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METHOD OF PRODUCING MALLEABLE IRON

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According to the so-called American process malleable iron is produced from white cast iron of suitable composition in the following manner. The castings are first annealed at a temperature above Ac_1, usually between 800 and 900° C. until all free cementite—Fe_3C—is consumed, i. e. until the original structure consisting of austenite and cementite has been transformed into austenite and graphite, and are then allowed to cool slowly, the temperature being usually kept constant, somewhat below Ar_1, for an extended period. Owing to the slow cooling, the amount of carbon that corresponds with the decreasing solubility is precipitated as graphite, not as cementite. While the temperature is held below Ar_1, the pearlite formed from austenite at Ar_1 is decomposed into ferrite and graphite. Thus, the end product, malleable iron, consists of ferrite with particles of graphite distributed in it. For the whole process several days are required.

Several years ago, two Japanese investigators, D. Saito and H. Sawamura, discovered the fact that, on first quenching the castings in water from a high temperature, about 850–950° C., and then subjecting them to the malleableizing anneal, the number of graphite particles formed are greatly increased and, in consequence the annealing treatment can be considerably shortened, say, to less than 48 hours. This is described in "Memoirs of the College of Engineering, Kyoto Imperial University," Vol. V., No. 1, July 1927, under the title: "A New Phenomenon Concerning the Graphitization of White Cast Iron and Its Application to the Manufacture of Black Heart Malleable Castings." The authors explain the phenomenon by assuming that the stresses produced on the transformation of austenite into martensite cause the cementite particles to be broken up into small fragments, in the free surfaces of which graphite nuclei are readily formed during the subsequent annealing treatment. Their hypothesis appears to be supported by the fact that the result described is obtained after very rapid cooling only. The practical development of this process, anticipated from the reduced cost of manufacture, has not, however, been realized.

The present invention developed out of an investigation carried out by the inventor with a view to ascertain the conditions required for shortening the malleableizing anneal by a previous quenching treatment. It was found that the hypothesis put forth by Saito and Sawamura for explaining the formation of numerous graphite nuclei is not correct. These nuclei are not formed in the cementite, but in the martensite that constitutes a great part of the matrix after quenching, the remainder of the matrix being austenite. On heating—tempering—martensite it is usually decomposed into an aggregate of ferrite and cementite. In this case, i. e. on tempering hardened cast iron, of the composition commonly used for malleable castings, numerous submicroscopic graphite particles are also formed which on continued heating to higher temperatures grow to particles visible in the microscope. These particles act as nuclei for the precipitation of graphite during the malleableizing anneal. Owing to the numerous graphite particles formed the malleableizing anneal, under favourable conditions can be shortened to such an extent that the whole process, including quenching, takes less than 12 hours. On quenching followed by rapid heating the number of graphite particles formed during malleableizing—as counted in unit area—was multiplied more than 100 times as compared with the number formed on ordinary malleableizing treatment. If the heating after quenching was retarded the number was doubled again. This is seen from the following figures:

On malleableizing at 925° C. without pre-quenching: 75–100 particles pro sq. mm.

On quenching from 975° followed by rapid heating and malleableizing at 975° C.: about 14,000 particles pro sq. mm.

On quenching from 975° C., rapid heating to 600° C., holding at 600° C. for ½ hour and malleableizing at 975° C.: about 20,000 particles pro sq. mm.

On quenching from 975° C., slow heating to 600° C., holding at 600° C. for ½ hour and malleableizing at 975° C.: about 30,000 particles pro sq. mm.

These results were obtained on 6 mm. rd. rods of white cast iron having the following composition: 3.0% C, 0.95% Si, 0.3% Mn, 0.10% P, 0.05% S. The rods were quenched in oil and then became martensitic.

If this process is applied to castings of white cast iron of ordinary analysis similar to the above and having the dimensions usually required for malleable castings it fails for the following reasons: (1) either quenching is done in oil, in which case the matrix becomes sorbitic and the graphite particles formed on annealing are not increased in number or (2) quenching is done in water, in which case quenching cracks cannot be avoided.

Thus, in order that the discovery made regarding the importance of martensite as a matrix for

enhanced graphite nucleation may be put to practical application the following conditions must be fulfilled.

(1) The cast iron should have such a composition that castings of the dimensions and shape required can be made largely martensitic by quenching without the formation of quenching cracks. By the use of suitable alloy additions, such as Mn, Ni, Cr, Mo etcetera, the hardening depth of steel and cast iron can be raised to such an extent that even heavy objects may be through-hardened on quenching in oil or even on cooling in air, thus preventing the formation of quenching cracks.

(2) The composition should be balanced in regard to tendency for graphitization, i. e. the castings, of required size and under existing casting conditions, should solidify white, with practically no graphite formation but graphite nuclei should readily form on tempering of the martensite and their growth on annealing should not be retarded or suppressed. C, Si, Ni and Cu favour graphitization, Mn, Cr and Mo retard it.

A common composition for making malleable iron is mentioned above. This is balanced in the sense of condition (2), i. e. the C and Si contents will, in the presence of the low Mn content, produce the desired graphitization tendency. The changes required in order to fulfil condition (1) can be brought about in different ways, for instance:

(*a*) By adding Ni and/or Cu and lowering the C and/or Si content.

(*b*) By raising the Mn and raising the C and/or Si content.

(*c*) By adding Cr and/or Mo and raising the C and/or Si content.

(*d*) By adding Ni and/or Cu on one hand, Cr and/or Mo on the other and maintaining the C and Si contents.

After the various ways of carrying out the invention have thus been defined in principle, the actual amounts of the respective alloy contents to be applied in each particular case are easily found by experiment, at the same time taking into consideration the cost and physical and chemical properties of the malleable iron produced.

The process for producing malleable iron for which patent is herewith applied consists in taking castings of a cast iron containing certain alloy components, on one hand at least one of such components as favour the graphitization, for instance, Si, Ni, Cu, on the other at least one of such alloy components as increase the depth of hardening on quenching or cooling, for instance, Ni, Cr, Mn, in such concentrations that with existing dimensions and casting conditions, the castings solidify white and, further, can be hardened to sufficient depth to a largely martensitic-austenitic state by cooling from a temperature exceeding A_1 in oil or equivalent or less efficacious cooling medium, and subjecting said castings first to cooling in a cooling medium at most as efficacious as oil from a temperature exceeding A_1 so as to transform the matrix into a largely martensitic-austenitic state, and then to a malleableizing anneal. The heating after hardening up to about 600° C. may be carried out at a rate not exceeding 20° pro minute. Preferably the hardened casting on subsequent heating is kept within 550–700° C. for more than 10 minutes.

For certain purposes, requiring a greater strength than is obtained from a malleable iron having a ferritic matrix, heat-treated or so-called pearlitic malleable iron is used. Either the objects are heat-treated after completed malleableization or cooled at a faster rate than ordinarily during the later stage of the malleableizing anneal. In making pearlitic malleable iron alloy cast iron is often employed. In that case, the object of the alloying additions is different from that of the present invention and the heat-treatment succeeds malleableization instead of preceding it as described above. On the other hand a subsequent or concluding heat-treatment may also be applied to castings that have been manufactured or treated according to the present invention, with the object of obtaining greater strength. The heat-treatment may consist in fairly rapid cooling from a temperature above A_1 to give a pearlitic or sorbitic matrix or in quenching in oil or the like from a temperature above A_1 to give martensitic structure followed by tempering to a temperature below A_1. When abrasive resistance combined with the lubricating properties of graphite are called for tempering may be omitted or carried out at a low temperature.

Having now described my invention, what I claim as new and desire to secure by Letters Patent is:

1. Method of producing malleable iron from cast iron, comprising making castings of white cast iron, containing a component increasing the depth of hardening taken from a group consisting of nickel, chromium and manganese, said component being in such concentration that the castings will be hardened to sufficient depth to a largely martensitic-austenitic state by cooling from a temperature exceeding A_1 in a cooling medium not more efficacious than oil, and subjecting the castings to such a cooling and then to a malleableizing anneal.

2. In a method claimed in claim 1, heating the heat-treated object, prior to the malleableizing anneal, up to about 600° C. at a rate not exceeding 20° per minute.

3. In a method claimed in claim 1, subjecting the heat-treated object to heating prior to the malleableizing anneal, the object being kept within a range of temperature of between 550 and 700° for more than 10 minutes.

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