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METHOD FOR MAKING MANGANESE STEEL SHEETS

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The object of the present invention is sheets made of a steel of the class known as austenitic manganese steel containing 1.00 to 1.40 per cent carbon, 10.00 to 14.00 per cent manganese, 0.30 to 1.00 per cent silicon, and other constituents in the amounts common to this grade of steel, which possess superior deep drawing properties when subjected to cold forming operations and, particularly, sheets made of the steel of the above class containing 1.25 to 1.35 per cent carbon, 12.75 to 13.25 per cent manganese, 0.30 to 0.45 per cent silicon, and other constituents in the amounts common to this grade of steel, which possess superior deep drawing properties.

A further object of the present invention is a process for making sheets manufactured of steels having the above mentioned composition which have superior deep drawing properties.

From the time of their introduction, about half a century ago, high manganese austenitic steels found a wide application for industrial purposes when high resistance to abrasion was required. Properties of this steel, particularly its easy response to cold working transforming the metal from austenitic and comparatively ductile and soft metal to a martensitic alloy, circumscribed the field of their practical use to applications not calling for any machining operations, other than grinding. For a long time, the use of the high manganese austenitic steels had to be limited exclusively to castings requiring a minimum of finishing operations. Further developments in the art of metallurgy indicated ways and means permitting rolling of these alloys into sheets, and cold forming these sheets into a number of comparatively simple shapes without incurring pronounced difficulties in the course of manufacturing processes.

Sheets of this type were made either in electric furnaces or by adding molten ferromanganese to the open hearth ladles prior to introducing molten steel into them. The alloyed steel was then cast into ingots, according to the generally accepted practice, bloomed, and hot rolled, in steps, into sheets or strip following the usual practice, but modified in the light of the peculiarities of the metal. As a penultimate step of the processing operation, a quenching operation was always employed, in which packs of sheets were commonly quenched in preference to the quenching of individual units. The final manufacturing step called for cold flattening warped quenched sheets. This practice was not based on theoretical considerations, but had to be conducted in this manner in the light of industrial considerations.

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Sheets made in the manner described and delivered to the pressings manufacturers could be drawn usually into simple shapes without undue complications, provided a proper care of the annealing operations involved between consecutive draws in the dies was exercised and the steel mill practice was conducted with the proper attention to the important details of metallurgical nature. However, when more complicated designs entered the industrial field, sheets, made with the greatest care and minute attention to details, failed badly in presses, rendering their use entirely impracticable from a commercial standpoint. When complex curvatures had to be produced, such as required in making visor spanking of military helmets, sheets found suitable for simpler designs could be drawn only with great difficulty irrespective of the number of anneals interposed between the drawing passes, resulting in 35 to 40 per cent breakage. A comprehensive research demonstrated that the breakage and cracking involved in this case could not be associated with any particularity of the die design and were connected, apparently, only with metallurgical features of the stock to be drawn. Among them a prominent position was occupied by the presence of undissolved carbides in the body of the metal, the existence of decarburization or of carburization at the surface, and the formation of martensite and of its decomposition products in the process of final cold flattening.

It has been found by me that many sheets failing to meet deep drawing requirements had a number of discrete particles of a substance resembling in its metallographic characteristics those of carbides, and which in the following discussion will be called carbides, disseminated through their body composed principally of austenitic grains. It has been observed further by me that there is an apparently direct relation between the tendency of sheets to fail in deep drawing and the amount of free carbides of this type present in the metal. These observations appear to be in a direct contradiction with the generally accepted ideas bearing on the behavior of the iron-carbon-manganese system. In spite of a comparatively high carbon and manganese content of these steels, the common opinion of metallurgists holds the austenitic nature of the alloys in question fully capable of holding carbon in solid solution after a moderately rapid cooling, and allows carbon precipitation in the

shape of carbides only after a slow cooling. Deep drawing sheets are always made with the use of a quenching step, in other words, applying to the metal the highest commercially known heat-removal rate. One can easily see that the ductility of a metallic body composed of comparatively soft austenitic grains would be greatly diminished by interposing at the grain boundaries of these grains a number of very hard particles of free carbides entirely lacking ductility. The production of sheets with higher forming qualities required, therefore, the removal of these carbides, specified by the composition of the stock, in some appropriate manner, preferably by heat treatment.

Equilibria considerations involved indicated a direct dependency of the carbide solubility on the temperature involved in the quenching operation. A series of tests conducted within a temperature range of 1400° to 2200° F. in steps of 25°, led to the determination of a critical temperature, at which the rate of solution of these carbides is adequate to meet conditions of practical operations within heating time suitable for industrial applications. Heating below 1750° F. yielded sheets with an elongation of 23 to 28 per cent in 2 inches, while heating at or above 1850° F. increased this value to 55 to 60 per cent.

Reducing the teachings of the above observation to practice does not present any difficulties from the standpoint of the equipment involved, but brings to the fore the effect of high temperature found necessary for achieving the desired results. Austenitic nature of the alloy used is associated with high chemical activity in respect to gases present in the furnace atmosphere. A comparatively slight excess of oxygen in a gaseous mixture surrounding the objects easily leads to carbon migration to the surface, and its elimination as carbon dioxide depletes a comparatively heavy layer at the surface of the metal of its carbon. Inversely, a recarburizing atmosphere present in the furnace increases the carbon content of the outside layers of the stock being treated to the extent leading to carbides retention in the course of the heat treating operation adjusted for the normal content of this element in the steel. As an example of changes in composition occurring with the use of a slightly oxidizing flame can be given cases when the original carbon content of 1.35 per cent dropped to from 0.95 per cent to 1.03 per cent on the average for the sheet, while the decarburization in the outside layers was, naturally, much more pronounced. Furthermore, the manganese content of the sheets showed a very definite decrease, frequently dropping from 13 per cent originally present in the steel to 11.5 per cent found in the finished and heat treated sheets. This peculiar behavior of the austenitic manganese steels was known prior to the present invention, but I found, in addition to this general observation, that the reactions of this type are limited, under steel mills operating conditions, to the surface layers of the sheets rather than to their bodies. A very pronounced difference in alloying elements content of steel between the outside layers and the body of the sheets created by this means, even when the average composition is but slightly changed, introduces surface conditions which are liable to have a deleterious effect on their drawing characteristics.

A metallographic study conducted on a large number of samples taken from satisfactory sheets and those which failed to draw properly in the presses supported the ideas expressed above. From the well known constitutional diagrams of the iron-carbon-manganese system a deduction can easily be reached associating reduced carbon content occurring in oxidizing atmospheres with the transformation of the homogeneous austenitic mass of the alloy to martensite, a combination of austenite with martensite, or its decomposition products. Microscopic analysis showed definitely the failure of sheets being associated, among other factors, with the structure of their outside layers consisting of constituents characterizing carbon-iron-manganese systems with a lower carbon concentration. In case of carburizing atmosphere, the presence of appreciable amounts of free carbides could be noted, again adding to the explanation of the mechanism taking place.

I have found, therefore, that a production of sheets containing 1.00 per cent to 1.40 per cent carbon, 10.00 per cent to 14.00 per cent manganese, 0.30 per cent to 0.45 per cent silicon giving satisfactory performance in the drawing presses is associated not only with the freedom from precipitated carbides within the body of the sheets but with the absence of either decarburization or carburization within the superficial layers of them, and that sheets of appropriate characteristics can be produced only when the atmosphere of the furnaces used for heating sheets prior to their quenching is properly controlled.

Controlling atmosphere of the heating furnaces used in treating ferrous and nonferrous metals is an old art, well known in application to many alloys containing iron as their major ingredient. However, no adequate atmospheres possessing a substantially neutral effect when used with the high-manganese alloys described in the present invention were known, or have been developed. In spite of a very large volume of accumulated data bearing on the action of controlled atmospheres on the reactions involved in the heat treating cycles, no atmosphere suitable for high manganese steels could be predicated on their basis.

After a long experimental investigation, I found that in order to be efficient, namely, preventive of either carburization or carbon removal from the manganese sheets of the type described, the atmosphere used should have specific characteristics. The exact composition of this atmosphere could not be determined as yet analytically, and can be defined only by the qualitative description of the flame issuing from the furnace doors and filling the heating space of the furnace proper. In order to be satisfactory, the atmosphere should fill the heating space of the furnace with a flame permitting seeing the objects to be heated with only a slight blurring, in other words, not exactly clear. On issuing from the furnace doors, the flame created by the proper atmosphere does not result in heavy smoke nor cause a clear flame, but has barely a touch of smoke on it. Even though no quantitative description can be given of the flame produced, which serves as an index or an indicator of the suitability of the atmosphere for the purpose intended, its qualitative aspects are easily discernible by those connected with the operation of satisfactory quenching the steel after a comparatively short experience, as it has been shown by an extensive, practical, and satisfactory use of the method in production of large tonnages of this type of sheets.

Furthermore, the appearance of the flame can serve for defining the composition of the atmos-

phere provident of the desired results only under specific conditions. During the early stages of the work leading to the present application I have discovered that the type of fuel used in the quenching furnaces has a very pronounced effect on the quality of the finished product. All attempts of using natural gas for the purpose resulted in marked decarburization, even when the combustion conditions were adjusted to result in a strongly reducing atmosphere, and the appearance of the flame issuing from the doors closely resembled the one desired for optimum results. This led me to the conclusion that hydrogen and water vapor present in burning natural gas in concentrations inherent to the latter have a decarburizing action, when brought in contact with steels of the class described, more pronounced than the carburizing effect exerted by the presence of an excess of carbon or its compounds in the atmosphere of the furnaces, rendering the use of natural gas unsuitable for the purpose.

The fuel problem was solved by substituting natural gas with oil, as a fuel for quenching furnaces, and controlling the composition of the atmosphere created by its combustion basing on the appearance of the flame issuing from the doors in a manner described. A combination of oil flame with proper regulation of combustion greatly reduced the loss of both carbon and of manganese. Average values illustrating losses to be expected with this practice and based on a large number of determinations indicated the maximum carbon drop to be expected varying under 0.15 per cent, and that of manganese being limited by 1.00 per cent maximum. With proper elimination of free carbides, and the changes of composition produced by heating being limited to figures given above, sheets having the desired response to deep drawing operations can be produced repeatedly, provided the manufacturing steps following the quenching operation are properly executed.

Among factors necessary for producing satisfactory manganese steel sheets, a prominent place is occupied, as it has been found by many, by cold work applied to sheets during the process of their straightening and flattening after the quenching operation. It is generally known that application of cold deformation to steels rendered austenitic by a judicious addition of manganese and carbon, heating to a proper temperature and cooling at a comparatively rapid rate causes a very pronounced transformation of the austenitic to martensite. This transformation, depending on the extent of cold deformation taking place, has a definite and a very deleterious effect on the ductility and the drawing characteristics of the sheets. However, a very pronounced warpage following quenching operations, even when conducted with the utmost care, inevitably calls for a considerable amount of flattening or straightening prior to the application of the sheets to the final forming operations. For production of quality deep drawing austenitic manganese steels a third factor must be added, therefore, to the two mentioned above, namely, prevention of martensitic transformation during the cold flattening process.

I have discovered that quenching sheets made of steel of the class described in water has the character of an isothermal transformation, and that for a certain length of time after immersing into water the metal remains in the state of a labile equilibrium responding differently to the application of cold deformation than it can be

expected in the light of common knowledge or theoretical considerations accepted by the metallurgical art. During this time interval, austenite remains substantially stable, irrespective of the cold deformation to which it might have been subjected, in a manner permitting any desired amount of straightening or flattening without inducing an undesirable formation of martensite and a deterioration of deep drawing properties ancillary to it. At the expiration of this time interval, steel responds to cold deformation in the commonly known manner. The time interval involved here is affected to a certain extent by the factors entering the processes. In a way of illustration, it can be said that for 0.044 inch gauge sheets of the grade described quenched vertically in water in packs of four from about 1850° F. this time interval is close to two minutes.

Quenching operations, according to my invention, are preferably conducted in a continuous oil-fired furnace provided with means for gradual moving of sheets through the heating zone at some predetermined rate. This furnace is, preferably, structurally connected with a cooling means, such as a tank filled with water and supplied with the necessary auxiliary equipment permitting sheets, directly on reaching proper temperature, being immersed in a cooling medium, preferably in a vertical position. The use of oil-fired furnaces is a convenient means for obtaining the desired results in connection with my invention, but other heating means can be advantageously employed, either of direct or indirect nature, provided they permit controlling the atmosphere filling the furnace in the manner suitable for avoiding changes in carbon and manganese content of the steel under treatment.

For the reduction of my invention to practice, I prefer to make steel containing 1.00 per cent to 1.40 per cent carbon, 10.00 per cent to 14.00 per cent manganese, 0.30 per cent to 0.45 per cent silicon, and other elements in the percentage common to this grade of steel, including about 0.05 per cent maximum of sulphur and 0.1 per cent maximum of phosphorus, in any appropriate manner, casting it into over-sized bodies, hot rolling the ingots so produced, in steps, to the sheets of proper size, following the generally used practice adjusted to the composition of these steels, placing packs, preferably containing four sheets of about 0.044 inch gauge, on the conveyor of the quenching furnace, heating them to slightly above 1850° F., adjusting, meanwhile, the speed of conveyor to the rate of heating in such a manner that on reaching this proper temperature, the conveyor pushes the packs into the quenching tank. After removal from the quenching tank, preferably with the use of an appropriate rack, heavily warped sheets are fed singly into a cold mill or a roller leveler, or a combination of the two, located close to the quenching tank, and are given a single pass to flatten, taking care to terminate the flattening process within one minute and thirty seconds from the time the sheets enter the quenching medium. On leaving the roller leveler, the sheets are perfectly flat and are ready for shipment to the forming plants without the need for any other treatment than an occasional squaring to size and oiling to prevent rusting. Sheets made in the manner described show an average total breakage in difficult drawing operations of 2 to 3 per cent.

Specific factors involved in the reduction of my invention to practice and given in a way of an example in the present specification are open

to many modifications and changes apparent to those skilled in the art without, in any way, digressing from the spirit and the teachings of my invention as presented in the following claims.

I claim:

1. Method for making deep drawing sheets of austenitic steel containing substantially 1.25 to 1.35 per cent carbon, 12.75 to 13.25 per cent manganese, 0.30 to 0.45 per cent silicon, 0.05 per cent maximum sulfur and 0.1 per cent maximum phosphorus, consisting in melting and finishing a heat of steel in an appropriate manner, casting it into oversized bodies, hot rolling said oversized bodies, in steps, to the final dimensions of sheets, heating said sheets for quenching under conditions leading to complete solution of carbides while avoiding appreciable changes in the original carbon content, quenching said sheets, and cold flattening said quenched sheets within a time interval after quenching provident of retaining the metal in austenitic state after the flattening.

2. In a method for making deep drawing sheets of austenitic steels containing substantially 1.25 to 1.35 per cent carbon, 12.75 to 13.25 per cent manganese, 0.30 to 0.45 per cent silicon, 0.05 per cent maximum sulphur and 0.1 per cent maximum phosphorus, consisting in melting and finishing a heat of steel in an appropriate manner, casting it into oversized bodies, hot rolling said oversized bodies, in steps, to the final dimensions of sheets, heating said sheets for quenching under conditions leading to complete solution of carbides, while avoiding appreciable changes in the original carbon content, quenching said sheets, and cold flattening said sheets within time interval after quenching provident of retaining the metal in austenitic state after the flattening, the step of completing cold flattening operations within two minutes after the sheets enter the quenching bath.

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