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PRODUCING COPPER-BASE-ALLOY ROD OR
THE LIKEBenjamin H. McGar, Marion, Conn., assignor to
Chase Brass & Copper Co. Incorporated, Water-
bury, Conn., a corporationNo Drawing. Application June 5, 1939,
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2 Claims. (Cl. 29—148)

This invention relates to improvements in processes of producing copper-base-alloy rod or the like.

One object of this invention is to provide an improved process of producing copper-base-alloy rod or the like from billets or bars without cracking the billets or bars.

With the above and other objects in view, as will appear to those skilled in the art from the present disclosure, this invention includes all features in the said disclosure which are novel over the prior art.

In the commercial production of copper rod or wire, it is almost universal procedure to produce it by hot rolling the copper in grooved rolls. The copper in the form of so-called wire bars of roughly square cross section and perhaps $3\frac{1}{2}$ " to 4" on the side, is heated to a suitable temperature and rolled on a mill having a series of successive smaller and properly shaped grooves so that the wire bar is reduced gradually to the desired final size and cross section. Depending on the exact finishing size, temper and contemplated use, the rod or wire may come from the hot mill anywhere from roughly 1" diameter to as small as about $\frac{1}{4}$ " diameter. For most purposes, such hot-rolled rod is subsequently cold-drawn one or more reductions to give improved smoothness of surface, accurate size and desired temper. Modern hot mills are designed to roll copper at quite high speeds and with a minimum number of individual passes. Copper being a very soft, malleable metal when hot, this reduction is accomplished with quite large changes in cross section per pass and with a relatively small expenditure of energy.

In the producing of certain copper-alloy wires, it is found desirable and economical also to use the hot rolling procedure. Some of these copper-base alloys are quite soft and malleable when hot and can be rolled fairly readily on a mill designed for copper. Other alloys, however, are much harder and less malleable and more susceptible to cracking, due to peculiarities of crystalline structure. While they are amenable to hot working in general and could be produced on hot mills having light reductions per pass and running at relatively low speed, they give difficulty when handled in copper mills.

It has been found that in hot rolling of certain copper alloys including copper-tin, copper-cadmium, copper-tin-cadmium, copper-nickel-phosphorus, etc., much more difficulty was encountered than in rolling of pure copper. In fact, when ordinary square castings of such alloys were rolled on a copper mill, a rather large percentage would crack during the procedure and had to be scrapped, the high scrap losses and consequent high cost being a very serious obstacle if not actually prohibitive.

One of the main reasons for cracking difficulties described, is the inverse segregation quite commonly encountered in casting of the alloys under consideration. It is found, for instance, that in tin or cadmium bronzes, the surface layers of the castings are markedly higher in tin or cadmium content than the portions within the body of the casting. Careful experiments on billets containing nominally 1.25% cadmium showed that the metal was quite uniform from the center of the casting to a position roughly $\frac{1}{8}$ " from the surface and had a cadmium content throughout most of that portion of approximately 1.27%. The cadmium content then increased markedly in going toward the extreme surface, the average cadmium content of the outer layer of 0.025" thickness being 3.73%. Material of such high cadmium content or anything even approaching it is distinctly brittle compared to one of 1.25% cadmium content and is especially tender when worked hot. A similar condition is found in tin bronzes.

Another cause of cracking in such alloy billets when hot worked, is the very coarse crystalline structure resulting from the normal solidification process in such alloys in billet type under discussion. Further, these coarse cast crystals are not homogeneous but are strongly cored and in addition, any non-metallic inclusions present are forced to the grain boundaries, causing planes of weakness. Such a grain structure is intrinsically weak and conducive of the type of cracking in hot rolling above referred to.

To eliminate the difficulty due to the surface segregation of alloying elements, as well as to eliminate actual defects in the cast surface, it is more or less common practice to scalp or machine off such surface layers from the castings. While such a procedure is obviously beneficial as regards eliminating one of the primary causes of cracking in hot rolling, it is not entirely effective and it is a costly and wasteful procedure, and therefore highly undesirable.

Such portion of the cracking difficulties as may be attributed to the cast structure can in part be remedied by a prolonged high temperature homogenizing anneal prior to the hot rolling. Such an anneal will eliminate the cored structure but of course does not refine the structure unless there has been some cold work applied, and thus will not cause the redistribution of mechanically entrained non-metallic particles. It also is an expensive extra operation which in its self is undesirable.

It is thus seen that the combined treatments of scalping and annealing are at best only partly effective in removing the cracking tendency referred to, so that even in billets so treated, much more cracking difficulty is encountered than is considered commercially tolerable.

I have discovered that the copper-base alloys which are susceptible to cracking in hot rolling can be so treated as to entirely prevent such cracking by first extruding to the cross-section required for hot rolling. In this procedure larger round billets are cast, perhaps 8" to 9" in diameter which are simpler and less expensive to cast than the round-cornered square wire bars used for rolling. Such billets when extruded through a round-cornered square die to the same general cross-section as ordinarily used for the wire bar castings, give a markedly superior material to be used for the hot rolling operation. I have found that it is not necessary to scalp or anneal either the billet as cast or the wire bar after extrusion. In all cases, the extruded section is found to be ideally adapted to the further hot rolling operation, and although this procedure has been applied to a number of alloys in considerable quantity, no single instance has been found where a billet has cracked in hot rolling.

The extrusion operation appears to overcome all the difficulties cited with regard to the cast billets. The high alloy surface layer is redistributed into the interior of the billet, the coarse crystalline structure is broken up and refined, the cored structure is entirely homogenized, and any non-metallic inclusions are redistributed in an innocuous manner throughout the mass. The combined casting and extrusion operation is less expensive than the casting and scalping, or casting, scalping and annealing previously resorted to with incomplete success as regards cracking tendency.

Commercial lots of a copper-cadmium alloy containing about 1¼% cadmium and the balance copper, a tin bronze alloy containing about 1.35% tin and the balance copper and various copper-nickel-phosphorus alloys have been produced by casting, extruding and subsequent hot rolling with entire success, and the procedure appears to be applicable to all copper alloys which are difficult to hot roll in the as-cast condition, whether or not scalped and/or annealed. Examples of alloys which are improved by the treatment described are the following:

Alloy No.	Copper	Tin	Aluminum	Nickel	Phosphorus	Cadmium	Iron	Silicon
1.....	98.65	1.35						
2.....	98.15	1.85						
3.....	97.20	2.80						
4.....	99.40					0.60		
5.....	99.15					0.85		
6.....	98.85					1.15		
7.....	98.70	0.50				0.80		
8.....	98.75	1.00	3.25					
9.....	98.50			1.25	0.25			
10.....	97.30	1.50		1.00	0.20			
11.....	97.75	0.75		1.25	0.25			
12.....	98.50			0.75	0.15	0.60		
13.....	97.75			1.25	0.25	0.75		
14.....	97.00			0.5			2.50	
15.....	96.00	1.00		0.5			2.50	
16.....	97.00	2.00						1.00
17.....	97.00		2.5					0.50

A comparative test on a large quantity of material was made to determine the relative merits of material rolled as cast and scalped, as cast annealed and scalped, and as extruded. Results of these tests are given in the following table:

Alloy No.	Rolled as cast and scalped		Rolled as cast scalped and annealed		Rolled as extruded	
	Crack-free	Cracked	Crack-free	Cracked	Crack-free	Cracked
9.....	4	8	12	0	12	0
11.....	2	11	9	5	13	0
13.....	3	8	6	5	10	0
	9	27	27	10	35	0

The results of these tests show that material as cast and scalped is very poor as only 9 out of 36 billets, or 25%, rolled satisfactorily. A soaking anneal in addition to scalping is beneficial but by no means entirely effective, as only 27 out of 37, or 73%, rolled satisfactorily. With the material as extruded, 35 rolled satisfactorily and none showed any sign of cracks. Generally similar results have been found on commercial lots of the other alloys named.

The invention may be carried out in other specific ways than those herein set forth without departing from the spirit and essential characteristics of the invention, and the present embodiments are, therefore, to be considered in all respects as illustrative and not restrictive, and all changes coming within the meaning and equivalency range of the appended claims are intended to be embraced therein.

I claim:

1. The process of producing copper-base-alloy rod or the like, comprising: hot-extruding a billet of copper-base-alloy containing at least one material from the group tin, cadmium, nickel, phosphorus, zinc, iron, silicon and aluminum, to a degree sufficient to bring about more than 25% reduction of area of the billet; and later hot-rolling the extruded billet to a degree sufficient to bring about more than 50% reduction of area of the extruded billet.

2. The process of producing copper-base-alloy rod or the like, comprising: casting a billet of copper-base-alloy containing at least one material from the group tin, cadmium, nickel, phosphorus, zinc, iron, silicon and aluminum; later hot-extruding the cast billet to a degree sufficient to bring about more than 25% reduction of area of the cast billet; and later hot-rolling the extruded billet to a degree sufficient to bring about more than 50% reduction of area of the extruded billet.

BENJ. H. MCGAR.