

[54] REDUCTION OF COPPER-CAUSED SURFACE CRACKING OF STEEL DURING HOT-WORKING

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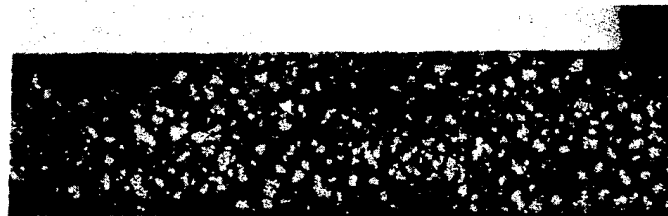
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[51] Int. Cl. B21c 23/24
[58] Field of Search 72/41, 42, 46, 47, 700; 29/424

[57] ABSTRACT
Steels containing small amounts of copper display surface hot shortness or cracking during hot-working caused by molten copper segregating at the steel surfaces. Coatings of borax-containing glass applied to steel prior to hot-working react with scale to form various iron-boron phases which inhibit the occurrence of liquid copper at the steel surface.

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6 Claims, 2 Drawing Figures



Scale, inches

Edge of rolled plate, with coating

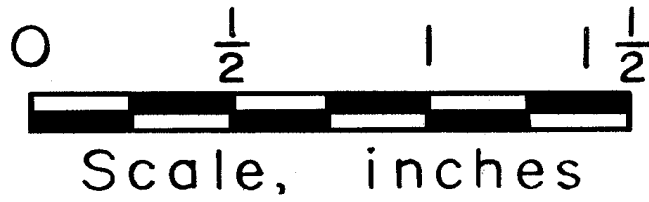
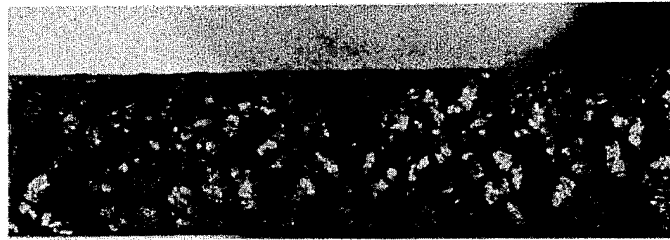


FIG. 1 Edge of rolled plate, without coating

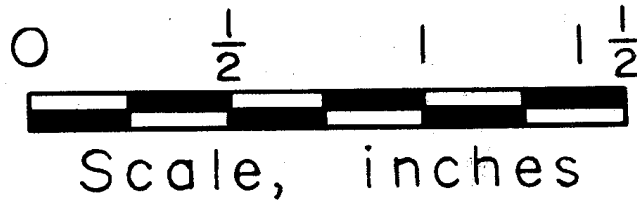
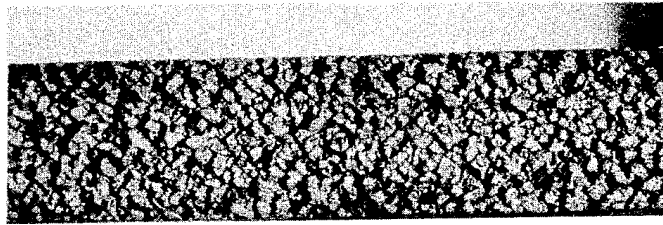


FIG. 2 Edge of rolled plate, with coating

REDUCTION OF COPPER-CAUSED SURFACE CRACKING OF STEEL DURING HOT-WORKING

BACKGROUND OF THE INVENTION

Steel which contains a small amount of copper is known to be hot short or brittle at temperatures at which hot-working operations such as rolling are performed. Surface cracks or imperfections which develop during hot-working continue to propagate causing failure during subsequent fabrication or use.

During hot-working, copper concentrates on the surface of the steel and, because iron preferentially oxidizes, the copper remains in elemental form and does not pass into the scale formed on the steel. Steel is typically hot-worked at temperatures on the order of 1000° to 1300°C; near or above the melting point of copper. As the copper concentrates at the surfaces of the steel and melts, it penetrates the steel surface thus weakening the surface and causing cracks to develop as hot-working is continued. The effect of copper on the hot shortness of steel is also dependent upon the concentration of other metals commonly present in steel. For example, if small quantities of tin are also present along with copper, the cracking observed on hot-worked steel increases markedly. On the other hand, the presence of nickel in association with copper decreases the sensitivity of steel to surface cracking. A discussion of the influence of residual elements on the surface hot shortness of steel is found in the Journal of the Iron and Steel Institute, Vol. 200, pages 290-299, April 1962.

Much iron and steel scrap, especially that derived from automobiles, contains significant amounts of copper. This scrap is generally unsatisfactory for use as a blast furnace charge unless provisions are made for either removing the copper from the scrap before melting or adding nickel or like metals to the charge so as to avoid the detrimental effect of copper. Both approaches are generally so expensive as to be economically prohibitive.

SUMMARY OF THE INVENTION

Surface cracking of copper-containing steels during hot-working is substantially reduced or prevented by coating the steel prior to hot-working with a borax-containing glass. Viscosity of the glass may be controlled by incorporating silica-containing materials such as feldspar as a component of the glass. Application of the glass to the steel may be accomplished by salting the steel with powdered, solid glass or by dipping the steel into molten glass.

Hence, it is an object of my invention to control the surface hot shortness of copper-containing steels.

It is a further object of my invention to provide coatings for steel which prevent the occurrence of liquid copper at the steel surface during hot-working.

It is yet another object of my invention to provide a technique which allows the use of copper-containing scrap in the manufacture of steel.

DETAILED DESCRIPTION OF THE INVENTION

Results obtainable by practice of my invention are illustrated by FIGS. 1 and 2 which are photographic representations of the edges of rolled steel plates showing the reduction of surface cracking by use of glass coatings during hot-working. The figures will be discussed in more detail later.

I have found that boron-containing glasses applied to the surface of hot steel ingots after they are stripped from the mold but before the ingots are preheated for subsequent hot-working will substantially reduce the surface cracking or hot shortness caused by segregation of copper at the steel surfaces. The coating ingredients melt and flow onto the surface of the oxide scale layer of the ingot. As the ingot is further heated to the maximum preheat temperature, generally on the order of 1100° to 1300°C, the glass coating penetrates and reacts with oxide scale. The reaction product appears to be a complex iron-boron-silicon oxide phase which prevents the formation of molten copper thus substantially reducing surface cracking during the hot-working operation.

Boron-containing glasses useful in my invention may comprise borax glass, which is vitreous, anhydrous sodium tetraborate, or may comprise boron oxide-silica glasses. The latter grouping of glasses, those containing silica, display higher viscosities than does borax glass and this higher viscosity is generally advantageous. High viscosities imparted by silica additions to borax glass tends to prevent the coating from running off an ingot before the coating reacts with scale to form less fluid iron borates and silicates during the initial stages of reheating. I particularly prefer to use feldspar as a silica source in combination with sodium borate. However, other sources of silica may be used as well.

The proportion of feldspar to borate used depends upon the viscosity of the glass desired which in turn depends upon the specific temperature or preheat treatment being utilized. As a general rule, higher preheat temperatures require higher glass viscosities for best results. Borax glasses containing as much as 50% feldspar, corresponding to 30-35% silica, have been used with good results. Feldspar content of the borax-containing glasses in the range of 20 to 50% is especially useful when ingots are reheated according to a soaking pit-type reheating schedule prior to hot-working. Borax glass coatings alone without silica generally are satisfactory when using a pusher-type reheating schedule.

Borax glass or borax-silica glass may be applied to an ingot by either dipping in molten glass or by salting. Salting, as the term is used here, is the application of solid, powdered glass on hot ingot surfaces. It was observed that dipping usually gave somewhat better results than salting but salting is generally a more convenient procedure. It is necessary that the ingot be at a temperature above the melting point of the glass at the time the coating is applied. In practice, temperature of the ingot should be above about 800°C, preferably about 1000°C, at the time the glass coating is applied.

My process is generally applicable to those steels containing copper in a concentration whereat surface hot shortness is troublesome during hot working. This in broad terms includes those steels having copper contents ranging from about 0.25 to 1.25% copper. The precise upper and lower limits of copper content depends also upon the presence or absence in the steel of such elements as tin or nickel.

The following examples serve to more fully illustrate specific embodiments of my process.

Example 1

An alloy consisting essentially of iron and 1% copper was prepared by nonconsumable-electrode arc melting

of a compact of that composition. Sections of the alloy were preheated in air at 1000°C for one-half hour to form a scale similar to that found on ingots after hot stripping. Alloy sections were then coated by salting with powders of hydrated and anhydrous borax and borax glass. After salting, the coated alloy sections were heated at 1,250°C for 2 hours, allowed to cool and were then examined metallographically. Copper was found to be present on the surfaces of those alloy sections coated with either hydrated or anhydrous borax but copper was absent on those alloy sections coated with borax glass.

Example 2

Alloy sections identical in composition to those of Example 1 were scaled in air at 800°C for one-half hour. The sections were then coated at that temperature by salting with borax glass and with borax glass containing 25% feldspar. Coated sections were then subjected to a simulated pusher-type heating schedule which consisted of heating the specimens in burnt natural gas-air mixtures to attain a maximum temperature of 1300°C in 2 to 2½ hours. Examination of the specimens disclosed that the inner scale was very thin and that copper was present on the alloy surfaces.

Example 3

Alloys sections identical in composition to those of Example 1 were scaled in air at 1000°C for one-half hour. Scaled specimens were then coated by immersion in molten borax glass and in borax glass containing 25% feldspar. The molten glasses were also at 1000°C. These samples were then subjected to a simulated pusher-type heating schedule as described in Example 2. Those specimens coated with borax glass gave fair results; copper segregation at the alloy surfaces was reduced but not prevented. Specimens coated with borax glass containing 25% feldspar gave much better results. This was attributed to the higher viscosity of the silica-containing glass which reduced the tendency of the coating to run off the alloy section.

Example 4

Ingots of an iron alloy were prepared which had the following composition: carbon, 0.18%; manganese, 0.45%; silicon, 0.28%; and copper 1.09%. Sections of the alloy were scaled in air at 1000°C for one-half hour and were then coated by immersion in molten borax glass containing 25% feldspar. The coated samples were then subjected to a simulated pusher-type heating schedule as described in Example 2.

After cooling, metallographic examination showed no evidence of copper segregation at the alloy surfaces. Retention of borax as complex phases in the inner scale was demonstrated by microprobe analysis as set out in the following table.

TABLE

Phase color	Content, weight percent						Probable phase or complex
	Fe	Si	Na	B	O	Mn	
Light brown	78.0	0.5	1.0	2.0	22.0	0.3	FeO
Steel gray	64.5	0.5	1.0	5.0	31.0	0.2	Fe ₃ B ₂ O ₇
Dark	30.0	19.0	8.0	4.0	36.0	0.9	Na ₂ O.FeO.2SiO ₂ .B ₂ O ₃

Example 5

Alloy sections having a composition identical to those of Example 4 were scaled in air at 1000°C for one-half hour and were then coated by salting with a borax glass containing 50% feldspar. The coated samples were then subjected to a simulated soaking pit-type heating schedule which consisted of heating the specimens in burnt natural gas-air mixtures to reach a maximum temperature of 1300°C in 8 hours. After cooling, there was no evidence of copper segregation on the alloy surface.

Example 6

An ingot of an iron alloy was prepared having the following composition: carbon, 0.22%; manganese, 0.27%; silicon, 0.19%; copper, 0.8% with the balance iron. The ingot was hot-stripped from the mold and one side of the ingot was coated with a glass containing 75% sodium borate and 25% potash feldspar while the other side was left uncoated. The half-coated ingot was then heated in air to a temperature of 1250°C over a 2-hour period and thereafter rolled to one-half thickness in 9 passes.

FIG. 1 illustrates the appearance of the uncoated edge of the rolled plate while FIG. 2 illustrates the coated edge of the plate. As is evident from a comparison of the figures, the glass coating greatly reduced the extent of edge cracking of the rolled plate.

I claim:

1. A method for preventing surface cracking of steels containing from about 0.25% to 1.25% copper during hot-working, said hot-working being performed at a temperature above the melting point of copper, which comprises coating the steel with a borax-containing glass prior to the hot working in an amount sufficient to prevent the formation and segregation of liquid copper at the steel surface.

2. The method of claim 1 wherein the borax-containing glass is applied to the steel at a temperature above about 800°C.

3. The process of claim 2 wherein the borax-containing glass is vitreous, anhydrous, sodium tetraborate.

4. The process of claim 1 wherein the borax-containing glass is a mixture of vitreous, anhydrous, sodium tetraborate and a silica-containing compound.

5. The process of claim 4 wherein the silica-containing compound is feldspar.

6. The process of claim 5 wherein the feldspar content of the borax-containing glass is in the range of 20 to 50%.