

REPUBLIC OF SOUTH AFRICA
PATENTS ACT, 1978**PUBLICATION PARTICULARS AND ABSTRACT**

(Section 32(3)(a) – Regulation 22(1)(g) and 31)

OFFICIAL APPLICATION NO.

LODGING DATE

ACCEPTANCE DATE

21 01 2004/7227

22 19 MAR 2003

43 14-12-2005

INTERNATIONAL CLASSIFICATION

NOT FOR PUBLICATION

51 C22C; C22F

CLASSIFIED BY: WIPO

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EARLIEST PRIORITY CLAIMED

COUNTRY

NUMBER

DATE

33 FR

31 02/03593

32 22 MAR 2002

TITLE OF INVENTION

54 AL-MG ALLOY PRODUCTS FOR A WELDED CONSTRUCTION

57 ABSTRACT (NOT MORE THAN 150 WORDS)

NUMBER OF SHEETS 36

If no classification is finished, Form P.9 should accompany this form.
The figure of the drawing to which the abstract refers is attached.

ABSTRACT

The invention relates to a welded Al-Zn-Mg-Cu alloy product characterized in that it contains in per cent by mass: Mg 4.8 5 5.35, Mn 0.20 0.50, Zn 0.20 0.45, Si < 0.20 Fe < 0.30, Cu < 0.25, Cr < 0.15, Ti < 0.15, Zr < 0.15, the remainder being aluminium with inevitable impurities. Preferably, the inventive product has a stretch at break A_(TL) of at least 24 %, and a R_{m(TL)} × A_(TL) parameter of at least 8500. It has a good intergranular resistance to corrosion characteristic under constraint and can be used for the welded construction of tank devices, car bodies and industrial vehicles.

Field of the invention

The present invention relates to high mechanical resistance Al-Mg type alloys, and more particularly alloys intended for welded constructions such as motor car bodywork, industrial vehicles and fixed or mobile tanks.

State of the related art

To increase the mechanical resistance of welded constructions while decreasing their weight, it is of interest to have, with respect to the 5083, 5086, 5182, 5186 or 5383 alloys currently used, enhanced mechanical characteristics without losing any of the properties for use such as weldability, corrosion resistance or formability, particularly in low cold-worked states such as the O state and H111 state. The designation of these alloys follows the rules of The Aluminum Association and that of the metallurgical tempers is defined in the European standard EN 515.

To design a structure, the parameters governing the user's choice are essentially the static mechanical characteristics : the ultimate tensile strength R_m , the tensile yield strength $R_{p0.2}$ and the elongation at fracture A. Other parameters which are involved, according to the specific requirements of the target application, are the mechanical characteristics of the welded seam, the corrosion resistance of the sheet and the welded seam, the fatigue strength of the sheet and the welded seam, the crack propagation rate, the

fracture toughness, the bendability, the weldability, the propensity for residual stress formation under determined sheet manufacturing and usage conditions, and the possibility to produce sheets of regular
 5 quality with the lowest possible production cost.

The state of the art offers several processes to enhance the mechanical characteristics to Al-Mg type alloys.

The European patent application EP 769 564 A1
 10 (Pechiney Rhenalu) discloses an alloy of the following composition (percentage by weight) :

Mg 4.2-4.8 Mn < 0.5 Zn < 0.4 Fe < 0.45
 Si < 0.30 where Mn + Zn < 0.7 and Fe > 0.5 Mn

which may also contain other elements, making it
 15 possible to manufacture sheets having in a low cold worked state a value of $R_m > 275$ MPa, a value of $A > 17.5\%$ and an $R_m \times A$ product > 6500 ; a better-controlled composition makes it possible to increase said $R_m \times A$ product to a value greater than 7000 and
 20 even greater than 7500.

Alloys of this type are used under the reference 5186 in welded road tanker construction. For this application, the $R_m \times A$ product is used as a parameter to estimate the behaviour of the structures
 25 under deep plastic deformation, for example in the event of an accident. Those skilled in the art know how to increase, in any of the known Al-Mg type alloys, one of the two parameters R_m and A to the detriment of the other ; said patent application discloses that sheets
 30 with an improved compromise between said two parameters may be obtained if the sheet has a very particular

microstructure. The 5186 alloy sheets are characterised not only by a high $R_m \times A$ product, but also by a high value of A, which favours the bending of said sheets and facilitates their use in mechanical construction.

5 Another approach is proposed by the patent application JP 62 207850 (Sky) which discloses alloys of the following composition (percentage by weight) :

Mg 2-6 Mn 0.05-1.0 Cr 0.03-0.3

Zr 0.03-0.3 V 0.03-0.3

10 also liable to contain Cu 0.05-2.0 and/or Zn 0.1-2.0

produced by continuous casting and wherein the intermetallic particle size is less than or equal to 5 μ m. Said alloys would be able to manufacture sheets
15 for motor car bodyworks, since they would make it possible to produce, by means of the very particular thermo-mechanical treatment procedures, sheets of a thickness of 1 mm which do not show Lüders lines.

Another approach is proposed by the patent
20 EP 0 892 858 B1 (Hoogovens Aluminium Walzprodukte GmbH) which discloses alloys of the composition

Mg 5-6 Mn 0.6-1.2 Zn 0.4-1.5 Zr 0.05-0.25

also liable to contain other elements, which make
25 it possible to manufacture very hard alloys, particularly with a zinc content of the order of 0.8%. These products show an elongation at fracture not exceeding a value of the order of 10% in the H321 temper and 20% in the O temper.

30 The patent EP 823 489 B1 (Pechiney Rhenalu) discloses products of the following composition

$3.0 < \text{Mg} < 6.5$ $0.2 < \text{Mn} < 1.0$ $\text{Fe} < 0.8$

$0.05 < \text{Si} < 0.6$ $\text{Zn} < 1.3$

also liable to contain other elements, and characterised by a very particular microstructure ;
 5 said products were not devised to be used for tanker construction but for welded constructions used in contact with seawater or in a maritime environment.

Problem statement

10 The problem which the present invention attempts to resolve is to enhance the mechanical characteristic of Al-Mg alloy products, particularly with a view to their use to produce welded constructions, such as road or rail hazardous substance transport tankers, while
 15 retaining the other characteristics of the material at a level at least comparable to that of existing materials.

Subject of the invention

20 The invention relates to an Al-Mg alloy worked product, characterised in that contains (percentage by weight)

Mg 4.85-5.35 Mn 0.20-0.50 Zn 0.20-0.45

Si < 0.20 Fe < 0.30 Cu < 0.25 Cr < 0.15

25 Ti < 0.15 Zr < 0.15

the remainder being aluminium with its inevitable impurities.

The invention also relates to a road or rail tanker produced at least partially with sheets of the
 30 following composition (percentage by weight) :

Mg 4.90-5.35 Mn 0.20-0.50 Zn 0.25-0.45

Si 0.05-0.20 Fe 0.10-0.30 Cu < 0.25 Cr < 0.15
 Ti < 0.15 Zr < 0.10

the remainder being aluminium with its inevitable impurities,

5 said sheets having an $R_{m(LT)} \times A_{(LT)}$ product of at least 8500, and preferentially of at least 9000.

Detailed description of the invention

The reference of the alloys follows the rules of
 10 The Aluminum Association. Unless indicated otherwise, the chemical compositions are given as percentages by weight. The metallurgical tempers are defined in the European standard EN515. Unless indicated otherwise, the static mechanical characteristics, i.e. the
 15 ultimate tensile strength R_m , the tensile yield strength $R_{p0.2}$ and the elongation at fracture A , are determined by a tensile test according to the standard EN 10002-1 on proportional test pieces (and characterised by an initial length between references
 20 $L_0 = 5.65 \sqrt{S_0}$ where S_0 represents the area of the initial cross-section) sampled in the LT (long transverse) direction.

The applicant surprisingly found that, to resolve the problem involved, it is necessary to select a very
 25 narrow Al-Mg-Mn-Zn composition range which is clearly distinguished from that of the 5186 alloy. Particularly, it is necessary to increase the magnesium content, to add a small amount of zinc, and to reduce the content of the minor additions elements, Fe, Si and Mn,
 30 contents, while keeping them above a minimum level.

Indeed, magnesium is well-known to increase the mechanical characteristics ($R_{0.2}$ and R_m) of certain aluminium alloy types : the applicant observed that a magnesium content of at least 4.85%, preferentially greater than 4.90% and more preferentially greater than 4.95% or even 5.00% makes it possible to obtain the required level of mechanical characteristics. However, above 5.35% magnesium, the corrosion resistance starts to deteriorate ; a maximum value of 5.30% is preferred.

10 The addition of zinc in sufficient quantity (minimum 0.20%, preferentially at least 0.25% and more preferentially at least 0.30%) proves to have a beneficial effect on the mechanical characteristics of sheets and on the yield strength at the welded seams. 15 In addition, it improves the corrosion resistance. Within the scope of the present invention, it is preferred not to exceed a content of 0.45%. A content between 0.25% and 0.40% is preferred.

The applicant observed that a minimal content of 20 0.20% manganese must be maintained to control the granular structure, but it must remain less than 0.50% and preferentially 0.40% in order to prevent coarse intermetallic phase formation and facilitate recrystallisation in the final temper. The preferred 25 range is 0.25 to 0.35%. The presence of manganese in sufficient quantity also contributes to obtaining the mechanical characteristics.

In the 5xxx alloys, copper is known to degrade the general corrosion resistance. The applicant found that 30 it is preferable to maintain the copper content less

than 0.25% ; a content less than 0.20%, less than 0.15% or even less than 0.10% is preferred.

Iron and silicon are usual impurities in aluminium. Within the scope of the present invention, the iron content must not exceed 0.30% and the silicon content 0.20%. However, the applicant observed surprisingly that the presence of a certain quantity of iron and silicon helps achieve the aim of the present invention : for example, a content of at least 0.05% of silicon favours a finely recrystallised granular microstructure. For iron, a content of at least 0.10% is preferred.

The product according to the invention may contain a low quantity of chromium, titanium and zirconium. The content of each of these elements must not exceed 0.15% and more preferentially 0.10%, since an excessively high content of these elements limits recrystallisation and leads to a fall in the value of A.

The products according to the invention are always produced by semi-continuous casting, followed by processing steps corresponding to the desired product shape : extrusion for extruded or drawn products (bars, tubes, profiles, wires) ; rolling for rolled products (sheets, strips, thick sheets). In the case of rolled products, the rolling ingots produced by semi-continuous casting are hot rolled, and then possibly cold rolled. The strips are planed and converted into sheets. In this manufacturing method, it is necessary to adjust the hot rolling mill output temperature and the coiling temperature and the cold working rate, which influence the mechanical characteristics of the product, must be adjusted carefully. The preferred

final thickness is between 3 and 12 mm. In a preferred embodiment of the invention, the sheet is obtained directly at the final thickness by hot rolling. In this case, a hot rolling mill output temperature is
 5 advantageously selected between 260°C and 330°C and preferentially between 290°C and 330°C. Below 260°C, the microstructure obtained is not well-suited to the target application, and above 330°C, a coarsening of the grain which degrades the desired mechanical
 10 characteristics is observed. This particular embodiment of the invention, i.e. the direct production of sheets at the final thickness by hot rolling, also facilitates the manufacture of very wide sheets, for example greater than 3000 mm, and preferentially greater than
 15 3300 mm and more preferentially greater than 3500 mm.

In a preferred embodiment, the product according to the invention is characterised by an elongation at fracture A of at least 24% and preferentially of at least 27%. This characteristic facilitates the use of
 20 the product. For example, it gives rolled sheets an excellent bendability and formability.

In another preferred embodiment, it is attempted to optimise the three parameters $R_{p0.2(LT)}$, $R_{m(LT)}$ and $A_{(LT)}$. The "LT" index indicates that these mechanical
 25 characteristics are measured on tensile test pieces sampled in the long transverse direction (perpendicular to the direction of rolling) of the sheets. By adjusting the chemical composition in the indicated zones in an appropriate manner, a product with a
 30 tensile yield strength $R_{p0.2(LT)}$ of at least 145 MPa, preferentially at least 150 MPa and more preferentially

at least 170 MPa, a ultimate tensile strength $R_{m(LT)}$ of at least 290 MPa and preferentially at least 300 MPa, and an elongation at fracture $A_{(LT)}$ of least 24% and preferentially at least 27% is obtained.

5 For example, it is possible to choose advantageously Mn 0.20-0.40, Zn > 0.25 and preferentially > 0.30, an iron content of at least 0.10% iron and a silicon content of at least 0.10%.

10 In another preferred embodiment, it is essentially attempted to optimise the $R_{m(LT)} \times A_{(LT)}$ product. By adjusting the chemical composition in the indicated ranges in an appropriate manner, a product with an $R_{m(LT)} \times A_{(LT)}$ product, wherein $R_{m(LT)}$ is expressed in MPa and $A_{(LT)}$ as a percentage, measured on test pieces sampled
15 in the LT direction, is greater than 8200, preferentially greater than 8500 and more preferentially greater than 9000, is obtained, while retaining a sufficient level of $R_{p0.2(LT)}$. This product, particularly in sheet form, is particularly suitable
20 for the manufacture of tankers, particularly for the road and rail transport of hazardous substances.

The products according to the invention show a corrosion resistance at least as good as the known comparable Al-Mg, despite a notably higher magnesium
25 content. Within the scope of the present invention, this corrosion resistance is preferentially characterised either by the loss of mass and by the maximum metal depth showing defects due to intergranular corrosion after an intergranular
30 corrosion test (Official Journal of the European Communities, 19/11/1984, No. L300-35 to 43) or by a

stress corrosion test conducted according to the standard ASTM G 30, G39, G 44 and G49. The stress corrosion test may be conducted advantageously with reference to the standard ~~ASTM~~ ASTM G 129, the applicant
5 having previously established the good correlation between said standards and the standard ASTM G 129 (see R. Dif et al., Proceedings of the 6th International Conference on Aluminium Alloys, 1998, Toyohashi, Japan, pp. 1615-1620, and R. Dif et al., Proceedings of the
10 Eurocorr Conference 1997, Trondheim, Norway, pp. 259-264).

The intergranular corrosion test selected is considered to be representative of natural exposure in a marine atmosphere (R. Dif et al., Proceedings of the
15 Eurocorr Conference, 1999, Aachen, Germany).

The corrosion behaviour is evaluated not only in the initial state but also after artificial ageing treatments wherein the conditions may vary. A 7-day treatment at 100°C has been conventionally used on 5xxx
20 series alloys in order to reproduce natural ageing at ambient temperature for around twenty years (E.H.Dix et al., Proceedings of the 4th annual Conference of NACE, San Francisco, USA, 1958).

In very particular cases of use, the structures
25 may be subjected to relatively high temperatures (above 60°C). Those skilled in the art know that under these conditions, some 5xxx series alloys may develop beyond a certain exposure time, a certain susceptibility to corrosion. In order to study this so-called
30 sensitisation phenomenon, it is advisable to conduct more extensive heat treatments than 7 days at 100°C.

The equivalent time concept is generally used to limit the number and duration of the treatments to be conducted. More specifically, a treatment of duration t_1 performed at a temperature T_1 will be equivalent to
 5 a treatment of duration t_2 performed at temperature T_2 , given by the equation (R. Dif et al., Proceedings of the 6th International Conference on Aluminium Alloys, 1998, Toyohashi, Japan, pp. 1489-1494) :

$$10 \quad t_1 \cdot \exp\left(-\frac{Q}{R \cdot T_1}\right) = t_2 \cdot \exp\left(-\frac{Q}{R \cdot T_2}\right)$$

where the temperatures are expressed in Kelvin. Q represents the thermal activation energy of magnesium diffusion (in J/mol). R is the gas constant. The value
 15 of the ratio $\frac{Q}{R}$ from the literature is of the order of 10,000 K to 13,500 K.

In a particular embodiment of the present invention, the products according to the invention show in the intergranular test an intergranular corrosion
 20 resistance which is characterised at least by a loss of mass of less than 20 mg/cm² after ageing for 7 days at 100°C, and by a maximum etching depth of less than 130 µm, and preferentially less than 70 µm.

Preferentially, said products also show, after
 25 ageing for 20 days at 100°C, a loss of mass of less than 50 mg/cm² and preferentially less than 30 mg/cm², and a maximum etching depth of less than 250 µm, and preferentially less than 100 µm. The most preferred products within the scope of the present invention show

after ageing for 20 days at 120°C, a loss of mass of less than 95 mg/cm² and preferentially less than 80 mg/cm², and more preferentially less than 60 mg/cm², and a maximum etching depth of less than 450 µm, and preferentially less than 400 µm, it being understood that this characteristic is added to at least one of the characteristics mentioned above, i.e. after ageing for 20 days at 100°C or 20 days at 120°C. These products, while they also have excellent mechanical characteristics (for example an $R_m \times A$ product of at least 8500 or 9000) are particularly well-suited to the manufacture of welded constructions, such as road or rail tankers, as explained below.

With respect to the study of the corrosion resistance under stress, the applicant prefers the slow strain rate testing method, described for example in the standard ASTM G129. This test is more rapid and has proved to be more discriminating than conventional methods consisting of determining the non-fracture threshold stress in stress corrosion, provided that the experimental conditions are well-controlled.

The principle of the slow strain rate test consists of comparing the tensile properties in inert media (laboratory air) and in corrosive media. The decrease in the static mechanical properties in corrosive media corresponds to the susceptibility to stress corrosion. The most sensitive tensile test characteristics are the elongation at fracture A and the maximum stress (contraction) R_m . The applicant observed that the elongation at fracture is a markedly more discriminating parameter than the maximum stress.

It is necessary to ensure that the decrease in the static mechanical characteristics indeed corresponds to stress corrosion, defined as the synergic and simultaneous action of mechanical stress and the environment. Therefore, the applicant also performed tensile tests in inert media (laboratory air), after preliminary pre-exposure of the test piece, without stress, in a corrosive medium, for the same time as the tensile test performed in said medium. If the tensile characteristics obtained are not different to those obtained in inert media, the susceptibility to stress corrosion may then be defined using an "SC susceptibility" index defined as :

$$I = \frac{A_{\text{inertmedium}}^{\%} - A_{\text{corrosivemedium}}^{\%}}{A_{\text{inertmedium}}^{\%}} \times 100$$

The critical aspects of the slow strain rate test relate to the choice of the tensile test piece, the deformation rate and the corrosive solution. The applicant used a test piece (sampled in the long transverse direction) having a scalloped shape with a radius of curvature of 100 mm, which makes it possible to locate the deformation and render the test even more severe.

With respect to the stress rate, an excessively rapid rate does not allow the stress corrosion phenomena to develop, but an excessively slow rate masks the stress corrosion. The applicant used a deformation rate of 5.10^{-5} s^{-1} (corresponding to a transverse movement speed of $4.5.10^{-2} \text{ mm/min}$) which

makes it possible to maximise the effects of stress corrosion (R. Dif et al., Proceedings of the 6th International Conference on Aluminium Alloys, 1998, Toyohashi, Japan, pp. 1615-1620).

5 With respect to the corrosive environment to be used, the same type of problem is involved given that an excessively corrosive medium masks the stress corrosion, but an insufficiently severe environment does not make it possible to demonstrate corrosion
10 phenomena. A 3%NaCl+0.3%H₂O₂ solution has been used successfully within the scope of the present invention.

 The products according to the invention may be used advantageously for welded construction, for the construction of road or rail tankers or for the
15 construction of industrial vehicles. They may also be used for the construction of motor car bodywork, particularly as reinforcement parts. They show a good formability.

 In a preferred use, the products according to the
20 invention are used in the form of rolled sheets in a low cold worked metallurgical temper, such as the O temoer or H111 temper, of a thickness between 3 mm and 12 mm, and preferentially between 4.5 mm and 10 mm, for the construction of road or rail tankers, said sheets
25 being characterised by an $R_{m(LT)} \times A_{(LT)}$ product greater than 8200, preferentially greater than 8500 and more preferentially greater than 9000, and by a good corrosion resistance. For this use, in a preferred manner, the loss of mass in an intergranular resistance
30 test is less than 30 mg/cm² after ageing for 20 days at

100°C, and the SC slow strain rate testing index is less than 50% after ageing for 20 days at 100°C.

The products according to the invention may be welded by means of any welding methods that can be used
5 for Al-Mg type alloys, such as MIG or TIG welding, friction welding, laser welding, electron beam welding. More particularly, the applicant observed that MIG welding of the products according to the invention results in welded seams characterised by a fracture
10 limit at least as high as with known alloys such as 5186. These welding tests were performed in the long transverse direction on butt-welded sheets in H111 temper with a V-shaped chamfer by smooth stream semi-automatic MIG welding, with a 5183 alloy filler
15 wire. The mechanical tests were performed on tensile test pieces sampled in the longitudinal direction (perpendicular to the weld seam) with a symmetrically flush seam and with a non-flush seam, or in the LT direction. On a test piece sampled in the longitudinal
20 direction, a value of R_m of at least 275 MPa is found, which underlines the material's excellent suitability for use in welded constructions.

The invention will be understood more clearly using examples, which are however not limitative in
25 nature.

Examples

Example 1

Rolling ingots were produced from various alloys
30 by means of semi-continuous casting. Their composition is given in table 1. The chemical analysis of the

elements was performed by spark spectroscopy on a spectrometry slug obtained from liquid metal sampled in the casting channel.

The rolling ingots were heated and then hot rolled.

5 For example, the ingot corresponding to example H1 was heated in three stages : 10 hours at 490°C, 10 hours at 510°C, 3 hrs 45 min at 490°C and then hot rolled with an entry temperature of 490°C and a winding temperature of 310°C. For the ingots corresponding to examples H2,

10 I1, I2, I3 and I4, the heating was performed in two stages (21 hrs at 510°C + 2 hrs at 490°C), the rolling entry temperatures were 477°C, 480°C, 479°C, 474°C and 478°C, respectively, while the coiling temperatures were 290°C, 300°C, 270°C, 310°C and 300°C, respectively.

15 After the coiling, all the sheets were planed and output.

Table 1

Alloy	Mg	Zn	Mn	Si	Fe	Cu	Zr	Ti	Cr
A	4.28	0.06	0.31	0.11	0.26	0.04	<0.01	0.02	0.08
B	4.45	0.12	0.43	0.14	0.28	0.06	<0.01	0.02	0.09
C	4.68	0.02	0.26	0.09	0.25	0.06	<0.01	0.03	0.01
D	4.54	0.03	0.27	0.10	0.23	0.04	<0.01	0.01	0.01
E	4.42	0.07	0.28	0.13	0.25	0.07	<0.01	0.02	0.03
F	4.31	0.04	0.32	0.13	0.27	0.05	<0.01	0.02	0.07
G	5.05	0.38	0.29	0.12	0.22	<0.01	<0.01	0.02	0.01
H1, H2	5.19	0.38	0.31	0.08	0.15	0.01	<0.01	0.02	0.01
I1 to I4	5.30	0.26	0.33	0.10	0.16	0.05	<0.02	0.02	0.02

20 Alloys A, B, C, D, E, and F are alloys according to the state of the art. Alloys G, H and I are alloys according to the invention.

The properties of the sheets produced from these alloys are given in Table 2. The sheets bear the same reference letter as the alloy wherein they were produced.

5

Table 2
Sheet properties

sheet	State	Thickness [mm]	$R_{m(LT)}$ [MPa]	$R_{p0.2(LT)}$ [MPa]	$A_{(LT)}$ [%]	$R_{m(LT)}$ x $A_{(LT)}$
A	H111	6.5	278	170	23	6394
B	H111	5.1	300	177	23	6900
C	O	5.4	290	149	26.5	7685
D	H111	6.2	274	138	28	7672
E	O	4.9	287	147	27	7749
F	H111	5.3	294	170	23.5	6909
G	H111	4.7	300	180	27.7	8310
H1	H111	5.0	308	154	28.5	8778
H2	H111	5.0	309	176	29	8961
I1	H111	6.1	301	148	28.1	8458
I2	H111	8.1	321	182	26.8	9602
I3	H111	6.1	300	149	29.6	8880
I4	H111	5.1	310	164	28.3	8773

Example 2 :

10 Two 5.0 mm thick sheets in H111 temper
corresponding to example H1 were butt-welded in the
long transverse direction with a V-shaped chamfer (45°
angle) by smooth stream semi-automatic MIG welding. A
5183 alloy (Mg 4.81%, Mn 0.651%, Ti 0.120%, Si 0.035%,
15 Fe 0.130%, Zn 0.001%, Cu 0.001%, Cr 0.075%) filler wire,

1.2 mm thick, supplied by Soudure Autogène Française was used.

The test piece was sampled in the longitudinal direction through the welded seam so that the seam was in the centre. With the symmetrically flush seam, a value of R_m of 285 MPa was found, along with a value of 311 MPa with a non-flush seam.

The same test was conducted on two sheets corresponding to the H2 sheet. With the symmetrically flush weld seam, a value of R_m of 290 MPa was found. With a non-flush seam, a value of 318 MPa was found. As a comparison, 283 MPa is obtained with a flush seam on sheets of comparable thickness according to the prior art (see L. Cottignies et al., "AA 5186 : a new aluminium alloy for welded constructions", Journal of Light Metal Welding and Construction, 1999).

The same test was conducted on two sheets corresponding to the sheets I2 and I4 ; for this test, the test pieces were sampled in the LT direction via the welded seam. The following results were found:

Sheet	Direction of stress	Direction of weld	Flush seam or not	$R_{p0.2}$ [MPa]	R_m [MPa]	A [%]
I4	LT	L	Flush	153	291	13.0
I2	LT	L	Flush	156	293	16.8
I4	LT	L	Non-flush	155	312	18.4
I2	LT	L	Non-flush	163	323	21.3

Example 3 :

On sheets produced as described in example 1, LDH
 5 (Limit Dome Height) tests were performed. The LDH is a
 peripheral blocked blank drawing test (R. Thompson,
 "The LDH test to evaluate sheet metal formability -
 Final report of the LDH committee of the North American
 Deep Drawing Research Group", SAE Conference, Detroit,
 10 1993, SAE Paper No. 93-0815). The 490 mm x 490 mm blank
 is subjected to equiaxed bi-expansion stress. The
 lubrication between the punch (diameter 250 mm) and the
 sheet is provided by a plastic film and grease. The LDH
 value is the displacement of the punch at fracture, i.e.
 15 the limit drawing depth.

A value of 101 mm is obtained for the H1 sheet,
 and a value of 94.1 mm for the H2 sheet. As a
 comparison, an LDH value of 94.3 mm had been obtained
 for an alloy of the prior art with a comparable
 20 thickness (see L. Cottignies et al., "AA 5186 : a new
 aluminium alloy for welded constructions", Journal of
 Light Metal Welding and Construction, 1999).

Example 4 :

25 On a sheet of the prior art and the sheet
 corresponding to example H1, we conducted slow strain
 rate testing according to the method and with the
 parameters described in the section "Detailed
 description of the invention". The elongation values
 30 obtained for the two alloys and the different ageing
 conditions are given in table 3.

Table 3
Slow Strain Rate Testing Results

Alloy	Ageing	A% Air	A% NaCl+H ₂ O ₂	A% Pre- Exposure	I% SC index
Prior art	None	22.8	22.8	Not tested	0%
	7 d 100°C	24.2	24.0	Not tested	1%
	20 d 100°C	25.0	10.5	24.4	58%
	20 d 120°C	24.6	5.4	24.4	78%
Invention (e.g. H1)	None	28.9	29.8	Not tested	0%
	7 d 100°C	30.4	30.5	Not tested	0%
	20 d 100°C	30.7	21.3	30.8	31%
	20 d 120°C	30.3	7.7	30.6	75%

5

It is observed that the alloy according to the invention shows an improved stress corrosion resistance after ageing, particularly for intermediate ageing levels, despite a higher magnesium content.

10

Intergranular corrosion tests were conducted on the H1, H2, I2 and I4 sheets, corresponding to the invention, and on a 5186 alloy sheet according to the

state of the art, according to the recommendations of the Official Journal of the European Communities, 19/11/84, No. L300, 35 to 43, using solution B (30 g/l NaCl + 5 g/l HCl), on 30 mm*30 mm*5 mm samples. The results obtained in these tests are given in Table 4, with reference to the results of the prior art.

Table 4

Sheet	Loss of mass [mg/cm ²]					Maximum pit depth [μm]				
	Not aged	7 d at 100°C	20 d at 100°C	20 d at 120°C	40 d at 120°C	Not aged	7 d at 100°C	20 d at 100°C	20 d at 120°C	40 d at 120°C
5186	20	47	77	101.5	122.5	100	220	400	550	650
H1	3.5	19	17.5	66	94	40	50	90	280	420
H2	3.5	6	12	54	75.5	30	130	110	350	450
I4	9.5	18.5	35.5	93.5		60	120	250	450	
I2	7.5	9.5	11	31		50	50	50	150	

The alloy according to the invention shows a comparable level of intergranular corrosion resistance, or improved with respect to that of the prior art.

Example 5 :

A rolling ingot of the following composition was produced by semi-continuous casting :

Mg 5.0%, Zn 0.30%, Mn 0.35%, Si 0.01%, Fe 0.15%, Cu 0.03%, Zr 0.02%, Cr 0.03%, Ni <0.01%, Ti 0.02%. After homogenisation for 19 hours at 505°C, the ingot was hot rolled to a thickness of 7mm. After light planing, the sheets were annealed with a temperature rise to 378°C for 8 hours, followed by maintenance for 30 minutes at a temperature between 378°C and 390°C.

The sheets obtained in this way have the following mean mechanical characteristics (LT direction) :

$$R_m = 297 \text{ MPa}, R_{p0.2} = 139 \text{ MPa}, A = 28.9\%.$$

CLAIMS

1. Al-Mg alloy wrought product, characterised in that contains (percentage by weight)

5 Mg 4.85-5.35 Mn 0.20-0.50 Zn 0.20-0.45
 Si < 0.20 Fe < 0.30 Cu < 0.25 Cr < 0.15
 Ti < 0.15 Zr < 0.15

the remainder being aluminium with its inevitable impurities.

10 2. Product according to claim 1, characterised in that Mg 4.90-5.30%.

3. Product according to any of claims 1 or 2, characterised in that Mn 0.20-0.40%.

15 4. Product according to claim 3, characterised in that Mn 0.25-0.35%.

5. Product according to any of claims 1 to 4, characterised in that Zn 0.25-0.40%.

6. Product according to any of claims 1 to 5, characterised in that Cu < 0.20%.

20 7. Product according to claim 6, characterised in that Cu < 0.15%.

8. Product according to claim 7, characterised in that Cu < 0.10%.

25 9. Product according to any of claims 1 to 8, characterised in that it contains at least 0.10% iron.

10. Product according to any of claims 1 to 9, characterised in that it contains at least 0.05% silicon.

30 11. Product according to any of claims 1 to 10, characterised in that it contains at least 4.95% magnesium.

12. Product according to any of claims 1 to 11, characterised in that it contains at least 5.0% magnesium.

13. Product according to any of claims 1 to 12, characterised in that its elongation at fracture A is at least 24%.

14. Product according to claim 13, characterised in that its elongation at fracture A is at least 27%.

15. Product according to any of claims 1 to 14, characterised in that its tensile yield strength $R_{p0.2(LT)}$ is at least 145 MPa, its ultimate tensile strength $R_{m(LT)}$ is at least 290 MPa and its elongation at fracture $A_{(LT)}$ is at least 24%.

16. Product according to claim 15, characterised in that its tensile yield strength $R_{p0.2(LT)}$ is at least 150 MPa.

17. Product according to claim 16, characterised in that its tensile yield strength is at least 170 MPa.

18. Product according to any of claims 15 to 17, characterised in that the elongation at fracture $A_{(LT)}$ is at least 27%.

19. Product according to any of claims 13 to 18, characterised in that its ultimate tensile strength $R_{m(LT)}$ is at least 300 MPa.

20. Product according to any of claims 1 to 19, characterised in that the $R_{m(LT)} \times A_{(LT)}$ product, wherein $R_{m(LT)}$ is expressed in MPa and $A_{(LT)}$ as a percentage, is greater than 8200.

21. Product according to claim 20, characterised in that the $R_{m(LT)} \times A_{(LT)}$ product is greater than 8500.

22. Product according to claim 21, characterised in that the $R_{m(LT)} \times A_{(LT)}$ product is greater than 9000.

23. Product according to any of claims 1 to 22, characterised in that the loss of mass after the
5 intergranular corrosion test after ageing for 7 days at 100°C is less than 20 mg/cm².

24. Product according to any of claims 1 to 22, characterised in that the loss of mass after the
10 intergranular corrosion test after ageing for 20 days at 100°C is less than 50 mg/cm².

25. Product according to claim 24, characterised in that the loss of mass after the intergranular corrosion test is less than 30 mg/cm².

26. Product according to any of claims 1 to 22, characterised in that the loss of mass after the
15 intergranular corrosion test after ageing for 20 days at 120°C is less than 95 mg/cm².

27. Product according to claim 26, characterised in that the loss of mass after the intergranular corrosion
20 test is less than 80 mg/cm².

28. Product according to claim 27, characterised in that the loss of mass after the intergranular corrosion test is less than 60 mg/cm².

29. Product according to any of claims 1 to 28, characterised in that it consists of a rolled sheet.
25

30. Product according to claim 29, characterised in that the sheet has a thickness of between 3 mm and 12 mm.

31. Product according to claim 30, characterised in that the sheet has a thickness of between 4.5 mm and 10
30 mm.

32. Product according to any of claims 29 to 31, characterised in that the sheet has been produced by hot rolling from an ingot obtained by means of semi-continuous casting.

5 33. Product according to claim 32, characterised in that the hot rolling mill output temperature is between 260°C and 330°C.

34. Product according to claim 33, characterised in that the hot rolling mill output temperature is between
10 290° and 330°C.

35. Use of a product according to any of claims 1 to 34 for welded constructions.

36. Use of a product according to any of claims 1 to 34 for road or rail tankers.

15 37. Use of a product according to any of claims 1 to 34 for industrial vehicle construction.

38. Use of a product according to any of claims 1 to 34 for motor car bodywork construction.

39. Road or rail tanker produced at least partially
20 with sheets of the following composition (percentage by weight) :

Mg 4.95-5.35	Mn 0.20-0.50	Zn 0.25-0.45
Si 0.05-0.20	Fe 0.10-0.30	Cu < 0.25 Cr < 0.15
Ti < 0.15	Zr < 0.10	

25 the remainder being aluminium with its inevitable impurities,
said sheets having an $R_{m(LT)} \times A_{(LT)}$ product of at least 8500.

40. Road or rail tanker according to claim 39,
30 characterised in that the sheets have an $R_{m(LT)} \times A_{(LT)}$ product of at least 9000.

41 . Tanker according to claim ~~39~~ or claim 40, characterised in that said sheets show a corrosion resistance characterised by a loss of mass during the intergranular corrosion test of less than 50 mg/cm² after ageing for 20 days at 100°C.

42 . Tanker according to claim 41, characterised in that said sheets show a corrosion resistance characterised by a loss of mass during the intergranular corrosion test of less than 30 mg/cm².

43 . Tanker according to any of claims 39 to 42, characterised in that said sheets show a stress corrosion resistance characterised by an SC index of less than 50% after ageing for 20 days at 100°C.

44 . Welded construction produced at least partially with product according to any of claims 1 to 34.

45 . Welded construction according to claim 44, characterised in that the weld seam, obtained by butt-welding in the long transverse direction with a V-shaped chamfer (45° angle) by MIG welding with a 5183 alloy filler wire, shows a value of R_m of at least 275 MPa, measured on a test piece sampled in the longitudinal direction through the welded seam and arranged such that said welded seam is located at the centre of the length of the test piece, after symmetric levelling of the weld seam.

46 . Al-Mg alloy wrought product according to claim 1, substantially as herein described with reference to any one of the illustrative examples.

47 . Road or rail tanker according to claim 39, substantially as herein described with reference to any one of the illustrative examples.

48. Welded construction according to claim 44, substantially as herein described with reference to any one of the illustrative examples.