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INFLUENCE OF THE IMPURITIES ON THE DEPTH OF PENETRATION WITH CARBON STEEL WELDINGS

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In this paper the results of the research about the influence of the impurities on the depth of penetration with carbon steels weldings of different chemical composition are presented. These data suggest that presence of those impurities, such as sulphure and oxygen, in the steel, increases the depth of penetration to 1,3 - 1,5 times compared to welding reĀned steels. Applying activating fluxes for welding high tensile steels, provides an increase in the depth of penetration of 2 - 3 times.

Key words: carbon steels, welding, activating flux, depth of penetration, impurities

INTRODUCTION

Laser and hybrid welding (laser arc) show that, having a goal, of simultaneously increasing productivity and quality of welded joints, one of main directions of development of welding is concentration of energy. This problem is present within the conventional methods of electric arc welding, which limitates its application in various areas of manufacture (production).

One of the directions of solving this problem is the application of special activating fluxes with welding in gas shielding. Until now, activating fluxes are developed and study of their technological performance are conducted in USA, Japan, China, India etc.. Researches in this direction are continued also in the EO Paton Institute of Electric Welding (Ukraine), which is representing the leader when it comes to this process of welding.

Basicly, this process is performed using thungsten electrodes in the shielding of argon gas. This process is worlwide known as ATIG. Nowdays, positive experiments already exists, in the application of activating fluxes when welding with soluble electrode is performed (AMIG) [1, 2].

Works on manufacture of activating fluxes were concieved in the period of wide application in the production of high tensile steels, which have been refined with the arc solubility under slag. Increased purity of these steels by the content of gasses and impurities, has contributed to the sharp reducton in the depth of penetration with their welding with thungsten electrode (TIG). Attempts to overcome those problems by increasing the welding current had negative effects on indicators of their weldabillity , and did not give the expected results.

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Overcoming these problems is possible with use of activating fluxes, which when introduced in the zone of electric arc provided increase of the depth of penetration. Such an effect of activating fluxes is explained by the contraction of electric arc, which contributes to the increase in current density within it. This contributes to an increased concentration of heat and gas dynamic pressure of electric arc weld fluid bath, which is why the depth of penetration is increased 2 - 3 times comparing with conventional methods, without increasing the welding current [1, 3-7]. Accordingly, energy is decreased, which is calculated by N.N. Rikalin [8]:

$$q/v_w = \frac{I \cdot U \cdot \eta}{v_w} \quad (1)$$

where: q - heat power of electric arc; v_w - welding speed; I - welding current; U - voltage of electric arc; η - efficency coefficient of electric arc.

Energy of welding determines amount of heat which is introduced in the welded joint in the process of its realization. In comparation, with conventional processes of welding, using the activating fluxes enables:

- 2 - 3 times of decreasing the amount of driven energy necessary for welding metal sheets of same thickness;
- increase of thickness of welded metal 2 - 3 times with same welding current.

All this shows that increasing the productivity of welding, and also, application of activating fluxes has positive effects, on heat characteristics of welded joints. Temperature of metal is determined form the expression:

$$T = \frac{Q}{c \cdot m} = \frac{Q}{c \cdot V \cdot \gamma} \quad (2)$$

where: Q - amount of heat, introduced to the metal; c - specific heat of metal; V - volume of metal in which the heat Q is introduced; γ - density of metal.

Volume of heated metal is determined as product of length, width, and height.

In this way, with Q = const., and increasing the volume of heated metal, its temperature is reduced, or with fixed temperature, volume of heated metal, stabilizes. If one of the parameters of the volume is increased, for example height, which is equivalent to the depth of penetration, other parameters will be reduced, in order to maintain a constant volume of heated metal. When welding it reflects the reduction in width of heat affected zone (HAZ), which, as known, is a possitive effect.

Analog legality, also appears in case of applying activating fluxes on metal inert gas welding (AMIG) [2].

THE RESEARCH RESULTS

Application of activating fl uxes has a possitive impact not only on the technological properties of arc welding (increase of productivity and reduce of ener gy used), but also mechanical properties of welded joints.

Figure 1 shows the results from impact toughness testing (Charpy testing) of welded carbon steel joints done with AMIG technology. These results confirm, increase of consistency of metal weld on apperance of cold crack, with the application of activating fl uxes. Value of impact toughness base metal (BM) (Figure 1- curvature 1), is decreased by 2 times (of - 50 °C) when temperature values are in the range below zero. In the same time, impact toughness of metal in HAZ (Figure 1- curvature 2), of - 20 °C is practicly not decreased, and of - 50 °C, 1,5 times surpasses BM.

The most stabile indicator of impact toughness is weld metal (WM) (Figure 1- curvature 3), which when tested in temperature interval of 0 °C to - 50 °C is practicly not reduced.

Activating fl uxes at ATIG and AMIG welding increase also enviromental indicators of these processes [9].

Multiannual experiments of the application of activating fl uxes when dif ferent kinds of steel are welded confirms that the degree of its influence on the depth of penetration does not depend only on the chemical composition, but also on pureness of steel. Because of that, this paper's task is to determine character of the infl uence of chemical pureness of the steel on the effectivity of the application of the activating fluxes.

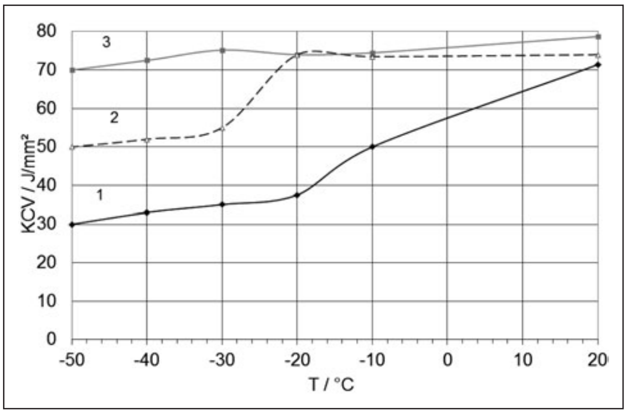


Figure 1 Influence of the testing temperature on impact toughness of welded joint, done by MIG welding with activating fluxes: 1 - BM; 2 - HAZ metal; 3 - WM

It is well known that the use of activating fl uxes for welding steel of high purity with current to 250 A, depending on the chemical composition of the activating flux, is provided to increase the penetration of 2 - 3 times in comparison with conventional TIG process.

However, in the case of application of an activating flux for welding of mild steel in the same range of welding current, increase of the depth of penetration is 1,4 - 1,8 times, and as a rule, does not exceed 2 times.

Table 1 shows the experimental results, which confirm that the application ATIG for welding carbon steels provide increased penetration of 2,1 - 2,6 times. Comparing the absolute value of the depth of penetration ATIG structural welding of carbon steel and refined carbon steel, shows that they are approximately the same. The difference does not exceed a few millimetres decile. The essential dif ference appears only in a relative increase in the penetration depth, depending on the degree of purity of welded steel.

Based on the difference between the steels (Table 1), it can be concluded about their pureness. Carbon structural steels, of ordinary steel solubility, contains slightly more contaminants than the steel of high purity. For this reason, it was necessary to determine how and to what extent these additives influence the depth of penetration of welding without activating flux. To exclude the influence of external contaminants, experiments were carried out on the steels of dif ferent chemical purity using TIG welding without additional welding material.

Table 1 **Influence of activation arc on the depth of penetration of welding with insoluble electrode refined and carbon structural steel**

Degree of steel purity	Welding process	Penetration depth / mm		
		I_w / A		
		150	200	250
Carbon structural steel of regular solubility	TIG	2,5	2,9	4,2
	ATIG	4,7	5,6	6,2
High purity steel (after arc solubility with slag)	TIG	1,9	2,3	3,9
	ATIG	4,9	6,0	6,2

Results (Table 2) is confi rmed that, throughout the following ranges of welding current characteristic for steel, minimum depth of penetration in TIG welding of steel of high purity, which are subjected to refi ning arc melting of the slag. Compared to high purity steel, welding under same circumstances structural high purity alloy steel, high quality carbon steel, and structural steel of standard quality, the depth of penetration is increased 1,3 - 1,5 times. The difference between these steels is only in the quantity of impurities. In steels with higher purity content of impurities is minimal.

Experiment applying TIG steel welding of different purity shows that basic impurities that signifi cantly influence the depth of penetration, are sulfur and oxygen.

Table 2 **Influence of steel pureness on the depth of penetration of arc welding with insolubale electrode in shielding with argon gas (TIG)**

Steel class	Si / %	S / %	Penetration depth / mm I_w / A 150	200	250
High purity steel (reﬁned with arc welding with slag)	1,4	0,005	1,9	2,2	2,8
Structural alloy steel of high purity	0,37	0,025	2,5	2,8	4,3
High quality carbon structural steel	0,37	0,040	2,5	2,9	4,4
Structural steel of regular quality	0,30	0,050	2,5	3,0	4,5

Comparing the data given in Table 2, we conclude that the steel of high purity, with whom it had the welding penetration depth minimum, contain a minimum amount of sulfur (0,005 %). Silicon content in steel is a maximum of 1,4 %. Therefore, the steel desoxidation level is very high, and the content of oxygen (O_2) is minimal.

During the transition to high-alloyed steels purity, depth of penetration increases. That is conditioned by increasing the sulfur content (up to 0,025 %) and a reduction of desoxidation steel level (Table 2). Silicon content in steel is reduced to 0,37 %.

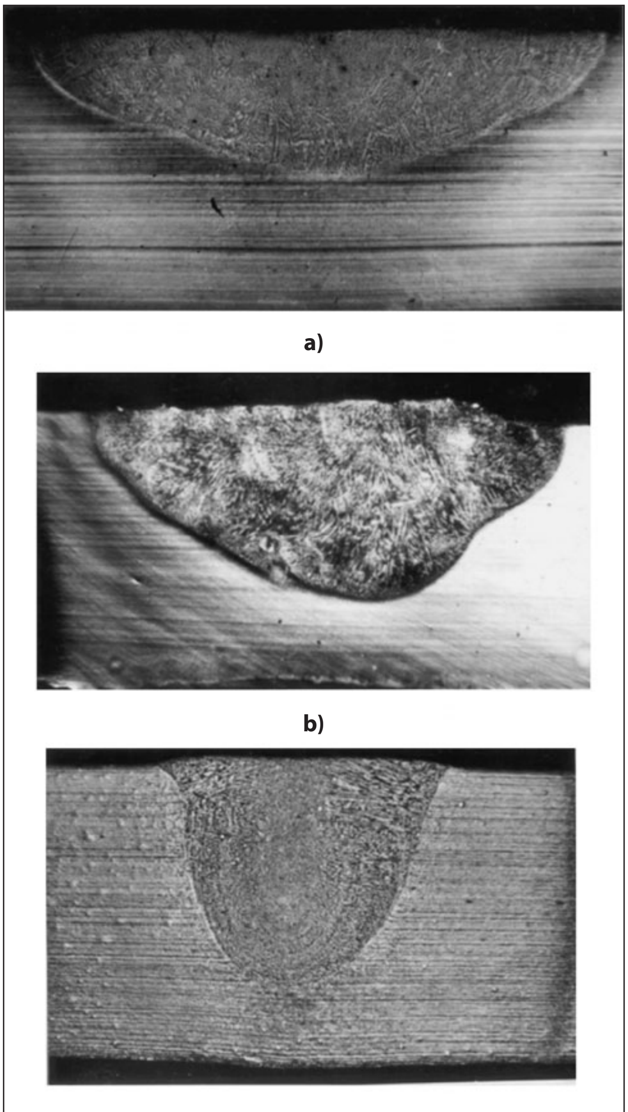
Further increase in the sulfur content in steel to 0,04 % (0,05 %), and also reduce of the desoxidation level of structural steel of ordinary solubility and general purposes at the expense of silicon content decrease to 0,3 %, a major impact on the penetration depth is not observed.

When welding with solubale electrode in a shielded atmosphere, the degree of purity of the steel by sulfur content practically does not affect the depth of penetration. The explanation for this, is either alloyed welding wire containing up to 0,025 % sulfur, and low carbon welding wire by 0,03 %. So, regardless of the degree of chemical purity of the BM, wire welding zone arc deposited sufficient amount of sulfur, which contributes to the contraction of the arc.

Assessment of the individual influences of sulfur and oxygen on the depth of penetration of high purity steel, is enabled by microgrinders of WM (Figure 2). The minimum depth of penetration and the maximum width of metal weld is obtained after cleaning the surface (Figure 2a). Metal weld achieved by a layer of sulfur (Figure 2b), is characterized by smaller width and greater depth. Maximum depth of penetration and the minimum width has metal weld obtained on oxide layer (Figure 2c).

Also, the degree of influence of sulfur and oxygen penetration depth confirms the test results shown in Figure 3. Experimental results show that the depth of penetration due to increased content of sulfur or oxygen in the steel increases.

Given the fact that in the structural steel are always simultaneously present sulfur and oxygen, we can only determine their combined effect on the geometry and welded depth of penetration. Also, it should be considered that the oxygen in the material is unevenly distributed, which contributes to the uneven penetration on length of weld (Figure 4).



a)

b)

c)

Figure 2 Macrogrinder of metal weld, achieved by TIG process with arc welded reﬁned steel with slag: a) cleaned surface; b) sulfure layer; c) oxyde layer

CONCLUSIONS

According to experimental results, the oxygen is approximately 1,5 times greater degree of influence then of sulfur.

Insoluble electrode welding (TIG and ATIG), the weldability of the material is mostly influenced by its purity. When ATIG welding it is manifested through the relationship of the relative increase in the depth of penetration of welding steel of high purity and ordinary structural steel. In steel with a high degree of purity relative increase in the depth of penetration is up to 3 times, and in ordinary structural steels increase the

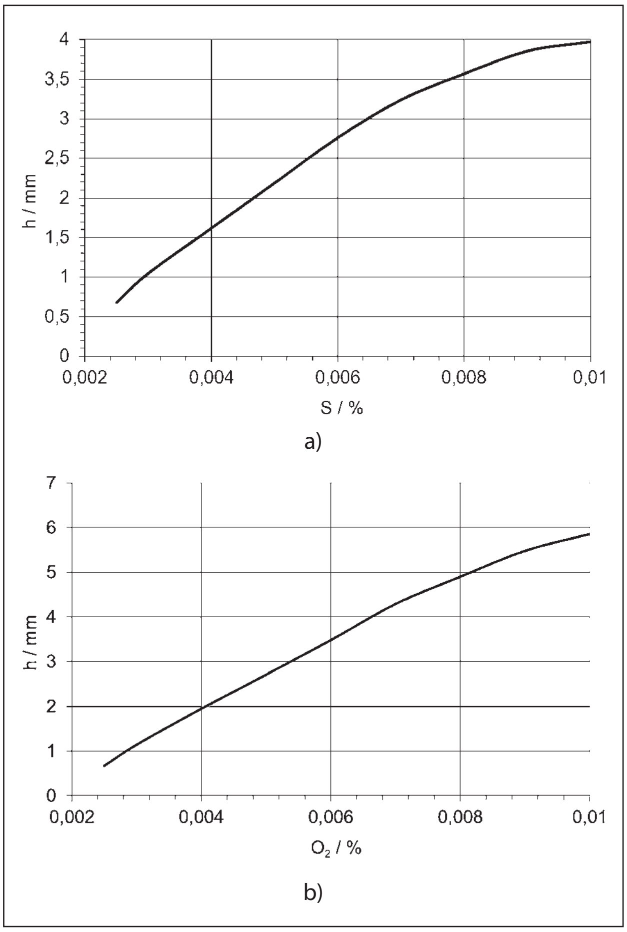


Figure 3 The dependence of the depth of penetration of the content in steel: a) of sulphure for constant content of 0,0038 % oxygen; b) of oxygen for constant content of 0,004 % sulphure

maximum of 2 times, although the absolute real depth of penetration in the approximately equal.

When MIG and AMIG welding, influence of the purity of the welded steel is of no essential role, because additional welding material contains impurities in sufficient quantities to significantly affect the depth of penetration of his.

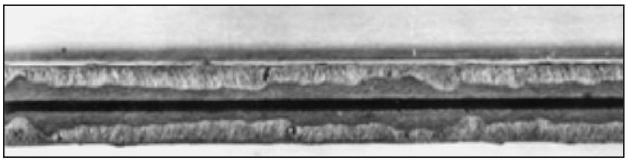


Figure 4 The influence of uneven distribution of oxygen in the material on the penetration by the length of weld

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Note: The responsible translator of the English language is S. Ćulafić - University of Montenegro, Faculty of Mechanical Engineering, Montenegro