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(54) Title: AL-MG-MN WELD FILLER ALLOY

(57) Abstract: The present invention relates to a filler wire alloy composition comprising, in wt.-%: Mg 6.0 to 9.5%, Mn 0.9 to 2.0%, Zn 0.2 to 0.9%, Zr ≤ 0.3%, preferably 0.05 to 0.25%, Cr ≤ 0.5%, Sc ≤ 2.8%, Cu ≤ 0.5%, preferably ≤ 0.25%, Fe ≤ 0.5%, Si ≤ 0.5%, Ti ≤ 0.3%, the balance aluminum and incidental elements and impurities. The invention further relates to a welded structure welded together with the present filler alloy and a method for constructing such a welded construction.

## AL-MG-MN WELD FILLER ALLOY

### FIELD OF THE INVENTION

The present invention relates to an Al-Mg-Mn weld filler alloy which is used for welding AlMg alloy members or structures which are used to construct large structures such as storage containers and vessels for marine and land transportation. Further, the invention relates to a welded structure which is produced by welding AlMg alloy members together with the Al-Mg-Mn weld filler alloy, thereby producing constructions such as transportation vessels, tanks, silos, tanker lorries, pressure vessels, bridges or trucks. Furthermore, the invention relates to a method for constructing such a welded structure or construction.

### BACKGROUND OF THE INVENTION

Al-Mg-Mn weld filler alloys are known for use in large welded constructions which consist preferably of plates or extrusion members selected from the group of aluminium alloys of the AA5xxx-series. One of the standard weld filler alloys is the AA5183 alloy having the nominal composition, in weight %: Mg 4.3 to 5.2, Mn 0.5 to 1.0, Zn 0.25 max., Cr 0.05 to 0.25, Ti 0.15 max., Fe 0.40 max., Si 0.40 max., Cu 0.10 max., the balance substantially aluminium and incidental elements and impurities. AA5183 weld filler wire provides a good balance of high strength, corrosion resistance, bendability and weldability. By increasing the amount of magnesium in the alloy the strength of the weld joint can be increased. However, an increase in magnesium is usually accompanied by a decrease in corrosion resistance in this type of AlMg alloys.

Other disclosures such as JP-A-05169290 or GB-A-2000806 disclose weld filler alloys containing up to 6.0 weight % Mg up to 6.0 weight % Zn and up to 2.5 weight % Mn. The latter is disclosed in connection with a copper content of 0.2 to 0.5 weight %.

The proposed filler alloys are applied in welding techniques having a solidifying speed of higher than  $1\text{-}3 \times 10^{20} \text{C/s}$  wherein Zr may be incorporated more than the quantity of the solid solution. The above mentioned British patent application thereby mentions copper as a compulsory element.

EP-1019217-B1 discloses an Al-Mg-Mn weld filler alloy comprising essentially the following composition (in weight %): Mg 5.0 to 6.5, Mn 0.4 to 1.2, Zn 0.4 to < 2.0, Zr 0.05 to 0.3, the balance essentially aluminium and incidental elements and impurities. The document discloses an improved strength compared with conventional AA5183 filler wire when welding a conventional AA5083 alloy plate under regular MIG welding conditions.

The known weld filler alloy provides improved welded constructions with considerable improved corrosion resistance in the base material, the heat effected zone and the weld seam.

The discussion of documents, acts, materials, devices, articles and the like is included in this specification solely for the purpose of providing a context for the present invention. It is not suggested or represented that any or all of these matters formed part of the prior art base or were common general knowledge in the field relevant to the present invention as it existed before the priority date of each claim of this application.

## 10 SUMMARY OF THE INVENTION

It is a preferred object of the present invention to provide an Al-Mg-Mn weld filler alloy, preferably in the form of a weld wire, with which improved strength of welded aluminium alloy joints can be achieved as compared to those of the standard filler alloys such as AA5183 filler alloy or the filler alloy as mentioned in EP-1019217-B1.

15 It is another preferred object of the present invention to provide an Al-Mg-Mn base weld filler alloy with improved ductility, bendability and a corrosion resistance which is at least as good as those of standard weld filler alloys such as AA5356 or AA5183.

It is another preferred object of the present invention to provide a welded structure with AlMg alloy members which are welded with an improved weld filler alloy and which have improved strength levels after welding and a good corrosion resistance in the weld seam.

It is yet another preferred object of the present invention to provide a method for constructing such a welded structure or welded construction.

According to the present invention one or more of these objects are solved by the weld filler alloy according to the invention and wherein there is provided an Al-Mg-Mn weld filler alloy having a good corrosion resistance and improved strength levels, having the following composition (in weight %):

	Mg	7.0 to 9.5
	Mn	0.9 to 2.0
30	Zn	0.2 to 0.9
	Zr	≤ 0.3, preferably 0.05 – 0.25
	Cr	≤ 0.5
	Sc	≤ 2.8
	Cu	≤ 0.5
35	Fe	≤ 0.5
	Si	≤ 0.5
	Ti	≤ 0.3,

the balance substantially aluminium and incidental elements and impurities, typically each <0.05, total <0.20.

The invention has most successfully found that an increase in the magnesium content results in higher strength levels without a decreasing corrosion performance by selecting respective manganese levels and zinc levels. Throughout the weld filler alloy according to the present invention welded aluminium joints have a higher strength than the standard AA5183 welds and welds as disclosed in EP-1019217-B1, incorporated herein by reference in its entirety. Weld filler alloys in accordance with the present invention have been found to be very successful for welding aluminium structures of Al-Mg alloys to themselves or to other aluminium alloys.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

In a preferred embodiment the weld filler alloy is provided in a form selected from the group consisting of wire, rod, or stick, and in this form preferably having a diameter in the range of 0.5 to 6.0 mm.

The present invention achieves its high strength levels by maintaining a good corrosion resistance throughout a good balance of an elevated magnesium content with adapted manganese and zinc contents. Magnesium is the primary strengthening element in the weld filler alloy. It has been found that it is possible to produce weld wires from the weld filler alloy having an amount of Mg in a range of 7.0 to 9.5 wt.%, more preferably in the range of 7.5 to 8.5 wt.%. By adjusting the manganese and zinc levels it was found that less cracking during casting and subsequent processing of the filler alloy could be achieved, while still providing a strength increase to the welded structures.

Manganese is an essential additive element to the filler wire. Mn in combination with Mg provides the strength to the welded joints. Manganese is present in an amount of 0.9 to 2.0 wt.%, and preferably in a range of 0.9 to 1.45 wt.%. These elevated manganese levels correspond with elevated magnesium levels and lead to the improved strength levels of the weld filler alloy.

Zn is an important additive for corrosion resistance of the weld seams, in particular when used for the welding of alloy products of the preferred composition defined above. It has been found that the amount of Zn is preferably in a range of 0.4-0.7 wt.%, preferably 0.45 to 0.7 wt.% when regular TIG-welding is applied, and a preferred range of 0.5 to 0.9 when regular MIG-welding is applied, in order to maintain a good weldability of the filler alloy and to provide a sufficient corrosion resistance.

Zr is important to also achieve a strength improvement in the weld seams. In

addition Zr is important for resistance against cracking during welding and it has been found that a preferred range of Zr is in a range of 0.05 to 0.25 wt.% and more preferably 0.1 to 0.2 wt.%. Zr levels above 0.3 wt.% result in very coarse needle-shaped primary particles which cause unacceptable failures during wire drawing operation and therefore the Zr level should be kept below 0.3 wt.%.  
5

Scandium in the weld filler alloy can be present in an amount of up to 2.8 wt.% which has the advantage of grain refinement during casting or welding and an additional increase in strength from  $Al_3Xc$  precipitates. When added in combination with Zr, the preferred range for the Sc in the filler wire is 0.25 to 2.8 wt.%.  
10

Ti is a known grain refiner element which may be present in a range of up to 0.3 wt.%, and a preferred range for Ti is 0.03 to 0.2 wt. %.

Each of iron and silicon are regular elements in weld filler alloys, and their presence should not exceed 0.5 wt. %, and preferably each of their content is not more than 0.25%.  
15

As high Cu-levels give rise to deterioration of the pitting corrosion performance in the welded structure when using the weld filler alloy of the current invention, the Cu content in the filler alloy should not exceed 0.5 wt. %, and preferably it should not exceed 0.25%. The more preferred Cu level is <0.10 wt. %, and most preferably the Cu is present at levels <0.03 wt. %.

The balance is aluminium and inevitable impurities. Typically, each impurity should be present at 0.05 % maximum and the total of impurities is 0.20. with regard to impurities content, it is preferable to limit the beryllium content to about 0.00008% or less.  
20

In particular embodiment of the filler wire according to the invention, the filler wire comprises, in wt. %:

25	Mg	7.0 to 7.5
	Mn	1.2 to 2.0, and preferably 1.25 to 1.8
	Zn	0.2 to 1.0, and preferably 0.3 to 0.9,

and the other elements Zr, Cr, Sc, Cu, Fe, Si, Ti as described above.

In another particular embodiment of the filler wire according to the invention, the filler wire comprises, in wt. %:  
30

	Mg	7.0 to 9.5, and preferably 7.5 to 8.5
	Mn	0.9 to 1.45, and preferably 0.9 to 1.25
	Zn	0.2 to 1.0, and preferably 0.3 to 0.9,

and the other elements Zr, Cr, Sc, Cu, Fe, Si, Ti as described above.

Particular suitable alloy products, in the form of rolled, or extruded or forged products for the constructional parts, comprising the following composition (in weight %):

	Mg	4.9 to 6.0, and preferably 5.0 to 5.6
	Mn	0.6 to 1.2, and preferably 0.65 to 1.1
5	Zn	0.25 to 1.5, preferably 0.30 to 0.8, and more preferably 0.30 to 0.6
	Zr	0.05 to 0.25
	Cr	0.3 max.
	Ti	0.2 max.
	Fe	0.5 max., and preferably 0.25 max.
10	Si	0.5 max., and preferably 0.25 max.
	Cu	0.25 max., and preferably 0.10 max.
	Sc	0.3 max.,

the balance substantially aluminium and incidental elements and impurities, and typically each <0.05, total <0.15, may be welded while using the weld filler alloy of this invention.

In a further aspect the invention relates to a method for constructing a welded construction, comprising the steps of: (a) providing separate component parts of the construction having a composition as defined hereinabove, and (b) welding the separate parts together with the Al-Mg-Mn weld filler alloy according to this invention. Preferably the component parts of the construction are provided in the form of an extrusion, plate, sheet, forging or a combination thereof.

The foregoing and other features and advantages of the weld filler alloy according to the invention will become readily apparent from the following detailed description of three preferred examples (Examples 2 and 3 are reference examples only).

25

## EXAMPLES

### Example 1.

Three filler wires having the composition according to the invention have been cast and produced into 3 mm diameter rods suitable for TIG welding. The alloy compositions are listed in Table 1. For comparison the known AA5183 filler wire has been used.

With these filler wires 6.5 mm aluminium plate material in the H111 temper have been TIG welded using two welding passes. The composition of the plate material is listed in Table 2. The cross weld tensile properties have been tested using tensile testing ASME

code for a gauge length of 32 mm, and the results are listed in Table 3.

**Table 1.** Chemical compositions filler wires in weight percentages.

Wire	Cu	Mn	Mg	Cr	Zn	Ti	Zr
<b>A</b>	<0.04	0.9	7.9	<0.01	0.5	0.01	0.14
<b>B</b>	<0.04	1.0	7.7	<0.01	0.5	0.01	0.14
<b>C</b>	<0.04	1.4	8.2	<0.01	0.5	0.01	0.14
<b>5183</b>	<0.04	0.66	4.4	0.08	<0.05	0.10	<0.01

5

**Table 2.** Chemical composition plate material in weight percentages.

Cu	Mn	Mg	Cr	Zn	Ti	Zr
<0.02	0.9	5.3	<0.01	0.6	0.01	0.10

**Table 3.** Cross weld tensile properties

Wire	PS [MPa]	UTS [MPa]	Elongation [%]
<b>A</b>	148	326	21.4
<b>B</b>	162	342	22.0
<b>C</b>	160	340	18.0
<b>5183</b>	131	301	22.9

10

From the results of Table 3 it can be seen that for welded thin plate material when using the filler wire according to this invention compared to the use of conventional AA5183 filler wire an increase of more than 15 MPa in PS (Proof Strength) is obtained, and in the best results (filler B) of more than 30 MPa. The UTS (Ultimate Tensile Strength) increases by about 25 to 40 MPa.

15

#### Example 2.

A filler wire has been cast and produced into 6 mm diameter rods suitable for TIG welding. The alloy composition is listed in Table 4. For comparison the known AA5183 filler wire has been used.

20

With this filler wire 25 mm aluminium plate material in the H111 temper has been TIG welded using ten welding passes. The composition of the plate material is listed in Table 5. The cross weld tensile properties have been tested using tensile testing ASME code for a gauge length of 40 mm, and the results are listed in Table 6.

25

**Table 4.** Chemical compositions filler wires in weight percentages:

Wire	Cu	Mn	Mg	Cr	Zn	Ti	Zr
D	<0.01	1.15	6.1	<0.01	0.54	0.01	0.13
5183	<0.01	0.65	4.4	0.08	<0.01	0.10	<0.01

**Table 5.** Chemical composition of the plate material in weight percentages:

Cu	Mn	Mg	Cr	Zn	Ti	Zr
<0.01	0.75	5.3	<0.01	0.5	0.01	0.10

5 **Table 6.** Cross weld tensile properties.

Wire	PS [MPa]	UTS [MPa]	Elongation [%]
D	153	324	20.5
5183	147	315	30.5

From the results of Table 6 it can be seen that for thick plate material an increase in UTS of about 10 MPa is reached compared to conventional 5183 filler wire.

10 **Example 3.**

A filler wire has been cast and produced into 3 mm diameter rods suitable for TIG welding. The alloy composition is listed in Table 7. For comparison the known AA5183 filler wire has been used.

15 With this filler wire 5 mm aluminium plate material in the H111 temper has been TIG welded using two welding passes. The composition of the plate material is listed in Table 8. The cross weld tensile properties have been tested using tensile testing ASME code for a gauge length of 20 mm, and the results are listed in Table 9.

**Table 7.** Chemical compositions filler wires in weight percentages:

Wire	Cu	Mn	Mg	Cr	Zn	Ti	Zr
E	<0.01	1.2	6.6	<0.01	0.5	0.03	0.14
5183	<0.01	0.65	4.4	0.08	<0.01	0.10	<0.01

20

**Table 8.** Chemical composition plate material in weight percentages.

Cu	Mn	Mg	Cr	Zn	Ti	Zr
<0.01	0.8	5.3	<0.01	0.5	0.01	0.12

**Table 9.** Cross weld tensile properties

<b>Wire</b>	<b>PS</b> [MPa]	<b>UTS</b> [MPa]	<b>Elongation</b> [%]
<b>E</b>	155	337	21.7
<b>5183</b>	146	329	30.3

From the results of Table 9 it can be seen that for thin plate material an increase in PS of about 10 MPa is reached compared to conventional AA5183 filler wire.

5        Similar trends as presented in Example 1 to 3 have been found for plate material in an H321-temper.

It should be apparent that embodiments other than those described above come within the spirit and scope of the present invention. Thus, the present invention is not  
10    limited by the above description but is defined by the claims appended here to.

**CLAIMS**

1. Al-Mg-Mn weld filler alloy having a good corrosion resistance and improved strength levels, comprising the following composition (in weight percent):

5	Mg	7.0 to 9.5
	Mn	0.9 to 2.0
	Zn	0.2 to 0.9
	Zr	≤ 0.3
	Cr	≤ 0.5
10	Sc	≤ 2.8
	Cu	≤ 0.5
	Fe	≤ 0.5
	Si	≤ 0.5
	Ti	≤ 0.3,

15 the balance aluminium and incidental elements and impurities.

2. Filler alloy as claimed in claim 1, wherein

	Mg	7.0 to 9.5
	Mn	0.9 to 1.45
20	Zn	0.2 to 1.0

3. Filler alloy as claimed in claim 1, wherein

	Mg	7.5 to 8.5
	Mn	0.9 to 1.25
25	Zn	0.3 to 0.9

4. Filler alloy according to any one of claims 1 to 3, wherein the amount of Zn is in a range of 0.4 to 0.6%.

30 5. Filler alloy according to any one of claims 1 to 3, wherein the amount of Zn is in a range of 0.5 to 0.9%.

6. Filler alloy according to any one of claims 1 to 5, wherein the Sc content is in a range

of 0.25 to 2.8%.

5 7. Filler alloy according to any one of claims 1 to 6, wherein the Zr content is in a range of 0.05 to 0.25%.

8. Filler alloy according to any one of claims 1 to 7, wherein the Zr content is in a range of 0.1 to 0.2%.

10 9. Filler alloy according to any one of claims 1 to 8, wherein the Fe content is in a range of not more than 0.25%, and wherein the Si content is in a range of not more than 0.25%.

10. Filler alloy according to any one of claims 1 to 9, wherein the Cu content is <0.10%.

15 11. Filler alloy according to any one of claims 1 to 10, wherein the Cu content is <0.03%.

12. Filler alloy according to any one of claims 1 to 11, wherein the filler alloy is provided in a form selected from the group consisting of wire, rod, or stick.

20 13. Filler alloy according to claim 12 having a diameter in the range of 0.5 to 6.0 mm.

14. A method for constructing a welded construction, comprising the steps of: (a) providing separate component parts in the form of an extrusion, plate, sheet, forging or a combination thereof, of the construction having a composition comprising (in weight percent):

Mg	4.9 to 6.0
Mn	0.6 to 1.2
Zn	0.25 to 1.5
Zr	0.05 to 0.25
30 Cr	0.3 max.
Ti	0.2 max.
Fe	0.5 max.
Si	0.5 max.
Cu	0.25 max.
35 Sc	0.3 max.,

balance inevitable impurities and aluminium, and (b) welding the separate parts together with the Al-Mg-Mn weld filler alloy according to any one of claims 1 to 13.

- 5
15. Method according to claim 14, wherein the components have a Zn content in the range of 0.30 to 0.8%.
16. Method according to claim 15 wherein the components have a Zn content in a range of 0.30 to 0.6%.
- 10
17. Method according to any one of claims 14 to 16, wherein the components have a Mg content in a range of 5.0 to 6.0%.
18. Method according to claim 17, wherein the components have a Mg content in a range of 5.0 to 5.6%.
- 15
19. Method according to any one of claims 14 to 18, wherein the components have a Mn content in a range of 0.65 to 1.2%.
- 20
20. Method according to claim 19, wherein the components have a Mn content in a range of 0.65 to 1.1%.
- 21.. Method according to any one of claims 14 to 20, wherein the components are welded by means of TIG welding and the Al-Mg-Mn weld filler alloy has a Zn content in a range of 0.4 to 0.7%.
- 25
22. Method according to claim 21, wherein the Zn content is in a range of 0.45 to 0.7%.
23. Method according to any one of claims 14 to 22, wherein the components are welded by means of MIG welding and the Al-Mg-Mn weld filler alloy has a Zn content in a range of 0.5 to 0.9%.
- 30