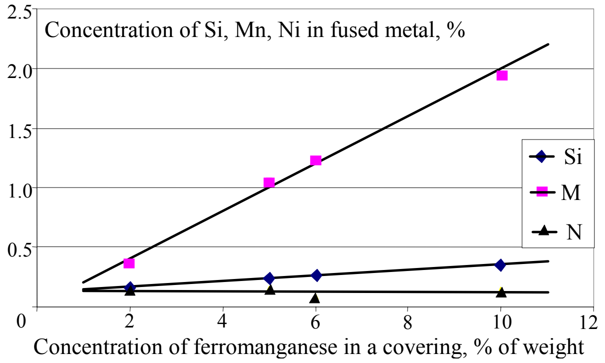


**Fig. 2.** The dependence of Si, Mn and Ni concentration in fused metal on concentration of ferromanganese in a covering, when FeSi = 5 % and Ni = 0,1 %

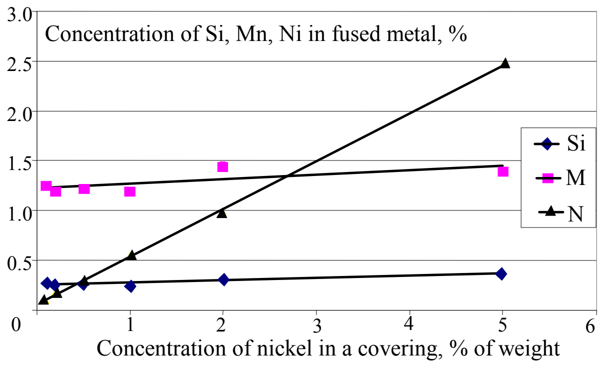


**Fig. 3.** The dependence of Si, Mn and Ni concentration in fused metal on concentration of nickel in a covering, when FeMn = 6 % and FeSi = 5 %

The content of nickel in fused metal does not change when the content of ferromanganese and ferrosilicium in a covering of an electrode is changed (Fig. 3). Nickel does not deoxidize metal of a weld but only alloys it.

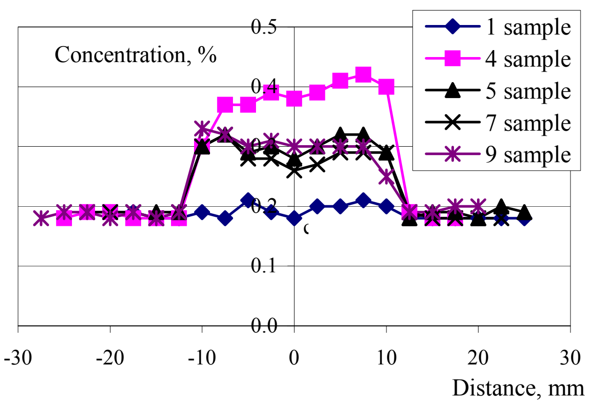


**Fig. 4.** Concentration of silicon in cross section of a weld; 0 – the central axis of a weld

When the content of the ferromanganese in composition of an electrode covering is increased, the concentration of manganese in fusing metal, at the complete deoxidation of metal by ferrosilicium, proportionally raises. The concentration of silicon is increased. It is connected to the small concentration of silicon (about 2 %) and its content in a ferromanganese.

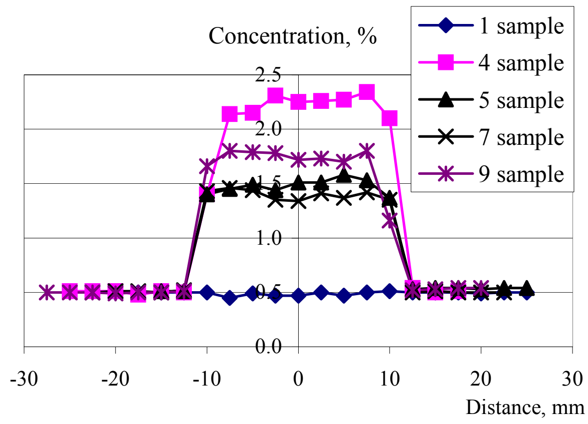


**Fig. 5.** Concentration of manganese in cross section of a weld; 0 - the central axis of a weld

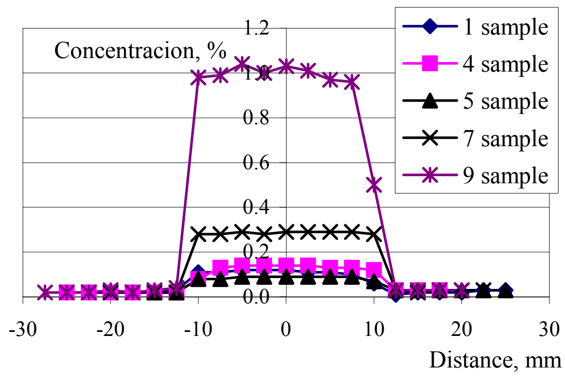


**Fig. 6.** Concentration of nickel in cross section of a weld; 0 – the central axis of a weld

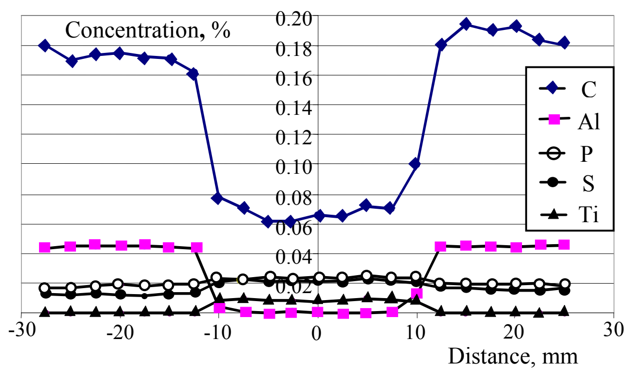


**Fig. 7.** Concentration of different elements in cross section of a weld; 0 – the central axis of a weld

Increase of manganese concentration in fused metal, at increase in the contents of nickel from 1 up to 2 % in a covering, can be related to decrease of the contents of a limestone ($CaCO_3$) in an electrode covering.

The concentration of silicon, manganese, nickel and other elements in cross section of a weld is graphically shown in Fig. 4 – 7.

The impact strength (at different temperatures) of a fused metal is presented in Table 4. The dependences of impact strength and the area of a fragile part of a fracture of sample Nr 9 from temperature test are graphically shown in Fig. 8.

**Table 4.** Impact strength of a weld metal at different temperatures

| № a sample | Temperature test, °C | KCV, J/cm$^2$ | The fragile area, % |
|---|---|---|---|
| 1 | –30 | 102 | 55 |
| 4 | –30 | 45 | 85 |
| 5 | –30 | 134 | 45 |
| | +18 | 211 | 0 |
| 7 | –30 | 170 | 42 |
| 9 | –60 | 62 | 82 |
| | –47 | 78 | 73 |
| | –38 | 101 | 62 |
| | –30 | 111 | 48 |
| | +18 | 184 | 0 |

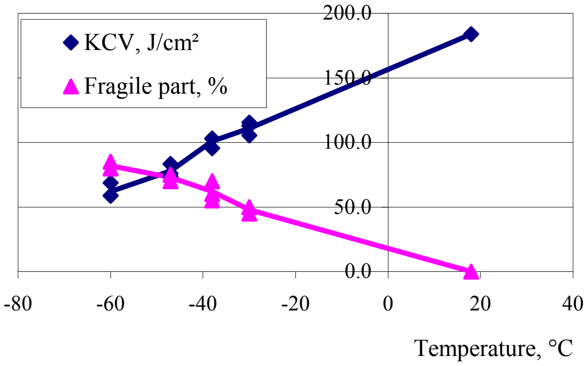


**Fig. 8.** The dependence of impact strength and the area of a break fragile part of sample Nr 9 on temperature

The highest impact strength of a weld metal is achieved to electrodes with covering of a samples No 7, a chemical composition of a fused metal of which is following: Mn – 1.22 %, Si – 0.27 %, Ni – 0.30 %. The maximum impact strength at temperature of 30 ºC is equal 170 J/cm$^2$ (Table 4).

The increase of manganese concentration in a fusing metal up to 1.96 % reduces a value of impact strength of a weld metal.

Change of temperature of testing of the samples on impact strength with 60 up to +18 °C results in increase of KCV value with 62 up to 184 J/cm$^2$, and the areas of a fragile fracture reduse from 82 up to 0 %.

## 5. CONCLUSIONS

1. The influence of components (ferrosilicium, ferromanganese and powder of nickel) of a welding electrodes covering on a chemical compound of fused metal is established.
2. It is established, that the greatest value of impact strength of a weld metal has been achieved for the sample No 7 which was welded by electrodes with the following chemical compound: Mn – 1.22 %, Si – 0.27 %, Ni – 0.30 %. Value of the impact strength at temperature of 30 ºC is equal 170 J/cm$^2$.
3. It is established, that at increase of manganese concentration in a fusing metal up to 1.96 %, impact strength of a weld metal considerably decreases.

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