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TENSILE PROPERTIES OF TWO Al-Mg WELDED PLATES AFTER APPLYING DIFFERENT WELDING CONDITIONS

Vencislav Grabulov
IMS Institute
Bul. V. Mišića 43, 11000 Belgrade, Serbia

Zijah Burzić
Military Technical Institute,
R. Resanovića 1, 11000 Belgrade, Serbia

Miljana Popović, Endre Romhanji
Department of Metallurgical Engineering, Faculty of Technology and Metallurgy
Karnegijeva 4, 11120 Belgrade, Serbia

ABSTRACT
Two Al-Mg alloys: (I) AA5182 type and (II) the same type additionally alloyed with a low amount of Zn and Zr (≈ 0.12%wt each) were processed to 6.5mm thick H116 and H321 marine grade plates. They were welded by applying Metal Inert Gas – 131, (MIG) and MIG-Pulsed welding process with AlMg4.5Mn and AlMg4.5MnZr filers. The given results indicate that the added amount Zn and Zr did not bring any improvement of mechanical properties. The after welding yield stress degradation was 45%-%50% independently on the welding conditions, and the fracture was always appeared in the weld metal.

1. INTRODUCTION

Aluminum and its alloys were assessed as a possible replacement for steel in shipbuilding [1] due to a high corrosion resistance and a potential of considerable weight saving, as its density is almost three times lower than the density of steel (2.73 g/cm^3 for aluminum vs. 7.85 g/cm^3 for steel). Proper vessel design, after introducing aluminum, can achieve a weight reduction of about 50% [2,3].
The most often used Al-alloys for plates in shipbuilding are the 5083/5383 type Al-Mg alloys [4]. The Aluminum Association received the specific H116 and H321 tempers as appropriate for marine application [5]. The H116 products are annealed and stretched, while the H321 is work hardened and thermally stabilized. In both conditions the same level of mechanical properties should be achieved, meeting the specified levels of corrosion resistance.
During welding a heat affected zone (HAZ) forms around the weld seam which in aluminum is much more pronounced than with steel alloys, and has a considerable influence on strength properties. The HAZ and the drop in properties vary in magnitude depending on the condition of the base material and the variables of welding process used [6]. Nowadays, many welding procedures are under investigation [7-9] in order to improve the mechanical properties of the welded structures. Impressive results achieved by applying the friction steer welding, laser or hybrid procedures [7]. However, in respect the cost effectiveness and technical applicability in the marine industry, the Mig-pulsed procedure seems to be the most reliable one today [9].
The aim of this work was to consider the degradation of basic tensile properties in two type welded plates after applying different welding procedures.

2 EXPERIMENTAL

Material. Two Al-Mg type hot rolled plates were delivered by IPOL-SEVAL Rolling Mill. The chemical compositions are listed in Table 2.1. The basic difference is related to the Zn and Zr alloying contents. Alloy I is rather typical 5182 type alloy with no added Zr and Zn. Alloy II is with added Zn

(0.118%) and Zr (0.121%). The alloy with Zn and Zr meets the composition range of 5383 type alloy. The as received hot rolled plates were at different thicknesses as follows: Alloy I (Lot 5893) -13,4 mm and Alloy II (Lot 63886) - 11,3 mm. Different TMT-s applied in order to achieve the H116/H321 conditions, and the processing route was defined for the final thickness of 6.5 mm. [10].

Welding. Two welding procedures were applied MIG and MIG – Pulsing process 131 according to EN4063, with AlMg4,5Mn and AlMg4,5MnZr type consumable materials.

Table 2.1. Chemical compositions of the hot rolled Al-Mg plates in wt.%

Alloy	Mg	Mn	Zn	Zr	Cu	Fe	Si	Ti	Na	Cr
Lot 5893 (**I**)	4.25	0.67	0.0138	0.0006	0.008	0.24	0.085	0.007	0.0003	0.089
Lot 63886 (**II**)	4.85	0.77	0.118	0.121	0.0067	0.29	0.106	0.009	0.0003	0.109

Figure 1. a. Sketch of the welding groove, b. Sketch of the weld and welding layers

Tensile testing. The base materials and the welded plates specimens with a gauge length of 100 mm are tested on “Schenck” tensile testing machine, at a crosshead rate of 10 mm/min. The yield strength and ultimate tensile strength of the base material (YS and UTS), as well as, for the butt-welded joints (YS* and UTS) were determined using by shaped specimens, as it is shown in Figure 2. The YS* yield stress is not a material property but it is an approximative value for comparative considerations of welded plates properties.

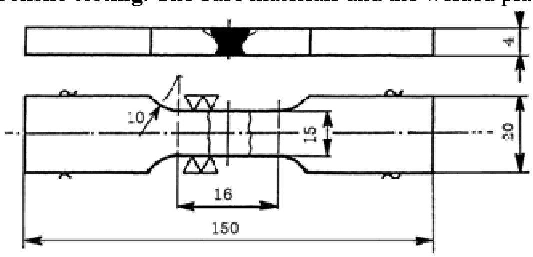

Figure 2. Tensile specimens used for YS and UTS measurement in butt-welded joint.

3. RESULTS AND DISSCUSSION

In Table 3.1 the mechanical properties of the two tested alloys after processing them to H116/H321 conditions are shown. The achieved mechanical properties in both conditions matching the properties of the 5083/5383 alloys in H116/H321 conditions (YS_{min}=215/220MPa, UTS_{min}=305 MPa and e_{min}= 10%, EN485-2:1999).

Table 3.1 *Tensile properties of the tested base materials in H116 and H321 condition [10]*

Al -alloys		YS	UTS	**El.**
AA Type	Temper	(MPa)	(MPa)	**(%)**
5182 (Lot 5893)	H116	240	307	13.5
	H321	240	330	15
5383 (Lot 63886)	H116/	250	340	15
	H321	240	350	14.5

Tables 3.2. and 3.3. show the tensile properties for the two tested alloys after welding, by applying different welding conditions. The given results indicate that the approximate yield strength (YS*), ultimate tensile strength (UTS) and the elongation (El.) parameters are ranged to 120-130 MPa, 230-300 MPa and 10-20%, respectively. Those values are comparable to the earlier published data for the welded 5083 plates: $YS^{*}_{min} = 125MPa$, UTS = 270MPa [11-13] for both conditions, but not for the 5383 type alloy, which attained the YS*~ 140 MPa and the UTS about 290 MPa. So, the chemistry change in respect the 5182 type alooy (Table 1.) made by adding 0.118 wt.% Zn and 0.121 wt.% Zr didn’t bring any important change in the tensile properties of alloy II plates, as well as in the welded plates. In the 5083 alloy the Zn content is limited to max.0.25 wt.%, in 5383 to 0.40 wt.% and

the Zr to 0.20 wt.%. Obviously, the range of added amounts of Zn and Zr in alloy II was not enough to improve the 5182 type alloy to meet the properties of the 5383 one, especially not in respect the after welding properties.
Tables 3.2 and 3.3 reveal that the failure in uniaxial tension was mostly positioned in the weld metal (WM) and in some cases passes also through the fusion line (FL). So, the WM appeared to be weaker than the heat affected zone (HAZ) in the base material**,** indicating that the heat input during welding was low enough to keep the HAZ harder than the WM. That problem of weaker WM in respect the surrounding material is known [14], but until now was not found a reliable way to improve the fracture resistance of the WM.

3.2. Tensile properties of the welded joint for the 5182 type plates (Lot 5893)

Alloy - Condition	Consumable material	Welding process	YS* (MPa)	UTS (MPa)	El.* (%)	Fracture position
5182-H321	AlMg4,5Mn	MIG - PULS	127.6	266.9	17.3	WM -FL
5182-H116	AlMg4,5Mn	MIG - PULS	120.3	277.1	21.0	WM -FL
5182-H116	AlMg4,5MnZr	MIG - PULS	124.3	273.4	18.9	WM
5182-H116	AlMg4,5Mn	MIG	133.0	256.2	12.0	WM-FL

3.3. Tensile properties of the welded joint for the 5383 type plates (Lot 63886)

Alloy Condition	**Consumable material**	**Welding process**	**YS* (MPa)**	**UTS (MPa)**	**El.* (%)**	**Fracture position**
5383-H321	AlMg4,5MnZr	MIG - PULS	125.0	251.7	11.7	FL-WM
5383-H321	AlMg4,5Mn	MIG - PULS	123.4	288.3	18.8	WM-FL
5383-H321	AlMg4,5MnZr	MIG	128.9	257.6	11.8	FL-WM
5383-H116	AlMg4,5Mn	MIG - PULS	128.3	299.5	20.2	WM
5383-H116	AlMg4,5MnZr	MIG - PULS	121.9	265.4	14.1	FL-WM
5383-H116	AlMg4,5MnZr	MIG	129.2	269.9	13.8	WM

In order to estimate the degradation of mechanical properties during welding, the mechanical properties of welded joints (YS*and UTS) were compared to the base material (Fig.3.1 and 3.3). In Figures 3.2 and 3.4 the percentage of YS and UTS degradation are shown for the applied welding

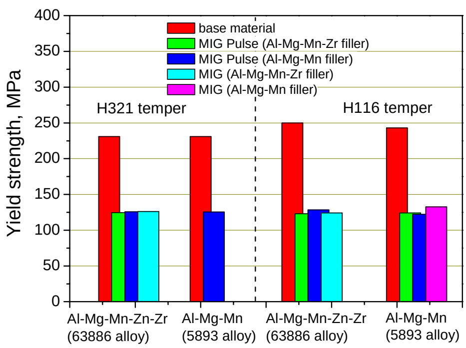

Figure 3.1 Yield stresses after welding both the H321 and H116 samples, and the base material.

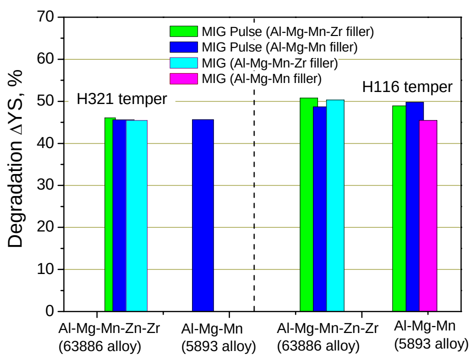

Fig.3.2 *Yield Stress degradation of the welded samples in respect the base material*

procedure. The YS degradation was ranged to 45% in the H321 condition and rather closer to 50% for the H116 temper (Figs.3.2) for all the applied welding conditions. The UTS degradation was rather changeable but generally considerably lower (Fig.3.4), as it never exceeds 30%. So, during the tension test the strain hardening appeared to be effective, even in the WM and enabled to achieve higher UTS values in the welded plates.

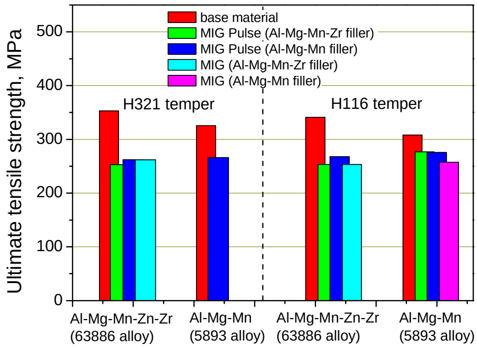

Figure 3.3 UTS values after welding both the H321 and H116 samples, and the base material.

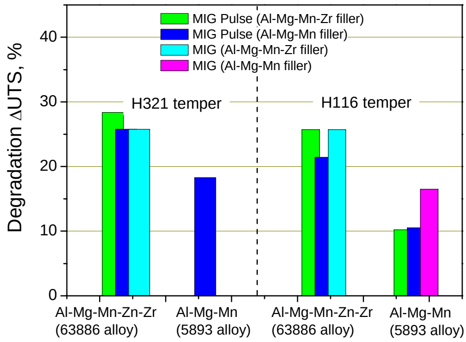

Fig.3.4 UTS *degradation of the welded samples in respect the base material*

4. SUMMARY

Two Al-Mg alloys: (I) AA5182 type and (II) the same type additionally alloyed with a low amount of Zn and Zr (≈ 0.12%wt each) were processed to 6.5mm thick H116 and H321 marine grade plates. They were welded by applying MIG and MIG-Pulsed procedure with AlMg4.5Mn and AlMg4.5MnZr filers. The results indicate that the added amount Zn and Zr did not bring any improvement of mechanical properties. The after welding yield stress degradation 45%-50% independently on the welding conditions, and the fracture was always appeared in the weld metal. Considerably lower degradation of the tensile strength was experienced (< 30% in all cases) was assumed to be the result of the strain hardening affected increase of both the HAZ and WM.

5. REFERENCES

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