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Processing Behavior of Electrodes Made with Addition of Nanopowder

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Abstract. The study analyzes the processing behavior of welding electrodes made with addition of nanopowder, and compares them to standard welding electrodes (without addition of nanopowder). The effect of nanopowder of complex composition on the electrode metal transfer process is analyzed as well.

Introduction

In the early 21st century it has been essential to raise the scientific and technical level of the economy throughout the world. To resolve this issue, it is essential to conduct extensive scientific research and to insure the large-scale application of cutting edge technologies in production processes. According to the forecasts of many relevant organizations, priority must be given to research on nanomaterials development [1].

Many scientists dealt with the influence of nanomaterials on the properties of welded joints. In article [2] an attempt was made to explain the influence of Ti-containing inclusions on the crystallization of acicular ferrite and the mechanical properties of metals for multi-pass welding. In the work, the dispersion of the particles was carried out by means of ultrasonic treatment. However, to evenly distribute the nanoparticles in the liquid glass, treatment is necessary for 6 hours, which is not practical in a batch production. The authors also established that the percentage of needle ferrite in welding metals increases with the increase in the amount of titan nanoparticles in the electrode coating.

Coated electrodes are extensively used in the petroleum, gas and petrochemical industries, but their low impact toughness has limited their potential for even wider use, especially in structural applications at low temperatures or in corrosive environments. In the last two decades, extensive studies have been carried out on the impact toughness of weld metal for new designed steels. In conventional coated electrodes, with the help of nanotechnology, their mechanical properties and microstructure can be improved to be better quality. More recently, a new generation of coated electrodes with highly anticipated materials properties has been introduced by adding the oxide nanoparticles to the electrode coating. For instance, a uniform dispersion of Ti-oxide inclusions within austenite grains can be obtained by using coated electrodes containing titanium oxide nanoparticles.

It was established in [3, 4] that, among nonmetallic inclusions, Ti-containing inclusions provide the required centers for intragranular crystallization of acicular ferrite. It was established in Ref. [5] that in the welded arc welding the elements of nonmetallic inclusions (Ti, Mn, Si, S and O) and Ti are necessary for the crystallization of intragranular ferrite. The small discrepancy between lattice parameters between inclusions and intragranular ferrites, increased stress and strain fields around the inclusions as a result of the difference in the thermal expansion coefficients of inclusions and the steel matrix, the reduction of the free energy barrier for ferrite crystallization, and the depleted regions around the inclusions are admissible mechanisms of crystallization of intragrain ferrite [6, 7].

It is established that needle ferrite improves the mechanical properties of steels and welding metals, in particular – impact strength, thanks to the intertwined structure of thin plates of ferrite. The best impact strength in steels and weld metal was achieved on the structure of acicular ferrite due to the fine ferrite grain and high-angle grain boundaries [8-9]. The grain boundaries change the direction of growth of cracks or at all prevent their spread [10-11].

As mentioned in studies [1], the essence of an experiment in adding nanopowder to the welding electrode is as follows: a complex-composition nanopowder (Al_2O_3, SiO_2, Ni, TiO_2,) with the nanoparticle size 90 nm and purity 99.85% is added to a water glass (Table 1). The nanopowder is added to water glass in the mechanical cavitation activator type facility at 30–35°C.

Table 1 – Performance index of double water glass

Name of Index	Serial	Experimental
Silicate module	3.1	3.2
Dynamic viscosity, cPs	611	387
Density, g/cm^3	1.43	1.43

Results and discussion

A series of experiments was performed to define the processing behavior of the electrodes under study. During these experiments pins welded on the surface of the plates. During the welding process, the changes in energy response (amperage, voltage) were recorded by the digital oscillograph.

Steel plates were used for welding: SS type St3, 300 mm long, 50 mm wide, and 4 mm thick. On the surface of the plates a bead of the electrode metal was welded. For welding, electrodes 4 mm in diameter were used, types MP-3, OK-46.00, UONI 13/55. The VD306-U3 rectifier was used as a source of supply. Welding was performed in single-pass under following conditions: amperage – 140…160A, voltage 24…26 V.

Along with the study of the processing behavior of electrodes, an experiment was performed to loss of metal during burning and spatter.

On the basis of the obtained results, the following values were determined:

Mass of the molten electrode:

$$m_{me} = m_e - m_{e\,gen} \tag{1}$$

Mass of the weld electrode material:

$$m_{we} = m_{p\,sv+s} - m_{p\,before} \tag{2}$$

Mass of the weld metal material:

$$m_{w\,e} = m_{p\,w} - m_{p\,before} \tag{3}$$

Mass of electrode loss from burning and spatter:

$$p = \frac{(m_{me\,r} - m_{we})}{m_{me}} \cdot 100\% \tag{4}$$

where m_e = mass of the electrode; $m_{p\,before}$= mass of plate before welding; $m_{p\,sv+s}$= mass of plate after welding with dross and spatter; $m_{p\,w}$ = mass of plate after welding without dross and spatter; $m_{e\,r}$ = mass of the rest of the electrode after welding; $m_{e\,gen}$ = mass of the rest of the electrode without dross.

The results of the experiment on welding a bead on the steel plate surface are shown in Figures 1-5. The digital oscillograph was used.

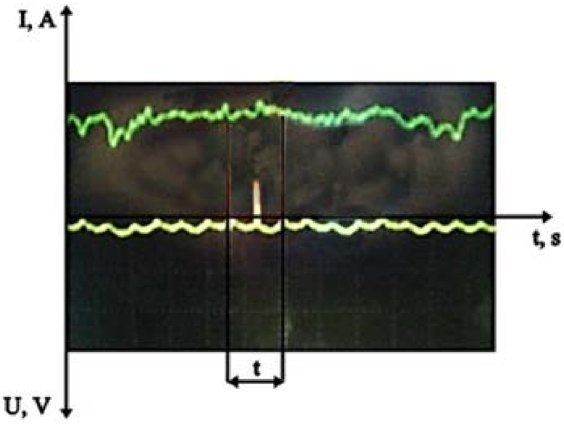

Figure 1. First specimen: oscillogram of welding process

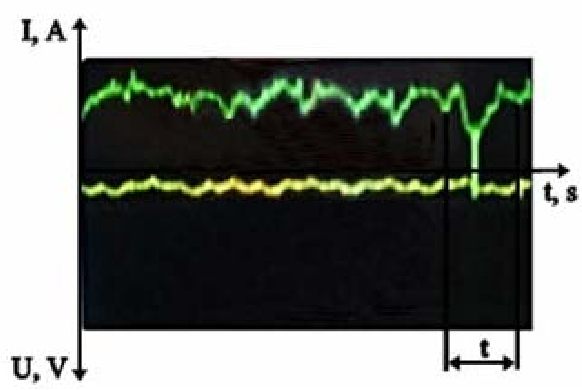

Figure 2. Second specimen: oscillogram of welding process

As is obvious, the process is characterized by high stability of the transfer of droplets of the electrode metal into the weld pool (in this situation stability is understood as the frequency of the microcycle transfer). The period of the droplet transfer amounts to 45…50 mc, prompting suggestions that the droplets transferred to the weld pool are small.

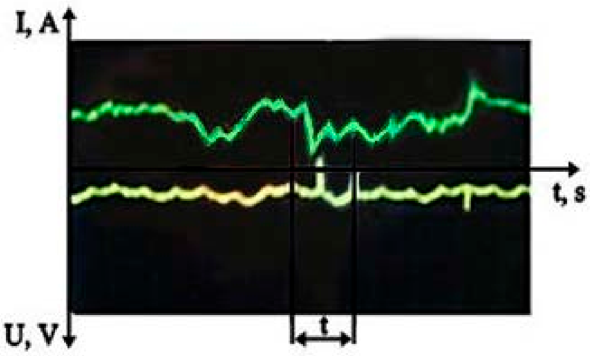

Figure 3. Third specimen: oscillogram of welding process

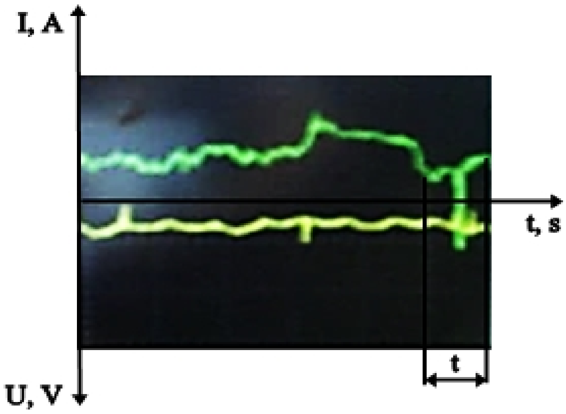

Figure 4. Fourth specimen: oscillogram of welding process

The processes in Figures 4 and 5 are less stable compared to the previous specimens and the frequency of the electrode metal droplet transfer is not evident. The period of droplet transfer is 30…60 mc. The amplitude values are different, which is a sign of a minor destabilization of the welding process.

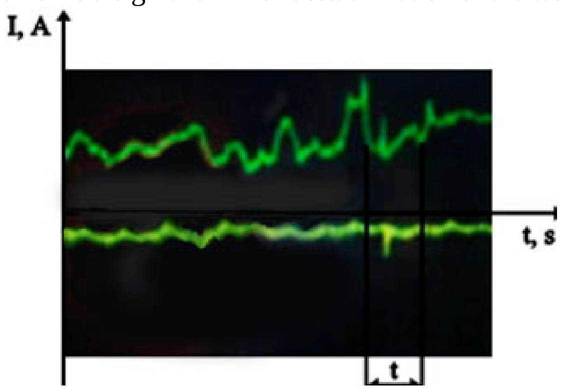

Figure 5. Fifth specimen: oscillogram of welding process

As seen from the pictures obtained, the welding process of specimens 1 and 2 is characterized by low stability of process, recurrence of short circuits, and a lower perturbation level.

A series of calculations was performed to determine the effect of the complex-composition nanopowder on the electrode metal loss during welding. Experimental results are shown in Table 2.

Table 2 – Results of studies on burning and spatter loss

	MP-3		OK-46.00		UONI 13/55	
	1	2	3	4	5	6
Mass of plate before welding, g	558.0	565.2	558.2	568.3	526.4	534.5
Mass of electrode before welding, g	59.0	59.1	57.3	57.4	58.5	58.4
Mass of plate after welding, with skimming, g	597.4	608.1	592.3	604.5	563.8	564.3
Mass of electrode after welding, g. Stubs	18.2	15	20.1	17.8	25.6	19.2
Electrode loss, %	3.4	2.7	8.5	8.3	12	10.6

As is seen from the derived experimental results, the lowest spattering was during welding of specimens 1 and 2, which demonstrably augments the data previously obtained, because stability of the transfer of droplets substantially affects both the stability of the welding process in general and the electrode losses in spattering.

Conclusions

The complex-composition nanopowder has an integrated effect on the processing behavior of the welding electrodes. As seen from the data and oscillograms, the nanopowder makes it possible to improve the stability of the transfer of droplets of the electrode metal.

Along with indicators of the dynamic properties of sources a great value for ensuring the stability of melting and transport electrode metal in the weld pool are also used for welding and surfacing materials. With the same chemical composition, electrode materials (MP-3 and UONI 13/45) differ in technological properties, expressed in the stability of arc combustion. Reduction of the size of the transferred drops of electrode metal promotes defect-free seam preparation, increase ductility, namely toughness at low temperatures.

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