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HIGH STRENGTH MAGNESIUM-LITHIUM BASE ALLOYS

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The invention described herein may be manufactured and used by or for the Government for governmental purposes without the payment to me of any royalty thereon.

This invention relates to magnesium-lithium base alloys and more particularly concerns such alloys modified by and incorporating therewithin minor additions of other metals for improving the mechanical and stability properties of the alloy.

Magnesium alloys are being extensively employed in the various structural and mechanical arts and appear promising as light weight materials for rocket and missile applications. Their use in such structural forms, however, which are subjected to elevated temperatures, has not developed to any marked degree due to the fact that magnesium alloys, in general, rapidly lose their strength properties and ability to withstand plastic deformation at elevated temperatures to the extent that they are generally unsuitable for such uses.

It is accordingly the principal object of the invention to provide a magnesium-lithium base alloy having improved mechanical and stability properties in the as cast and heat-treated conditions.

Other objects and advantages of the invention will be apparent as the description of the invention proceeds.

I have found that alloys containing magnesium and lithium and suitably determined percentages of several or all of the four elements, aluminum, zinc, silver and silicon, in varying combinations and proportions, are particularly favorable in the achievement of the aforementioned objects.

According to the present invention, alloys of the kind referred to contain about 10.3 to 15 weight precent lithium and between 0.5 to 5.75 weight percent of the aforementioned additive metals, the remainder being substantially all magnesium. The phrase "substantially all magnesium" is intended to indicate a high purity magnesium with trace amounts of customary impurities, the sodium content being extremely low. The other additive elements comprising my useful alloys are similarly of high purity, the total sodium content contained within the resultant alloy falling below about 0.02 weight percent.

In a preferred embodiment of my invention, the weight percent composition is as follows: 1.0 to 1.5 aluminum, 1.0 to 1.5 zinc, 1 to 3 silver, 0.1 to 2.0 silicon, 10.5 to 15 lithium, remainder substantially all magnesium.

This alloy, when, by way of example, tested in the as cast condition, shows excellent ultimate tensile strength with a good refined grain size. When heat treated at 800° F. for 4 hours, water quenched, aged at 225° F. for 6 hours and then held at 165° F. for 80 days, the alloy exhibited excellent stability properties.

In the following tabulations, some more examples of alloys according to my invention are given, it being understood that for all alloys in the tabulations, the remainder is substantially all magnesium as defined above.

Table I

Alloy No.	Alloy Composition, Weight Percent					As Cast		Heat Treated at 800° F., 4 hrs.; Water Quenched; Aged 2 hrs., 225° F.		Heat Treated at 800° F., 4 hrs.; Water Quenched; Aged 6 hrs., 225° F.		Heat Treated at 800° F., 4 hrs.; Water Quenched; Aged 6 hrs., 225° F.		Heat Treated at 800° F., 4 hrs.; Water Quenched; Aged 24 hrs., 225° F.	
	Li	Al	Ag	Zn	Si	Ultimate Tensile Strength, p.s.i.	Elongation in 2", Percent	Uts	Elongation in 2", Percent	Uts	Elongation in 2", Percent	Uts	Elongation in 2", Percent	Uts	Elongation in 2", Percent
1	14.0					15,000	30.0	Generally stable							
2	14.0				0.5	19,750	23.0	Generally stable							
3	14.0	1.0		1.0	0.5	36,400	1.0	30,000	6.0	30,000	7.0	27,000	12.0		
4	14.0	1.0	3.0	1.0		26,300	nil	33,000	3.0	27,900	8.0	27,900	7.0	22,000	12.0
5	14.0	1.3	3.1	1.0	0.5	36,700	0.5	40,000	0.5	42,450	1.0	32,000	11.0	28,600	12.0
6	14.0	1.0	3.0	1.0	1.5	35,000	1.0	33,100	1.0	34,100	2.0	34,800	3.0	28,200	8.0

Table II

[Heat Treated at 800° F., 4 Hours; Water Quenched; Aged at 225° F. for 6 Hours]

Alloy No.	Alloy Composition, Weight Percent					Time at 165° F.									
						0 Days		5 Days		14 Days		30 Days		80 Days	
	Li	Al	Ag	Zn	Si	Uts	Elong. in 2", Percent	Uts	Elong. in 2", Percent	Uts	Elong. in 2", Percent	Uts	Elong. in 2", Percent	Uts	Elong. in 2", Percent
5	14.0	1.0	3.0	1.0	0.5	32,000	11.0	27,500	9.0	26,700	13.0	26,200	21.0	26,000	21.0
6	14.0	1.0	3.0	1.0	1.5	34,800	3.0	29,200	7.0	27,000	9.0	27,500	8.0	27,000	10.0

Table III

[As Cast; Time at 225° F.]

Alloy No.	Alloy Composition, Weight Percent		0 Days		5 Days		14 Days		30 Days		80 Days	
	Li	Si	Uts	Elong. in 2", percent	Uts	Elong. in 2", percent	Uts	Elong. in 2", percent	Uts	Elong. in 2", percent	Uts	Elong. in 2", percent
1	14.0	----------	15,090	30.0	14,520	32.0	14,690	32.0	14,500	35.0	14,500	35.0
2	14.0	0.5	19,750	23.0	19,500	23.0	19,900	25.0	19,760	26.0	19,900	28.0

In Table I, Alloy No. 5, when heat treated at 800° F. for 4 hours, water quenched, and aged at 225° F. for 24 hours, yielded an ultimate tensile strength value of 28,600 p.s.i. with 12% elongation in 2 inches as compared to the less stable Alloy Nos. 1 and 2 which contained no silver or silicon. Alloy No. 4, identical with Alloy No. 5, but having no silicon content, produced a slightly more ductile material only when heat treated at 800° F. for 4 hours, water quenched and aged at 225° F. for 2 and 4 hours. Its tensile strength was lower in all cases than when silicon was employed. In each of the alloys tested, silicon additions were made to the molten alloy in the form of high purity silicon metal or as a master alloy of aluminum.

Table I shows the outstandingly superior stability properties of my alloys. For example, Alloy No. 5, when heat treated at 800° F. for 4 hours, water quenched, and aged at 225° F. for 6 hours, and then maintained at 165° F. for 80 days, still yielded an ultimate tensile strength of 26,000 p.s.i. and an elongation in 2 inches of 21%. Similarly, Alloy No. 6 yielded an ultimate tensile strength of 27,000 p.s.i. and an elongation in 2 inches of 10%. Alloy No. 1, consisting only of magnesium and lithium possesses an ultimate tensile strength of about 15,000 p.s.i., and remains generally stable even after the aforementioned 80 day test.

Alloy No. 1 is considerably improved by the addition of 0.5% silicon, as evidenced by Alloy No. 2 in Table III. When these alloys were held at 225° F. for 80 days, Alloy No. 2, consisting of Mg—Li—Si, showed an increase of 37% in ultimate tensile strength over the Mg—Li alloy and a decrease of 25% in elongation in 2 inches.

It is apparent from the foregoing description that I have provided new and useful magnesium-lithium base alloys having high ultimate tensile strength values even after subjection to elevated temperatures for very prolonged periods. And even though my alloys are accompanied by some brittleness, it is not enough to prevent their being employed for many useful purposes.

I claim:

1. A magnesium base alloy consisting essentially of aluminum, zinc, silver, silicon, lithium and magnesium, aluminum being present in the amount from 1.0 to 1.5 percent, zinc being present in the amount from 1.0 to 1.5 percent, silver being present in the amount from 1.0 to 3.0 percent, silicon being present in the amount from 0.1 to 2.0 percent, lithium being present in the amount from 10.5 to 15.0 percent, and the balance essentially all magnesium.

2. A magnesium base alloy characterized by having an ultimate tensile strength of at least 28,000 p.s.i. and an elongation of about 12% in 2 inches after being heat treated at 800° F. for 4 hours, water quenched and aged at 225° F. for 24 hours and consisting essentially of about 1.0% aluminum, about 3.0% silver, about 1.0% zinc, about 0.5% silicon, about 14.0% lithium and the balance magnesium.

3. A magnesium base alloy characterized by having an ultimate tensile strength of at least 42,400 p.s.i. and an elongation of about 1% in 2 inches after being heat treated at 800° F. for 4 hours, water quenched and aged at 225° F. for 6 hours and consisting essentially of about 1.0% aluminum, about 3.0% silver, about 1.0% zinc, about 0.5% silicon, about 14.0% lithium and the balance magnesium.

4. A magnesium base alloy characterized by having an ultimate tensile strength of at least about 26,000 p.s.i. and an elongation of about 21% in 2 inches after being heat treated at 800° F. for 4 hours, water quenched, aged at 225° F. for 6 hours and held at 165° F. for 80 days and consisting essentially of about 1.0% aluminum, about 3.0% silver, about 1.0% zinc, about 0.5% silicon, about 14.0% lithium and the balance magnesium.

5. A magnesium base alloy characterized by having an ultimate tensile strength of at least about 27,000 p.s.i. and an elongation of about 12% in 2 inches after being heat treated at 800° F. for 4 hours, water quenched and aged at 225° F. for 6 hours and consisting essentially of about 1.0% aluminum, 1.0% zinc, 0.5% silicon, 14.0% lithium and the balance being magnesium.

6. A magnesium base alloy characterized by having an ultimate tensile strength of about 19,900 p.s.i. and an elongation of about 28% in 2 inches when the as cast alloy is held at 225° F. for 80 days and consisting essentially of about 14.0% lithium, 0.5% silicon and the balance being magnesium.

7. A magnesium base alloy characterized by having an ultimate tensile strength of about 28,600 p.s.i and an elongation of about 12% in 2 inches after being heat treated at 800° F. for 4 hours, water quenched and aged at 225° F. for 24 hours and consisting essentially of about 14.0% lithium, 1.0% aluminum, 3.0% silver, 1.0% zinc, 1.5% silicon and the balance being magnesium.

8. A magnesium base alloy characterized by having an ultimate tensile strength of about 22,000 p.s.i. and an elongation of about 12% in 2 inches after being heat treated at 800° F. for 4 hours, water-quenched, aged at 225° F. for 24 hours and consisting essentially of about 14.0% lithium, 1.0% aluminum, 3.0% silver, 1.0% zinc, and the balance being magnesium.

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