Dec. 10, 1935. A. W. WINSTON 2,023,498

METHOD OF PRODUCING COMPOSITE WROUGHT FORMS OF MAGNESIUM ALLOYS

Filed July 21, 1932

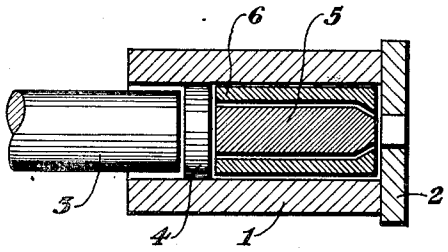


Fig. 1

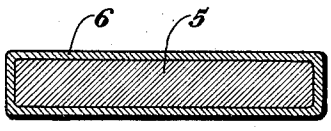


Fig. 2

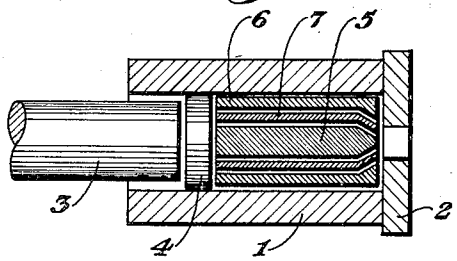


Fig. 3

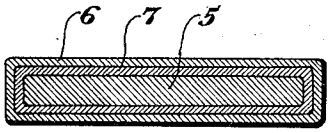


Fig. 4

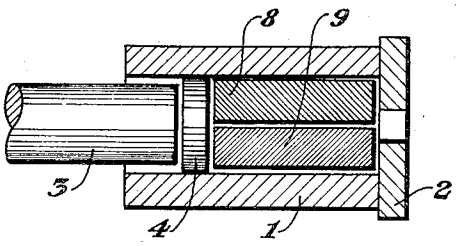


Fig. 5

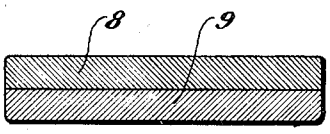


Fig. 6

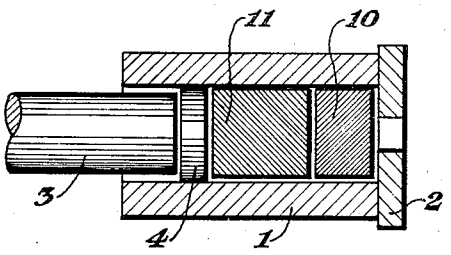


Fig. 7

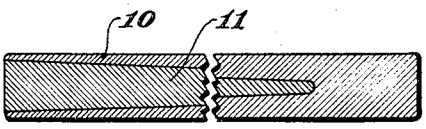


Fig. 8

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METHOD OF PRODUCING COMPOSITE WROUGHT FORMS OF MAGNESIUM ALLOYS

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8 Claims. (Cl. 29—148)

The present invention relates to the manufacture of composite wrought metal products, such as plates and sheets, which are produced from two or more magnesium alloys by plastic deformation in heated condition.

One of the objects of my invention is to provide a method of producing plates, sheets, bars, angles, channels, and the like from magnesium alloys having an integral coating of a magnesium alloy of one character overlaid upon and integrally bonded to a core or base consisting of a magnesium alloy of a different character, whereby a combination of special properties, such as corrosion resistance and high tensile strength, may be obtained simultaneously. By the term "metal" or "magnesium alloy" as used herein and in the appended claims I mean magnesium or an alloy thereof in which the magnesium content exceeds 75 per cent.

The resistance to corrosion, tensile strength, toughness, and other properties of the commercial magnesium alloys depend upon the proportions and identity of the constituent metals and no one such alloy possesses simultaneously the highest known values for any two or more of these properties. For example, the most resistant to corrosion of such alloys are from 10 to 25 per cent lower in tensile strength than the mechanically strongest magnesium alloys, while their resistance to corrosion is from two to thirty times greater than that of the stronger alloys. Similarly, other combinations of properties, such as ductility and hardness, do not normally occur in greatest degree in one and the same alloy.

So far the only known methods for overcoming the deficiency in resistance to corrosion, for example, of the strongest magnesium alloys has been to treat the surface of the metal with a chemical agent, such as a phosphate, chromate, phenol compound, or the like, either with or without a subsequent application of paint or varnish. However, such coatings are necessarily mechanically weak and therefore may be rubbed off or otherwise damaged, and they are not resistant to heat. Moreover, the metal so coated cannot be formed into shapes by bending or drawing without injury to, or destruction of, the coating. The attempted electrolytic application of metallic protective coatings, which would be strong and adherent as well as corrosion resistant, has been unsuccessful. Two or more magnesium alloys each possessing such properties as may be desired in the finished article have not heretofore been united together into a single plate or sheet or other rolled form inasmuch as no method has heretofore been available by which a layer consisting of one magnesium alloy may be overlaid and integrally joined to a base of another magnesium alloy. Thus the problem of producing plates, sheets, and the like of magnesium alloys that exhibit simultaneously certain desired combinations of properties, for example high strength and resistance to corrosion, in one and the same magnesium alloy article has heretofore remained unsolved.

I have now discovered that I may coincidentally produce a firmly bonded layer or coating of a corrosion resistant magnesium alloy upon another magnesium alloy possessing high tensile strength by rolling or otherwise plastically shaping composite metal billets formed by extruding ingots of two or more magnesium alloys simultaneously through a common die opening and thus obtain an article which combines strength with corrosion resistance and having the light weight characteristic of such metals. My invention is based upon the fact that, if in a process of extrusion I substitute for the one ingot normally employed two or more ingots consisting of different alloys and simultaneously extrude these through a common die opening, the cross sectional area of which is less than that of the ingots, a composite billet may be extruded therefrom which is composed of the original metals in physically distinct layers each of which is integrally joined to the other by the combination of heat, pressure, and mechanical working resulting from the extrusion. I then find that such composite metal may be subsequently wrought into various shapes by forging or other method of plastic deformation, such as rolling, whereby the individual metals are preserved in physically distinct layers without disrupting the integrity of the composite metal. Therefore, inasmuch as the exterior metal of the composite extruded billet may be composed of a metal or alloy differing from the metal or metals constituting the interior of the same, the wrought article made therefrom may possess corrosion resistance, for example, when the exterior metal is corrosion resistant, simultaneously with high tensile strength, for example, if the interior metal or metals have such a property. Furthermore, the composite wrought metal thus produced possesses the same integral quality of a single wrought magnesium alloy; that is, it may be bent, drawn, heat treated, forged, welded or otherwise subjected to processes for working magnesium alloys as are known to the art, as may be a homogeneous metal or alloy.

I have further found that the arrangement

of the metal layers constituting the composite wrought article depends upon the original arrangement of the ingots in the extrusion press. For example, an enveloping layer or coating of uniform thickness of one metal may be overlaid upon a core metal by placing an ingot of a metal to constitute the interior body of the article more or less concentrically within a hollow ingot of the metal to constitute the surface coating metal, both ingots being longitudinally disposed in the container of the press, and extruding the two ingots simultaneously through a common die opening in a direction parallel to the axes of the ingots. Then, on subsequently rolling such extruded composite billet I may obtain a sheet having a uniform layer of metal of one composition overlaid upon and firmly bonded to a core of another metal. On the other hand, if I place the ingots in the container so that they are transversely disposed therein, that is, one ingot is placed ahead of the other, then the extruded billet is coated with the exterior metal in varying thickness from one end of the extruded billet to the other and when subsequently rolled or forged into a bar or similar form the coating metal still remains in varying thickness from one end of the wrought bar to the other. I may also place the ingots side by side within the container and thereby extrude a composite billet consisting of the different metals side by side in integrally joined, but physically distinct and uniformly thick layers which, when rolled into plates, for example, have a layer of the one metal integrally joined to a layer of the other metal.

The invention, then, consists of the steps and the product hereinafter fully described and particularly pointed out in the claims, the annexed drawing and the following description setting forth in detail certain means and modes illustrating, however, but several of the various ways in which the principle of my invention may be used.

In said annexed drawing:—

Fig. 1 is a diagrammatic view of an extrusion apparatus illustrating concentrically disposed ingots placed therein.

Fig. 2 is a cross section view perpendicular to the direction of extrusion of a composite billet extruded from the arrangement illustrated in Fig. 1.

Fig. 3 is a similar view to Fig. 1 showing an intermediate metal between the outer coating and the core.

Fig. 4 illustrates in cross sectional view the disposition of the layers of metal in a composite billet extruded from the arrangement illustrated in Fig. 3.

Fig. 5 is a similar view to Fig. 1 showing ingots placed side by side in the container.

Fig. 6 is a cross sectional view perpendicular to the direction of extrusion of a composite billet extruded from the arrangement illustrated in Fig. 5.

Fig. 7 is a similar view to Fig. 1 showing an ingot of coating metal placed ahead of an ingot of core metal in the container.

Fig. 8 is a longitudinal section of a composite billet extruded from the arrangement in Fig. 7.

In Figs. 1, 3, 5, and 7 are shown the container 1 of an extrusion press provided with a die 2 on the one end thereof. A ram 3 is associated therewith and a steel or other hard metal dummy block 4 is provided at the head of the ram. These several indicated parts are all of conventional design and form no part of the present invention.

The type of wrought form desired may be varied in accordance with the type of composite billet employed. In the drawing I have illustrated the preparation of several types of composite billets which I will now describe. In carrying out the preparation of composite billets suitable to be wrought into various forms, such as sheets, plates, etc., according to my invention, I first prepare appropriately shaped ingots for extrusion by casting, followed by machining to remove the outer surface and to shape them so that they may be put into the container, as indicated; or I may cast a composite ingot suitable for extrusion. Then I preheat the ingots to a temperature suitable for extruding the metals into a composite billet. The container 1, the die 2, and the dummy block 4 are likewise preheated to approximately the temperature of extrusion. Suitable temperatures for extruding magnesium alloys are from 550° to 900° F., about 750° F. being preferable in most instances.

To produce rolled composite metal having a continuous layer of one metal of uniform thickness overlaid upon a core metal, I first prepare a suitable rolling billet by extrusion as illustrated in Figs. 1, 3, or 5. In Fig. 1 I have shown concentrically arranged ingots, the core metal 5 being of a metal of one composition and the coating metal 6 being of another. These ingots are so shaped that as they are extruded through a common die opening, a continuous layer of uniform thickness will be produced upon the core metal in the extruded billet. The ratio of the thickness of the coating compared to that of the core in a composite extrusion is substantially the same as the ratio of the thickness of the wall of the outer ingot to the thickness of the inner ingot. In Fig. 2 I have shown a cross section of composite billet extruded as above through a rectangular die opening.

In the preparation of composite billets wherein the outer and inner ingots employed differ considerably as to composition it is preferable to interpose an ingot between them which has a composition intermediate between that of the outer and inner ingots, respectively. For example, in applying a corrosion resistant magnesium alloy containing from 0.1 to 2.5 per cent of manganese (balance magnesium), to a high tensile strength magnesium alloy containing from 6 to 12 per cent aluminum, 0.1 to 0.3 per cent manganese (balance magnesium), a magnesium alloy may be employed having an intermediate composition such as from 2 to 4 per cent aluminum, 0.2 to 0.4 per cent manganese (balance magnesium). In Fig. 3 I have illustrated the arrangement of an ingot of intermediate metal 7 concentrically disposed between the metals 5 and 6 in order to produce a composite billet consisting of an external and internal metal provided with a metal of intermediate composition between the same. In Fig. 4 I have shown a cross section of a composite billet extruded as above through a rectangular die opening.

To produce a rolled form such as a plate or sheet, one face of which consists of one magnesium alloy while the other face consists of another magnesium alloy, I first prepare a composite rolling billet as illustrated in Fig. 5. In said figure I have shown an ingot 8 consisting of an alloy of one composition and an ingot 9 consisting of an alloy of different composition placed

side by side in the container and with their ends toward the die opening. Then I extrude said ingots through the common die opening and thereby produce an extruded composite rolling billet shown in Fig. 6 in which each of the metals 8 and 9, respectively, are present in physically distinct layers integrally joined one to the other.

Another type of composite billet suitable for rolling or forging in which a coating metal may be overlaid upon a core metal so as to produce a continuously varying thickness of coating from one end of the extruded form to the other may be produced as indicated in Fig. 7. In said figure I have shown an ingot of a coating metal 10 placed in the container next to the die opening and an ingot of a core metal 11 placed behind the coating metal ingot. On extruding said ingots through the die opening I obtain a composite billet as illustrated in Fig. 8 wherein the coating metal forms an enveloping covering 10 over the core metal 11 which has a continuously tapering cross section from one end of the extruded billet to the other.

Having prepared composite billets as above described I may then proceed to roll or otherwise shape the same in accordance with the following procedure:—I take a suitable length of composite billet adapted to the width of the rolling mill and I preheat said billet to the rolling temperature which may be from 425° to 850° F. and proceed to roll the same in a number of passes so as to produce a reduction in thickness at each pass. It is preferable to begin the rolling passes at the higher temperatures in the range indicated and continue the passes until the temperature of the metal has reached the lower temperatures of the range, and then, if the desired reduction in thickness has not been reached, to reheat the metal to the upper temperature and continue the rolling. The reduction in thickness per pass is regulated to the plasticity of the alloys and the overall thickness of the metal. Reductions of approximately 5 to 15 per cent may be produced at each pass, but I do not wish to limit myself to any specific reduction inasmuch as the permissible reductions which may be produced with magnesium alloys depend upon their composition and other factors.

The rolling may be carried out in a direction perpendicular to the direction of extrusion or parallel to the same or it may be alternated in either direction which may be suitable to produce the width, length, and reduction in thickness to adapt the rolled product to the application in view.

The final overall thickness to which such composite metal may be rolled is limited by the thickness of the thinnest external layer or layers of metal. Inasmuch as the relative thickness of each of the layers remains substantially the same during the overall reduction in thickness produced by rolling or other shaping methods, continued reduction in thickness eventually reduces the thickness of the thinnest metal layer to a practical limit. When the thinnest layer is the external metal, the limiting thickness is from 0.005" to 0.01". Thinner external layers than these are liable to be punctured during further mechanical working.

While I have more particularly described the method of rolling as an example of a mode of shaping such composite extruded magnesium billets, it is to be understood that I do not wish to limit myself thereto inasmuch as hammer or press forging to the final desired wrought shape may be preferable in some instances. For example, a composite extruded billet produced according to the arrangement of the ingots, illustrated in Fig. 7, is adaptable to making an aeroplane propeller blade by forging. In such an example the outer metal of the blade could be made of a ductile magnesium alloy, which would not be easily fractured by a blow and the hub section, where the strength is required, could be made of harder, stronger magnesium alloy.

The composite billets herein described may be plastically shaped as by forging at a temperature between 500° and 800° F. or even slightly outside these indicated temperature limits. It is preferable, however, to carry out hammer or press forging at the lowest temperature at which the metals can be plastically worked without fracturing the same. Normally about 700° F. is a suitable temperature.

Suitable magnesium alloys to employ in a given wrought product are to be chosen in accordance with the properties they possess which adapt them to the application in view. In the accompanying table are shown by way of illustrative examples the properties of a number of magnesium alloys, any two of which may be rolled, forged or similarly shaped together according to my invention from a composite billet made therefrom. The relative resistance to corrosion as herein expressed refers to the relative length of time that the alloys lose the same weight of metal per unit area when subjected to the well known alternate immersion test in a 3 per cent sodium chloride solution.

TABLE

Properties of magnesium alloys measured on roiled samples

Alloy No.	Approximate composition (bal. Mg)	Tensile strength lbs./sq. in.	Yield strength [a] lbs./sq. in.	Brinell hardness	Relative resistance to corrosion	Impact toughness foot, lbs.
1	1-2% Mn	41,200	24,000	56.5	100	12
2	4% Al 0.3% Mn	42,300	30,000	50	3	16
3	6% Al 0.3% Mn	41,400	32,000	55	4	18
4	8% Al 0.2% Mn	47,400	32,000	58	3	15
5	2% Al 4% Cu 2% Cd 0.2% Mn	42,000	31,000	50	1	8
6	6% Sn	32,000	18,300	40	40	9
7	1% Sn	31,000	13,300	36	24	13
8	4% Zn	37,000	21,000	44	40	12
9	6% Sn 1% Mn	40,000	32,000	46	11	8

[a] Yield strength is defined as the load in lbs./sq. in. at which the stress-strain curve deviates 0.1% elongation from the modulus line.

This invention provides a method for the production of composite wrought forms from a wide variety of combinations of magnesium alloys. For example, with reference to the table, I may produce a composite sheet having a corrosion resistant outside layer of alloy No. 1 and a core of an alloy having a high yield strength such as one of the alloys Nos. 2, 3, 4, 5, 9. As examples of combinations of metals having a high corrosion resistance combined with high electrical conductivity, I may form the core of pure magnesium and the coating of one of the alloys Nos. 6, 7, 8, 9. For an exterior with great hardness and an interior having high thermal conductivity, I may employ an alloy such as No. 4 upon an alloy such as No. 5.

Inasmuch as the physically distinct layers which are integrally joined one to the other remain thus joined throughout the process of final shaping by compression methods such as forging or rolling when conducted at suitable temperatures, I am enabled to produce wrought forms which possess the characteristic advantages possessed by a single magnesium alloy such as lightness and mechanical workability simultaneously with a wider range of properties such as tensile strength and corrosion resistance than has been possible hitherto. Furthermore, the strength of the union of the layers is substantially the same as that of the metals constituting the same and, therefore, my wrought product may be bent, drawn, forged and the like without destroying the integrity of the union between the layers.

Other modes of applying the principle of my invention may be employed instead of those explained, change being made as regards the method and the steps herein disclosed, provided those stated by any of the following claims or their equivalent be employed.

I therefore particularly point out and distinctly claim as my invention:—

1. The method of producing composite rolled forms consisting of magnesium alloys in integrally joined layers which comprises arranging the propriately shaped ingots of said metal within the container of an extrusion press, extruding said ingots through a common die opening at a temperature between 450° and 850° F. so as to form a composite billet, heating said composite billet to a temperature between 425° and 850° F., and then rolling said heated billet.

2. The method of producing composite rolled forms consisting of magnesium alloys in integrally joined layers which comprises placing an ingot of a magnesium alloy of one composition concentrically within a hollow ingot of a magnesium alloy of another composition in the container of an extrusion press, extruding said ingots through a common die opening at a temperature between 450° and 850° F. so as to form a composite billet, heating said composite billet to a temperature between 425° and 850° F., and then rolling said heated billet.

3. The method of producing composite wrought forms consisting of magnesium alloys in integrally joined layers which comprises placing an ingot of a magnesium alloy of one composition concentrically within a hollow ingot of a magnesium alloy of another composition in the container of an extrusion press, extruding said ingots through a common die opening at a temperature between 450° and 850° F. so as to form a composite billet, heating said billet to a temperature between 500° and 800° F., and then forging said heated billet.

4. The method of producing composite rolled forms consisting of magnesium alloys in integrally joined layers which comprises placing an ingot of a magnesium alloy of one composition and an ingot of a magnesium alloy of another composition side by side in the container of an extrusion press, extruding said ingots simultaneously through a common die opening at a temperature between 450° and 850° F. to form a composite billet, heating said composite billet to a temperature between 425° and 850° F., and then rolling said heated billet.

5. The method of producing composite wrought forms consisting of magnesium alloys in integrally joined layers which comprises placing an ingot of a magnesium alloy of one composition and an ingot of a magnesium alloy of another composition side by side in the container of an extrusion press, extruding said ingots simultaneously through a common die opening at a temperature between 450° and 850° F. to form a composite billet, heating said composite billet to a temperature between 500° and 800° F., and then forging said heated billet.

6. The method of producing composite rolled forms consisting of magnesium alloys in integrally joined layers which comprises arranging ingots of said metals so that they are placed one ahead of the other in the container of an extrusion press, simultaneously extruding said ingots through a common die opening at a temperature between 450° and 850° F. to form a composite billet, heating said billet to a temperature between 425° and 850° F., and then rolling said heated billet.

7. The method of producing composite wrought forms consisting of magnesium alloys in integrally joined layers which comprises arranging ingots of said metals so that they are placed one ahead of the other in the container of an extrusion press, simultaneously extruding said ingots through a common die opening at a temperature between 450° and 850° F. to form a composite billet, heating said billet to a temperature between 500° and 800° F., and then forging said heated billet.

8. In a process of producing composite rolled metal shapes consisting of magnesium alloys, the method of providing a corrosion resistant coating of one magnesium alloy upon another which comprises interposing between the ingot of core metal and the ingot of coating metal an ingot of another metel intermediate in composition between that of the core metal and that of the coating metal, placing said ingots one within the other and in longitudinally disposed position in the container of the extrusion apparatus, simultaneously die-expressing said ingots through a common die opening at a temperature between 450° and 850° F., to form a composite billet, heating said billet to a temperature between 425° and 850° F., and then rolling said heated billet.

ARTHUR W. WINSTON.