Stabilization of Root Parameters for Shielded Arc Welding

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Abstract. The study revealed that the application of flux paste to the back side of the welded joint during welding of low-alloyed steels provides control over the sizes of the root and its defect-free formation. It was found that the back bead height of the root welded with flux paste is 1.5 to 3 times less than that of the root welded with the same welding variables without flux paste.

1. Introduction
Modern production rates require high and consistent quality of the welded joints.

In terms of economy and performance for many constructions the most efficient and sometimes the only possible mode is series welding with unsupported formation of the root. Such joints are the least laborious.

The study of reasons for the defects of these joints reveals unacceptable deviations in the root dimensions as the main problem which results in a poor penetration or a burn-through [1].

There is a number of techniques and methods being used to enhance the efficiency of welding and fabrication. The development of improved, extra proficient and cost-effective techniques is always targeted by researchers and industry [2-4].

The work [2] studied the modified short circuit GMAW process for the root seam and compared it with the conventional GMAW process. The comparison has been done on the parameters like current, voltage, wire feed rate, and travel speed and it was found that the weld quality in modified short circuit GMAW has been improved with the smooth appearance of the weld bead along with less spattering.

The literature has studied in sufficient detail welding process with single-component activating fluxes applied on the plate face, which increases penetration due to less surface tension of the weld pool [6-9, 11-14] and arc contraction [5,10].

The studies of automatic submerged arc welding also proved that there is an increase in tensile strength with increase in TiO2, SiO2 and CaF2 content of coating mixture whereas microhardness significantly reduced with higher increase of SiO2 content [15]. In previous research it has been studied that flux constituents and microstructure developing during welding; widely affect the mechanical behaviour of welds. In case of submerged arc welds the content of oxygen has considerable effect on microstructure or impact behaviour [16-18].

But there is almost no information on the flux pastes application to improve the root formation and its dimensions stabilization, which is the subject of this study.

2. Experimental part
Experiments in penetration of low-alloyed steel plates were performed with a non-consumable electrode in argon; the whole process was recorded with the video camera with optical filters (fig. 1). A number of refractory compounds were applied as components, such as SiO2, ZrO2, Al2O3, TiO2, CaO, CrB2, ZrB2, TiB2, CaF2 with particle size up to 60 µm. They were dissolved in alcohol into suspension and applied on the back side of the plate with the coating thickness 200 - 250 µm. With the optimal composition of the flux paste selected, the 10-mm thick low-alloyed steel plates were welded automatically with a
consumable electrode in the shielding gas mixture. Without the flux paste the chosen welding variables of automatic welding do not ensure consistent formation of the back bead.

**Figure 1.** Scheme of the experiment: 1 – plate, material 09G2S; 2 – a non-consumable electrode $d_{el} = 4$ mm, $l_{el} = 2$ mm; 3 – SAMSUNG VP-HMX-20C camera; 4 – coating from the selected compounds; penetration mode: $I_w = 240$ A, $t_w = 4$ s.

3. Results and discussion

The studies indicate that the beginning of the back bead formation without flux paste is characterized with fast increase in the back bead dimensions. The height increases from about 0.5 mm to 5.02 mm, and its width – from 4.7 to 10.7 mm in the time interval from 3.04 s to 3.26 s (in 0.22 s). The situation is different when the back bead is formed using zirconium oxide-based flux paste: the height increases from 0.46 mm to 3.08 mm, and the width - from 5.18 mm to 12 mm in the time interval from 3.26 s to 3.78 s (in 0.52 s). It proves that the applied coating can retain larger volume of the weld pool compared to the penetration without flux paste as well as protect from the negative influence of the arc and eliminate such root defects as a burn-through and deviations of geometric dimensions from permissible ones.

The experiments with the selected components proved that the weld pool melt is retained when using all the selected active compounds. The most significant retention was observed with flux paste on the basis of aluminium and calcium oxide: the maximum sag height was 2.25 mm and 2.65 mm respectively (figure 2). Apparently, it is associated with the higher surface tension of the initial substances. For example, according to the reported data [19] the surface tension of $\text{Al}_2\text{O}_3 = 580$ mN/m, $\text{CaO} = 510$ mN/m, while of $\text{TiO}_2 = 250$ mN/m, $\text{SiO}_2 = 280$ mN/m.
The study of root formation kinetics with the automatic welding with a consumable electrode in the shielding gas mixture without flux paste proved that at certain welding modes the weld pool sags with subsequent melt break-through out of the groove which results in burn-throughs (figure 3, a). When the flux paste is used as an active component (Al₂O₃) for the welding at the same modes, the weld pool sagging is acceptable and the formation of both face and back side of the root is defect-free (figure 3, b).

![Weld face view](image1)

![Weld root view](image2)

**Figure 3.** Weld root after welding with single-component Al₂O₃ flux paste (b), and without it (a):

Iₜₐₙₐ = 270 A; Uₜₐₜ = 29 V; Vₜₐₜ = 34 m/h; dₑ = 1.2 mm; Vₚₚ = 8 m/min; shielding gas 82%Ar+18%CO₂
Mechanical tests of the welded joints proved that the tensile strength and the impact hardness for welding with coatings are on a par with the base metal for 09G2S steel (figure 4, 5). The macro- and microsections (figure 6) demonstrate the defect-free root with deeper penetration, which allows to use high-performance automatic welding for subsequent filler bead formation.

4. Conclusion
Applying the flux paste on the back side of the welded joint during welding low-alloyed steels makes it possible to control the sizes of the root and its defect-free formation. The back bead height of the root welded with flux paste is 1.5 to 3 times less than that of the root welded with the same welding variables without flux paste.

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