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THE EFFECT OF THE SHIELDING ATMOSPHERE ON POROSITY IN WELD METAL OF AlMg4,5Mn ALLOY

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ABSTRACT
Application of inert gas mixtures for TIG welding of aluminium and its alloys has many advantages comparing to the pure Argon, like higher penetration, welding speed increase and lower porosity. In this paper, the influence of adding N_2 and He to Ar has been shown in the case of AlMg4,5Mn welding. It has been established that increase of He content influence on porosity decreasing in AlMg4,5Mn weld metal. The optimum content of Ar and He, producing the lowest porosity, has been also established.
Keywords: AlMg4,5Mn, porosity, shielding atmosphere, TIG welding

1. INTRODUCTION
Shielding gases, as a result of their physical properties and compositions affect weld quality, weld penetration and cross-section geometry, wetting and degasifcation of molten weld metal. The type and composition of the shielding gas was also found to affect metal transfer modes, arc formation and stabilization, metal weld chemical composition and viscosity of molten weld metal. Final choice of shielding gas include analysis of economical, technology and metallurgical aspects
Pure inert gases like argon (Ar), helium (He) and mixtures Ar+He are used for welding of aluminum cooper, nickel and their alloys.
Argon provide adequate shielding because of their relatively high density in comparison to air (1.37:1.0 at t = 15°C and p = 1bar). Because of their high density argon blankets the weld from contamination better than helium, assure greater cleaning action and low turbulence and also provide pronounced cathode cleaning effect. As an addition argon promotes electric arc formation which tends to be more stable than with helium, as a shielding gas. Usually, nitrogen is added to argon in small quantity (up to 0,2%), in the case of tungsten inert gas (TIG) or metal inert gas (MIG) welding of aluminum, which provide higher heat input.
Helium, like argon, is an inert gas but there are few similarities between the two gases. Argon is heavier than air and helium is lighter than air (density ratio: 0.14:1.0 at t = 15°C and p = 1bar). Because helium is lighter than air, their consumptation during welding is substantialy higher for the

same shielding effect. Also, helium has higher ionization potential than argon and hence provides higher arc voltage for the same welding current. Because of its high cost, helium is primarily used for special welding tasks and for welding nonferrous metals, usually in combination with other gases because of problems with stability of metal transfer. Usually very high purity helium is use for welding. Different metal transfer modes could be established with helium shielding atmosphere: globular, spray and pulsed-spray using reverse-polarity welding mode. Mixtures of Ar and He have higher density than pure He and hence provided better shielding. Because of He in mixtures, arc voltage and weld speed tend to be higher and weld bead broader with deeper penetration. Usually mixtures of Ar with addition of 25%-75% He were used. Mixture of 50%Ar+50%He provide generally the same effects as a pure He with reduced weld spattering [1,2,3,4].
Aluminum is the one of the most difficult alloy to weld. Potential problems with aluminum welding are connecting with: presence of porosity, inclusions and oxide layer Al_2O_3; predisposition for hot and cold cracking; as weel as HAZ softening and decrease of material corrosion resistance [5].
Porosity is one of the major problem. Pores originate as a result of gases apsorbtion, diffusion and dissolution on the surface and within the weld metal. Porosity is ussualy a result of hydrogen gas becoming entrapped within solidifying aluminum during welding and leaving voids in the completed weld. Hydrogen is highly soluble in molten and for this reason, the potential for excessive amounts of porosity during arc welding of aluminum is considerably high. Hydrogen can be unintentionally introduced during the welding operation through contaminants within the welding area such as hydrocarbons and/or moisture.
Moisture provoked porosity of Al alloys was connected with rapid generation of porous oxide layer Al_2O_3 which was prone to moisture absorption. Al-Mg alloys are highly prone to metal weld porosity, particularly with increase of Mg content in alloy. The reasons for high porosity of this type of alloy is the presence of β-phase (Al_3Mg_2), with 36,5% of Mg, as a result of rapid cooling. These phase starts melting at estimate 448^{0}C. In the temperature range 550-650^{0}C water dissociate, when hydrogen react with Mg and provoked porosity. During vapor dissolution at 550^{0}C β-phase is also in liquid state and their intensive oxidation is taking place followed with hydrogen dissolution and porosity. When designing AlMg alloys welding procedures, intended to produce low levels of porosity, it is important to incorporate degreasing and oxide removal.
During welding of thick Al plates preheating is essential, while preheating temperature is in the 100-400^{0}C range (depend of alloy type). Preheating retard welds metal crystallization and promotes removing of gases (primarily hydrogen) and hence has effect on porosity reduction. AlMg alloys welding procedures require preheating in the 100-150^{0}C range. However, mechanical properties of weld metal made with preheating application is very low [1,5].

2. EFFECT OF SHIELDING ATMOSPHERE COMPOSITION ON POROSITY

In the aim of clarification of effects of shielding atmosphere during TIG welding on metal weld porosity wrought aluminum alloys - AlMg4,5Mn (5xxx series) was used. The major alloying element is magnesium and when it is used as a major alloying element, the result is a moderate-to-high-strength work-hardenable alloy. Al-Mg alloys usually contain 1-5% of Mg, with addition of Mn (0.1-1%) and Cr (0.1-0.25%) for the strength increase. Manganese has low solubility in aluminum and does not formed low temperature eutecticum and therefore reduced alloy predisposition for hot weld cracking.
Experimental investigations on effects of different shielding atmosphere were performed using 12mm thick base plates made of AlMg4,5Mn aluminium alloy and filler rod (Ø5mm, lenght 1000mm) made of the same alloy (classification DIN1732/SG- AlMg4,5Mn or BS2901/5183 or AWS A5.10/ER 5183). Chemical compositions of base material and filler material were presented in Table 1.
Tensile strength of AlMg4,5Mn aluminium alloy base plates was 293-305 Mpa, yield strength 131-145 MPa and elongation 23-28%.
Chemical compositions of different shielding gases, which were used, are presented in Table 2. Gases were delivered in 10 l bottles under pressure of 150 bars.

Table 1. Chemical compositions of aluminium alloy AlMg4,5Mn base plate and filler material.

Element	wt %							
	Si	Fe	Cu	Mn	Mg	Zn	Cr	Ti
Base material	0,13	0,21	0,04	0,66	3,95	0,03	0,06	0,025
Filler material	< 0,40	< 0,40	< 0,10	0,5-1,0	4,3-5,2	<0,25	0,05-0,25	0,15

Table 2. Chemical composition of shielding gases.

Shielding gas	Welded plate mark	Component content, vol.%		
		Ar	He	N_2
1	4	99,99999	-	-
2	2	balance	-	0,015
3	1	balance	15	0,015
5	5	balance	50	0,015

Plate samples (dimension 500x250x12mm), made of AlMg4,5Mn aluminium alloy, were prepared by cuting, while single-V butt groves were prepared by milling. Rot gaps were 5 mm. Plate samples were butt-welded by TIG process in the shielding atmosphere of metioned gas and gas mixtures in forehand horizontal-vertical welding position. During welding backing strips were used. Backing strips were made of aluminium with additional groves in the middle in which stainless steel strips were inserted. The purpose of backing strip is to retain molten metal at the root of the weld and to increase the thermal capacity of the joint so as to prevent excessive warping of the base metal. Four passes (1 root pass + 3 filler pass), according to the conditions in Table 3, were carried out to produce butt joints.

Table 3. TIG welding conditions

Ambient temperature	20ºC
Preheating temperature	>110 ºC
Interpass temperature*	>110 ºC
Shielding gas flow rate	17-19 l/min
Calculated heat input	17-26 kJ/cm

* - controlled by contact thermometer

It was also observed that with increase of He content in mixtures liquidity of metal pool and weld width also increase, while weld face reinforcement decrease.

3. MICROSTRUCTURAL INVESTIGATIONS

Specimens for microstructural investigations were cut from all welded plates, polished and prepared by etching in 10% H_3PO_4. Microstructural characterization of weld metal was carried out using light microscopy. Microstructure of weld metal of four welded plates were presented on Figure 1.

Weld metal microstructure for all welded plates are the same, as expected, because of the similar welding conditions. Only different shielding gas mixtures were used for welding of different plate samples, Table 2. Microstructure of the weld metal was dendrite, which growth direction correspond to the weld metal cooling gradient. Dendrite microstructure was a result of rapid solidification of liquid weld pool.

Partial transformation of primary dendrite was a consequence of heat input during subsequent passes. Also, different intermetalic phases were observed ((Fe, Mn, Cr)Al_6, (Fe, Mn, Cr)$SiAl_{12}$ and Mg_2Al_3).

Main difference in weld metal microstructures of investigated welded plates are in the degree of porosity. Porosity was predominately detected in the vicinity of two subsequent interpass and in the vicinity of fussion line between base metal and weld metal. The highest degree of porosity, particularly in the vicinity of two subsequent interpass, was observed in weld metal of plate number 4 (100%He). Detected porosity in weld metal of plate number 2 (Ar+0.015%N_2 mixture) was lower than in weld metal of previous plate. Further decrease in porosity was observed in weld metal of plate number 1 (Ar+15%He+0.015%N_2).

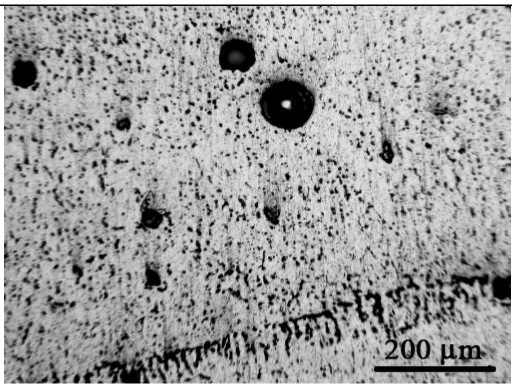
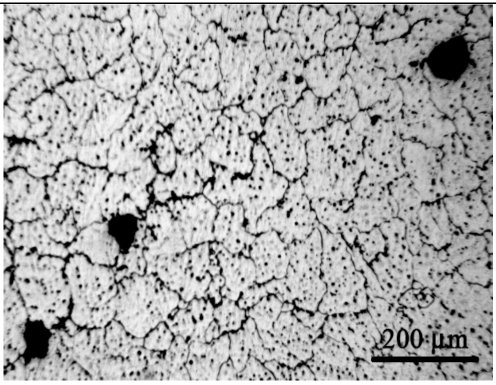
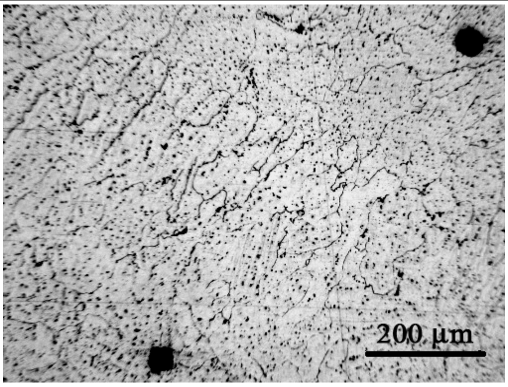
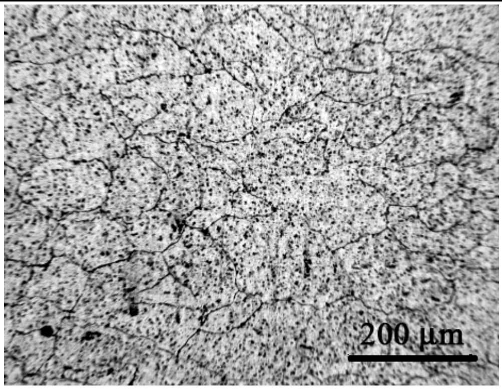
plate	Weld metal microstructure	plate	Weld metal microstructure
4	 Ar	2	 Ar+0.015%N_2
1	 Ar+15%He+0.015%N_2	5	 Ar+50%He+0.015%N_2

Figure 1. Microstructure of weld metal.

In particular, the Ar+50%He+0.015%N_2 mixture used for welding of plate number 5 led to the best weld pool, without any detected porosity.
On the basis of obtained results it may be concluded that application of shielding atmosphere Ar+50%He+0.015%N_2 during welding of AlMg4,5Mn aluminium alloy provide significant decrease of weld metal porosity.

4. CONCLUSIONS

1. During welding of 12mm thick plate made of AlMg4,5Mn aluminum alloy preheating above 100^0C is essential. Literature data for this Al alloy suggested that the preheating is recommended only when the plate thickness is above 14mm. Preheating retard welds metal crystallization and promotes removing of gases and hence has effect on porosity reduction.
2. Addition of only nitrogen to argon in gas mixture has negligible effect on the quality of weld metal. Experimental investigations indicated that using of pure argon or Ar+0.015%N_2 mixture does not provide satisfactory weld metal quality without porosity even with preheating application.
3. Additions of He to Ar-N_2 mixture provide decrease of weld metal porosity. With the increase of He content in mixture liquidity of metal pool and weld width increase, while weld face reinforcement decrease. On the basis of obtained results it may be concluded that application of shielding atmosphere Ar+50%He+0.015%N_2 during TIG welding of AlMg4,5Mn aluminum alloy provide significant decrease of weld metal porosity.

5. REFERENCES

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