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MAGNESIUM-BASE ALLOY

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The invention relates to a novel magnesium-base alloy and to the method of making high quality extrusions therefrom. The invention more particularly relates to magnesium-base alloys containing lithium and at least one of the metals tin and lead.

Magnesium-lithium alloys have been considered of interest heretofore because the crystal structure of magnesium is changed from hexagonal to cubic when about 12 or more percent of lithium is added to magnesium. The cubic magnesium-lithium alloys can be markedly strengthened by age hardening, but overaging occurs at room temperature and the high strength cannot be retained.

Prior investigations of the magnesium-lithium alloys containing less than about 5 percent of lithium and exhibiting a hexagonal crystal structure have failed to uncover high strength alloys.

It has now been found that additions of lead or tin or a binary mixture of lead and tin to magnesium containing lithium in a critical range of proportions produces alloys which are markedly improved on aging and which, consequently, exhibit unusually high strength values. These alloys may be cast, rolled or extruded. The alloys offer special advantages where extruded metal is desired since the extrusion process can be carried out at speeds of at least 100 feet per minute. The extruded product readily exhibits a tensile yield strength of at least 45,000 pounds per square inch and a compression yield strength of at least 30,000 pounds per square inch.

For the purpose of the present invention, the term magnesium-base alloy refers to an alloy consisting of at least 70 percent by weight of magnesium.

In its broader aspects, the alloy of the invention contains lithium in the range of 0.05 to 4 percent by weight. To the basic magnesium-lithium alloy there is added from 0.5 to 20 percent by weight of tin or from 1 to 30 percent by weight of lead or from 0.5 to 30 percent by weight of a binary mixture of tin and lead. In more preferred ranges of compositions, the alloy contains from 0.5 to 2 percent by weight of lithium and from 3 to 10 percent by weight of tin or from 5 to 15 percent of lead or from 3 to 15 percent by weight of a binary mixture of tin and lead.

The alloy containing, by weight, from 0.5 to 2 percent of lithium and from 3 to 10 percent of tin or 5 to 15 percent of lead may be further improved or modified by the addition of other elements such as up to 4 percent of aluminum, up to 2 percent of manganese, up to 3 percent of zinc and up to 0.2 percent of zirconium. These additions are generally made to improve mechanical properties and may be made severally, or plurally in any combination. The addition of manganese tends also to improve the corrosion resistance of the alloy. Additions of aluminum and manganese are often made concurrently to the same alloy. More preferred ranges of additions are: up to 2 percent of aluminum, up to 1.5 percent of manganese, up to 1.5 percent of zinc, and up to 0.1 percent of zirconium.

It is to be noted that while tin and lead both improve the properties of the basic magnesium-lithium alloy and both additions produce a metal which is quite advantageously extruded, the alloys containing tin and the alloys containing lead are different in some respects and are not

equivalents. The alloys containing lead exhibit reasonably good resistance to salt water, which is surprising on considering the wide spread in solution potential between lead and magnesium. The corrosion resistance of the tin alloys is better than the lead alloys. To attain maximum strength, the alloy containing tin must be rapidly cooled as by water quenching the metal immediately after subjecting the metal to a wrought operation such as extrusion. The alloys containing lead show high strength even without water quenching.

The alloy may be made in the desired proportions according to the invention by melting together the alloying ingredients in proper proportions or by using hardeners of magnesium alloys containing the alloying constituents. Protection from oxidation during alloying is effected by the use of a saline flux, as in conventional alloying of magnesium. The molten alloy may be flux defined, if desired, by stirring the alloy with additional flux. The so-refined metal is allowed to settle and then is separated from the flux as by decanting into a suitable casting mold, e.g., a round mold for extrusion stock.

In preparing cast products, the metal is cast in a conventional manner as into a sand mold.

In preparing the metal in sheet form, the metal is generally cast in rolling slabs or ingots. Generally, the rolling slab or ingot is scalped before being heated and passed through the rolls of a mill, thereby to reduce the thickness of the ingot and roll the metal into sheet form.

In preparing extruded material, it is desirable first to scalp the cast extrusion stock so as to present a smooh, clean surface to the extrusion die. The clean extrusion stock is heated to a suitable temperature, e.g., about 600 to 800° F., inserted in the container of an extrusion press and die expressed. The present alloy may be advantageously extruded at speeds of at least 50 feet per minute and may even be expressed at speeds of 100 feet per minute or more, substantially without reduction in mechanical strength properties. According to the method of the invention, the present alloys containing tin are advantageously water quenched as the extrusion emerges from the die. The extruded metal, with or without water quenching, is then essentially subjected to an aging step. Aging is carried out by heating the metal at a temperature of about 300 to 350° F. for the requisite period of time, e.g., 24 hours, for a substantial amount of precipitation hardening to take place.

The following examples of the compositions and method of the invention serve to illustrate the invention and are not to be considered limitative thereof.

Melts of compositions according to the invention as well as alloys used for comparison were prepared by melting together, under saline flux, magnesium and the individual metallic constituents. The melts were flux refined and settled in a conventional fashion and cast into 3-inch diameter extrusion billets. The billets were scalped, preheated to about 650° F., inserted in the 3-inch diameter container of an extrusion press which had been preheated to about 600 to 650° F. The metal was pushed into 1/16-inch by 7/8-inch strip at a rate of 100 feet per minute. Part of each push was water quenched. Samples of quenched and unquenched extruded metal were aged at 350° F. for 24 hours and then subjected to physical testing along with samples of the extrusion which had not been aged. The test results and the compositions prepared and the processing conditions are indicated in the following tables.

In Table I there is illustrated the beneficial effect of adding various amounts of lithium to a magnesium-base alloy containing 5 percent of tin. Note also the beneficial consequences of aging and of water quenching. In Table II

there is illustrated the improvement in properties on adding various amounts of tin to a magnesium-lithium alloy containing 1.5 percent of lithium. In Table III there is illustrated the high level of strengths obtained on making additions of aluminum, manganese, zinc, or, aluminum and manganese to a magnesium-lithium-tin alloy. In Table IV there is illustrated the property levels obtained on adding various amounts of lithium, including amounts greater than 4 percent, to a magnesium alloy containing 9 percent of lead. In Table V there is illustrated the increased strength properties exhibited on adding increasing amounts of lead to a magnesium-lithium alloy containing 1.5 percent of lithium. In Table VI there is illustrated the effect of adding zirconium or zirconium and zinc to magnesium-lithium-lead alloy.

The composition and method of the invention having been thus described, various modifications thereof will at once be apparent to those skilled in the art and the scope of the invention is to be considered limited only by the scope of the claims hereafter appended.

TABLE I

Test No.	Composition, percent by Weight *		Temper and Mechanical Properties											
			Q-F				Q-T5				NQ-T5			
	Sn	Li	Percent E	TYS	CYS	TS	Percent E	TYS	CYS	TS	Percent E	TYS	CYS	TS
1-C	5		10	23	12	37	10	23	12	37				
2	5	0.3	6	27	15	39	7	34	18	44	8	30	16	40
3	5	0.8	3	26	18	33	3	50	27	53	4	41	22	46
4	5	1.6	4	22	18	31	2	47	28	50	4	38	22	41
5	5	3.7	9	17	18	26	4	27	23	33	8	16	16	25
6-C	5	6.9	14	20	23	26	12	20	22	26	12	17	18	25

* Balance magnesium.
C=Comparison test.
Percent E=Percent elongation.
TYS=Tensile yield strength in 1,000's of pounds per square inch.
CYS=Compression yield strength in 1,000's of pounds per square inch.
TS=Ultimate tensile yield strength in 1,000's of pounds per square inch.
Q-F=Water quenched on emerging from die, no subsequent heat treatment.
Q-T5=Water quenched on emerging from die, then aged at 350° F. for 24 hours.
NQ-T5=Not quenched, extruded strip aged at 350° F. for 24 hours.

TABLE II

Test No.	Composition, percent by Weight *		Temper and Mechanical Properties											
			Q-F				Q-T5				NQ-T5			
	Sn	Li	Percent E	TYS	CYS	TS	Percent E	TYS	CYS	TS	Percent E	TYS	CYS	TS
7	1.5	1.5	3	17	14	25	4	35	18	38	6	31	17	34
8	3	1.5	4	21	15	29	2	41	22	43	6	31	18	36
9	5	1.5	4	22	18	31	2	47	28	50	4	38	22	41
10	7	1.5	6	25	21	33	2	44	29	48	5	32	20	36
11	9	1.5	5	27	24	36	1	45	32	45	2	36	26	41
12	11	1.5	2	31	25	37			34	30	4	37	25	46
13	14	1.5	4	30	27	39	2	49	35	55	4	38	28	45

* Balance magnesium.

TABLE III

Test No.	Composition Percent by Weight *					Temper and Mechanical Properties											
						Q-F				Q-T5				NQ-T5			
	Sn	Li	Al	Mn	Zn	Percent E	TYS	CYS	TS	Percent E	TYS	CYS	TS	Percent E	TYS	CYS	TS
14	7	1	1			11	26	21	36	1	53	32	57	6	42	26	47
15	7	1		1		5	27	21	36	2	55	33	57	4	46	28	50
16	7	1	1	1		6	27	21	38	1	54	33	56	1	48	28	50
17	7	1	2	1		8	27	23	40	2	57	35	61	3	49	31	51
18	7	1			1	11	23	22	38	2	52	33	56	4	45	28	51

* Balance magnesium.

TABLE IV

Test No.	Composition Percent by Weight *		Temper and Mechanical Properties											
			Q-F				Q-T5				NQ-T5			
	Li	Pb	Percent E	TYS	CYS	TS	Percent E	TYS	CYS	TS	Percent E	TYS	CYS	TS
19	0.4	9	12	28	18	38	8	45	22	48	5	46	20	49
20	0.8	9	6	22	19	35	3	50	27	54	3	51	26	53
21	1.7	9	6	21	18	31	2	46	24	48	2	44	22	46
22	3.8	9	10	15	17	27	4	29	22	35	4	26	20	33
23-C	7.5	9	14	19	22	26	10	22	24	28	11	17	20	25
24-C	11.7	9	20	12	13	18	19	12	13	18	18	12	14	18

* Balance magnesium. C=Comparison test.

TABLE V

Test No.	Composition Percent by Weight *		Temper and Mechanical Properties											
			Q-F				Q-T5				NQ-T5			
	Li	Pb	Percent E	TYS	CYS	TS	Percent E	TYS	CYS	TS	Percent E	TYS	CYS	TS
25	1.5	1.5	4	12	11	24	4	35	16	37	2	34	14	36
26	1.5	3	4	17	13	25	2	39	18	41	2	38	17	41
27	1.5	6	4	20	17	28	1	44	23	45	2	42	21	44
28	1.5	9	6	21	18	31	2	46	24	48	2	44	22	46
29	1.5	12	5	20	20	32	1	49	28	50	1	48	26	49
30	1.5	15	8	22	24	35	----	----	32	54	----	----	28	46
31	1.5	20	10	25	27	38	2	55	33	59	----	----	31	51

* Balance magnesium.

TABLE VI

Test No.	Composition, Percent by Weight*				Temper and Mechanical Properties											
					Q-F				Q-T5				NQ-T5			
	Li	Pb	Zr	Zn	Percent E	TYS	CYS	TS	Percent E	TYS	CYS	TS	Percent E	TYS	CYS	TS
32	1	9	Trace	----	8	24	19	35	----	53	27	53	----	----	26	50
33	1	9	Trace	1	14	24	23	38	1	55	30	57	1	54	29	56
34	1	9	Trace	2	8	25	26	40	----	----	31	51	1	53	30	54

* Balance magnesium. Trace=0.08 to 0.1 percent of zirconium, as determined spectrographically.

I claim:

1. An extruded magnesium base alloy having a tensile yield strength of at least 45,000 pounds per square inch and a compression yield strength of at least 30,000 pounds per square inch which consists essentially of by weight from 0.5 to 2 percent of lithium, an alloying addition selected from the group consisting of 3 to 10 percent of tin, 5 to 15 percent of lead and from 3 to 15 percent of a binary mixture of tin and lead, and the balance substantially magnesium.

2. The alloy as in claim 1 which contains, in addition, up to 4 percent of aluminum, up to 2 percent of manganese, up to 3 percent of zinc, and up to 0.2 percent of zirconium.

3. The magnesium-base alloy as in claim 1 which contains, by weight, from 3 to 10 percent of tin, up to 2 percent of aluminum, up to 1.5 percent of manganese, and up to 1.5 percent of zinc.

4. The magnesium-base alloy as in claim 1 which contains, by weight, from 5 to 15 percent of lead, up to 2 percent of aluminum, up to about 0.1 percent of zirconium, and up to about 1.5 percent of zinc.

References Cited

UNITED STATES PATENTS

1,975,120	10/1934	Paine	75—168
1,998,169	4/1935	Paine	75—168
3,119,689	1/1964	Saia	75—168
3,147,156	9/1964	Foerster	75—168

FOREIGN PATENTS

987,195	4/1951	France.
165,188	10/1958	Sweden.

OTHER REFERENCES

A.P.C. Application of Aurthur Burkhardt et al., Ser. No. 303,611, published May 1943, abandoned.

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