United States Patent

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[54] **PROCESS FOR FORMING SPHEROIDAL GRAPHITE IN HYPEREUTECTOID STEELS**
4 Claims, 1 Drawing Fig.

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[50] **Field of Search** 75/51, 59, 130

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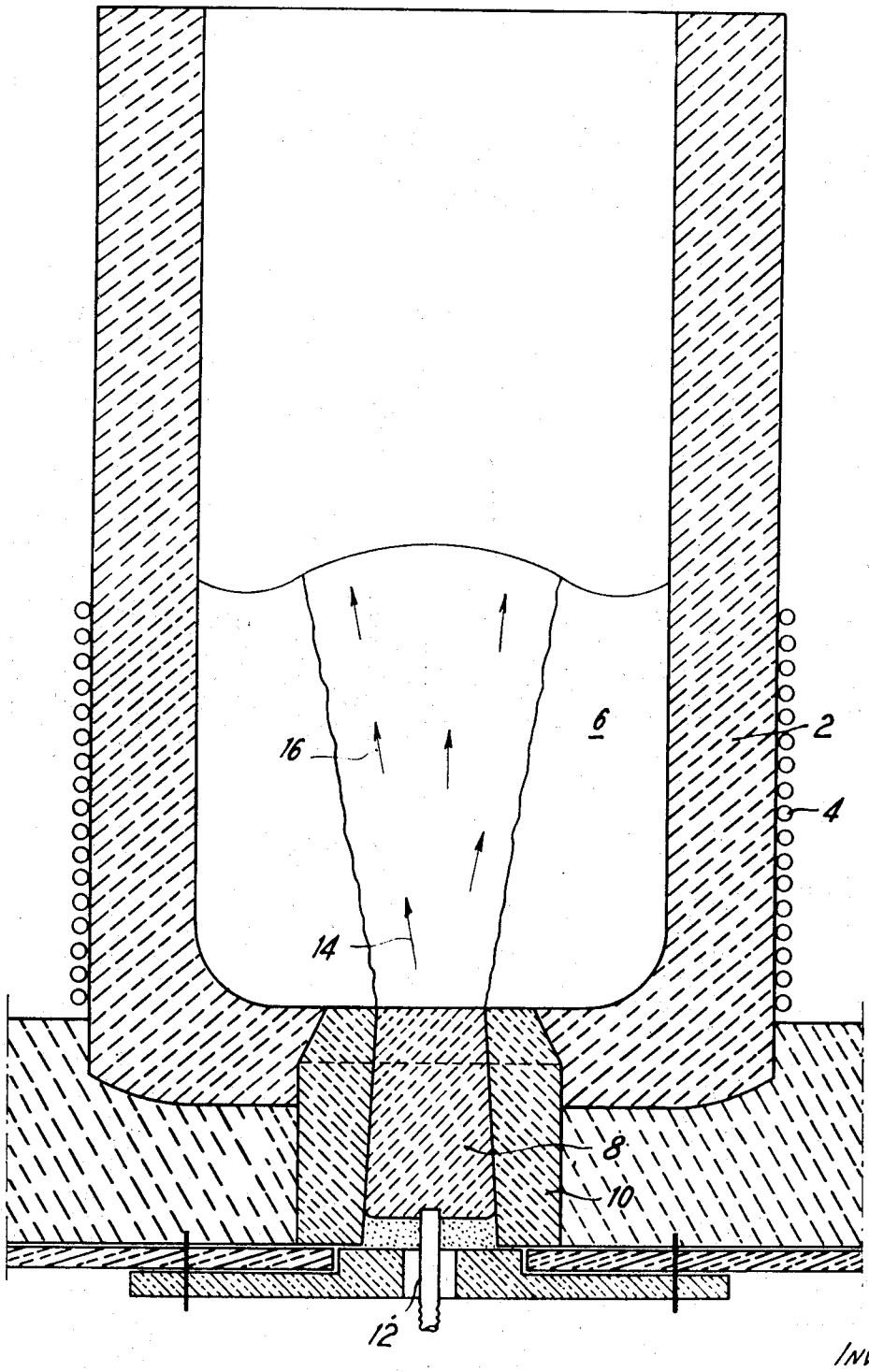
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ABSTRACT: Process for improving the castability and the mechanical characteristics of iron-carbon alloys containing between 0.8 and 2.5% by weight of carbon by precipitating at least part of the carbon in excess of that of the eutectoid in the form of spheroidal graphite. This process comprises injecting into the molten iron alloy argon or other rare gas in the form of a multitude of very fine bubbles.

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PROCESS FOR FORMING SPHEROIDAL GRAPHITE IN HYPEREUTECTOID STEELS

This application is a continuation of application Ser. No. 662,939, filed Aug. 24, 1967, and now abandoned.

This invention relates to the manufacture of iron-carbon alloys, and more particularly is concerned with a process for improving the castability and the mechanical characteristics of hypereutectoid iron-carbon alloys, for example steels.

It is known to produce a hypereutectoid iron-carbon alloy containing fee graphite in the form of spherical nodules. Thus, for example, there are known the so-called spheroidal graphite steels which contain between 0.8 percent and 2.5 percent by weight of carbon and are intermediate normal steels and cast irons. The spheroidal form of the graphite is usually obtained by treatment of the liquid iron-carbon alloy with a nodulizing agent, for example with a ferroalloy or, more frequently, a calcium alloy. A spheroidal graphite steel which has been prepared by this treatment contains the spheroidal graphite in the as cast condition before any thermal treatment.

According to the present invention, there is provided a process for improving the castability and the mechanical characteristics of a hypereutectoid iron-carbon alloy, which comprises injecting a rare gas in the form of a multitude of very fine bubbles into the molten alloy so as to cause the precipitation of at least part of the carbon which is in excess of that of the eutectoid, in the form of spheroidal graphite.

The process of the invention has been found to be particularly useful in the treatment of iron-carbon alloys containing from 0.8 to 2.5 percent by weight of carbon.

The injection of a rare gas into a iron-carbon alloy, in accordance with the process of the present invention, obviates the need to treat an iron-carbon alloy with a conventional nodulizing agent in order to precipitate spheroidal graphite. Conventional nodulizing agents are expensive and are irregular as regards their efficiency. It has been found that a rare gas forms a very efficient nodulizing agent if it is blown in as very fine bubbles and obviates the necessity of using an inoculant for facilitating the elimination of the free cementite.

The rare gas employed in the process of the invention is advantageously argon or helium when the latter is available at low cost.

As will be seen from the examples of iron-carbon alloys which have been treated by the process of the present invention, given hereinafter, the process of the invention is also applicable to hypereutectoid steels which are not particularly pure.

The rare gas can be injected into the molten iron-carbon alloy through a porous member disposed in the wall of a hearth or ladle containing the molten alloy. The porous member can be a simple porous plug; it can also be large and form, for example, the base of a ladle or hearth or a part of the sidewall of a ladle or hearth. The rare gas can also be injected into the molten iron-carbon alloy by means of a lance, which is introduced into a cavity in the hearth. When a porous element is used it is found that an element having pores with a diameter smaller than 0.5 mm. and generally equal to 0.2 to 0.3 mm. give good results. In more general terms, it is possible to employ any means for injecting the gas in the form of a multitude of bubbles of very small diameter.

The iron-carbon alloys treated by the process of this invention are of the hypereutectoid type, that is to say, they contain more than about 0.8 percent of carbon; they can contain or be free of alloying elements such as chromium, nickel and molybdenum, and if desired they can contain relatively large proportions of manganese and sulfur; for example, they may contain from 0.3 percent to 1.0 percent by weight and even more of manganese.

The process of the invention considerably improves the mechanical properties of the iron-carbon alloys, as well as their castability, i.e. their fluidity in the molten state; these advantages are obtained with the crude casting steel, no subsequent thermal treatment generally being necessary. In certain cases, it may be advisable to add an inoculant, for example ferro-silicon, silicon-calcium alloy, or silico-mangano-zirconium-graphite, to the steel bath. The injection of the rare gas into the molten steel assists the action of the inoculant by the mixing which it effects.

Whatever the composition of the treated hypereutectoid iron-carbon alloy, the process according to the invention reduces the hardness of the resulting metal and tends to make the structure perlitic; it can cause the carbides to disappear or almost disappear. These tendencies can be achieved to a greater or lesser degree by a greater or lesser blowing action when injecting the rare gas into the molten alloy, for example by regulating the duration of blowing according to the structure which is desired. The injection into the molten alloy of a rare gas, as very fine bubbles, preferably by means of a porous plug, permits a high proportion of the carbon of hypereutectoid iron-carbon alloys of very diverse compositions to be transformed into spheroidal graphite; it is even possible in this way to transform all the carbon exceeding the carbon content of the eutectoid.

The consumption of rare gas, e.g. argon, varies with the tonnage and the depth of the bath of molten metal; for example, in the treatment of the steels set forth in the last line of the table given below there was consumed 0.4 cubic meters (measured at s.t.p.) per ton, this treatment bearing on 5.5 tons and having been extended beyond the moment when the spheroidal graphite has appeared; it can reach 2 cubic meters (measured at s.t.p.) per ton in the case of a laboratory furnace of low capacity.

The injection period is a function of the injection conditions, particularly of the area of the porous element, if such an element is used; it is generally longer than 5 minutes.

The iron-carbon alloy is heated between its melting temperature and 1600° C.

For a better understanding of the invention and to show how the same may be carried into effect, reference will now be made, by way of example, to the accompanying drawing which shows diagrammatically an induction furnace in which the process of the present invention can be carried into effect.

The hearth **2** of the furnace is surrounded by an inductor winding **4** and contains 5 tons of a steel **6** which is to be treated. This steel has the following analysis: 1.10 percent by weight C, 1.60 percent by weight Si, 0.45 percent by weight Mn, 0.025 percent by weight P, 0.065 percent by weight S, 0.95 percent by weight Ni, 0.60 percent by weight Cr. The temperature is kept at about 1575° C. Through a porous plug **8**, which is embedded in a seating brick **10** and which is fed with argon through a tube **12**, argon gas is injected into the steel; the arrows **14** and **16** indicate the ascending movement of the fine argon bubbles. In addition to their physicochemical action on the steel, the bubbles stir the latter and renew the fraction of the steel which comes into contact with them.

The injection of argon is carried out for 15 minutes, at the rate of 14 cubic meters (measured at s.t.p.) per hour, that is to say, a consumption of 1.2 cubic meters (measured at s.t.p.) per ton of steel. The steel is then poured into a mould, in which it is cooled, preferably with acceleration of the cooling when a heavy and solid casting is concerned.

The steel thus obtained has a completely perlitic matrix, in which all the carbon in excess of that of the eutectoid is precipitated in the form of graphite spheroids. The tensile strength is increased by 18 to 20 percent; the hardness is reduced, the cementite having been entirely dissociated.

Instead of the furnace described above a simple unheated ladle can be used, the temperature then falling a little during the treatment, for example from 1575 to 1500° C.

The following table indicates other iron-carbon alloys which have been satisfactorily treated by the process of the present invention, the given analysis having been carried out after the treatment.

TABLE

Element	C	Si	Mn	P	S	Ni	Cr	Mo
Number:								
1	1.35	1.84	0.43	0.022	0.03	0.84	0	0
2	1.49	2.03	0.70	0.017	0.031	1.06	0	0
3	1.99	0.94	0.58	0.048	0.030	0.460	0	0
4	1.37	1.80	0.47	0.055	0.031	0	0	0
5	1.04	0.95	0.52	n.d.	n.d.	1.51	0.31	0
6	1.34	0.98	0.44	n.d.	n.d.	0.52	0	0
7	1.05	1.90	0.67	n.d.	0.100	0.91	0	0
8	1.46	0.89	0.31	n.d.	n.d.	0.93	0.37	0
9	0.95	1.84	0.33	0.032	0.033	0.81	0.87	0
10	1.14	1.82	0.45	0.026	0.065	0.96	0.62	0
11	1.26	1.16	0.78	0.041	0.110	1.03	0	0
12	1.76	1.63	0.75	0.04	0.017	0.99	0.99	0.346

n.d. = not determined

Steels Nos. 1, 6 and 12 were inoculated during the injection of the argon.

The cooling action after casting is of little significance. An accelerated cooling assists the precipitation of the carbon in the form of spheroids, but sand casting of 1½ tons of steel No. 12 of the above table, in the form of a cylinder with a diameter of 0.56 m., had the desired texture.

The increase in the tensile strength, resulting from the treatment of the invention, is generally of the order of 20 to 30 percent and the fluidity of the molten metal is considerably increased.

As well as its effect on the texture, the argon, or other rare gas, has the advantage of causing the impurities which are in the solid state in the molten metal to ascend; at the surface of said metal, these impurities are trapped by the slag and are not recirculated.

In the case of the test indicated in the last line of the foregoing table and which applied to 5½ tons, the pouring or casting is effected perfectly at a temperature of 1320° C. (reading on optical thermometer: 1300° C.); the contents of carbon and of

alloying elements of a usual steel of the same composition would make the said steel difficult to pour at such a low temperature.

The process described can be modified without departing from the scope of the present invention. For example, instead of an induction furnace, it is possible to use a heated or unheated mixing pot.

We claim:

1. A process for manufacturing a hypereutectoid iron-carbon alloy containing a substantial amount of carbon in excess of that of the eutectoid but less than 2.5 percent carbon and having in the form of spheroidal graphite in the as-cast condition all of the carbon which is in excess of that of the eutectoid, consisting of establishing a melt of hypereutectoid iron-carbon alloy containing a substantial amount of carbon in excess of that of the eutectoid but less than 2.5 percent carbon, injecting a rare gas into the melt through at least one porous gas-permeable member in the absence of any other nodularizing agent, in a quantity of 0.4 to 2 cubic meters per ton of the melt, for a period of time in excess of 5 minutes until all of the carbon which is in excess of the eutectoid will be in the form of spheroidal graphite in the as-cast condition, and thereafter casting said melt in the absence of any other nodularizing agent.

2. A process as claimed in claim 1, in which said rare gas is argon.

3. A process as claimed in claim 1, in which said rare gas is helium.

4. A process as claimed in claim 1, in which said alloy contains from about 0.3 to about 1.0 percent by weight of manganese.

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