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Dynamic Action of the Shielding Gas Jet Upon the Process of Consumable Electrode Welding

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Abstract. The author considers the gas-dynamic action of the shielding gas jet during consumable electrode welding on the processes in the welding area and properties of the weld joints produced from alloyed high-strength steel 30HGSA. The results of the research on the gas-dynamic action of the jet on the process of consumable electrode welding are provided. It was established that the method of consumable electrode welding with double-jet gas shielding ensures regulated gas dynamics in the welding area and allows controlling the electrode metal transfer, the chemical composition of the weld metal, stabilizing the process of welding and ensures stable high mechanic properties of the weld joints.

Introduction.

At the present time welding is applied for producing permanent joints of the widest range of metallic, nonmetallic and composite constructional materials under the conditions of earth atmosphere, World's ocean and aerospace. In spite of continuously growing application of light metal alloys, polymer and composite materials in construction, steel remains the basic constructional material. Consumable electrode welding in the atmosphere of shielding gases stays one of the main production methods in the process of developing the material basis of modern civilization.

The history of the thermal processes determines the productivity of the basic metal and welding filler fusion, trend and completeness of the metallurgic processes in the weld pool, conditions of weld and heat-affected zone metal structure formation, performance characteristics of the weld joints [1-5].

The shielding gas is normally used to protect the welding area from the harmful action of the air but, under certain conditions, it can become the instrument for controlling the processes in the weld zone and the properties of weld joints. A number of studies [6-13 and other] investigating the influence of the shielding gas flow upon the process of consumable electrode welding notice that increase in the gas flow rate is associated with improvement of the quality of the weld zone protection, weld formation, welding process stabilization, improvement of the weld metal properties. Increase of the shielding gas flow ensures increased hardness of the gas jet which is especially important when completing the welding works in an exposed position [2, 6, 10].

Methodology.

Significant change of the dynamics of shielding gas (Fig. 1) results in changing processes taking place in the weld zone (transfer of electrode metal droplets, metallurgic processes in the drop, thermal processes, dynamics of the weld pool, etc.) and, as a result, changing the performance characteristics of the weld joints [7, 14].

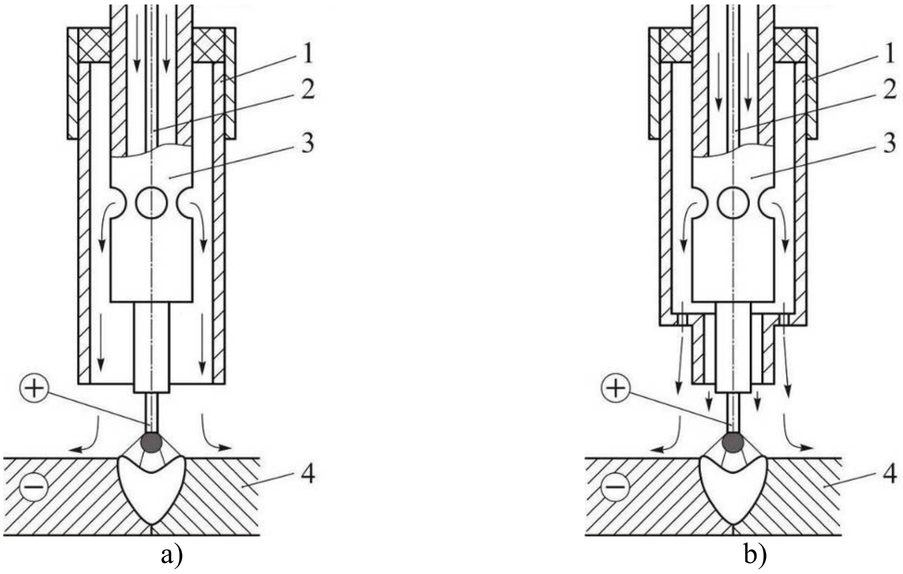


Fig. 1. The diagram of the shielding gas flow from the weld nozzle:
a) traditional single-jet gas shielding; b) double-jet gas shielding: 1 – the nozzle; 2 – the electrode wire; 3 – the contact tip;4 – the part

Action of the shielding gas jet upon the electrode metal droplet is 12 times more efficient under the double-jet gas shielding than under the single-jet one (Fig. 2).

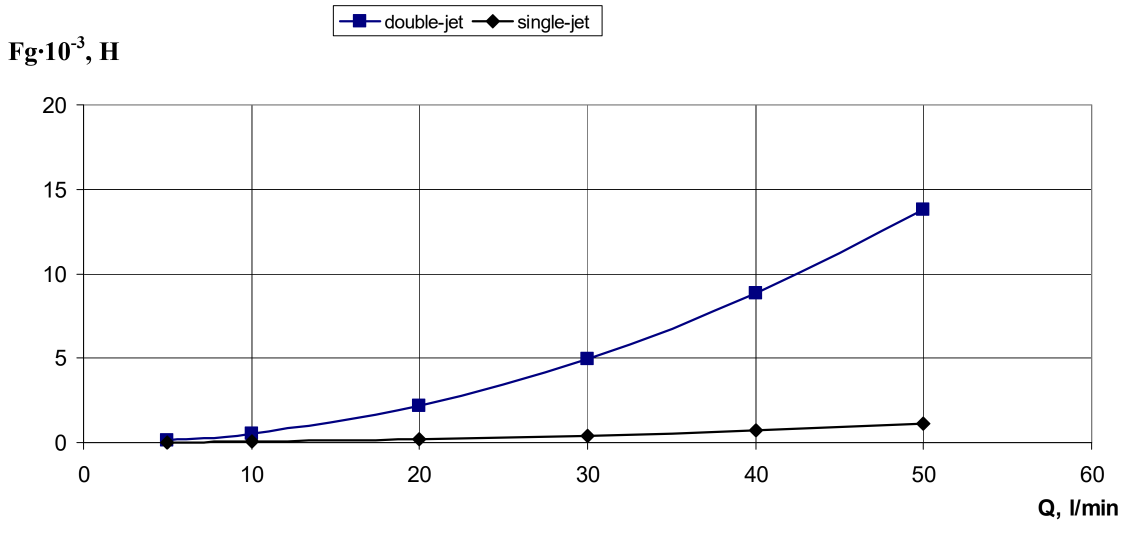


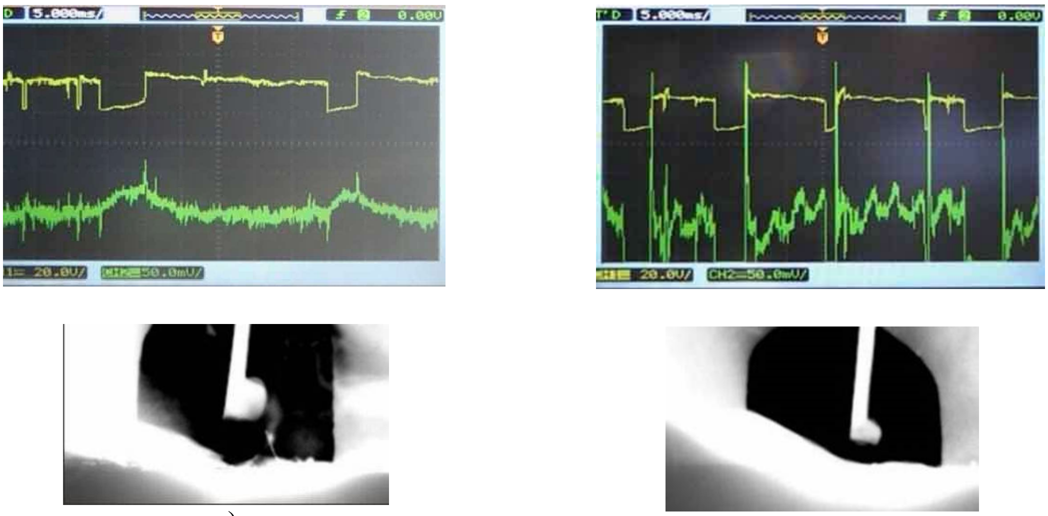
Fig. 2. The diagram of the changes of the efficiency of shielding gas jet action depending upon the gas flow rate

With the increase of the shielding gas flow acting upon the electrode metal droplet under the double-jet gas shielding we observe growth of frequency and stability of droplets transfer into the weld pool as the droplet takes up the coaxial position with the electrode and the chaotic oscillations of the droplet reduce.

The conditions of the experiment: automated single-pass welding of the plates from 30HGSA steel completed with Sv-08G2S welding wire 1.2 mm in diameter in CO_2 with stationary arc downhand with single-jet (traditional) and double-jet (developed), welding current I= 195…200 A, electrode wire stick-out distance L = 12 mm, shielding gas flow rate = 20 l/min, arc voltage U = 26…27 V, welding speed V = 25 cm/min.

Results and discussion.

The results of analysis of oscillograms and frames of high-speed video recording of the experimental studies (Fig. 3) showed that frequency of droplet transfer increases upon the average by 1.6 under double-jet shielding as compared to the single-jet one, together with reduction of the droplet size from the mean of 2.4 mm to 2.00 mm.



a) b)

Fig. 3. Oscillograms and frames of high-speed video recording:
a) traditional single-jet gas shielding; b) double-jet gas shielding

As the gas-dynamic action of active shielding gas jet upon the processes in the weld area increases the controlled change of the chemical composition and structure of the weld metal [7, 15] and, as a result, change of the performance characteristics of the weld joints also take place. The dynamics of the weld pool changes as well and here two aspects should be considered and taken into account (Fig. 4). First, the direct action of the active shielding gas upon the liquid metal of the weld pool around the welding arc. It results in growth of the liquid layer under the arc as there is no way out for the molten metal in the volume limited by solid metal and it starts flowing under the arc and rising it (Fig. 5 b). Growth of the liquid layer (b) results in reduction of the penetration depth (h).

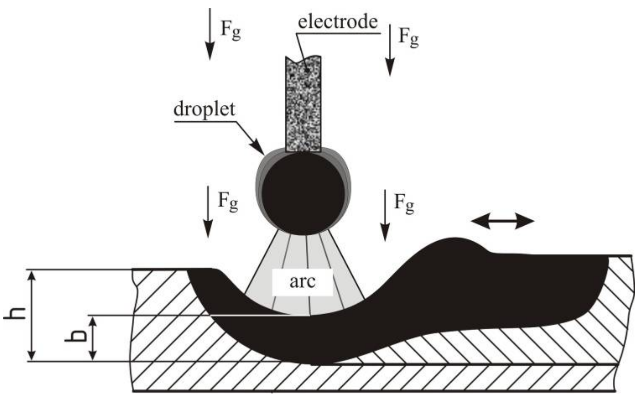


Fig. 4. The diagram of the jet action upon the weld pool under the double-jet gas shielding

In the second case, with increase of the shielding gas action upon the electrode metal droplet under the double-jet gas shielding the stability and frequency of droplet transfer into the weld pool grow and the size of the droplets reduces. Increase of the frequency of droplet transfer leads to reduction of time between short circuits, i.e. the workpiece heating time reduces and so does the penetration depth. The reproducibility and predictability of the chemical composition and properties of the weld increase.

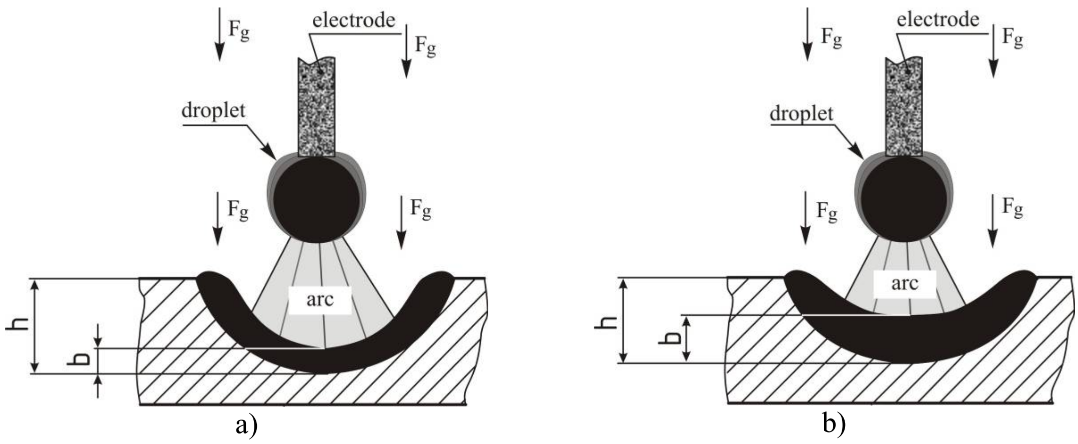


Fig. 5. The diagram of the changes of penetration depth and size of the liquid layer under the arc in the weld pool: a) single-jet gas shielding, b) double-jet gas shielding

In Table 1 we present the mechanic properties of 30HGSA steel samples welded with the welding methods under study. It is obvious that the welding method with application of double-jet gas shielding ensures more stable, better mechanic properties. The metal of the weld becomes stronger with some reduction of plasticity which is an indirect indicator of more intense stirring of metal in the weld pool [7, 15].

Table 1. The results of mechanic tests of the welded samples produced from 30HGSA steel

Welding method	Ultimate tensile strength, MPa	Flow limit, MPa	Impact hardness, J/cm2 under +20 °C, notched		Hardness	
			Along the weld center	Along HAZ	Weld, HRB	HAZ, HRC
Single-jet	540…640	435…535	138…150	121…163	86…90	22…23
Double-jet	750…790	590…610	88…126	106…176	93…98	24…26

Chemical analysis of the weld metal was completed on the welded samples (Table 2)

Table 2. Chemical analysis of the basic metal, welding wire and weld metal of the welded samples

Material	Mass fraction of the elements, %				
	C	Mn	Si	Cr	Ni
Basic metal 30HGSA	0.28…0.34	0.8…1.1	0.9…1.2	0.8…1.1	–
Welding wire Sv-08G2S	0.05…0.11	1.8…2.1	0.7…0.95	≤ 0.2	≤ 0.25
Single-jet	0.18	1.29	0.78	0.52	0.12
Double-jet	0.18	1.2	0.75	0.57	0.12

When welding with application of double-jet gas shielding the content of chromium increases by 0.05%. This indicates that when welding with double-jet gas shielding the stirring of the basic and electrode metal in the weld pool is more intense. The amount of manganese is reduced by 0.09% and that of silicon – by 0.03%. The explanation for this fact is that more intense gas-dynamic action on the droplet of molten electrode metal when welding with application of double-jet gas shielding results in increased frequency of droplet transfer, reduction of their size and growth of their surface activity [7, 15]. When changing the gas-dynamic action we can control the electrode metal droplets transfer, the chemical composition of the weld metal, thermal and other processes of consumable electrode welding and, this way, form the required properties of the weld joints.

Conclusion.

We have established that when completing consumable electrode welding in CO_2 the rate of the gas flowing from the welding nozzle has a significant impact upon the processes in the weld zone and upon the characteristics of the weld joint. The method of consumable electrode welding with application of double-jet gas shielding ensures regulated gas dynamics in the weld area and allows controlling electrode metal transfer, chemical composition of the weld joint metal, stabilizing the welding process, ensures stable high mechanic properties of the weld joints.

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