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WROUGHT ZINC PRODUCT

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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 developing superior resistance to cold flow in a wrought zinc product made from an appropriate zinc base alloy.

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 Edmund A. Anderson and myself, 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 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. While aluminum produces the desired increase in resistance to cold flow, its tendency to cause intercrystalline oxidation upon aging impairs its practical utility for the purposes of the invention. 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 number	Per cent		
1	1 Cu	0.15 Cd	0.01 Mg
2	1 Cu	0.01 Mg	
3	1 Cu	0.4 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 foregoing zinc base alloys 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 now customarily used in mechanically working high grade or common zinc metals, I have 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. Accordingly, the present invention is particularly concerned with the method of mechanically working such zinc base alloys as hereinbefore described, with the view of securing as great an increase as possible in the resistance to cold flow of the resulting wrought zinc products.

In my investigations, I 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 invention is based on the fact (not generally recognized) that hot working, for example hot rolling, of zinc produces a wrought zinc product of greater static tensile strength than is produced by cold working. It has been commonly recognized that cold working, as contrasted with hot working, increases the tensile strength of metals as measured by the ordinary tensile strength test, and with such metals as iron, copper and brass this higher tensile strength is construed as permitting higher safe working stresses. Accordingly, metals for uses where strength is required are often deliberately work hardened, for example by cold rolling, drawing or extrusion, to secure higher tensile strength and higher safe working stresses. Indeed, commercial corrugated zinc sheets have been commonly made by a cold sheet rolling practice that produces appreciably work hardened metal.

While the increase in static tensile strength brought about by hot working, as compared with cold working, is noticeable in the case of the usual commercial grades of zinc, such as high grade or common zinc metal, it does not result in sufficient improvement to be of much commercial value. On the other hand, I have discovered that when mechanically working such zinc base alloys as hereinbefore described, the improvement (increase) in static tensile strength brought about by hot working, as compared with cold working, is very substantial and commercially important.

The present invention accordingly involves the development of superior resistance to cold flow in a wrought zinc product by subjecting a zinc base alloy of suitable composition for the purpose to mechanical working at a temperature sufficiently high to substantially inhibit work hardening, whereby and as a direct consequence of this character of mechanical working a superior resistance to cold flow is developed in the finished wrought zinc product. The mechanical working contemplated by the invention 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 accordance with the invention, the mechanical working of the zinc base alloy is conducted, during the entire operation, or at least during its final stages, at a temperature sufficiently high to prevent, so far as possible, the presence of any appreciable work hardening in the finished wrought zinc product.

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 high grade zinc metal is in the neighborhood of 125° C., while the recrystallization temperature of common zinc metal is somewhat higher, being usually in the neighborhood of 140–150° C. I have found, however, that the recrystallization temperature of the zinc base alloys to which the invention particularly relates is substantially higher than in the case of any of the usual commercial grades of zinc metal, being in fact in the neighborhood of 175–200° C. for such of these zinc base alloys as I have examined in this connection.

In carrying out the present invention the zinc base alloy is subjected to the desired mechanical working while maintained at a temperature sufficiently high to give a resulting wrought zinc product substantially free from work hardening. From my actual experience with these zinc base alloys I have found that in commercial practice the working temperature should be above 175° C. to produce a wrought zinc product substantially devoid of work hardening. The actual working temperature is of course difficult of ascertainment, because the metal at the time of actual working is confined within or between the working agency, such as rolls, dies, etc. In practice, I have found it satisfactory to estimate the actual working temperature from the surface temperature of the metal observed or measured within a fraction of a minute after the metal emerges from the working agency. This observed or measured temperature may be conveniently obtained by a contact pyrometer as promptly as possible after the metal emerges from the working agency. It is of course the temperature at the surface of the metal, and is obviously lower than the temperature of the metal, while actually undergoing the preceding working treatment. The thinner the wrought zinc product, the greater is the difference between its observed surface temperature and its actual working temperature during the immediately preceding working operation. With one wrought zinc product of the invention rolled to a thickness of 0.032 inches, an observed surface temperature of 160° C. has been found to indicate that the condition of hot working characteristic of the invention actually existed during the immediately preceding rolling operation.

The high working temperature characteristic of the invention should be maintained throughout the entire working operation, thereby substantially inhibiting any work hardening, or should be maintained throughout a sufficient period prior to and including the final stage of the working operation to bring about recrystallization and substantial removal of any work hardening incurred in earlier stages of the working treatment. The maintenance of this high working temperature may be accomplished (1) by applying heat to the metal being worked by suitable means either prior to, or at various stages of the working operation, (2) by applying heat to the rolls, dies, or other working agency, and (3) by appropriately conserving the heat added to the metal or the working agencies, or generated in both by the working operation. Conservation of heat may be effected through reducing the total time of the working operation by means of heavy metal reductions, high working speeds, shortened intervals between working operations; through the provision of insulating shields to minimize radiation losses; and by other appropriate means. It is of course possible that commercial practice may make desirable such heavy metal reductions and high speeds of operation that temperatures in excess of those required for the purposes of the invention are attained. Such excessive temperatures may be reduced, if desirable, by such means as cooling the working agency or the metal being worked by air, water or other suitable cooling medium.

In the rolling of strip or sheet zinc, it is frequently the practice to subject the cast slabs to a homogenizing anneal preparatory to the rolling operation. Such an anneal ordinarily involves subjecting the slab to a temperature of about 200° C. in an appropriate annealing furnace for from 8 to 24 hours. In the mechanical working of cast slabs of zinc base alloys in accordance with the present invention, it has been found desirable to subject the slabs to such a homogenizing anneal.

Where the invention is applied to the rolling of strips or sheets, the cast slab, of an appropriate zinc base alloy, is first subjected to the homogenizing anneal, and is then transferred to the rolling mill, preferably without substantial lowering of its temperature. The slab temperature, the roll temperature, the metal reductions and other factors must combine to produce a high enough temperature in the metal during rolling to substantially inhibit any work hardening. The surface temperature of the finished sheet or strip measured immediately after the metal emerges from the rolls has been found to be a suitable guide to the proper combination of these temperature-controlling variables. In commercial rolling mill practice, with certain zinc base alloys, very satisfactory results have been obtained by controlling the temperature variables to give a surface temperature on a finished sheet or strip rolled to a thickness of 0.032 inches of about 200° C.

By making the metal reductions of successive roll passes sufficiently great and minimizing the time interval and hence the heat radiation between passes, it may be practicable to maintain the alloy undergoing working at the required elevated temperature without artificially heating the rolls. Where this is not practicable, however, the rolls may be heated in any appropriate manner. Where the heat radiation from the partially rolled stock between successive roll passes is excessive, it may be necessary to provide appropriate means for heat-insulating or even supplying heat to the stock during such periods.

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 accordance with the invention; the entire reduction was carried out with the rolls at a temperature above 160° C.; the metal entering the initial rolls at a temperature above 160° C., and the metal leaving the final rolls at a temperature above 175° 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 300,000	1.25	1.5

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 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.

I claim:—

1. The method of producing wrought zinc products by mechanically working a zinc base alloy containing 0.05 to 2.0% copper, 0.005 to 0.5% magnesium, and the remainder zinc, which comprises conducting at least the final stages of the mechanical working operation at a temperature not less than 175 to 200° C. adapted to avoid any appreciable work hardening in the finished wrought zinc product while preserving its resistance to slow plastic deformation or cold flow.

2. The method of producing wrought zinc products according to claim 1, in which the copper is replaced at least in part by cadmium.

3. The method of producing wrought zinc products according to claim 1, in which the copper is replaced at least in part by not more than 1% nickel.

4. The method of producing wrought zinc products according to claim 1, in which the magnesium is replaced at least in part by lithium.

5. The method of producing wrought zinc products by mechanically working a zinc base alloy containing one or more of the alloy elements copper or cadmium from 0.05 to 5%, manganese from 0.01 to 2%, and also containing one or more of the alloy elements magnesium or lithium from 0.005 to 0.5%, or nickel from 0.05 to 1%, which comprises conducting at least the final stages of the mechanical working operation at a temperature not less than 175 to 200° C. adapted to avoid any appreciable work hardening in the finished wrought zinc product while preserving its resistance to slow plastic deformation or cold flow.

In testimony whereof I affix my signature.

WILLIS M. PEIRCE.