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STEEL STRIP AND ITS PRODUCTION

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My invention covers a new form of strip steel and an improved method of producing such material, one of my objects being the production of strip steel having a smooth surface and of such physical and microstructural character that this surface is not impaired to any great extent when the material is fabricated into various articles of commerce by deep-drawing operations. Another of my objects is the production of strip steel that is characterized by being sufficiently ductile to permit its easy deformation yet which is sufficiently stiff to permit such deformation in curved planes without incidental kinking or folding. Other objects may be inferred.

According to my invention, the steel strip reduced by the cold mill is originally hot-rolled from a large slab. However, it is distinguished in that it contains from .05 per cent to .15 per cent phosphorus, whereas it has been quite generally heretofore conceded that this element should be kept to a much smaller percentage in steel to be cold-rolled.

In fact, it has been generally thought that the content of phosphorus should be as low as is possible considering the limitations of present day open-hearth practices and the fact that the element phosphorus causes "cold brittleness" or the tendency to be quite brittle while in a cold state. The reason that I consider this phosphorus content important will now be explained.

When the usual low metalloid steel containing carbon within the usual practical range between .02 to .08 per cent is hot rolled to final gage and subsequently annealed or normalized, a very ductile product results, having physical characteristics which apparently make it ideal for fabrication into articles requiring highly finished deep-drawn parts. Unfortunately, deep-drawing of this material develops minute surface defects on the deformed parts which are very undesirable in some instances. Furthermore, the plasticity is such that it is at times impossible to form the strip into curved planes without incidental kinking and folding of the metal. Even after the part is formed it is quite liable to be dented and twisted out of shape because of its softness.

The ordinary way of remedying the above troubles is to cold work the strip slightly prior to its drawing operation. Sometimes this is a remedy but oftentimes it simply develops surface defects so that they are immediately apparent. This expedient also increases the cost of the strip. The degree of this cold working is, of course, varied to suit the product to the working to which

it is to be subjected, it being understood that different forming and drawing operations require different degrees of stiffness.

Now I have discovered that the same low carbon steel as above described but having a high phosphorus content that is cold-rolled in strip form to effect at least a 50 per cent reduction in its thickness while bringing it to its final gage and which is subsequently heat treated has a very smooth surface which does not develop defects as an open surface when drawn quite deeply. Also, the final strip is sufficiently ductile to permit its easy deformation yet is sufficiently stiff to resist kinking or folding when formed into a curved plane. The results are actually superior to those attained by either the skin-rolling or leveling operation formerly considered a necessary additional step following heat treating, the need for this costly operation being entirely eliminated.

By high phosphorus steels I mean that at the time when the steel was molten and immediately prior to its being poured into ingots and solidified, its phosphorus content is definitely fixed somewhere between .05 per cent and .15 per cent depending on the amount of inherent stiffness desired in the finished strip metal at the time it is drawn or formed. At the same time the degree of ductility of the strip metal is determined principally by the carbon content which may be fixed somewhere between .02 to .08 per cent inclusive.

This high phosphorus low carbon bearing metal is now hot rolled into slabs and thence reduced into strip form. This hot rolled strip is then pickled and thereafter cold reduced to the desired gage by the mill involving at least a 50 per cent or more reduction in its thickness. The cold reduced strip is then heat treated in the furnace and is ready for drawing or forming so far as its physical characteristics are concerned.

Preferably, the furnace used is rather short, electrically heated by high resistance bars and provided with a short cooling chamber having a water jacket. The completely reduced strip is drawn from a coil of the same through a friction guide and so, in span form, through the furnace and cooling chamber by means of powered pinch-rolls.

Now to describe the heat treatment that I have discovered is ideal for the high-phosphorus cold-rolled strip, it being understood that this part of the process may also have advantages as applied to low-phosphorus strip.

My treatment is characterized in that, as previously partly described, steel strip is cold-rolled

to effect at least a 50 per cent reduction in its thickness while bringing it to its final gage, thereby causing its crystalline structure to become highly strained. This strain is then removed from the strip by continuously passing it through the furnace, the speed of the strip and the temperature of the heating zone in the furnace being proportioned so that the steel strip is rapidly heated, whereupon recrystallization occurs so as to initially produce a fine grain structure. The time that the strip is in the furnace's heating zone is proportioned so that the heating is continued only until the grain size of the strip grows sufficiently to impart the desired physical characteristics to the same. As the steel strip leaves the furnace it enters the cooling chamber which is maintained at a temperature which cools the strip as rapidly as is possible without causing its mechanical deformation.

Thus, for example, I may consistently produce a 31 gage (.0107") strip steel containing about .06 per cent of carbon and .07 per cent phosphorus, by cold reducing the same from about 16 gage (.065") hot rolled strip to effect at least a 50 per cent cold reduction.

Thereafter I may run such a cold reduced strip through the furnace, which should have only about a 6 foot heating zone exposed to 2100 degrees Fahrenheit, wherein it is very rapidly heated to the desired temperature within a time interval of between ten to fifteen seconds, depending on the grain size desired. Thereafter it is rapidly cooled in the cooling chamber.

The resulting high-phosphorus strip generally has a very fine equiaxed grain structure as compared with large equiaxed grain structures common to a similar strip steel if heat treated in the conventional and well known normalizing furnaces. Furthermore, my strip, as reduced to gage and heat treated, exhibits a very high yield point which may average ten thousand pounds per square inch (10,000#/sq. in.) above a low-phosphorus strip (less than .05 per cent phosphorus) cold reduced and heat treated in a like manner, all other elements of the strip being common to both.

Thus, by my method I am able to produce high-phosphorus strip which, while having ductile properties, exhibits an inherent stiffness very much desired in certain classes of drawn materials.

For example, in the making of tin cans and the like from my high-phosphorus strip steel thus mechanically and thermally treated, and subsequently tinned, I may form can covers and tops without causing visible strains, such as opening up of the grains, to produce a rough surface, and without breaking or cracking the metal under the necessarily severe drawing operations.

Such covers and tops when assembled are usually tested for leakage. The rigidity of shape and the smoothness of the strip's surface after drawing permit my steel to withstand leakage tests in excess of one hundred per cent greater than similar strip made of low-phosphorus steels and produced in even a similar manner.

The success of my high-phosphorus strip in resisting these pressure tests is no greater than its ability to resist denting and bending, which is by virtue of its abnormal stiffness. Such stiff strip is finding rapid commercial use in can bodies where "buckling" and "paneling" resulting from the softness of tin plate are serious difficulties. The can stands up better not only in its manufacture and testing but particularly in its transportation and storage in piled relationship.

I claim:

1. In the art of producing steel strip adapted for deep drawing and which normally includes the steps of producing low metalloid steel, hot rolling said steel into strip, cold rolling said strip to effect at least a fifty percent reduction in its thickness to produce a fine finish and even gage but resulting in excessive crystalline strain, heat treating said strip to refine its crystalline structure but resulting in said strip becoming excessively plastic and cold working said strip to impart the required stiffness to the final product, the step of treating the steel while molten to provide it with a phosphorus content sufficient to impart the required stiffness to the final product without resorting to said cold working subsequent said heat treatment and so that said steel is otherwise of low metalloid composition.

2. In the art of producing steel strip intended for deep drawing and which normally includes the steps of producing low metalloid steel, hot rolling said steel into strip, cold rolling said strip to effect at least a fifty percent reduction in its thickness, whereby to produce a fine finish and an even gage but resulting in excessive crystalline strain, heat treating said strip to release said strain but resulting in excessive plasticity and subsequently cold working said strip a predetermined extent to impart a predetermined stiffness to the final product required to adapt it to the working to which it is to be subjected; the step of regulating the phosphorus content of said steel while it is molten to result in said strip having a phosphorus content providing a predetermined inherent stiffness subsequent said heat treatment without being stressed that equals said stiffness acquired by said cold working required for the working to which it is to be subjected and so that said steel is otherwise of low metalloid composition.

3. Cold rolled steel strip having the stiffness required for deep drawing in addition to the necessary ductility, said strip being characterized by a crystalline structure and chemical composition showing that said stiffness is inherent and due to a sufficient phosphorus content and that it is not the result of cold working, said strip having a low metalloid composition except for its phosphorus content and being otherwise characterized by a lack of brittleness such as results from obtaining said stiffness by an increase in the carbon content of cold rolled steel strip above low metalloid composition required to provide equal stiffness.

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