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TREATMENT OF STEEL

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This invention relates to the production of steel products and has for an object the provision of an improved method of forming copper steel products. More particularly, the invention contemplates the provision of a process for preventing surface checking of copper steel during forging or rolling.

Copper steels have long had the reputation of being "red short" and "cold short", the reason being that copper magnified the ill effects of oxygen and sulphur present in the steel. Copper steels in which the sulphur and oxygen contents have been reduced sufficiently low may be forged or rolled easily, but, after forging or rolling under usual conditions, the finished shapes have had very poor surfaces due to surface checks or cracks. Also, due to penetration of scale into these checks or cracks, the scale is very adherent, can not be removed readily, and may be rolled into the steel.

The severity of surface checking of copper steels varies with the copper content, the higher the copper content the worse the checking. A copper content of about 2% or more, in steel, will cause severe surface checking when the steel is forged or rolled under usual conditions of heating and working. A copper content of 1.5% causes only a moderate amount of surface checking, and a copper content of less than 1% causes only very slight surface checking. A copper-free steel scales easily but under comparable conditions shows little or no checking.

The surface checks on copper steels have the effect of reducing the apparent strength of the steels in that they act as "nicks" or "notches" and cause premature failure or rupture when the steel is strained beyond its elastic limit, either hot or cold. This is especially serious in steel that must be bent to shape, after being forged or rolled under usual conditions, since the checks are the beginnings of tears in the metal and result in serious weakening or complete failure at the bend.

We have demonstrated that the surface checks on copper steels are not the result of "red shortness" or "cold shortness" by grinding or machining off the surface of a forged copper steel bar, below the depth of penetration of the checks, and then testing the bar. A bar so treated will bend hot or cold as well as a bar of copper-free steel of equal hardness, thus showing that the surface checks are not the result of "red shortness" or "cold shortness".

Our researches indicate that surface checking of copper steel probably can be attributed to the existence of a film of liquid copper on the surface of the steel, resulting from selective oxidation of iron. When a copper steel is heated in the presence of a gas that will oxidize iron, the iron is selectively oxidized to iron oxide which forms scale and the copper is concentrated on the steel surface, the degree of concentration depending on the temperature and amount of scaling. The maximum concentration seems to take place at a temperature near the melting point of copper.

The following is an example of scaling tests made to determine the effect of temperature on the concentration of copper on a steel surface during scaling. Pieces of copper steel containing 2% copper were heated in an electric muffle furnace, with fairly free access of air, for times and temperatures indicated below. The pieces were cooled in air, and the scale was cracked off and analyzed for iron and copper.

Temperature	Time	Percent Fe	Percent Cu
950° C.	1 hr.	73.0	0.80
1000° C.	1 hr.	74.4	0.51
1050° C.	1 hr.	73.1	0.25
1086° C.	1 hr.	74.0	0.15
1100° C.	½ hr.	73.2	0.40
1150° C.	½ hr.	72.2	0.25

The above figures appear to indicate that a very considerable concentration of copper on the steel surface takes place during scale formation while the steel is being heated to forging temperatures. Once the copper film is formed on the surface of the steel, further scale formation apparently takes place by transfer of iron through the copper plate. The copper tends to alloy with the iron and the iron is oxidized away from the outer copper surface. We probably have the following conditions when copper steel is being treated in an oxidizing atmosphere: starting with the body of the iron and proceeding to the exterior, we have—Fe; Cu-rich Fe; Fe-rich Cu grading into Fe lean-O_2 rich Cu; and finally Fe oxide scale. Under these conditions, and especially above the melting point of copper, the copper becomes an active corrosion agent dissolving iron and expediting its oxidation. The attack of the iron by the copper proceeds relatively uniformly over the iron surfaces, that is, without apparent relation to the Fe grain boundaries. Likewise, the liquid copper appears capable of readily wetting the iron surface, when the temperature is above the melting point of copper.

The above described precipitation of copper on the surface of copper steel, together with the attack of the iron by the combination of oxygen and copper does not in itself effect surface checking, a surface plating of copper being the result. However, if the steel is worked at a temperature at which the copper film is liquid, serious surface checking will result. This probably is due to the forcing of the copper between the iron grains or its capillary penetration into minute crevices opened up by the working.

We have discovered that objectionable surface