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(54) Title: WROUGHT MAGNESIUM ALLOY



(A) Alloy A



(B) Alloy B

Figure 1

(57) Abstract: A magnesium-based alloy consisting of, by weight: 0.5 to 1.5% manganese, 0.05 to 0.5% rare earth of which more than 70% is lanthanum, 0 to 1.5% zinc and 0 to 0.1% strontium, the balance being magnesium except for incidental impurities.



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Field of the Invention

The present invention relates to a magnesium alloy, in particular to a wrought magnesium alloy. A wrought alloy is an alloy which has the potential to be worked into a shape or condition after casting. The present invention also relates to a method of manufacturing a wrought magnesium alloy article.

Summary of the Invention

10 According to a first aspect of the present invention, there is provided a magnesium-based alloy consisting of, by weight:

0.5 to 1.5% manganese,
0.05 to 0.5% lanthanum,
15 0 to 1.5% zinc, and
0 to 0.1% strontium
the balance being magnesium except for incidental impurities.

According to a second aspect of the present invention, there is provided a magnesium-based alloy consisting of, by weight:

0.5 to 1.5% manganese,
0.05 to 0.5% rare earth of which more than 70% is lanthanum,
25 0 to 1.5% zinc and
0 to 0.1% strontium,
the balance being magnesium except for incidental impurities.

Preferably more than 80% of the rare earth content is lanthanum, more preferably more than 90%. The rare earth content may be 100% lanthanum, less any incidental impurities.

Preferably the rare earth content is at least 0.1, more preferably at least 0.2%, preferably no more than 0.4%, preferably no more than 0.3%. The rare earth content may be greater than 0.25%.

The rare earth content may be added as a "misch

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metal" which is understood to comprise an amount of at least two of the rare earth elements.

Throughout the specification, "rare earth" and "rare earth elements" is understood to mean any of the elements with atomic numbers 57 (lanthanum) through 71 (lutetium),

In addition to lanthanum, the rare earth content may also comprise cerium. The cerium content is less than the lanthanum content.

10 The rare earth content may also comprise praseodymium and/or neodymium, typically only in small amounts (<5% of the total rare earth content).

Preferably, the lanthanum content of the alloy is 0.05 to 0.5%, more preferably at least 0.09%, more preferably at least 0.1%, more preferably at least 0.15%, preferably no more than 0.4%, more preferably no more than 0.3%. The lanthanum content of the alloy may be greater than 0.25%.

Preferably, the manganese content is greater than 0.6%, more preferably less than 1.3%, more preferably 0.7 to 1.2%, and most preferably about 1%.

Zinc is an optional component of the alloy, which may be added to strengthen the alloy. When present, the zinc content is preferably less than 1.3%, more preferably 0.2 to 1.3%, more preferably 0.2 to 1.1%, more preferably 0.4 to 1.1%, and most preferably 0.5 to 1.0%.

Incidental impurities may comprise aluminium and silicon. The weight of aluminium in the alloy is preferably no greater than 0.03%. The weight of silicon in the alloy is preferably no greater than 0.03%.

Strontium is an optional component of the alloy, which may be added to strengthen the alloy. When present, the strontium content is preferably greater than 0.01%, preferably no more than 0.1%, more preferably about 0.02%.

35 According to a third aspect of the present invention, there is provided a wrought magnesium alloy article comprising an amount of an alloy according to the

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first or second aspect of the present invention which has been worked into a shape or condition.

According to a fourth aspect of the present invention, there is provided a method of manufacturing a wrought magnesium alloy article, the method comprising the steps of:

- (a) heating a casting of a magnesium-based alloy at a first temperature for a first period of time,
- (b) cooling the casting, and
- (c) working the casting into a shape or condition.

Step (c) may comprise extruding, forging or any other type of working of the casting.

The method may also comprise the step of:

- (d) ageing the casting at a second temperature for a second period of time, after step (b) and prior to step (c).

Preferably, the first temperature is 450°C - 650°C, more preferably 540°C - 580°C.

Preferably, the first period of time is 0.5 - 6 hours, more preferably 1 - 5 hours.

Preferably, the second temperature is 300°C - 400°C, more preferably 325°C - 375°C.

Preferably, the second period of time is 2 - 24 hours, more preferably 5 - 16 hours.

According to a fifth aspect of the present invention, there is provided a method of manufacturing a wrought magnesium alloy article, the method comprising the steps of:

- (a) heating a worked casting of a magnesium-based alloy at a first temperature for a first period of time;
- (b) cooling the worked casting; and
- (c) re-working the casting into a shape or condition.

Step (c) may comprise extruding, forging or any other type of working of the casting.

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The method may also comprise the step of:

(d) ageing the worked casting at a second temperature for a second period of time, after step (b) and prior to step (c).

5 Preferably the first temperature is 450°C-650°C, more preferably 540°C-580°C.

Preferably, the first period of time is 6-20 hours, more preferably 8-14 hours, most preferably 12 hours.

10 Preferably, the second temperature is 300°C-400°C, more preferably 325°C-375°C.

Preferably, the second period of time is 2-24 hours, preferably 5-16 hours.

The following embodiments may be incorporated
15 into the fourth or fifth aspects of the present invention:

Preferably, the magnesium-based alloy may be any magnesium-based alloy which is amenable to precipitation.

In an embodiment, the magnesium-based alloy may be the alloy according to the first or second aspect of
20 the present invention.

In another embodiment, the magnesium-based alloy consists of, by weight:

0.5 to 1.5% manganese,

0.05 to 0.5% rare earths,

25 0 to 1.5% zinc, and

0 to 0.1% strontium

the balance being magnesium except for incidental impurities.

Preferably, the rare earth content is 0.1 to
30 0.5%, more preferably 0.2 to 0.5%, more preferably, 0.3 to 0.5%, most preferably about 0.4%.

In an embodiment, the rare earth content is provided by a "misch metal".

Preferably, the rare earth content comprises at
35 least lanthanum.

Preferably, the rare earth content also comprises cerium.

Detailed Description of Preferred Embodiments

A number of alloys according to embodiments of the present invention were cast as 2kg billets by gravity casting. It is noted however, that other suitable casting methods such as direct chill casting may be employed. Table 1 below sets out the contents of the magnesium alloys prepared.

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TABLE 1 - Alloys Prepared

Alloy	Manganese (wt%)	Lanthanum (wt%)	Zinc (wt%)
A	1.0	0.2	-
B	1.0	0.2	0.5
C	1.0	0.1	-
D	1.0	0.3	-
E	1.0	0.1	0.5
F	1.0	0.3	0.5
G	1.0	0.2	1.0

In each of alloys A to G, magnesium constituted the balance except for incidental impurities. Upon chemical analysis, impurities were found to comprise approximately 0.01 wt% aluminium and less than 0.002 wt% iron in all of the alloys.

Figures 1A and 1B show the microstructure of alloys A and B as cast. Alloy B, which contains 0.5 wt% zinc has smaller grains than alloy A, which contains no zinc but the same amounts of manganese and lanthanum.

Samples of alloys A and B were subsequently extruded after being subjected to a solutionising pre-treatment in which the samples were heated at approximately 580°C for approximately 1 hour. The samples were extruded at different billet temperatures and ram

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speeds (ie. the speed at which the alloy is extruded in mm/sec) to establish the extrusion limits of these alloys. Extrusion limits of an alloy are understood to be the limits of the speed and temperature at which the alloy can be satisfactorily extruded. At high billet temperatures, cracking may occur in the extruded alloy if the ram speed is too high. Furthermore, at low temperatures, the maximum ram speed at which the alloy may be extruded is limited by the load capacity of the extrusion press, such that at a certain low temperature, the alloy is not extrudable at all.

Figures 2A and 2B are extrusion limit diagrams of alloys A and B. It is noted that alloy A has wider extrusion limits than alloy B. It would therefore appear that adding the 0.5% zinc (alloy B) narrows the extrusion limits of the alloy. For all alloys A and B, however, Figures 2A and 2B demonstrate that they may be satisfactorily extruded at high speeds and high temperatures. Figure 3, for example, shows the extrusion limit windows for a number of industry common alloys, AZ31, ZK60, AZ61 and ZM21 which have the following nominal compositions:

Table 2

Alloy	Nominal Composition				
	Al (wt%)	Zn (wt%)	Mn (wt%)	Zr (wt%)	Bal.
AZ31	3.0	1.0	0.2	-	Mg
AZ61	6.5	1.0	0.15	-	Mg
ZM21	-	2.0	0.5	-	Mg
ZK60	-	5.5	-	0.45 min	Mg

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It can be seen from Figure 3 that alloys A and B compares favourably with the industry alloys, in particular AZ31, which is the most commonly used.

The effect of the lanthanum addition on the extrudability on the alloy was also considered by preparation and extruding alloy H which contained (by

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weight) 1% manganese, 0.2% rare earth as a misch metal (consisting of 0.13% cerium and 0.07% lanthanum), with the balance magnesium except for incidental impurities. Figure 4 provides an extrusion limit diagram which compares alloy H to alloy A. Figure 4 demonstrates that alloy A has improved extrudability over alloy H. Without wishing to be bound by theory it is believed that the improved extrudability of alloy A (over alloy H) is due to the lanthanum addition not lowering the solidus temperature nor increasing the hot working flow stress as much as the misch metal addition consisting predominantly of cerium.

Alloy A, at least, was found to have a proof stress in tension of approximately 160-200 MPa and a proof stress in compression of 110 MPa, which may be improved by ageing of the alloy. It is noted that the proof stress in tension is dependent on the solutionising temperature and the grain size of the alloy.

The grain size of alloys A and B was also measured following extrusion (the alloys having been subjected to a solutionising treatment prior to extrusion) at a ram speed of 15mm/sec for different billet temperatures. It was found that a lower grain size was achieved at lower extruding temperatures.

Sample Castings of alloys A to F were also extruded at a ram speed of 15mm/sec and 375°C following a pre-treatment of the cast billets. Different pre-treatments were carried out and the grain size of the extruded alloys measured. Each pre-treatment first involved a solutionising step in which the casting was heated at a temperature of 500 to 580°C. Some pre-treatments further involved an ageing step in which, after quenching the heated casting, further heating of the casting at a lower temperature (approximately 350°C). Table 3 below provides details of the pre-treatments carried out, and the resulting grain size of the extruded alloys.

TABLE 3 - Grain Size of Extruded Alloys having undergone Pre-treatment

Alloy	Solutionising Temperature	Solutionising Time	Ageing Temperature	Ageing Time	Grain Size (μm)
A	580°C	1 hr	350°C	8 hrs	7.7
A	550°C	1 hr	-	-	7.3
A	500°C	1 hr	-	-	8.5
A	580°C	1 hr	-	-	11.4
A	580°C	4 hrs	-	-	5.6
B	580°C	1 hr	350°C	8 hrs	5.8
B	550°C	1 hr	-	-	10.6
B	500°C	1 hr	-	-	11.7
B	580°C	1 hr	-	-	14.1
B	580°C	4 hrs	-	-	7.6
C	580°C	4 hrs	-	-	9.7
C	580°C	4 hrs	350°C	8 hrs	8.6
D	580°C	4 hrs	-	-	8.3
D	580°C	4 hrs	350°C	8 hrs	8.3
E	580°C	4 hrs	-	-	7.5
E	580°C	4 hrs	350°C	8 hrs	8.8
F	580°C	4 hrs	-	-	7.4
F	580°C	4 hrs	350°C	8 hrs	7.4

Referring to Table 3, it is notable for alloys A and B that a longer homogenisation time (ie. time spent at the solutionising temperature) appears to result in finer grain sizes being obtained in the extruded alloy. It is also noted that the addition of zinc (alloy B) appears to render the alloy sensitive to aging prior to extrusion, such that finer grain sizes may be obtained by ageing magnesium-manganese-lanthanum alloys also containing zinc.

The deformation and annealing behaviour of alloy A was further assessed. Samples were machined from extrudates of alloy A which had been subjected to a pre-treatment prior to extrusion involving solutionising and

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ageing or just solutionising. Compression testing was conducted at a temperature of 350°C and at a strain rate of 0.1s⁻¹. The samples were deformed to an equivalent strain of 1.5, after which the samples were held at the deformation temperature for times ranging from 1 s to 1000 s prior to being water quenched.

No substantial change in the grain size was observed in the alloy following the deformation and annealing conditions employed. Average grain sizes of approximately 6-7µm were found in all samples, regardless of the pre-treatment undergone by the alloy prior to extrusion. By way of comparison, Figure 5 shows the stability of the microstructure of alloy A against AZ31 after compression at 350°C at a strain of 1.5, followed by annealing at the same temperature. As can be seen in Figure 5, after a 1000 seconds of annealing, the grain size of AZ31 increases from 6 microns to 25 microns, while the grain size of alloy A remains generally unchanged during this time. Without wishing to be bound by theory, it is understood that the ability of alloy A to maintain a fine grain size is due to the lanthanum addition as the lanthanum restricts the mobility of grain boundaries during recrystallisation. The stability of the grain size of the alloy means that when it is worked (ie. extruded or forged) at elevated temperatures, a small grain size is maintained during slow cooling and/or subsequent annealing. By comparison, when alloy A and AZ31 were both extruded under the same conditions (billet temperature of 370°C, extrusion speed of 6m/min), the average grain size developed in AZ31 was three times greater than that of alloy A (23 microns compared to 7 microns). This can also be seen in the microstructures shown in the comparative micrographs of Figure 6. In general, however, it is shown that advantageously, lanthanum reduces the grain size of the alloy.

The effect of pretreatment of alloy A was further studied by measuring the electrical resistivity of the

alloy during heat treatments of increasing time and at temperatures ranging from 460°C to 580°C. Generally, it is understood that resistivity will decrease during precipitation (at lower temperatures) and will increase as precipitates are dissolved (at higher temperatures):
 Figure 7 shows the change in resistivity for the increase in heat treatment times at the various temperatures. It can be seen from Figure 7 that the resistivity remains fairly constant at intermediate temperatures, but increases at 580°C possibly due to the dissolving of precipitates and decreases at 460°C possibly due to precipitation and/or to the coarsening of precipitates already present in the alloy from casting.

To determine whether these results for the resistivity indicated an important microstructural change in the alloy, billets of alloy A were heat treated at 580°C and 460°C for times of 1 and 4 hours, and then extruded at 375°C and 15mm/s. Table 4 below sets out the resultant grain sizes and tensile elongations (both uniform and total) in comparison to an as-cast billet which was extruded under the same conditions (i.e. did not undergo heat treatment).

TABLE 4

Alloy	Solutionising Temperature	Solutionising Time	Grain Size (µm)	Uniform Elongation (%)	Total Elongation (%)
A	-	-	10.6	8.3	13.2
A	460 °C	1 hr	13.9	9.0	13.6
A	460 °C	4 hr	16.5	8.9	12.2
A	580 °C	1 hr	9.2	11.5	18.6
A	580 °C	4 hr	11.1	10	15.9

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As indicated in Table 4, the solution treatment at 580°C did yield a slightly smaller grain size relative to the untreated billet (when the heating time was 1 hour). However, solution treatment at 460°C resulted in

larger extruding grain sizes. Without wishing to be bound by theory, it is believed that this is due to particle precipitation occurring at 460°C leaving less lanthanum in solid solution to inhibit grain coarsening. It is also noted that solution treatment at 580°C enhanced the tensile ductility of the untreated alloy whereas treatment at 460°C had little or no effect on the ductility.

The effect of solution treatment on extruded alloys (as opposed to as cast alloys) followed by a second extrusion step was also conducted. Electrical resistivity measurements were taken on wrought billets of alloy A after they had been subjected to solution treatment at 580°C for increasing times. Billets were machined from industrial scale extruded rods of alloy A. Figure 8 shows the change of electrical resistivity for increasing solution treatment times. As indicated by Figure 8, the electrical resistivity increased for solution treating times of up to 12 hours, after which it was substantially constant. It therefore appears that a longer solution treatment time is required for alloy which has already been extruded compared to as cast alloys. The solution treated billets were subsequently extruded at 375°C at 15mm/s. Table 5 below sets out the grain sizes for the billets.

TABLE 5

Alloy	Solutionising Temperature	Solutionising Time	Grain Size (µm)
A	580 °C	4 hr	11.9
A	580 °C	8 hr	8.1
A	580 °C	12 hr	7.6
A	580 °C	24 hr	7.2

It can be seen from Table 5 that with increasing solution treatment time, the extruded grain size is reduced.

Alloys were also prepared to determine the effect of the addition of strontium to the alloy. Alloys were prepared containing (by weight) 1.0% manganese, 0.2% lanthanum and either 0.02% or 0.04% strontium with the balance magnesium except for incidental impurities. These alloys were extruded at 375°C and 15mm/s and the grain size and mechanical properties of the extruded alloys were measured. Table 6 below sets out these properties as compared to Alloy A (having 1.0% manganese, 0.2% lanthanum, 0% strontium, balance magnesium).

TABLE 6

Strontium (wt%)	Grain Size (µm)	Yield Strength (MPa)	Tensile Strength (MPa)
0	5.6	161	251
0.02	5.8	203	259
0.04	8.6	165	245

As shown in Table 6, a strengthening effect was observed for the 0.02% strontium addition but not for the 0.04% strontium addition.

Pre-treatment of other magnesium-based alloys prior to extrusion was also trialled. In one trial, samples of a magnesium-manganese-rare earth alloy (Alloy I) were pretreated using various solutionising and ageing processes. Alloy I contained 1 wt % manganese, 0.27 wt % cerium and 0.13 wt % lanthanum, with the balance magnesium except for incidental impurities. The cerium and lanthanum were added to Alloy I as a "misch-metal". It was found that both solutionising and solutionising and ageing this alloy prior to extruding resulted in an extruded alloy which had finer grain sizes. Table 6 shows the results of this trial below.

TABLE 7 - Grain Size of Extruded Alloy having undergone Pre-treatment

Alloy	Solutionising Temperature	Solutionising Time	Ageing Temperature	Ageing Time	Grain Size (µm)
I	580°C	1 hr	350°C	8 hrs	6.6
I	550°C	1 hr	-	-	9.0
I	500°C	1 hr	-	-	10.1
I	580°C	1 hr	-	-	10.0
I	580°C	4 hrs	-	-	7.5

5 Trials were also conducted to study the effects of aluminium and silicon on wrought magnesium alloys. Aluminium and silicon are incidental impurities in any such alloys. Magnesium based alloys consisting of 1.0% manganese and 0.2% lanthanum were prepared with differing
 10 amounts of aluminium and silicon as set out in Table 8 below, and extruded at 375°C and 15 mm/s.

TABLE 8

Aluminium (wt%)	Silicon (wt%)	Grain Size (µm)	Uniform Elongation (%)	Total Elongation (%)
0.01	0.03	5.6	13.7	29.8
0.01	0.08	10.8	12.2	21.0
0.03	-	7.9	11.3	16.6
0.045	-	7.3	12.4	21.2
0.06	-	7.4	11.7	15.5
0.5	-	47.6	4.7	6.4

15 As can be seen from Table 8, aluminium and silicon were found to have a deleterious effect on the grain size and ductility of the alloy. Without wishing to be bound by theory, it is understood that the deleterious
 20 effect caused by aluminium and silicon is due to both aluminium and silicon readily forming Mg-Al-La and Mn-Si-La particles respectively, which are at least partially responsible for the increase in grain size because some of the lanthanum content is used up in these particles.

25 It has been found that an additional benefit of a

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strontium addition to the alloy is that it suppresses the detrimental effect of aluminium. By way of example, an alloy containing (by weight) 1.0% manganese, 0.2% lanthanum, 0.5% aluminium, 0.04% strontium, with the balance magnesium except for incidental impurities was prepared and extruded at 375°C and 15mm/s. This alloy was found to have a grain size of 7.4µm, a uniform elongation of 12.1% and a total elongation of 19.6%. This compares favourably to the alloy containing 0.5% aluminium and 0% strontium, the properties for which are set out in Table 8 above.

In the claims which follow and in the preceding description of the invention, except where the context requires otherwise due to express language or necessary implication, the word "comprise" or variations such as "comprises" or "comprising" is used in an inclusive sense, ie. to specify the presence of the stated features but not to preclude the presence or addition of further features in various embodiments of the invention.

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CLAIMS

1. A magnesium-based alloy consisting of, by weight:
0.5 to 1.5% manganese,
5 0.05 to 0.5% rare earth of which more than 70% is
lanthanum,
0 to 1.5% zinc and
0 to 0.1% strontium,
the balance being magnesium except for incidental
10 impurities.
2. A magnesium based alloy as claimed in claim 1,
wherein more than 80% of the rare earth content is
lanthanum.
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3. A magnesium based alloy as claimed in claim 1,
wherein more than 90% of the rare earth content is
lanthanum.
- 20 4. A magnesium based alloy as claimed in claim 1,
wherein 100% of the rare earth content is lanthanum, less
any incidental impurities.
5. A magnesium based alloy as claimed in any one of
25 the preceding claims, wherein the alloy consists of 0.1 -
0.3% rare earth.
6. A magnesium based alloy as claimed in any one of
the preceding claims, wherein the alloy consists of
30 greater than 0.25% rare earth.
7. A magnesium based alloy as claimed in any one of
the preceding claims, wherein the lanthanum content of the
alloy is at least 0.09%.
- 35 8. A magnesium based alloy as claimed in any one of
the preceding claims, wherein the lanthanum content of the

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alloy is 0.1 - 0.3%.

9. A magnesium based alloy as claimed in any one of the preceding claims, wherein the lanthanum content of the alloy is greater than 0.25%.

10. A magnesium based alloy as claimed in any one of the preceding claims, wherein the manganese content is greater than 0.6% and less than 1.3%.

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11. A magnesium based alloy as claimed in any one of the preceding claims, wherein the zinc content is 0.2 to 1.3%.

15 12. A magnesium based alloy as claimed in any one of the preceding claims, wherein the strontium content is greater than 0.01%.

20 13. A magnesium based alloy as claimed in any one of the preceding claims, wherein the strontium content is approximately 0.02%.

25 14. A magnesium based alloy as claimed in any one of the preceding claims, wherein the incidental impurities comprise aluminium at no greater than 0.03% of the alloy.

15. A magnesium based alloy as claimed in any one of the preceding claims, wherein the incidental impurities comprise silicon at no greater than 0.03% of the alloy.

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16. A magnesium-based alloy consisting of, by weight:
0.5 to 1.5% manganese,
0.05 to 0.5% lanthanum,
0 to 1.5% zinc, and
0 to 0.1% strontium

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the balance being magnesium except for incidental impurities.

17. A magnesium-based alloy consisting of, by weight:
0.5 to 1.5% manganese,
0.05 to 0.5% rare earth of which more than 70% is
5 lanthanum,
0 to 1.5% zinc,
0 to 0.1% strontium,
no greater than 0.03% aluminium, and
no greater than 0.03% silicon,
10 the balance being magnesium except for incidental
impurities.

18. A wrought magnesium alloy article comprising an
amount of an alloy as claimed in any one of the preceding
15 claims, which has been worked into a shape or condition.

19. A method of manufacturing a wrought magnesium
alloy article, the method comprising the steps of:
(a) heating a casting of a magnesium-based
20 alloy at a first temperature for a first period of time,
(b) cooling the casting, and
(c) working the casting into a shape or
condition.

25 20. A method of manufacturing a wrought magnesium
alloy article, the method comprising the steps of:
(a) heating a worked casting of a magnesium-
based alloy at a first temperature for a first period of
time;
30 (b) cooling the worked casting; and
(c) re-working the casting into a shape or
condition.

21. A method as claimed in either claim 19 or 20,
35 wherein the method also comprises the step of:
(d) ageing the casting at a second temperature
for a second period of time, after step (b) and prior to

step (c).

22. A method as claimed in any one of claims 19-21, wherein the first temperature is 450°C - 650°C.

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23. A method as claimed in any one of claims 19-21, wherein the first temperature is 540°C - 580°C.

24. A method as claimed in claim 19, wherein the first period of time is 0.5 - 6 hours.

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25. A method as claimed in claim 20, wherein the first period of time is 6 - 20 hours.

26. A method as claimed in claim 21, wherein, the second temperature is 300°C - 400°C.

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27. A method as claimed in either claim 21 or 26, wherein the second period of time is 2 - 24 hours.

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28. A method as claimed in any one of claims 19-27, wherein the magnesium-based alloy is any magnesium-based alloy which is amenable to precipitation.

29. A method as claimed in any one of claims 19-27, wherein the magnesium-based alloy is the alloy as claimed in any one of claims 1-17.

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30. A method as claimed in any one of claims 19-27, wherein the magnesium-based alloy consists of, by weight:

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0.5 to 1.5% manganese,
0.05 to 0.5% rare earths,
0 to 1.5% zinc, and
0 to 0.1% strontium

35

the balance being magnesium except for incidental impurities.

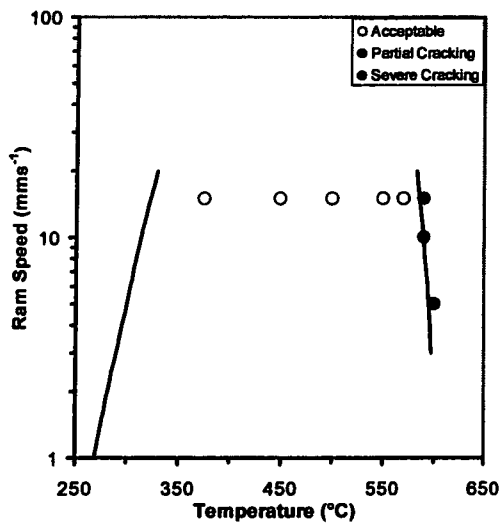


(A) Alloy A

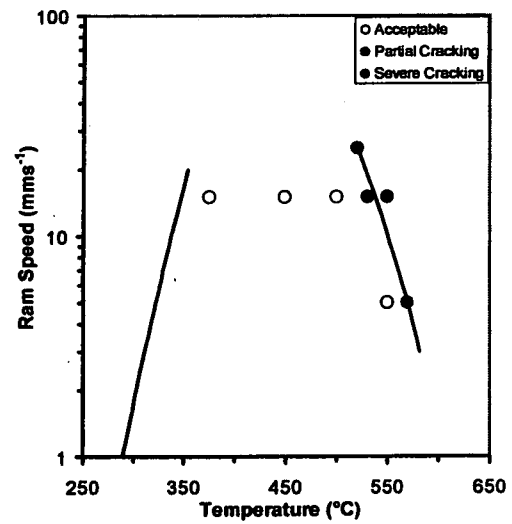


(B) Alloy B

Figure 1



(A) Alloy A



(B) Alloy B

Figure 2

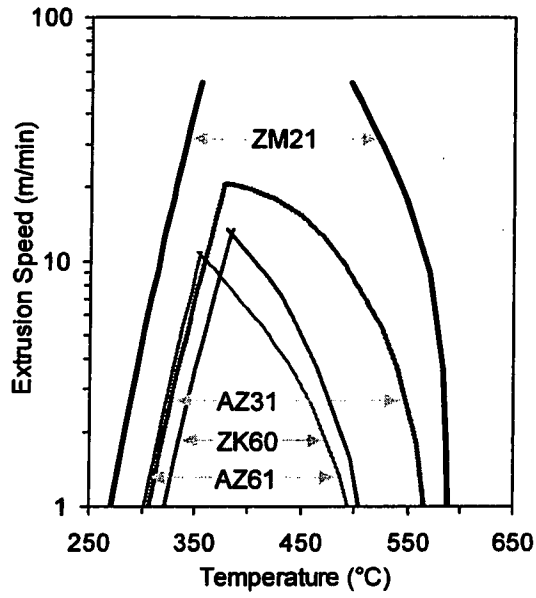


Figure 3

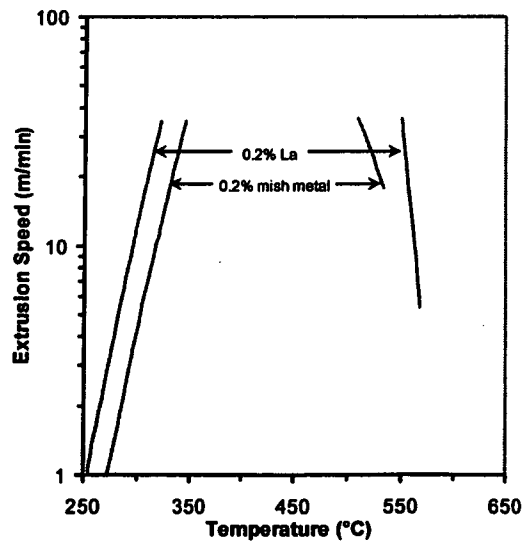


Figure 4



Figure 5

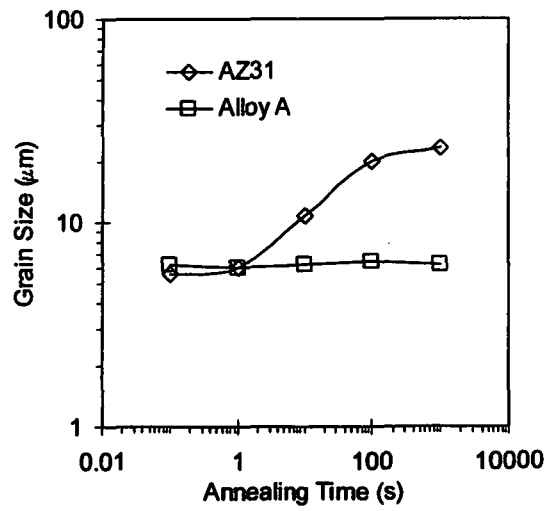


Figure 6

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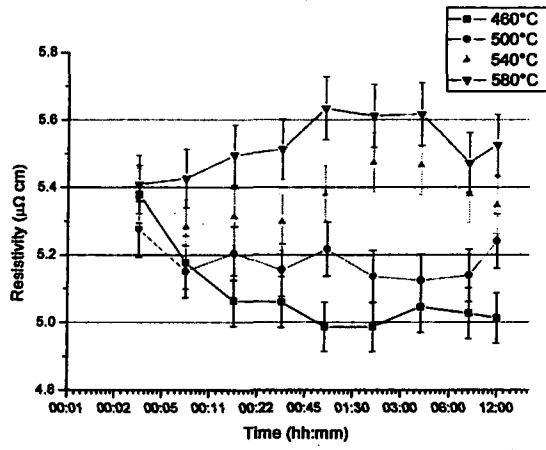


Figure 7

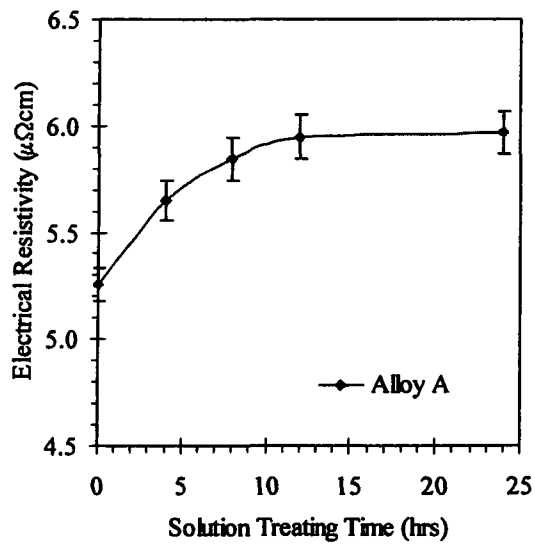


Figure 8

INTERNATIONAL SEARCH REPORT

International application No.

PCT/AU2008/001285

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl. C22C 23/00 (2006.01) C22C 23/04 (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPOQUE ALLOYS - BASE (MG or Magnesium), NVAL (MnL \leq 1.5, MnH \geq 0.5; REL \leq 0.5, REH \geq 0.05); EPODOC & WPI - IPC C22B23/-, B22D and keywords (solut+, aging, age+)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2270190 A (MCDONALD) 13 January 1942 See column 1 line 28 to column 2 line 26, column 3 lines 1-18	1-10, 14-21, 28-30
X	US 3157496 A (FOERSTER) 17 November 1964 See column 1 lines 11-55, column 3 lines 44-75	1-11, 14-20, 22, 24, 28-30
X	American Society for Metals, <i>Metals Handbook: v. 4 'Heat Treatment'</i> (9 th Ed: 1981) ISBN 0-87170-010-7, pages 744-754 See page 747	19-25, 27, 28
X	GB 1463609 A (MAGNESIUM ELEKTRON LIMITED) 2 February 1977 See page 2 lines 53-65, page 3	19-28

 Further documents are listed in the continuation of Box C See patent family annex

* Special categories of cited documents:		
"A" document defining the general state of the art which is not considered to be of particular relevance	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention	
"E" earlier application or patent but published on or after the international filing date	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone	
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art	
"O" document referring to an oral disclosure, use, exhibition or other means	"&" document member of the same patent family	
"P" document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search
22 October 2008Date of mailing of the international search report
04 NOV 2008Name and mailing address of the ISA/AU
AUSTRALIAN PATENT OFFICE
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INTERNATIONAL SEARCH REPORT

International application No.

PCT/AU2008/001285

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	GB 858200 A (MAGNESIUM ELEKTRON LIMITED) 11 January 1961 See column 2 lines 68-83	19, 22-24 and 28

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a)

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. Claims 1-18
A magnesium alloy consisting of manganese, rare earth metal, zinc and strontium in specific ranges;
 2. Claims 19-30
A method of producing a wrought magnesium product by heat treating and working;
as reasoned on the extra sheet.
1. As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
 2. As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
 3. As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

 4. No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- No protest accompanied the payment of additional search fees.

Supplemental Box

(To be used when the space in any of Boxes I to IV is not sufficient)

Continuation of Box No: III

This International Application does not comply with the requirements of unity of invention because it does not relate to one invention or to a group of inventions so linked as to form a single general inventive concept.

In assessing whether there is more than one invention claimed, I have given consideration to those features which can be considered to potentially distinguish the claimed combination of features from the prior art. Where different claims have different distinguishing features they define different inventions.

This International Searching Authority has found that there are different inventions as follows:

- Claims 1-18 are directed to a magnesium alloy consisting of: 0.5-1.5wt% manganese, 0.05-0.5wt% rare earth metal, 0-1.5wt% zinc and 0-0.1wt% strontium. It is considered that the defined composition of the magnesium alloy comprises a first distinguishing feature.
- Claims 19-30 are directed to a method of manufacturing a wrought magnesium alloy article, the method comprising the steps of: (a) heating a casting of a magnesium based alloy at a first temperature for a first period of time, (b) cooling the casting, and (c) working the casting into a shape or condition. It is considered that a method of manufacturing a wrought magnesium alloy article comprising steps (a), (b) and (c) comprises a second distinguishing feature.

PCT Rule 13.2, first sentence, states that unity of invention is only fulfilled when there is a technical relationship among the claimed inventions involving one or more of the same or corresponding special technical features. PCT Rule 13.2, second sentence, defines a special technical feature as a feature which makes a contribution over the prior art.

The only feature common to all of the claims is a magnesium alloy. However this common feature is generic in the art. This means that the common feature can not constitute a special technical feature within the meaning of PCT Rule 13.2, second sentence, since it makes no contribution over the prior art.

Because the common feature does not satisfy the requirement for being a special technical feature it follows that it cannot provide the necessary technical relationship between the identified inventions. Therefore the claims do not satisfy the requirement of unity of invention *a posteriori*.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/AU2008/001285

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report	Patent Family Member
US 2270190	NONE
US 3157496	NONE
GB 1463609	NONE
GB 858200	NONE

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.

END OF ANNEX