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ZINC BASE ALLOY

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This invention relates to zinc base alloys and wrought products made therefrom, and has for its object the provision of an improved zinc base alloy (as well as wrought products made therefrom) capable of being mechanically worked to produce wrought zinc products possessing superior resistance to cold flow.

Zinc, like other metals of relatively low melting point, undergoes slow plastic deformation or cold flow when subjected continuously to loads as low as a quarter of the ultimate tensile strength as measured by ordinary tensile testing methods. All wrought or mechanically worked zinc products made of high grade or common zinc metal are readily susceptible to such plastic or progressive and permanent deformation under constant and continuously applied loads materially below the ultimate tensile strength,—a phenomenon frequently designated as cold flow. In other words, at ordinary temperatures a continuously applied constant load (far below the ultimate tensile strength as determined by ordinary methods) causes permanent deformation in the heretofore available wrought zinc products of commerce. Under sufficiently low continuous loads the rate of progressive deformation becomes so small as to be unmeasurable by known methods, if not actually reaching the zero value, and such low or negligible loads may be interpreted as safe working stresses for these heretofore available wrought zinc products when used as structural materials, for example, in the form of corrugated sheets. From the structural engineer's viewpoint, however, these wrought zinc products have so low a safe working stress, as determined by actual practical experience, as to seriously restrict their commercial application.

In the production of rolled zinc, either by strip rolling or pack rolling, the properties of the finished rolled strips or sheets depend upon the composition of the zinc metal as well as upon the rolling practice. Thus, a high grade zinc metal, such as the well-known Horsehead or other high grade brands, yields a very soft and ductile strip or sheet under appropriate conditions of rolling. On the other hand, the more common grades of zinc metal, such as the well-known Prime Western or other grades of common metal, which are natural alloys of zinc, lead and cadmium containing higher percentages of cadmium than present in high grade zinc metal, yield when rolled under appropriate conditions a stiffer and harder product than can be obtained from high grade zinc metal.

The stiffer strip or sheet rolled from common zinc metal possesses for certain purposes distinct advantages over the softer product rolled from high grade zinc metal. For example, one of the uses of rolled zinc is in the fabrication of corrugated sheets for roofing and siding purposes on buildings. Here resistance to cold flow is of great importance, since it determines the gauge of zinc necessary to give adequate strength and resistance to plastic deformation when the sheets are laid on the building purlins.

Our investigations and experiments have indicated that the increase in the resistance to cold flow which can be secured through solid solution forming alloying elements, such as cadmium and copper, is limited, and we have, therefore, experimented with alloying elements which introduce a separate hardening constituent or constituents into the structure of the ultimate zinc base alloy. We have investigated a very large number of zinc base alloy combinations in the wrought form and have found that the resistance to cold flow can be very substantially increased when the zinc base alloy is of appropriate composition. By zinc base alloy we mean an alloy consisting principally of zinc, say, for example, not less than 90% zinc and preferably not less than 95% zinc.

The principles involved in the compounding of zinc base alloys capable of being mechanically worked into wrought products possessing superior resistance to cold flow are disclosed in our co-pending patent application, Serial No. 346,493, filed March 12, 1929. Briefly, such zinc base alloys contain one (or more) metallic element present in the alloy in solid solution in the zinc to a measurable extent and one (or more) other metallic element present in the alloy in an amount greater than its limit of solid solubility in binary association with zinc at ordinary room temperature, say 20° C. The first element (present in solid solution in the zinc) appears to produce a slight increase in the resistance to cold flow of the alloy. It may be present in amount exceeding its limit of solid solubility in zinc, but need not necessarily be present in such amount. The second element forms (alone or combined with zinc or with the first element) a hardening constituent (or constituents) whose function appears to be to produce a very substantial increase in the resistance to cold flow by hindering slip within or between the crystals. The present invention is a species of the broad invention disclosed and claimed in our copending application and is specifically directed to a zinc base alloy conforming to the principles underlying that broad invention.

The zinc base alloy of the present invention contains manganese, either as the metallic element present in the alloy in solid solution in the zinc to a measurable extent or as the metallic element present in the alloy in excess of its limit of solid solubility in binary association with zinc at about 20° C. The limit of solid solubility of manganese in zinc at about 20° C. has been reported to be 0.1% although our investigations indicate that it may be slightly less than this figure. In the practice of the present invention, the zinc base alloy should contain from 0.01 to 0.1% manganese, where manganese is included in the alloy as the metallic element in solid solution in the zinc to a measurable extent. Where manganese is included in the alloy as the metallic element in excess of its limit of solid solubility in zinc at about 20° C. (i. e. as the hardening constituent), we have found that the manganese content of the alloy should preferably be from about 0.1 to 2%, although we have found that 0.07% manganese (by analysis) forms an effective hardening constituent in a zinc base alloy containing 1% copper.

Where manganese is included in the zinc base alloy as the metallic element in solid solution in the zinc to a measurable extent, the other metallic element of the alloy may be magnesium from 0.005 to 0.5%, lithium from 0.005 to 0.5%, nickel from 0.05 to 1%, and probably other metals, alone or in combination. Where manganese is the metallic element present in the alloy in excess of its limit of solid solubility in zinc at about 20° C., the other metallic element of the alloy may be copper or cadmium from 0.05 to 2% and possibly to 5%, and probably other metals, alone or in combination.

Manganese may be solely relied upon to produce the contemplated effect in the zinc base alloy of either of the two essential metallic elements, or it may be included in the alloy in conjunction with one or more metallic elements of equivalent functional character. Either high grade zinc metal relatively free from lead and cadmium or lower grade zinc metal containing natural or usual amounts of lead and cadmium may be used as the zinc base. The normal lead and iron content of either high grade or common zinc metal does not unfavorably affect those properties of the alloy with which the invention is particularly concerned. However, taking all factors into consideration, we have found that the optimum results are ordinarily attained when the zinc base is high grade zinc metal. We have secured unusually satisfactory rolling properties with alloys in which the zinc base was a very high grade zinc metal containing less than 0.01% total impurities.

In our investigations, we have used the static tensile strength of a wrought zinc product as a measure of its resistance to cold flow. The static tensile strength may be conveniently measured by applying a static or dead load to a suitable test specimen and observing the rate of elongation at intervals over an extended period of time. A series of such tests made with loads giving varying stresses in pounds per square inch is required for the complete evalution of the static tensile strength. A similar method for measuring the analogous phenomenon of creep in steel is described by French in Technological papers of the Bureau of Standards No. 296.

The high static tensile strength, and hence the superior resistance to cold flow, of wrought zinc products made from zinc base alloys of the invention is indicated in the following table. The alloying elements specified are those responsible for the alloy's capacity of imparting marked resistance to cold flow to wrought products made therefrom. The balance of each alloy was high grade zinc metal. For the purposes of comparison, the table gives the static tensile strength of similarly wrought zinc products made of high grade and common zinc metal:

Table

Composition of metal from which wrought product was made	Resistance to cold flow of wrought product. Time in minutes to produce 10% elongation under static tensile load of 10,000 lbs. per sq. in.
High grade zinc metal	480
Common zinc metal	3,000
Alloy No. 1. 1% Cu; 0.4% Mn	65,000
Alloy No. 2. 1% Cu; 0.01% Mg; 0.5% Mn	over 50,000
Alloy No. 3. 0.5% Mn; 0.01% Mg	over 21,000

The numerical figures of static tensile strength given in the foregoing table are expressed as the time in minutes required to produce 10% elongation in a standard test specimen at a temperature of 20–25° C. with a dead load calculated to give a stress of 10,000 pounds per square inch on the original section of the test specimen. The standard test specimen was a representative sample of the wrought zinc product (rolled sheet zinc in these instances), 0.032 inch thick, 2 inch gauge length, ½ inch reduced section width, 1 inch wide grips, and 1 inch radius fillets.

The percentages of the alloying elements present in the zinc base alloy are susceptible of variation over a certain range, rather difficult of exact definition. While it is essential that the alloy contain such amount of the hardening constituent (or constituents) as will introduce the desired slip resistance, an excessive amount of any such constituent, whether resulting from an excess of the first element (e. g. manganese) beyond its solid solubility in zinc or from too large an addition of the second element (e. g. manganese) beyond its solid solubility limit in binary association with zinc at 20° C., may affect the alloy unfavorably in respect to either its mechanical working properties or its resistance to cold flow. It has been our experience, particularly with respect to copper, that the best results are usually attained by including in the alloy such a percentage of the first element as goes entirely into solid solution in zinc, which in the case of copper and cadmium is about 1%. On the other hand, we have produced satisfactory alloys of the invention with manganese present, as the first element, considerably in excess of its limit of solid solubility in zinc (see alloys No. 3 in the foregoing table). Subject to these considerations, we believe that, with appropriate methods of mechanical working, the alloying elements may be present within the limits hereinbefore specified. Where manganese is included in the alloy as the metallic element present in excess of its limit of solid solubility in zinc, we have found that ordinarily about 0.3 to 0.5% of manganese produces entirely satisfactory results.

While the zinc base alloys of the invention can be wrought or mechanically worked by the methods or practices heretofore customary in mechanically working high grade or common zinc metals, it has been found that these methods and prac-

tices do not ordinarily produce wrought zinc products of that superior resistance to cold flow which the zinc base alloys are capable of developing under more suitable methods of mechanical working. In general, it may be said that the mechanical working of the zinc base alloy should be so conducted as not to cause any substantial condition of work hardening in the finished wrought product, if the maximum resistance to cold flow is to be developed. Such absence of appreciable work hardening in the wrought product may advantageously be effected by hot working of the zinc base alloy, at temperatures above 175° C. throughout or during the final stages of the working treatment, as disclosed in the copending patent application of Willis M. Peirce, Serial No. 347,195, filed March 14, 1929. Where the mechanical working of the zinc base alloy causes any substantial or objectionable condition of work hardening in the resulting wrought product, such condition of work hardening may be removed by the improved method of heat treatment disclosed in the copending patent application of Edmund A. Anderson and Elihu H. Kelton, Serial No. 347,196 filed March 14, 1929. This heat treatment is characterized by rapidly heating (preferably in 20 seconds or less) the wrought zinc product, made of a zinc base alloy of the invention, to the predetermined elevated temperature of heat treatment, preferably in the neighborhood of 200–400° C., and holding the product at that temperature for a sufficient length of time to remove any condition of work hardening therein.

The wrought zinc products of the invention may be made or fabricated by any operation involving mechanical working of the zinc base alloy. Thus, the mechanical working may be rolling, drawing, extruding and the like or may be punch-press or forming operations such as drawing, extruding, squirting, spinning, bending, folding etc. In practice, it frequently happens that a particular mechanical working operation causes a condition of work hardening in the resulting wrought product which unfavorably affects the desired superior resistance to cold flow of the product. In such cases resort may advantageously be had to the heat treatment described in the aforementioned Anderson and Kelton patent application. This heat treatment may also be advantageously applied to a wrought zinc product of the invention, irrespective of its condition of work hardening, for the purpose of improving certain physical properties, such as dynamic ductility, essential to the successful conduct of various subsequent fabricating or forming operations, such as punch-pressing etc.

The improved zinc products of the invention possess very superior physical properties as compared with heretofore commercially available wrought zinc products. We have already emphasized the importance and economic advantages of the superior resistance to cold flow. This property imparts to the products of the invention a safe working stress under a continuously applied load very substantially greater than is possible with any heretofore available wrought zinc product made of the usual commercial grades of zinc metal. The improved physical properties of the zinc products of the invention make them useful in many fields and for many purposes where the heretofore available wrought zinc products have not been used, as well as greatly superior to the wrought zinc products which have been heretofore used, such as corrugated zinc roofing and the like.

We claim:

1. A zinc base alloy having a resistance to cold flow superior to pure zinc and containing from .01 to 2% manganese and nickel in excess of its limit of solid solubility in zinc at room temperature, but not exceeding 1%, substantially all of the balance being zinc.

2. A zinc base alloy having a resistance to cold flow superior to pure zinc and containing from .01 to 2% manganese, from .005 to .5% magnesium and nickel in excess of its limit of solid solubility in zinc at room temperature but not exceeding 1%, substantially all of the balance being zinc.

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