Nov. 17, 1953 T. E. LEONTIS ET AL 2,659,133

COMPOSITE ALLOY

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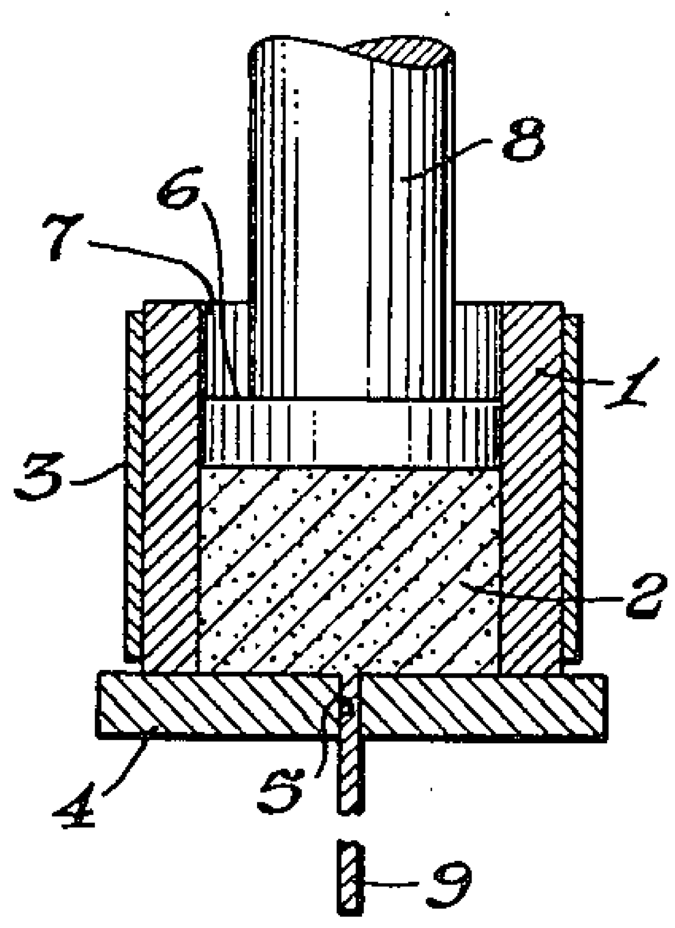


Fig. 1

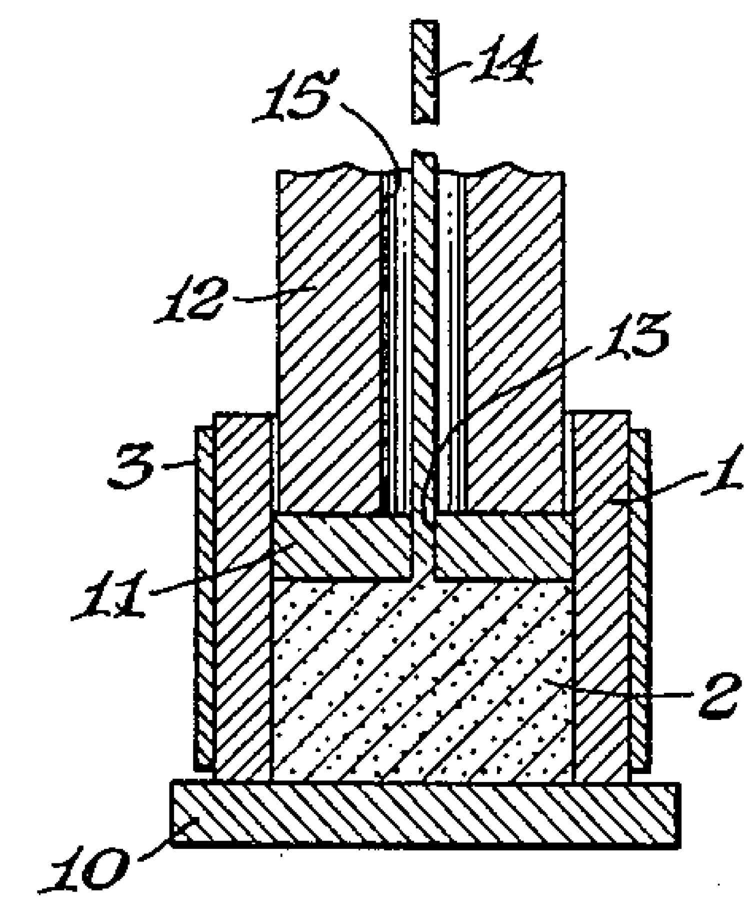


Fig. 2

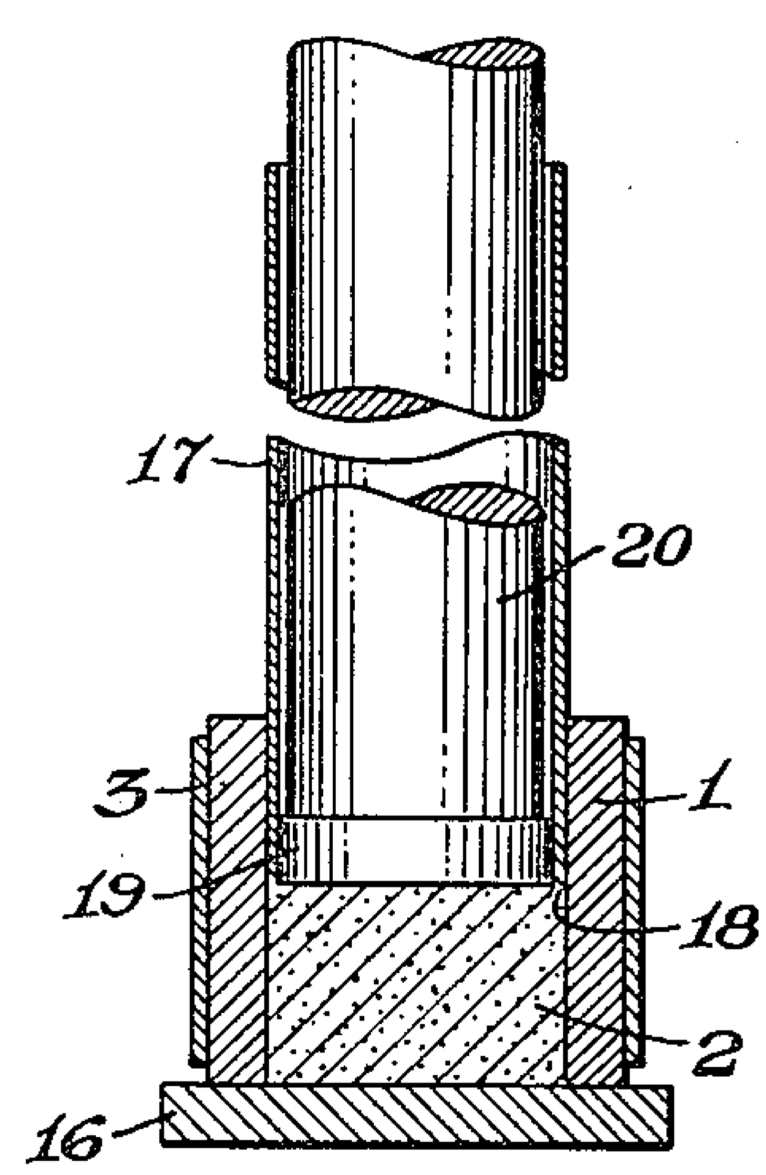


Fig. 3

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## COMPOSITE ALLOY

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7 Claims. (Cl. 29—182.2)

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The invention relates to a composite metal body of which magnesium is the predominant constituent. It more particularly concerns an improved magnesium-base alloy product containing magnesium with which aluminum is alloyed.

The term "magnesium-base alloy" used herein means a magnesium alloy containing at least 80 per cent of magnesium by weight.

The common magnesium-base alloys used for structural purposes owe their strength at least in part to the aluminum with which they are alloyed. In addition to aluminum, these alloys usually also contain either or both zinc and manganese and sometimes also calcium. Although the aluminum-containing magnesium-base alloys are among the strongest of the magnesium-base alloys, nevertheless there is an ever present desideratum in the art to provide still stronger magnesium-base alloys.

According to the present invention, composite magnesium-base alloys containing aluminum are formed by extruding an aluminum-containing magnesium-base alloy in particulated form in admixture with an additional amount of particulated aluminum. The mixture of particulated metals thus extruded may also contain other particulated magnesium-soluble metals, such as silver, cerium, manganese, lead, tin, and zinc in amount up to 1 per cent by weight. The extrusion obtained is a composite alloy having the same compactness and integrity as the usual magnesium-base alloy extrusions made by extruding a solid mass, such as an ingot of a magnesium-base alloy and can be worked, as by rolling, forging, pressing, drawing, etc., like conventional magnesium-base alloys, but the metallographic structure of the composite alloy is uniquely different. Metallographic examination reveals a new type of structure in a magnesium-base alloy article. The structure is essentially multimetallic. Each of the two particulate metals of the mixture which is extruded is changed to the form of elongated fine particles with the long axis parallel to that of the extrusion and these elongated particles are interspersed and welded one to the other without voids forming a solid composite mass. There is diffusion of some of the particulated aluminum ingredient into the particulated aluminum-containing magnesium-base alloy; and there is some diffusion of magnesium from the particulated aluminum-containing magnesium-base alloy into the particulated aluminum. When manganese is

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present in the particulated aluminum-containing magnesium-base alloy more or less may be precipitated by the diffused aluminum. The composite alloy obtained may be subjected to the same types of metal working operations as employed with conventional magnesium-base alloys, e. g. rolling, welding, forging, heat treatment, chemical finishing, electroplating, etc. The mechanical properties of the composite alloy generally surpass those of the conventional aluminum-containing magnesium-base alloy. A particular advantage of the composite alloy is its ability to resist loss of strength when worked in heated condition.

In carrying out the invention, the aluminum content of the aluminum-containing magnesium-base alloy is not sharply critical. Amounts as low as 0.1 per cent and as high as 12 per cent may be used. Generally desirable results are had with from about 3 to 6 per cent of aluminum particularly when the alloy also contains zinc. The amount of zinc, if present in the aluminum-containing magnesium-base alloy, may be from about 0.5 to 3 per cent. If desired, manganese in conventional amount, e. g. 0.1 to 2 per cent also may be present in the aluminum-containing magnesium-base alloy, the amount actually used being subject to its solubility limit in magnesium containing alloyed aluminum as understood in the art; also up to 0.5 per cent of calcium may be present.

The aluminum-containing magnesium-base alloy used as one of the ingredients of the composite alloy of the invention is reduced to particulate form in any suitable way, such as by grinding or atomizing. The atomized form is preferred and may be produced by forming a melt of the alloy and atomizing it by impinging a jet of a cool gas, e. g. natural gas, against a thin falling stream of the molten alloy. The atomized alloy consists of a mixture of various sized fine spherical rapidly solidified particles, the particles having a very fine grain structure. It is desirable to screen out particles coarser than those passing about a 10 to 20 mesh sieve.

The aluminum ingredient of the mixture of particulate metals to be extruded according to the invention, is elementary aluminum which has been finely divided in any convenient manner. Its particle size is preferably made finer than that of the aluminum-containing magnesium-base alloy with which it is to be mixed.

Before extrusion, the metals in particulate form are mixed together in any convenient manner to form a uniform mixture of the metal particles comprising the extrusion charge. The relative amounts of the particulated aluminum-containing magnesium-base alloy and the particulated aluminum are adjusted so that there is in the mixture at least 0.1% by weight of particulated aluminum. Beneficial results are had with up to as much as about 6% of particulated aluminum in the mixture. A preferred proportion is about 3% of the particulated aluminum in the mixture.

The mixture of particulate metals is charged into the heated container of a ram extruder, having a suitable size container and die opening and subjected to extrusion pressure to cause the mixture of particulate metals to be heated and extruded through the die opening.

As to the extrusion conditions, the temperature of the particulated mixture in the container may be about the same as that conventionally employed for extruding solid ingots of the known aluminum-containing magnesium-base alloys, e. g. from about 650° to 850° F. The ratio of the cross-sectional area of the extrusion container to that of the die opening has a material effect on the mechanical properties of the composite extrusion product obtained. A desirable ratio is at least about 30 to 1, although ratios as high as 150 to 1 or more may be used. The speed of extrusion may be varied over a wide range and depends to some extent upon the size and shape of the die opening, in any case the speed is to be held down to that at which the extrusion produced is free from hot shortness. A safe extrusion speed may be ascertained by visual examination of the product as it extrudes, the hot shortness being evident as cracks in the extruded product and sharply reduced strength.

The invention may be further illustrated and explained in connection with the accompanying drawing in which:

Fig. 1 shows a schematic sectional elevation of an extrusion apparatus suitable for use in practicing the invention;

Fig. 2 is a similar view to Fig. 1 showing a modification of the apparatus; and

Fig. 3 is a similar view to Fig. 1 showing another modification of the apparatus.

As shown, the apparatus comprises, in its three forms, an extrusion container 1 adapted to confine a charge 2 of the mixture of the particles of the metals to be coextruded. The container is provided with a heating element 3. In Fig. 1, one end of the container 1 is closed by the die plate 4 in which is provided the die opening. In this form of the apparatus, the charge 2 is caused to be compacted in the container and extruded through the die opening 5 by application of pressure by means of the dummy block 6 forced into the bore 7 of the container by the ram 8 to form the composite alloy extrusion 9.

In the form of the apparatus shown in Fig. 2, the container 1 is closed at one end by the plate 10. The other end of the container receives the die block 11 carried by the hollow ram 12 which forces the die block into the container causing the charge 2 to be compacted and to extrude through die opening 13 to form the composite alloy extrusion 14 which extends into bore 15 of the hollow ram 12.

In the modification of Fig. 3, the container 1 is closed at one end by a plate 16. The charge 2 is extruded as a tubular composite alloy extrusion 17 through the annulus 18 around the die block 19 while the block is forced into the container by the ram 20.

The forms of the apparatus shown are conventional.

By putting a charge of the mixture of the two particulate metals involved under pressure while at heat, as with the apparatus shown, the mixture of metal particles is compacted but not subjected to further mixing before extrusion. The metals in the charge as individual particles become welded together without voids and substantially without losing their original distinctive composition except at the surfaces of the union of the different kinds of particles which become extended and lengthened during extrusion. At these surfaces, some intermixing occurs, as by diffusion, between the particles of the different metals in the extrusion charge, forming composite alloy. In this diffusion, some of the aluminum ingredient of the aluminum particles diffuses into the aluminum-containing magnesium alloy particles and some of the magnesium of the aluminum-containing magnesium alloy particles diffuses into the aluminum particles. In addition, some precipitation of manganese may be induced when contained in the aluminum-containing magnesium alloy particles.

The following series of examples set forth in the table herewith are illustrative of the invention:

*Table*

| Example No. — Blank No. | Composition of extrusion charge of particulated A mixed with particulated aluminum | | | Extrusion conditions | | | Mechanical properties in 1,000's p. s. i. of extrusions* | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Weight percent A | Analysis of A | Weight percent Al | Temp., °F. | Reduction in area | Extrusion diameter, inch | ASX | | Aged | | H. T. | | H. T. A. | |
| | | | | | | | TYS | TS | TYS | TS | TYS | TS | TYS | TS |
| 1 | 99.5 | 5.6% Al, bal. Mg | 0.5 | 670 | 34:1 | 0.086 | 30 | 44 | 30 | 44 | 25 | 41 | 26 | 39 |
| 2 | 94.0 | do | 6.0 | 650 | 34:1 | 0.086 | 32 | 43 | 31 | 43 | 26 | 38 | 27 | 34 |
| 3 | 99.0 | do | 1.0 | 700 | 34:1 | 0.086 | 30 | 43 | 31 | 43 | 28 | 41 | 29 | 42 |
| Blank 1 | 100 | do | None | 700 | 34:1 | 0.086 | 28 | 42 | 30 | 44 | 26 | 41 | 26 | 42 |
| 4 | 99.9 | 2.8% Al, 1.04% Zn, 0.39% Mn, bal. Mg. | 0.1 | 665 | 34:1 | 0.086 | 39 | 45 | 37 | 47 | 27 | 41 | 26 | 42 |
| 5 | 99.5 | do | 0.5 | 665 | 34:1 | 0.086 | 38 | 45 | 38 | 45 | 24 | 39 | 23 | 39 |
| 6 | 94.0 | do | 6.0 | 665 | 34:1 | 0.086 | 40 | 45 | 38 | 41 | 29 | 37 | 32 | 37 |
| Blank 2 | 100 | do | None | 700 | 34:1 | 0.086 | 40 | 47 | 40 | 47 | 24 | 38 | 25 | 38 |
| 7 | 99.0 | 2.7% Al, 1.0% Zn, 0.4% Mn, bal. Mg. | 1.0 | 700 | 34:1 | 0.086 | 40 | 47 | 40 | 47 | 31 | 40 | 31 | 39 |
| Blank 3 | 100 | do | None | 700 | 34:1 | 0.086 | 39 | 46 | 38 | 46 | 27 | 39 | 25 | 39 |
| 8 | 98.0 | do | [1] 2 | 670 | 34:1 | 0.086 | 39 | 46 | 38 | 45 | 29 | 42 | 31 | 42 |
| 9 | 98.0 | do | [2] 2 | 670 | 34:1 | 0.086 | 38 | 46 | 38 | 46 | 30 | 41 | 30 | 42 |
| 10 | 98.0 | do | [3] 2 | 670 | 34:1 | 0.086 | 38 | 45 | 39 | 45 | 29 | 42 | 31 | 42 |
| 11 | 98.0 | do | [4] 2 | 670 | 34:1 | 0.086 | 37 | 45 | 38 | 44 | 28 | 43 | 27 | 42 |
| 12 | 98.0 | do | [5] 2 | 670 | 34:1 | 0.086 | 38 | 46 | 38 | 45 | 29 | 42 | 28 | 41 |
| 13 | 98.0 | do | [6] 2 | 670 | 34:1 | 0.086 | 39 | 48 | 38 | 45 | 28 | 41 | 30 | 40 |
| 14 | 99.9 | 0.85% Al, 0.55% Zn, 0.05% Mn, 0.09% Ca, bal. Mg. | 0.1 | 740 | 30:1 | 0.092 | 45 | 49 | 46 | 50 | 40 | 46 | 40 | 46 |
| 15 | 99.5 | do | 0.5 | 740 | 30:1 | 0.092 | 45 | 50 | 47 | 41 | 40 | 47 | 42 | 48 |

*Table*—Continued

| Example No.—Blank No. | Composition of extrusion charge of particulated A mixed with particulated aluminum | | | Extrusion conditions | | | Mechanical properties in 1,000's p. s. i. of extrusions* | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Weight percent A | Analysis of A | Weight percent Al | Temp., ° F. | Reduction in area | Extrusion diameter, inch | ASX | | Aged | | H. T. | | H. T. A. | |
| | | | | | | | TYS | TS | TYS | TS | TYS | TS | TYS | TS |
| 16 | 99.0 | 0.85% Al, 0.55% Zn, 0.05% Mn, 0.09% Ca, bal. Mg. | 1.0 | 740 | 30:1 | 0.092 | 46 | 50 | 45 | 50 | 41 | 48 | 42 | 48 |
| 17 | 97.0 | do | 3.0 | 740 | 30:1 | 0.092 | 45 | 49 | 46 | 49 | 41 | 47 | 43 | 49 |
| 18 | 94.0 | do | 6.0 | 740 | 30:1 | 0.092 | 44 | 46 | 47 | 47 | 45 | 49 | 46 | 47 |
| Blank 4 | 100 | do | None | 740 | 30:1 | 0.092 | 43 | 48 | 45 | 48 | 38 | 45 | 38 | 44 |

[1] 1% Al+1% Ag.
[2] 1% Al+1% Ce.
[3] 1% Al+1% Mn.
[4] 1% Al+1% Pb.
[5] 1% Al+1% Sn.
[6] 1% Al+1% Zn.
*ASX=as extruded.
Aged=heated 16 hours at 350° F.
H. T.=heated 1 hour at 750° F.
H. T. A.=heated 1 hour at 750° F. followed by heating for 16 hours at 350° F.
TYS=Tensile yield strength defined as the stress at which the stress strain curve deviates 0.2% from the modulus line.
TS=tensile strength.

In making the composite alloys and blanks for comparison, set forth in the said table, the particulated aluminum-containing magnesium-base alloy and the particulated elementary aluminum used comprised particles of various sizes substantially all passing a No. 20 standard sieve, although the particulated elementary aluminum was generally finer than the particulated magnesium-base alloy. The two particulated metals were mixed together in the proportions indicated and the mixture charged into the heated container of a ram extruder of the type illustrated in Fig. 1. For the blanks, individual particulated metals were extruded in similar manner. The rate of extrusion did not exceed about 5 feet per minute. It will be seen by referring to the table that in Examples 1, 2 and 3 the particulated magnesium-base alloy used to make the composite alloy contained aluminum; in Examples 4, 5, 6 and 7 the particulated magnesium-base alloy contained aluminum, zinc, and manganese; in Examples 8 to 13, inclusive, the same magnesium-base alloy was used as that in Example 7 together with 1 per cent of each of two particulated elementary (unalloyed) metals, including aluminum, as shown by the footnotes 1 to 6, inclusive. In Examples 14 to 18, inclusive, the particulated magnesium-base alloy contained zinc, in addition to aluminum, manganese, and calcium.

Among the advantages of the invention are that the metal product obtained has the characteristic lightness of conventional magnesium-base alloys but with increased strength.

We claim:

1. The method of making a solid composite article comprising an aluminum-containing magnesium-base alloy which comprises forming a mixture consisting of up to 1 per cent by weight of a particulated magnesium-soluble metal selected from the group consisting of silver, cerium, manganese, lead, tin, and zinc, from 0.1 to 12 per cent of particulated aluminum, the balance of the mixture being a particulated magnesium-base alloy containing 0.1 to 12 per cent of aluminum, up to 3 per cent of zinc, up to 2 per cent of manganese, and up to 0.5 per cent of calcium, the balance of the alloy being magnesium, and die-expressing the mixture at a temperature between about 650° and 850° F.

2. The method according to claim 1 in which the particulated magnesium-base alloy containing from 0.1 to 12 per cent of aluminum, also contains 0.5 to 3 per cent of zinc.

3. The method according to claim 1 in which the particulated magnesium-base alloy containing from 0.1 to 12 per cent of aluminum, also contains 0.5 to 3 per cent of zinc, and 0.1 to 2 per cent of manganese.

4. The method according to claim 1 followed by subjecting the die-expressed article to a prolonged heating at about 350° F.

5. The method according to claim 1 followed by subjecting the die-expressed article to a prolonged heating at about 750° F.

6. The method according to claim 5 followed by subjecting the heated die-expressed article to a further prolonged heating at about 350° F.

7. A composite metal body consisting of a plurality of metals in particulate form one of the metals being a magnesium-soluble metal selected from the group consisting of silver, cerium, manganese, lead, tin, and zinc in amount up to 1 per cent of the weight of the body, another of the metals being aluminum in amount between 0.1 and 12 per cent, and the balance of the metals being a magnesium-base alloy containing 0.1 to 12 per cent of aluminum, up to 3 per cent of zinc, up to 2 per cent of manganese, up to 0.5 per cent of calcium, the balance of the magnesium-base alloy being magnesium, the particles of each of the said metals being elongated, orientated in the same direction, and all welded together into an integral solid.

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ROBERT S. BUSK.

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