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WROUGHT ZINC PRODUCT

No Drawing. Application filed March 14, 1929. Serial No. 347,196.

This invention relates to wrought or mechanically worked zinc products, such for example as rolled sheet or strip zinc, and has for its object the provision of a method of improving the physical properties of wrought zinc products made from a zinc base alloy capable of being worked into wrought products possessing superior resistance to cold flow. More particularly, the invention aims to provide a method of improving the dynamic ductility of such wrought products in order to permit successful conduct of certain subsequent fabricating or forming operations, such as punch-pressing, folding, bending etc. Again, the invention aims to provide a method of improving the resistance to cold flow of such wrought zinc products where, as a consequence of a preceding mechanical working operation, the wrought product does not possess such superior resistance to cold flow as it might. The method of the invention may be practiced primarily for improving either or both of these particular physical properties of the wrought zinc product.

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.

Certain zinc base alloys have recently been discovered to possess the capacity of being wrought or mechanically worked into zinc products possessing superior resistance to cold flow, as compared with wrought zinc products made from either high grade or common zinc metal. The principles involved in the compounding of such zinc base alloys are disclosed in the copending patent application of Willis M. Peirce and Edmund A. Anderson, Serial No. 346,493; filed March 12, 1929. Briefly, such zinc base alloys contain one (or more) metallic element which goes into solid solution in the zinc to a measurable extent and one (or more) other metallic element which is 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. A zinc base alloy is to be here understood as one consisting principally of zinc, say for example not less than 90% zinc and preferably not less than 95% zinc. The element (or elements) in solid solution in the zinc may be copper, cadmium, manganese, aluminum, and probably others. Of these the most satisfactory results have been secured with copper, cadmium and manganese. The element (or elements) present in excess of its limit of solid solubility in zinc may be magnesium, lithium, manganese, nickel, and probably others.

The following list of alloys is here included merely as examples of such zinc base alloys capable when appropriately wrought of producing products possessing superior resistance to cold flow. 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 alloy No. 1 was common zinc metal containing 0.15% cadmium,

while the balance of each of the other alloys was high grade zinc metal.

Alloy No.
1----------1% Cu; 0.15% Cd; 0.01% Mg;
2----------1% Cu; 0.01% Mg;
3----------1% Cu; 0.04% Mn;
4----------1% Cu; 0.05% Li;
5----------1% Cu; 0.1% Ni;
6----------1% Cu; 0.01% Mg; 0.5% Mn;
7----------1% Cu; 0.01% Mg; 0.4% Ni;
8----------1% Cu; 0.01% Mg; 0.04% Li;
9----------0.55% Cd; 0.01% Mg;
10----------0.55% Cd; 0.05% Li;
11----------0.55% Cd; 0.3% Ni;
12----------0.5% Mn; 0.01% Mg.

The percentages of the alloying elements present in the zinc base alloy are susceptible of variation over a certain range, as discussed in the aforementioned patent application. From that discussion, it appears that, with appropriate methods of mechanical working, the alloying elements mentioned in the foregoing list may vary within the following limits:—copper or cadmium from 0.05 to 2% and possibly to 5%; manganese (as first element within limit of solid solubility in zinc) from 0.01 to 0.1%, and (as second element exceeding limit of solid solubility in zinc) from 0.1 to 2%; magnesium or lithium from 0.005 to 0.5%; and nickel from 0.05 to 1%.

While the zinc base alloys hereinbefore described can be wrought or mechanically worked by the methods or practices heretofore customarily used in mechanically working high grade or common zinc metals, it has been found that these methods and practices do not ordinarily develop the optimum resistance to cold flow which these zinc base alloys are capable of imparting to wrought zinc products. Thus, Willis M. Peirce has disclosed in his copending patent application, Serial No. 347,195, filed March 14, 1929, a method of developing superior resistance to cold flow in wrought zinc products made from such zinc base alloys by hot mechanical working of the alloy with the view of substantially inhibiting any condition of work hardening in the finished wrought product. While it appears to be the fact that the resistance to cold flow of wrought products made from these zinc base alloys is deleteriously affected when any condition of work hardening exists therein, such work hardening can be subsequently removed by appropriate heat treatment of the wrought product, and we have found that such heat treatment produces an attendant improvement in the resistance to cold flow of the so heat-treated wrought product.

Commercial wrought zinc products are often produced by two or more different mechanical working operations. The first or primary working operation is designed to produce suitable forms or blanks of the metal for the subsequent secondary or fabricating operations. Thus, in the manufacture of corrugated sheet zinc roofing, the metal is first rolled into sheets—the primary working operation, and is then bent or corrugated—the secondary or fabricating operation.

It has been found in practice that even when the zinc base alloys hereinbefore described have been appropriately wrought to develop the optimum resistance to cold flow, the wrought product may be deficient in certain other physical properties essential to successful subsequent fabrication or forming. In a general way, the ability of the wrought zinc product to successfully undergo various fabricating and forming operations is indicated by its dynamic ductility,—the higher the dynamic ductility the better suited being the product for successfully withstanding such operations as bending, folding, punch-pressing and the like. We have found that deficient or inferior dynamic ductility in wrought zinc products (of the character herein contemplated) may be ameliorated by the heat treatment hereinbefore mentioned and now to be described in detail.

The present invention accordingly involves a novel heat treatment of wrought zinc products made of such zinc base alloys as hereinbefore described. This heat treatment may be advantageously applied to such wrought products to remove work hardening resulting from a preceding working treatment, for the purpose of improving the resistance to cold flow of the resulting heat-treated wrought product. Again, the heat treatment of the invention may be advantageously applied to any wrought product of these zinc base alloys, 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 or forming operations like drawing, extruding, squirting, spinning, bending, folding, etc. Obviously, the heat treatment may at one and the same time remove a condition of work hardening and improve other physical properties, such as dynamic ductility.

The heat treatment of the invention is characterized by rapidly heating the wrought zinc product (made of a zinc base alloy of the character hereinbefore described) to the predetermined elevated temperature of heat treatment, and holding the product at that temperature for a sufficient length of time to produce the desired contemplated change in its physical properties. The essential features of this heat treatment are (1) that the wrought product be brought to and maintained at the required heat treating temperature for such time as is necessary to remove work hardening or to effect other advantageous changes in its physical properties,

and (2) that the heating of the wrough product from its initial (usually room) temperature to the minimum temperature of the permissable range of heat treatment temperature be brought about very rapidly, preferably in 20 seconds or less. Following this heat treatment the wrought product may be cooled in any appropriate manner.

In the rapid heating of the wrought zinc product of the heat treatment temperature, it is important that the entire mass of the wrought product be brought to that temperature in as short an interval of time as possible. Accordingly, the wrought product should be exposed to the heating medium in a form capable of promptly and rapidly absorbing heat, so that the necessary rapid heating may take place promptly and uniformly throughout the entire mass or bulk of the product. In our preferred practice, we aim to bring the wrought product to the heat treatment temperature in 20 seconds or less. While somewhat longer time intervals may, in some instances, be tolerated, we have found that the more rapidly the product is brought to the heat treatment temperature the better will be the results.

The minimum or critical temperature to which the wrought product should be brought for the purposes of the invention cannot be precisely stated since it varies not only with the particular composition of the alloy but with the previous working treatment. Our experience indicates that temperatures from 200° C. to 400° C. are ordinarily satisfactory for the purpose. In a general way, the higher the temperature the shorter is the time required to bring about the desired change in the physical properties of the wrought product. Having rapidly brought the wrought product to the correct elevated temperature of heat treatment, the contemplated change in its physical properties proceeds with alacrity. With temperatures in the neighborhood of 300° C., the desired change in physical properties takes place in one minute or perhaps less, while at temperatures of about 200° C., 5 to 10 minutes may be required. For economic reasons, we generally prefer the higher temperatures and shorter times of heat treatment.

Prolonged maintenance of the wrought product at the high temperature of heat treatment produces no harmful affect on the resistance to cold flow, dynamic ductility, or equivalent physical properties, of the heat treated wrought product. Indeed, after the contemplated change in physical properties of the wrought product has been brought about by the heat treatment of the invention, continued exposure of the product to the elevated temperature of heat treatment appears to be without further effect on the product. Consequently, while prolonged heating does no harm, the aim in practice is to continue the heat treatment only so long as is necessary to bring about the contemplated change in physical properties of the wrought product.

The cooling of the heat treated wrought product may be effected in any appropriate manner. So far as concerns those physical properties with which we are here interested, the manner and character of cooling is immaterial. Accordingly, after the completion of the heat treatment, the wrought product may be cooled rapidly or gradually as desired.

The heat treatment may be carried out in any appropriate apparatus designed to rapidly heat the entire mass of the wrought product to the required elevated temperature of heat treatment. Thus, the heat treatment may advantageously be conducted by immersing the wrought product in a bath of oil or other suitable liquid heated to the required heat treatment temperature. Various types and forms of annealing furnaces designed for rapid heating of materials may be used. The heat treatment may be carried out as an intermittent or continuous operation, depending upon the manner in which the wrought product is brought into contact with or exposed to the heating medium.

Where the invention is practiced primarily for the purpose of removing work hardening, it is generally desirable that the condition of work hardening in the wrought product be substantial in order to provide numerous nuclei for readjustment of the crystalline structure in the subsequent heat treatment. While the heat treatment of the invention is applicable for removing any condition, however slight, of work hardening in the wrought product, the readjustment of the crystalline structure brought about as a consequence of the heat treatment is promoted by a uniform distribution of numerous nuclei about which such readjustment may originate and progress. It is for this reason that we find it desirable, where practicing the invention primarily for removing work hardening, to deliberately impart to the wrought product a substantial condition of work hardening in the course of the preceding working treatment.

Work hardening results from the mechanical working of a metal at relatively low temperatures. The temperatures at which metals should be worked to produce work hardening in the wrought product differ considerably with different metals. In general, it may be said that work hardening results from the mechanical working of the metal at temperatures below the recrystallization temperature of the metal, which may be defined as the temperature at which the metal rapidly returns to an unstrained crystalline structure.

The recrystallization temperature of the zinc base alloys hereinbefore described appears to be in the neighborhood of 175–200° C.

Consequently, mechanical working of these alloys at temperatures well below 175° C. produces in the resulting wrought product a substantial condition of work hardening. The degree or amount of work hardening in the wrought product will depend upon the composition of the alloy as well as upon the character, particularly the temperature, of the working treatment.

The invention is particularly adapted for the development of superior resistance to cold flow in cold worked or wrought products. As an example of such an application of the invention, we will described the rolling of strip or sheet zinc. The cast slab, of a zinc base alloy such as herein contemplated, is first subjected to the usual homogenizing anneal, involving the exposure of the slab to a temperature of about 200° C. in an appropriate annealing furnace for from 8 to 24 hours. The slab is then transferred to the rolling mill, and the rolling treatment is conducted to produce a substantial condition of work hardening in the finished strip or sheet. Any cold rolling practice will bring about this result. The metal may be rolled in the form of continuous strips or sheets or in the form of packs as will be well understood in the art.

The rolled product is now subject to the heat treatment characteristic of the invention. To this end, the strips or sheets are preferably heated to about 300° C. in about 20 seconds or less. In order to obtain this rapid heating of the strips or sheets, it is desirable to expose them to the heating medium in the form in which they will most readily absorb heat. For this reason, it is preferable not to coil or stack the strips or sheets, but rather to expose as much surface as practicable to the heating medium at the instant of subjecting the strips or sheets thereto.

In our investigations, we have used the static tensile strength of the 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 evaluation 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 following table shows the results of static tensile tests upon two wrought zinc products made of the same zinc base alloy. The alloy was composed of 1% copper, 0.01% magnesium, and the balance common zinc metal. Specimen A was cold rolled; that is the last 5% reduction was carried out with rolls below 110° C., the metal entering the rolls for the finishing passes below 40° C. and ultimately leaving the rolls below 75° C. Specimen B was rolled in the same manner as specimen A, and was then subjected to the heat treatment of the invention, by immersion for 10 minutes in an oil bath maintained at 300 ° C.

	Static tensile strength expressed as		
	Minutes to elongate 10% with load of 10,000 lbs. per sq. in.	Per cent elongation, with load of 15,000 lbs. per sq. in. in	
		3,000 min.	9,000 min.
Specimen A	15,000	2.75	9.0
Specimen B	over 90,000	0.75	----------

The numerical figures of static tensile strength given in the foregoing table are expressed, first, as the time in minutes 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, and, second, as the percent elongation of the test specimen in (*a*) 3,000 minutes and in (*b*) 9,000 minutes with a dead load calculated to give a stress of 15,000 pounds per square inch. The standard test specimen was a representative section of the wrought zinc products (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.

It is commonly known that certain physical properties of wrought zinc products, made of the ordinary commercial grades of zinc metal, are usually deleteriously affected by annealing. For example, annealing over a wide range of temperatures (150–300° C.) is usually deleterious to the dynamic ductility of rolled strip or sheet zinc made of either high grade or common zinc metal. In the light of these known facts, it would not be expected that heat treatment could improve the dynamic ductility of wrought zinc products made from the zinc base alloys with which we are here concerned. However, we have abundantly demonstrated that the heat treatment of the invention does accomplish such an improvement in wrought products made from such zinc base alloys.

The following table indicates the improvement brought about by the heat treatment of the invention in the dynamic ductility of two specimens of wrought zinc made from a zinc base alloy composed of 1% copper, 0.01% magnesium and the balance common zinc metal. (For test method see A. S. T. M. Tentative Standards 1928, page 158). Specimens A were rolled to low hardness and

high ductility—essentially hot rolling; while specimens B were rolled to high hardness and low ductility—essentially cold rolling. In each case of heat-treatment, the wrought product was raised from room temperature to the annealing temperature in less than 20 seconds:

Condition	Heat treatment temperature	Duration of heat treatment	Dynamic ductility
	Degrees C.	*Min.*	
A. As rolled			.260
A. Heat-treated	300	1	.290
A. Heat-treated	300	10	.295
B. As rolled			.205
B. Heat-treated	200	5	.295
B. Heat-treated	200	20	.295

While the dynamic ductility has been used as an example of a mechanical property of the wrought zinc product which may be beneficially affected by the heat treatment of the invention, other physical properties such as cold bends, percent elongation, etc., may likewise be improved.

The heat treatment of the invention may be advantageously applied at various stages in the course of the complete mechanical working of the wrought zinc product. Thus, it may be applied to rolled sheet or strip zinc to remove work hardening and hence improve the resistance to cold flow or to increase the dynamic ductility or for both purposes. Also, it may be applied between different fabricating or forming operations to overcome a decrease in dynamic ductility occasioned by a preceding operation, in order to permit the successful conduct of a further fabricating operation or operations. Again, it may be applied to the finished wrought zinc product to remove any condition of work hardening caused by any preceding mechanical working, with the view of imparting to the finished product as great a resistance to cold flow as possible.

We claim:—

1. The method of improving the physical properties of a wrought zinc product made from a zinc base alloy capable of being worked into a wrought product possessing marked resistance to cold flow, which comprises subjecting the wrought product to heat treatment characterized by rapidly heating the wrought product to an elevated temperature of about 300° C., and maintaining the wrought product at that temperature until the contemplated improvement in its physical properties has taken place, said temperature being adapted to avoid work hardening in the wrought product while improving its resistance to slow plastic deformation or cold flow and increasing its dynamic ductility.

2. The method of improving the physical properties of a wrought zinc product made from a zinc base alloy capable of being worked into a wrought product possessing marked resistance to cold flow, which comprises subjecting the wrought zinc product to heat treatment characterized by rapidly heating the wrought product to a temperature of 200–400° C. and maintaining the wrought product at that temperature until the contemplated improvement in its physical properties has taken place.

3. The method of improving the physical properties of a wrought zinc product made from a zinc base alloy capable of being worked into a wrought product possessing marked resistance to cold flow, which comprises subjecting the wrought zinc product to heat treatment characterized by heating the wrought product to an elevated temperature of about 300° C. in a time interval not exceeding 20 seconds and maintaining the wrought product at that temperature until the contemplated improvement in its physical properties has taken place.

4. The method of improving the physical properties of a wrought zinc product made from a zinc base alloy capable of being worked into a wrought product possessing marked resistance to cold flow, which comprises heating the wrought product to a temperature of 200–400° C. in a time interval not exceeding 20 seconds and maintaining the wrought product at that temperature until the contemplated improvement in its physical properties has taken place.

5. The method of improving the physical properties of a wrought zinc product made from a zinc base alloy capable of being worked into a wrought product possessing marked resistance to cold flow, which comprises heating the wrought product to a temperature of 200–400° C. in a time interval not exceeding 20 seconds and maintaining the wrought product at that temperature for a period of 1 to 10 minutes.

6. The method of developing superior resistance to cold flow in a wrought zinc product made from a zinc base alloy of suitable composition for the purpose, which comprises subjecting the wrought product to heat treatment characterized by rapidly heating the wrought product to an elevated temperature of 200–300° C., and maintaining the wrought product at that temperature until the contemplated superior resistance to cold flow has been developed.

In testimony whereof we affix our signatures.

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