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APPLICATION OF GAS MIXTURES FOR GAS SHEILDED ARC WELDING

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ABSTRACT
Application of gas mixtures for gas shielded arc welding has many advantages comparing to the pure gases, like more efficient filler metal transfer, more stable arc, higher penetration, lower spattering and welding speed increase. In this paper the influence of gas mixture on weld metal toughness has been shown in the case of high strength low alloyed steels. Five different gas mixtures have been used, base on Argon with varying content of Oxygen and Carbodioxide. The optimum content of gas mixture, producing the highest level of acicular ferrite and highest toughness at the same time, has been established.
Keywords: *gas mixture, toughness, oxygen equivalent, acicular ferrite*

1. INTRODUCTION
Gaseous mixtures are physical mixtures of various gasses. For a gas mixture production high purity starting gasses are used. Theoretically, these mixtures can be produced in any rate unless mixing is limited by physical or chemical component properties, as also by valid safety specification. Mixtures can be delivered either prepared in advance or directly obtained by an adequate device for gas mixing.
Gas shielded arc welding in shielding atmosphere of argon usually does not provide stable arc that results with defects forming such as undercut, porosity and insufficient penetration and their effects on decreasing of strength and ductility. For welding of carbon and low alloy steels is used pure CO_2 where is possible spattering of filler metal even up to 5%. The addition of O_2 and/or CO_2 to Argon increases arc stability, decreases arc vibrating and prevents undercut [1]. The addition of Oxygen to Argon decreases the surface tension of liquid metal, and as a consequence the required current intensity to convert a short-circuit arc metal transfer mode to a spray arc mode decreases, the liquidity of metal pool increases and spattering decreases [2,3]. In welding in protective gas mixture atmosphere ,as a rule, comes to droplet refinement [3,4]. Welding in protective gas mixtures Ar + CO_2 or Ar + CO_2 + O_2 provides better weld forming and less spattering then those obtained by welding in pure CO_2, and comparing with welding in protective atmosphere of pure argon provides better penetration.
The content of oxygen in a metal weld increases due to oxygen and/or carbon dioxide content increase in protective gas mixture (Figure 1), and essentially effects the structural changes in the metal weld, and will be discussed latter. To obtain the same content of oxygen in the metal weld it is necessary to add more CO_2 than O_2 to protective gas, and that can be observed following horizontal and vertical broken lines in Figure 1. [1].

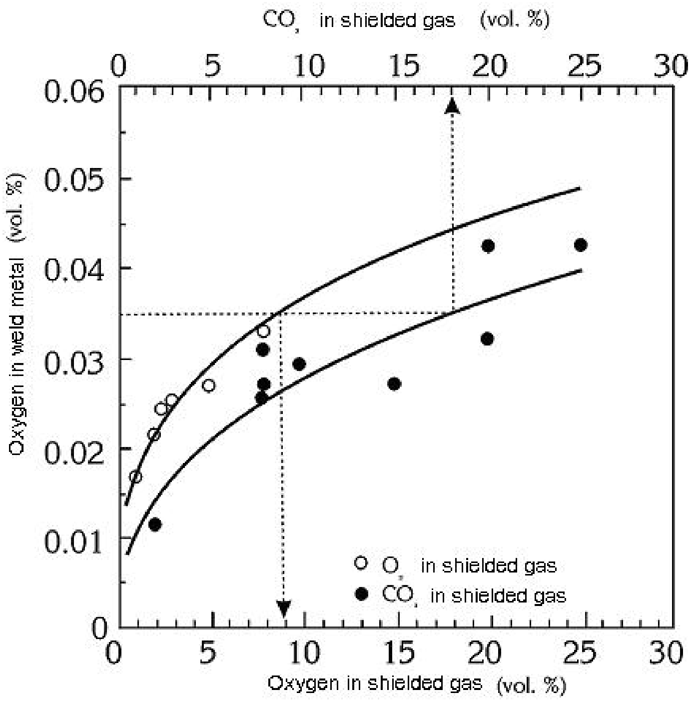

Figure 1. Oxygen content in a metal weld (low-alloy steel) as a function of oxygen and carbon dioxide content in protective gas [1].

Data about rate of oxygen and carbon dioxide content in the protective gas and oxygen content in a metal weld can be found in the literature [1, 5, 6, 7] and based on those results are made calibration curves which connect the oxygen and carbon dioxide content in protective gas and the oxygen content in metal weld (low-alloy steels). Accordingly, equivalent oxygen content in Ar-CO_2 mixture points at its adequate influence in mixture. Using the equivalent of protective gas oxygen enables direct comparing of results obtained by various mixtures. Technical term for the oxygen equivalent, can be determined by regressive analyze using a real oxygen content in the metal weld and protective gas content, is as following [1]:

$$\text{Oxygen Equivalent}_{\text{of protective gas}} = -0{,}088 + 0{,}148 \cdot [CO_2]^{1{,}542}_{\text{of protective gas}} + [O_2]_{\text{of protective gas}} \quad (1)$$

where $[CO_2]$ and $[O_2]$ are volume percents of respective gasses in mixture.
Carbon content in the metal weld changes very slow with the increase of the oxygen equivalent, because the other elements easier react with Oxygen and prevent more intensive Carbon reaction.

2. EXPERIMENT AND DISCUSSION

The oxygen influence on the metal weld microstructure was analyzed from several authors [1,8]. In welding with consumable electrode in a protective inert gas atmosphere, the addition of oxygen and/or carbon dioxide to protective gas significantly increases possibility of oxygen absorption in the metal weld. However, only a part of oxygen from arc atmosphere would form oxides with alloying elements in a metal pool, because the most of oxygen would go in an environment. Oxides would emerge on the top of the metal pool and transform in a dross or would get captured as inclusions in the metal weld. As possible place for forming an acicular ferrite or other austenite dissolution products, these inclusions are important for the determination of metal weld final structure.

Steel, low alloyed by Ti, Nb and V is welded in the protective atmosphere of five different gas mixtures. The chemical compositions of these mixtures, the oxygen equivalent in protective gas mixture are presented in Table 1. In this table is, also, shown the influence of gas mixture content on arc stability, weld appearance and spattering. As filler metal is used electrode wire VAC 60Ni, 1,2 mm. Heat input during welding was 7 kJ/cm.

Table 1. Chemical composition of the gas mixture and their oxygen equivalent

Ordinal number of mixture	Component content in mixture (vol %)			Oxygen equivalent in protective gas mixture	Characteristics of gas mixture behavior during welding /13/:
	CO_2	O_2	Ar		
1	5,24	-	Balance	1,76	Arc relatively stable (vibrating very little). Weld appearance relatively smooth. Spattering minimal.
2	5,00	0,91		2,54	Arc stability is better than in the previous case. Weld appearance is smooth; the filler material spilling is good. No spattering.
3	4,70	2,30		3,78	Arc is stable (the most stable with this mixture). Weld appearance is smooth; the filler material spilling is good. No spattering.
4	10,30	-		5,09	Arc vibrating very little. Weld appearance is relatively smooth; a little spattering.
5	14,80	-		8,90	The arc is less stable than in the previous cases. The weld is relatively smooth and spattering is higher.

Gasses were delivered from Messer-Tehnogasa as already prepared mixtures in 10l bottle size (except mixture No. 2, which was delivered in 40l bottle size), and under pressure of 150 bar.

In Table 1. is noticeable that the mixtures are argon-base prepared, with addition of definite active gasses volumes. The carbon dioxide is present in all mixtures in various volumes, and in the mixtures 2 and 3 is added oxygen too. The most arc stability was in welding with mixture No 3, where spilling of filler material was the best. Also, the weld appearance was the best for welding in protective atmosphere of gas mixture No 3, and spattering almost did not exist.

Besides of noticed influence of protective gasses on the arc stability and weld appearance, it is important to emphasize that the type of protective gas effects a metal weld toughness as well. The influence of the equivalent oxygen content on the weld metal toughness at +20°C, - 40°C and -55°C was analyzed, as it is presented in Figure 2. [9]

As Figure 2. shows, the weld metal toughness changes as a function of oxygen equivalent content in the shielded gas. With the oxygen equivalent increase, toughness, firstly, increases but latter decreases, that is directly connected to the metal weld microstructure [13]. The oxygen equivalent increase effects on the content increase of acicular ferrite in weld metal until the certain limit, and after that limit effects on the content decrease. Acicular ferrite morphology has better toughness then all other ferrite morphology, including bainite, due to the small grain size and the high angle grain boundaries. Figure 3. shows microstructures of acicular ferrite (AF) and proeutectic ferrite (PF), from which can be clearly noticed the grain size difference of these two morphologies.

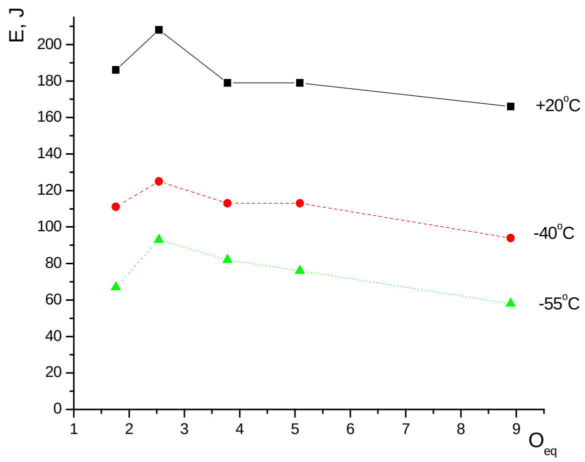

Figure 2. Metal weld toughness of a low alloy steel as a function of oxygen equivalent at different temperatures

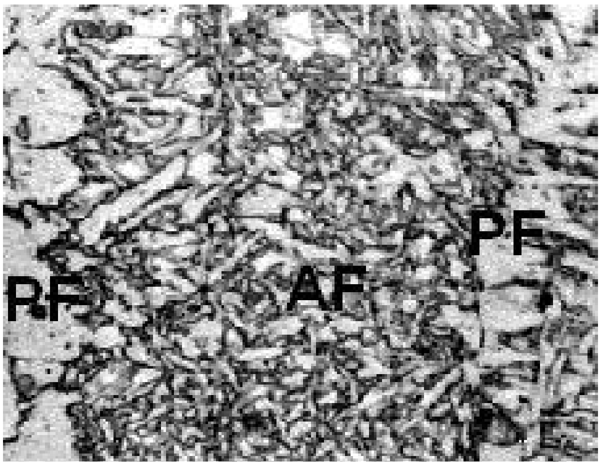

Figure 3. Microstructures of acicular ferrite (AF) and proeutectic ferrite (PF)

During welding in protective atmosphere of mixture 2, the highest presence of acicular ferrite is observed. The best metal weld toughness at all temperatures has weld joint carried out in protective atmosphere of mixture 2, which oxygen equivalent is 2,54.

3. CONCLUSIONS

Considering performed tests the following is concluded:

1. The oxygen equivalent content in protective gas is very important parameter which adequately describes gas mixtures behavior and offers possibility for comparing their influence on metal weld properties of the weld joints.
2. The increase of oxygen equivalent content in protective gas influences the toughness increase until the certain limit, and after that limit influences toughness decrease.
3. The addition of oxygen to Ar + CO_2 mixture effects on arc stability increase and the filler metal spattering decrease.
4. Gaseous mixtures should be used prepared in advance by gas producers or, if it is possible, to use a very precision device for mixing certain components from special bottles. Since it was shown that different gas mixtures with similar oxygen equivalent content have a pretty influence on weld metal toughness, it is necessary that gas mixture composition be strongly controlled.

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