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METHOD OF PRODUCING A DEEP DRAWN ARTICLE OF SHEET IRON

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This invention relates to electrolytically deposited sheet iron. It consists in the heat treatment of sheet of specific metallurgical characteristics. The sheet is obtained by deposit from an electrolyte of specific composition, and presumably is obtainable by deposit from other electrolytes of like general character.

A rolled sheet of iron or steel is of crystalline structure; and the component crystals, in consequence of the rolling operation, have been greatly elongated in the direction of the extension of the sheet. The long axes of the crystals lie in the plane of extension. The sheet has a fibrous, stringy, "pulled-taffy" structure.

For many uses this stringy structure of rolled sheet is not disadvantageous; but for deep-drawing purposes—that is to say, for elaborate shaping between dies, shaping such as is called for in many industries—this structure is highly disadvantageous. And it has been found that, if the rolled sheet be heated (in inert atmosphere, to prevent scaling) to a temperature above the upper critical (1600° to 1650° F.—the figure varies somewhat with the minute composition of the material) and maintained at such high temperature for a sufficient length of time (the interval being great or less, according to the margin by which the critical point is exceeded), the stringy, fibrous texture of the sheet will disappear, the elongate crystals will disappear, and when the material is cooled again a new crystalline structure will be assumed, a structure in which the crystals are of no greater extent in one direction than in another. This new crystalline structure has been characterized the "normal" structure, and the heat-treating operation by which it is realized has been called "normalizing." The sheet material thus changed may be drawn between dies.

Electrically deposited sheet iron also is of crystalline structure, and is fibrous; but the fibres or crystals lie, not in the direction of the extent of the sheet, but transversely, and perpendicular to the surface upon which the electrodeposition took place. Electrolytically deposited sheet iron is, furthermore, brittle; and it is known that if such sheet material be submitted to the normalizing operation, not only will the fibrous structure be lost and replaced by a new crystalline structure, but the brittleness that characterizes the newly formed sheet will be removed, and the sheet will be rendered more widely useful. In the normalizing of the electrolytically deposited sheet, as in the normalizing of rolled sheet, the initial crystalline structure disappears, and a new and normalized structure is brought about.

We have perceived that the crystalline structure that is characteristic of electrolytically deposited sheet is not, in itself, disadvantageous; but, to the contrary, is highly advantageous for deep-drawing; and we have discovered that, following a particular procedure and obtaining a sheet of particular metallurgical character, it is possible by heat treatment to gain ductility without loss or substantial change of crystalline structure; and thus to produce a sheet of exceptional and peculiar value for deep-drawing purposes.

The electrolytically deposited sheet involved in the practice of our invention has a small amount of iron oxide occluded at its grain boundaries, and is substantially free of impurities of a reducing nature, such as under the temperatures of heat treatment would react with iron oxide; and it is the iron oxide content that, continuing in the substance of the iron sheet, prevents grain growth at the heat-treating temperatures and insures the continuance in the heat-treated product of the crystalline structure that is characteristic of electrolytically deposited sheet. In any event, the quantity of reducing impurities is small and insufficient to reduce all of the iron oxide during the normalizing process.

We obtain a sheet having the metallurgical characteristics that have been indicated by employing in the electrolytic cell a stripping cathode, a soluble iron anode, and an electrolyte that is an aqueous solution of an inorganic iron salt, specifically ferrous ammonium sulphate. The alkalinity of the electrolyte is maintained at the pH value of approximately 6 (5.9–6.5); the temperature is maintained at approximately 158° F. (70° C.); a current strength of 75–130 amperes per square foot is maintained; and the electrolyte is kept in agitation. We have found that electro-deposits made under these conditions contain little or no hydrogen as such, but do contain small amounts of iron hydroxide. On heating, the iron hydroxide breaks up into water and iron oxide. Some of the water escapes, but a considerable amount reacts with the iron, producing more iron oxide and hydrogen. The iron oxide present, we believe, stabilizes the crystal structure, and thus in the absence of substantial quantities of reducing materials no grain growth takes place during the normalizing treatment.

For the obtaining of sheet metal having the metallurgical characteristics indicated, solutions of organic salts as electrolytes are not suitable; for the by-products of reducing nature, conse-

quent on cell operation, must inevitably be prejudicial to the formation and continuance of the iron oxide that we desire.

We have discovered that, if the sheet produced in the manner and possessed of the metallurgical characteristics described be heated substantially to (but not beyond) the upper critical, while the characteristic crystalline structure will remain (normalizing will not have occurred), the brittleness will have been taken away. We do not intend to say that there will be no molecular change; but any such change as may occur will occur within, and without substantial modification of, the existing crystalline framework. The essential characteristic of crystals that in extent are perpendicular to the extent of the sheet will continue.

We have discovered that it suffices to remove, in the manner indicated, the characteristic of brittleness of the sheet as it comes from the cathode; and that then the material is such in texture and quality as to be peculiarly suited to deep-drawing operations. The crystals, though prolonged, are prolonged, not in the direction of the extent of the sheet, but in a direction perpendicular to the extent of the sheet; and, in the direction of the extent of the sheet, the crystals are minute. The sheet, then, from the point of view of one who practices deep drawing, is exceedingly fine grained, and as such is peculiarly well suited to his purposes. The fineness of grain is such as is not easily to be attained in normalizing operations, for grain-growth is an incident to detention at the high temperatures requisite to effect normalizing. Thus it is that, by the elimination of brittleness, and without rearrangement of the crystalline structure of the sheet, we bring the sheet to condition well suited to deep-drawing operations. The material spreads freely over the die surfaces, without splitting or tearing, and the shaped article has the superior surface texture characteristic of fine-grained material.

Electrolytically deposited sheet is in chemical purity vastly superior to the rolled sheet of the present day. It is consequently relatively inert, less susceptible to deterioration by chemical reaction, and more readily responsive to welding, tinning, and enamel coating operations; it affords a more excellent surface for lacquers and paints.

In practising the invention, we take the sheet as it is stripped from the cathode of the electrolytic cell and we heat it in a furnace chamber from which oxygen in excess is carefully excluded, to the end that the material shall not scale, and we raise it approximately to, but preferably not beyond, the upper critical (about 1650° F.), hold it at such peak temperature for a brief interval, and we then allow it to grow cold again. This heating and cooling may be effected either in an intermittently heated and cooled chamber, or in the chamber of a continuous furnace in which the proper heat gradients are maintained, the knowledge of the art being available in all such matters to one who practises the invention.

In practice we so control operation as to attain a peak temperature as near to the upper critical as is possible, and we hold the sheet at such peak for at least twenty seconds. If the peak temperature be less, the time of maintenance at peak temperature may be prolonged. For example, maintaining a peak temperature of 1476° F., and prolonging time at peak temperature to thirty minutes, excellent ductility may still be gained. But prolongation of the time to thirty minutes at a temperature of 1650° will result in a recrystallized sheet—a sheet that, compared with the properly treated sheet, is, for deep-drawing purposes, inferior. We prefer to approximate the upper critical temperature and to maintain the material at peak temperature for about, though not less than, twenty seconds. While we recommend a peak temperature not exceeding the upper critical (since our invention is achieved in the removal of brittleness without recrystallization), it is entirely possible, proceeding with speed, momentarily even to exceed the upper critical in the peak temperature of our procedure. When, therefore, in the ensuing claims we define the method as involving a heating of the material approximately to the upper critical, the possibility here explained will be recognized to be within our contemplation as a performance of the method of our invention.

By way of illustration and definition, our material of a thickness of 0.011 of an inch, brought in heat treatment to a peak temperature of 1285° F. and maintained at such peak for thirty minutes, manifests a ductility that, under the Erichsen test, using a seven-eighths inch ball, gives a 0.46 inch cup. This is fairly good. The same material, maintained for thirty minutes at a peak of 1470° F., gives a 0.51 cup. This is excellent. The same material, maintained for thirty minutes at 1630° F., gives a 0.51 cup. The same material, maintained for twenty seconds at 1640° F., gives a 0.55 cup. In all these cases the crystalline structure characteristic of electrolytically deposited sheet remains unchanged. If, however, the same material be maintained for thirty minutes at a peak of 1650° F., the crystalline structure will be changed; a recrystallized structure produced; and the ductility will, under the Erichsen test, be found to afford not greater than a 0.34 cup. We are the first to produce a heat-treated sheet having the crystalline structure characteristic of electrolytic deposition and having a ductility that, by the Erichsen test, made upon a sheet of 0.011 of an inch in thickness, affords a cup of 0.35 of an inch or better.

We claim as our invention:

1. The method of producing a deep-drawn article of sheet-iron which consists in depositing electrolytically upon a stripping cathode a sheet of iron having a small amount of iron oxide occluded at its grain boundaries and being substantially free of impurities of a reducing nature, removing the deposited sheet from the cathode, heating the sheet substantially to the upper critical and cooling it again before appreciable change has occurred in its crystalline structure, and deep-drawing the so treated sheet between dies, whereby tendencies to tear are diminished and a surface of superior excellence is afforded.

2. The method herein described of producing a deep-drawn article of sheet-iron which consists in depositing a sheet of iron electrolytically within a cell that includes a soluble iron anode and a stripping cathode in an electrolyte of an aqueous solution of an inorganic iron salt, stripping the deposited sheet from the cathode, heating the sheet substantially to the upper critical and cooling it again before appreciable change has occurred in its crystalline structure, and deep-drawing the so treated sheet between dies, whereby tendencies to tear are diminished and a surface of superior excellence is afforded.

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