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(54) **A METHOD OF MANUFACTURING CAST PRODUCTS WHICH ARE CAST IN A SINGLE-PIECE  
HAVING CONTROLLED VARIATIONS OF COMPACTED GRAPHITE IRON AND GREY CAST IRON**

HERSTELLUNGSVERFAHREN VON GUSSSTÜCKEN DIE IN EINEM STÜCK GEGOSSEN  
WERDEN, MIT KONTROLLIERTE VARIATION VON KUGELGRAPHIT UND GRAUGUSS

PROCEDE DE FABRICATION DE PRODUITS DE FONTE COULES D'UN SEUL TENANT ET  
PRESENTANT DES VARIATIONS CONTROLEES DE FER AU GRAPHITE COMPACTE ET DE  
FONTE GRISE

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(56) References cited:  
**WO-A-93/20969** **DE-A- 4 308 614**  
**US-A- 5 373 888**

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**EP 0 806 996 B1**

## Description

[0001] The present invention relates to a method of manufacturing cast products which are cast as a one-piece objects having controlled inhomogeneous graphite structure. According to the invention, the products can be cast in a manner to obtain a grey cast iron having a flaky graphite structure in certain parts thereof, and a vermicular graphite structure in other parts thereof, therewith imparting to the cast product different properties in different parts of said product.

## Background Art

[0002] The background art comprises WO-A1-93/20969, WO-A1-89/04224, US-A-4 667 725, US-A-5 316 068, DE-A-43 08 614, SE-B-469 712, SE-B-444 817 and JP-A-6/106 331.

[0003] Compacted graphite iron (CGI) or cast iron having a vermicular graphite structure, when viewed on a two-dimensional section, is an intermediate form between grey cast iron having a flaky graphite structure and ductile iron having a nodular graphite structure.

[0004] Compacted graphite cast iron possesses desirable and unique properties, which include good mechanical and physical properties and good machinability, which makes the material highly suitable for a number of components in mechanical devices. This includes machine constructions that are manufactured in large numbers, chiefly engines and, for instance, brake discs and hydraulic pumps of all sorts.

[0005] Compacted graphite iron will thus contain graphite that, during solidification, has precipitated in the form of vermicular graphite and is defined according to ISO/R 945-1975(E) as "Form III"-graphite or "Type IV"-graphite in accordance with ASTM A 247. The graphite form was first described in England (1948) and has since been used for the manufacture of special components on a small scale. The reason for this small scale of manufacture is because it has not been possible to control properties and composition of the iron melts with sufficient accuracy to guarantee the composition and graphite structure of the cast product with sufficient reproducibility.

[0006] The properties of compacted graphite iron lie somewhere between the properties of grey iron and ductile iron. For instance, the elastic modulus of compacted graphite iron is from 30-40% higher than the elastic modulus of grey iron, which means that the elastic modulus of compacted graphite iron is almost the same as that of ductile iron. Compacted graphite cast iron has a ductility which is higher than that of grey iron, often more than ten times higher than that of grey iron, and has a much higher tensile strength, in the order of twice the tensile strength of grey iron. The fatigue strength of compacted graphite iron is 100% higher than that of grey iron, and essentially the same as that of ductile iron. The thermal conductivity of compacted

graphite iron is of the same order of magnitude as that of grey iron, and 30-50% higher than that of ductile iron. The machinability and castability of compacted graphite iron is also similar to grey iron.

[0007] It will be seen, therefore, that good reasons are found for using compacted graphite cast iron in machine designs where high strength requirements are combined with requirements of good castability, machinability and high thermal conductivity. Due to the difficulties experienced in obtaining compacted graphite cast iron in a reproducible manner, it has not earlier been possible to manufacture cast products in this type of cast iron.

[0008] However, it is possible to determine the concentration of nucleants and modifying agents of a melt, by analyzing temperature data in relation to time obtained with the aid of temperature sensors during solidification of sample volumes taken from the melt concerned. This enables the manner in which the melt will solidify in a mould to be determined accurately, and also enables the content of inoculating agent and modification agent to be corrected in a manner to impart desired properties to the cast product. See SE-B-469 712, SE-B-444 817 or US-A-4 667 725 in this respect. According to these patent specifications, the aforesaid values are measured with the aid of two temperature sensors placed in a sample bath in which the melt is essentially in thermo-dynamical equilibrium with the temperature of the sample vessel at the start of the solidification process.

[0009] One of these temperature sensors is placed in the centre of the melt in the sample vessel while the other sensor is placed in the melt in the proximity of the vessel wall. During the solidification process, there are recorded values concerning undercooling of the melt at the vessel wall ( $T^*_{\text{w}}$ ), recalescence at the vessel wall ( $\text{rec}_{\text{w}}$ ), the positive difference between the temperature at the vessel wall and at the vessel centre, ( $\Delta T_+$ ), and the derivative of the temperature at the vessel wall and at the vessel centre ( $dT/d\tau_{\text{w}}$ ), at constant equivalent growth temperatures ( $dT/d\tau_{\text{c}} = 0$ ), with the aid of which in relation to known reference values for analogous sampling conditions, the presence of and the amount of crystallization nucleants and the amount of structure modifying agent can be determined and corrected by additions to the melt or by introducing residence times so that the amounts of crystallization nucleants and structure modifying agents present will correspond to the amounts required to obtain the desired graphite structure in the cast product.

[0010] The structure modifying additives normally consist of magnesium optionally together with rare earth metals, particularly cerium or mischmetal.

[0011] When the amount of dissolved magnesium, and therewith equivalent amounts of other structure modifying agents, i.e. the amount of such elements present in solution except those having separated as oxides and sulfides thereof in solid form, reaches about 0.035% or more, graphite will precipitate in nodular form

when the melt solidifies. If the aforesaid content falls to about 0.015%, the graphite will precipitate as compacted graphite, while if the aforesaid contents fall still further to beneath about 0.008%, the graphite will precipitate as flaky graphite and the cast iron will solidify as grey cast iron. It will be evident from this that between values of about 0.010 and 0.020%, mainly compacted graphite cast iron will be formed.

[0012] In some applications, it is advantageous to use a cast iron product that contains an inhomogenous graphite structure. WO-A-93/20969 discloses a method of manufacturing cast iron products, where some parts of the products have a compacted graphite structure and other parts of said products have a nodular graphite structure.

[0013] It would also be advantageous to use a grey flake cast iron in certain areas, which require the highest possible thermal conductivity together with a relatively low elastic modulus for operational performance reasons and possibly also excellent castability and machinability for productivity reasons, and compacted graphite iron in other areas which require higher strength and stiffness for operational performance reasons.

[0014] Similar attempts to achieve inhomogenous graphite in engine blocks have previously been proposed. JP-A-6/106 331 relates to a process for producing ductile iron engine blocks for improved strength and stiffness and, by placing a reactive coating on the sand cores which form the cylinder bore walls, the active magnesium in the melt adjacent to the wall of the iron is reduced thus providing elongated graphite flakes and hence, good thermal conductivity and machinability in the bore walls.

[0015] However, the reactive coating applied to the surface of the cylinder cores can only reduce the magnesium to a certain amount. Therefore, reproducible results are difficult to obtain when the magnesium content of the iron to be poured into the moulds is constant. Variations in the magnesium content, which are common, are directly manifested as variations in the graphite structure in the bore walls.

[0016] By beginning with a ductile base iron, as is necessary with JP-A-6/106 331 due to the absence of an adequate process control, the relatively poor castability of ductile iron restricts the ability to successfully produce complex, thin-wall castings such as state-of-the-art engine blocks and cylinder heads.

[0017] The initial overtreatment with magnesium also results in a restricted ability to produce thick layers of flake graphite adjacent to the reactive core surfaces. The magnesium content of the iron changes from its bulk concentration value to a sufficiently lower level near the wall which allows flake formation. However, because of the excess magnesium required to produce spheroidal graphite, and the combined effect of magnesium variations found in the day to day treated iron, the thickness of the flake layer can be rather small. This is par-

ticularly important when it is realised that up to 3 mm of the surface iron may be removed as machining stock and thus, much of the flake graphite can be lost.

[0018] Additionally, it is not clear that the dramatic changes in mechanical and physical properties between grey and ductile iron are beneficial to the long term performance of a casting. The vast differences in strength, stiffness, ductility and thermal conductivity can give rise to extraordinary internal stress and strain gradients, which may ultimately result in more negative than positive effects.

[0019] US-A-5 316 068 also begins with a ductile iron base material, but the graphite transition mechanism is changed from reactive cores to high speed spinning of the moulds during solidification to promote grey iron in the outer region and compacted graphite iron in the central bore areas. Not only does this technique seem physically awkward, but it is also plagued by the same problems as outlined in the discussion concerning JP-A-6/106 331, which stem from a ductile starting point.

[0020] DE-A-43 08 614 relates to a method for producing a cast iron product where parts of the product contain flaky grey iron and other areas contain compacted graphite iron. Parts of the mould are covered by oxygen or sulphur emitting substances in order to reduce the active magnesium content of the part of the melt that is adjacent to the covered mould wall.

[0021] However, DE-A-43 08 614 does not disclose anything about how to control the composition of the melt in order to make the casting method reproducible. It has already been mentioned in this application that it is difficult to cast compacted graphite iron in a reproducible manner, and it must be considered to be extremely difficult to use the method according to DE-A-43 08 614 in order to reproducibly cast an inhomogenous graphite structure without having the possibility of controlling the composition of the melt. Moreover, when using said method, it is usual to use an excess of magnesium or similar metals. Hence, up to now, it has not been possible to cast an inhomogenous graphite structure consisting of parts containing flaky grey iron and parts containing compacted graphite iron.

#### Summary of the invention

[0022] The above mentioned problems, connected to the manufacture of single-piece cast iron products having an inhomogenous distribution of the graphite crystals in compacted and flaky form in different parts of the finished cast product are solved by a method, according to which

I) molten cast iron having an inherent ability to solidify as compacted graphite cast iron, due to a controlled high concentration of active Mg and/or some other component(s) having similar effect on said ability, is produced;

II) said molten cast iron is poured into casting

moulds, said moulds having at least one portion having mould walls and/or mould cores covered with reactive material that diffuses or penetrates into the molten cast iron and thereby lower the concentration of active Mg and/or said component(s), so that the molten cast iron in said portion solidifies as flaky cast iron, while the molten cast iron in the other parts of the moulds solidifies as compacted graphite cast iron, characterized in that the inherent ability of the molten cast iron to solidify as compacted cast iron is controlled and corrected by means of a method comprising the steps of

- extracting a sample quantity from the molten cast iron in a sample vessel that is equipped with two temperature responsive means, one of which is positioned in the centre of the vessel and the other one in the vicinity of the vessel wall, whereby the inner wall of the vessel consists of a material which contains or is covered with a layer of a substance which will lower the concentration of active Mg or corresponding percentage of said component(s) in the sample quantity, in the vicinity of the wall and in the vicinity of the temperature responsive means positioned adjacent said wall, in a manner and to an extent that simulates the lowering of the concentration of active Mg and/or said component(s) by said reactive material in the molten cast iron that is poured into casting moulds in step II),
- permitting the vessel to essentially reach thermal equilibrium with the sample quantity,
- recording the temperatures registered by the two temperature responsive means,
- evaluating from the recorded curve in a manner known per se the characteristics of the molten cast iron and registering such deviations that indicate precipitation of flaky graphite crystals around the temperature responsive means in the vicinity of the vessel wall; and
- correcting the content of active Mg and/or content of said other component(s) in the molten cast iron with the aid of the deviation of the temperature time curve and the equipment parameters such that this concentration will be sufficient to, upon solidification of the molten cast iron, form compacted graphite crystals in molten cast iron that is essentially uninfluenced by said reactive material, and low enough to permit formation of flaky graphite crystals in molten cast iron that is influenced by said reactive material.

[0023] The invention will now be described in more detail with reference to exemplifying embodiments thereof and also with reference to the accompanying

drawings, in which

Figure 1 illustrates a diagram showing the nodularity percentage as a function of the magnesium percentage. In this diagram 0% nodularity corresponds to a complete compacted graphite cast iron, whereas 100% corresponds to a completely nodular iron, i.e. a ductile cast iron. Finally, values below 0% nodularity relate to grey cast iron. Actually, 0% nodularity corresponds to 100% compacted graphite cast iron and the bottom of this axis corresponds to 100% flaky grey cast iron;

Figure 2 illustrates the core section of an inhomogeneous compacted/flaky grey iron cylinder head showing graphite structures and general design; and

Figure 3 A-B are micrographs showing the transition from flaky grey cast iron to compacted graphite cast iron. The enlargement is 100 x.

[0024] According to the present invention, it is possible to reliably reproduce a compacted graphite iron of optimal solidification potential so that single castings can be consistently generated with a preferred mixture of compacted graphite particles and flake-type graphite. By beginning with a compacted graphite base iron, the thickness of grey flake iron which can be produced by a given reactive coating is increased, and simultaneously, the internal stress and strain gradients are lessened because the mechanical and physical properties of grey iron and vermicular iron are more similar than those of grey iron and ductile iron. The castability and machinability of the finished components will also be markedly better.

[0025] Additionally, the method according to SE-B-469 712 allows a precise determination of the proximity of the treated iron to the rapid transition between compacted and flake graphite. By strategically altering the distance between the measuring point of the thermocouple and the reactive wall coating in the sample or by altering the reactivity of the coating placed on the inner wall of the vessel, it is possible to accurately produce a compacted graphite base iron which is rather close to the left hand edge of the stable vermicular plateau (point A in Figure 1) and is therefore prone to producing considerable amounts of grey flake iron when poured into moulds containing cores and mould sand which are coated with reactive coatings. In contrast, a vermicular base iron starting point in the region of point B in Figure 1 will require more reduction of magnesium and therefore will not produce such an extensive graphite network. In this way, by directly choosing and reproducing the proper starting point of the treated liquid iron, the superior degree of control over the as-cast microstructure will ensure an optimal and consistent layer of flaky graphite, and a hitherto unattainable product.

[0026] The following example relates to a cylinder head, but the method according to the invention can also be used in the casting of engine blocks, where, for example, the cylinder bore and water jacket cores can contain grey iron, while the bulk head, top deck, pan rail and crank case areas contain higher strength compacted graphite iron, or brake discs where, for example, the outer flange contains lamellar iron with high thermal conductivity and the inner hub contains compacted graphite iron to provide higher strength.

#### Example

[0027] The maximum thermally induced stress that develop on the hot-face of a cylinder head can be represented by the relationship:

$$\sigma_{\max} = \frac{\Delta T E_0 \alpha}{2(1-\mu)} \quad (1)$$

where

$\sigma_{\max}$  = maximum thermally induced stress (MPa)  
 $\Delta T$  = temperature gradient from hot face of cylinder head to cooling water channel (°C)  
 $E_0$  = elastic modulus (MPa)  
 $\alpha$  = thermal expansion (°C<sup>-1</sup>)  
 $\mu$  = Poisson's ratio (dimensionless)

[0028] Now, it is well-known that the thermal expansion and Poisson's ratio of vermicular iron and grey iron are essentially equal. Therefore, the only means of minimizing the thermal stresses which accumulate at the hot-face and ultimately lead to crack formation between the valve ports, is to minimize the parameters  $\Delta T$  and  $E_0$ , where  $\Delta T$  is inversely related to thermal conductivity. The objective therefore is to have a material with high thermal conductivity and low elastic modulus at the hot-face which can only be satisfied by grey cast irons. Simultaneously, it is preferred that the bulk material of the cylinder head and the outer peripheral regions are made from a material with higher strength, stiffness, and ductility. This objective can be satisfied by a high quality (< 10% nodularity) vermicular iron which will also result in lower internal strains than a comparative grey iron/ductile iron mix, and, due to the controlled proximity of the iron's solidification behaviour to the vermicular iron/grey iron transition point (point A in Figure 1) it will be possible to produce a more extensive flake graphite network than could be achieved if the solidification behaviour starting point was at "B" in Figure 1, or even worse, if the base iron solidification behaviour starting point was from ductile iron (point C in Figure 1).

[0029] The reduction in active magnesium content and the resultant growth of flake rather than compacted graphite particles is achieved by applying a variety of standard foundry coatings to any mould or core sur-

faces where graphite flakes are desirable. In the case of the cylinder head (Figure 2), reactive coatings can be applied to the hot face mould surface and to the lower half of the water channel core. The coatings contain a controlled amount of sulphides and/or oxides which chemically react with active magnesium to form MgS and/or MgO. The necessary amounts of coating can be iteratively defined for each casting application depending on the desired flake thickness, and are obvious to persons skilled in the art.

[0030] The present invention is particularly useful in existing cylinder head designs where it is not possible to re-design the head because it must continue to fit an existing engine. Recently, with the power-up and turbo-charging demands on gasoline and particularly diesel engines, many designs are candidates for conversion to a stronger material, and compacted graphite iron is ideal for this. However, if the head is prone to failure due to thermal loading, the lower thermal conductivity and higher elastic modulus of compacted graphite iron compared to grey iron will actually increase the thermal load and may result in a shorter service life. For a compacted graphite iron cylinder head, the only possible way to reduce the  $\Delta T$  term in equation (1) would then be to reduce the thickness of the flame deck. However, this would make the cylinder head incompatible with the existing engine design. The present invention is an ideal solution in these cases since the introduction of grey iron flakes in the flame deck provides the necessary thermal conductivity and lower elastic modulus to withstand the thermal loading, while the compacted graphite iron provides the necessary strength, stiffness and ductility to withstand the mechanical loading, without sacrificing machinability or castability behaviours.

#### Claims

1. A method for the manufacture of single-piece cast iron products having an inhomogeneous distribution of the graphite crystals in compacted and flaky form in different parts of the finished cast product, whereby

I) molten cast iron having an inherent ability to solidify as compacted graphite cast iron, due to a controlled high concentration of active Mg and/or some other component(s) having similar effect on said ability, is produced;

II) said molten cast iron is poured into casting moulds, said moulds having at least one portion having mould walls and/or mould cores covered with reactive material that diffuses or penetrates into the molten cast iron and thereby lowers the concentration of active Mg and/or said component(s), so that the molten cast iron in said portion solidifies as flaky cast iron, while the molten cast iron in the other parts of the moulds solidifies as compacted

graphite cast iron,  
**characterized** in that

the inherent ability of the molten cast iron to solidify as compacted cast iron is controlled and corrected by means of a method comprising the steps of

- extracting a sample quantity from the molten cast iron in a sample vessel that is equipped with two temperature responsive means, one of which is positioned in the centre of the vessel and the other one in the vicinity of the vessel wall, whereby the inner wall of the vessel consists of a material which contains or is covered with a layer of a substance which will lower the concentration of active Mg or corresponding percentage of said component(s) in the sample quantity, in the vicinity of the wall and in the vicinity of the temperature responsive means positioned adjacent said wall, in a manner and to an extent that simulates the lowering of the concentration of active Mg and/or said component(s) by said reactive material in the molten cast iron that is poured into casting moulds in step II),
- permitting the vessel to essentially reach thermal equilibrium with the sample quantity,
- recording the temperatures registred by the two temperature responsive means,
- evaluating from the recorded curve in a manner known per se the characteristics of the molten cast iron and registering such deviations that indicate precipitation of flaky graphite crystals around the temperature responsive means in the vicinity of the vessel wall; and
- correcting the content of active Mg and/or content of said other component(s) in the molten cast iron with the aid of of the deviation of the temperature time curve and the equipment parameters such that this concentration will be sufficient to, upon solidification of the molten cast iron, form compacted graphite crystals in molten cast iron that is essentially uninfluenced by said reactive material, and low enough to permit formation of flaky graphite crystals in molten cast iron that is influenced by said reactive material.

2. A method according to claim 1, **characterized** in that the sample vessel wall consists of a material which contains or is covered with a layer of a substance which will lower the concentration of active Mg by 0.002 - 0.010 percent by weight, or by the

corresponding percentage of said component(s), in the sample quantity.

## Patentansprüche

1. Verfahren zur Herstellung von einstückigen Gußeisenerzeugnissen, die eine inhomogene Verteilung der in vermikularer und lamellarer Form vorliegenden Graphitkristalle in verschiedenen Teilen des fertigen Gußeisnerzeugnisses aufweisen, wobei

I) schmelzflüssiges Gußeisen hergestellt wird, welches eine inhärente Fähigkeit aufweist, aufgrund einer vorgegebenen hohen Konzentration an aktivem Mg und/oder einer oder mehrerer anderer Komponenten, die einen ähnlichen Effekt auf diese Fähigkeit haben, als Vermikulargraphitgußeisen zu erstarren; und wobei

II) das schmelzflüssige Gußeisen in Gußformen gegossen wird, wobei die Formen wenigstens einen Bereich aufweisen, der Formwandungen und/oder Formkernzonen aufweist, die mit reaktivem Material bedeckt sind, welches in das schmelzflüssige Gußeisen eindiffundiert oder eindringt, und dadurch die Konzentration an aktivem Mg und/oder der Komponente(n) erniedrigt, so daß das schmelzflüssige Gußeisen in diesem Bereich als lamellares Gußeisen erstarrt, während das schmelzflüssige Gußeisen in den anderen Teilen der Form als Vermikulargraphitgußeisen erstarrt, dadurch gekennzeichnet, daß die dem schmelzflüssigen Gußeisen inhärente Fähigkeit, als Vermikulargußeisen zu erstarren mittels eines Verfahrens gesteuert und korrigiert wird, welches die Schritte umfaßt:

- Gewinnen einer Probenmenge aus dem schmelzflüssigen Gußeisen in ein Probengefäß, das mit zwei auf Temperatur ansprechenden Mitteln ausgestattet ist, wobei eines davon im Zentrum des Gefäßes und das andere in der Nähe der Gefäßwandung positioniert ist, wobei die innere Wandung des Gefäßes aus einem Material besteht, welches einen Stoff enthält, oder mit einer Schicht eines Stoffes bedeckt ist, der die Konzentration des aktiven Mg oder des entsprechenden Prozentsatzes der Komponente(n) in der Probenmenge, in der Nähe der Wandung und in der Nähe des auf Temperatur ansprechenden Mittels, welches der Wandung benachbart positioniert ist, derart und in einem Ausmaße erniedrigt, welches

- die Erniedrigung der Konzentration des aktiven Mg und/oder der Komponente(n) durch das reaktive Material in dem schmelzflüssigen Gußeisen, welches in Schritt II) in die Gußform gegossen wird, simuliert, 5
- Zulassen, daß das Gefäß im wesentlichen ein thermisches Gleichgewicht mit der Probenmenge erreicht, 10
  - Aufzeichnen der Temperaturen, die von den zwei auf Temperatur ansprechenden Mitteln registriert werden, 15
  - Bewerten der Charakteristika des schmelzflüssigen Gußeisens ausgehend von der aufgezeichneten Kurve in einer an sich bekannten Art und Weise und Registrieren von denjenigen Abweichungen, die das Ausfällen von lamellaren Graphitkristallen um das in der Nähe der Gefäßwandung positionierte auf Temperatur ansprechende Mittel herum, anzeigen; und 20
  - Korrigieren des Gehaltes an aktivem Mg und/oder des Gehaltes der anderen Komponente(n) im schmelzflüssigen Gußeisen mit Hilfe der Abweichung der Temperatur-Zeit-Kurve und den Ausrüstungsparametern, derart, daß diese Konzentration hinreichend ist, 25
  - um bei Erstarrung des schmelzflüssigen Gußeisens vermikulare Graphitkristalle in schmelzflüssigem Gußeisen, welches im wesentlichen durch das reaktive Material unbeeinflusst ist, zu bilden, und niedrig genug ist, um die Bildung von lamellaren Graphitkristallen in schmelzflüssigem Gußeisen, welches durch das reaktive Material beeinflusst ist, zu ermöglichen. 30
2. Verfahren gemäß Anspruch 1, dadurch gekennzeichnet, 45
- daß die Probengefäßwandung aus einem Material besteht, welches eine Substanz enthält oder mit einer Schicht einer Substanz bedeckt ist, welche die Konzentration in der Probenmenge an aktivem Mg um 0,002 - 0,010 Gewichtsprozent oder um den entsprechenden Prozentsatz der Komponente(n) erniedrigt. 50

## Revendications

1. Procédé de fabrication d'objets en fonte coulés d'une seule pièce, présentant une répartition inhomogène des cristaux de graphite vermiculaire et de

graphite lamellaire dans les différentes parties de l'objet coulé fini, dans lequel procédé :

I) on produit de la fonte en fusion qui est intrinsèquement apte à se solidifier en donnant de la fonte à graphite vermiculaire, ce qui est dû à une concentration assez élevée, bien ajustée, de magnésium actif et/ou d'un ou de certains autre(s) composant(s) ayant un effet similaire sur cette aptitude, et

II) on verse ladite fonte en fusion dans des moules de coulée, lesquels moules comportent au moins une région où les parois de moule et/ou les noyaux de moule sont recouverts d'une substance réactive qui diffuse ou pénètre au sein de la fonte en fusion et y abaisse la concentration de magnésium actif et/ou dudit ou desdits composant(s), de sorte que, dans cette région, la fonte en fusion donne en se solidifiant une fonte à graphite lamellaire alors que, dans les autres régions du moule, elle donne en se solidifiant une fonte à graphite vermiculaire,

ledit procédé étant caractérisé en ce que l'on maîtrise et corrige l'aptitude intrinsèque que possède la fonte en fusion à se solidifier en donnant une fonte à graphite vermiculaire, grâce à un procédé qui comporte les étapes suivantes :

on prélève un échantillon de fonte en fusion que l'on met dans un récipient pour échantillon, muni de deux capteurs de température, dont l'un est placé au centre du récipient et l'autre près de la paroi du récipient, la paroi interne de ce récipient étant faite en un matériau qui contient une certaine substance ou est revêtu d'une couche de cette substance, laquelle abaisse la concentration de magnésium actif ou, d'un pourcentage correspondant, celle(s) dudit ou desdits composant(s) dans l'échantillon, au voisinage de la paroi et autour du capteur de température placé près de la paroi, selon un mode et à un point qui simulent l'abaissement, par ladite substance réactive, de la concentration de magnésium actif et/ou dudit ou desdits composants dans la fonte en fusion qui est versée dans les moules de coulée au cours de l'étape (II) ;

on laisse pratiquement s'établir l'équilibre thermique entre le récipient et l'échantillon ;

on enregistre les températures indiquées par les deux capteurs de température ;

on évalue à partir des courbes enregistrées, d'une façon connue, les caractéristi-

ques de la fonte en fusion, et l'on mesure les écarts qui sont les indices de la précipitation de cristaux de graphite lamellaire autour du capteur de température placé près de la paroi du récipient ; et 5  
on corrige la concentration de magnésium actif et/ou la concentration dudit ou desdits autre(s) composant(s) dans la fonte en fusion, en se basant sur les paramètres de l'appareillage et sur les écarts des courbes 10  
de température en fonction du temps, de telle manière que ces concentrations soient suffisantes pour qu'il se forme, lors de la solidification de la fonte en fusion, 15  
des cristaux de graphite vermiculaire dans la fonte en fusion qui n'est pratiquement pas influencée par ladite substance réactive, mais assez faibles pour permettre la formation de cristaux de graphite lamellaire dans la fonte en fusion qui est influen- 20  
cée par ladite substance réactive.

2. Procédé conforme à la revendication 1, caractérisé en ce que la paroi du récipient à échantillon est faite en un matériau qui contient une substance qui 25  
abaisse de 0,002 à 0,010 % en poids la concentration de magnésium actif ou d'un pourcentage correspondant celle(s) dudit ou desdits composant(s) dans l'échantillon, ou qui est revêtu d'une couche d'une telle substance. 30

35

40

45

50

55



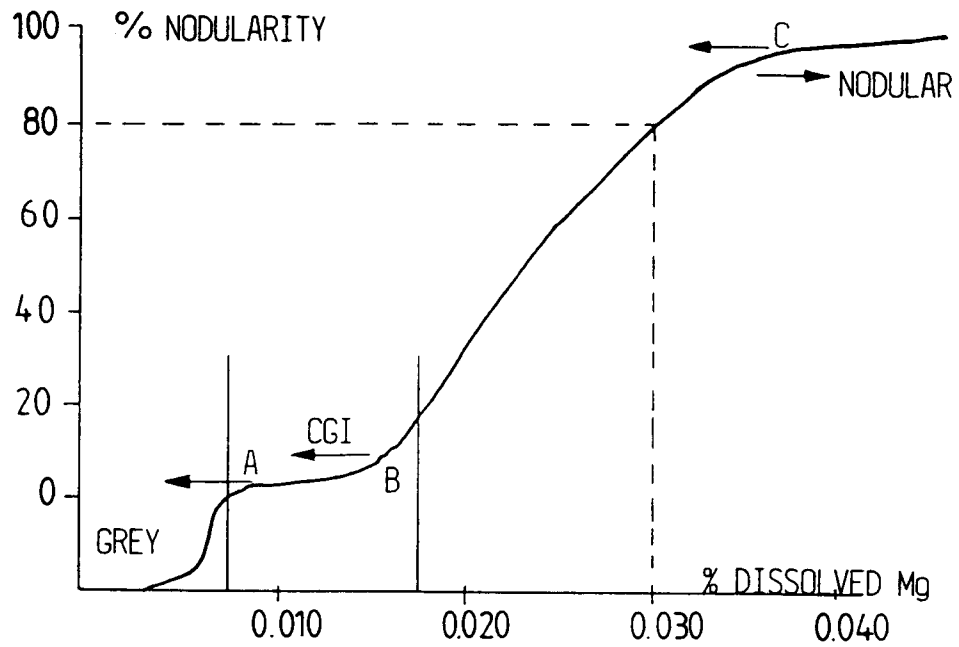


FIG. 1

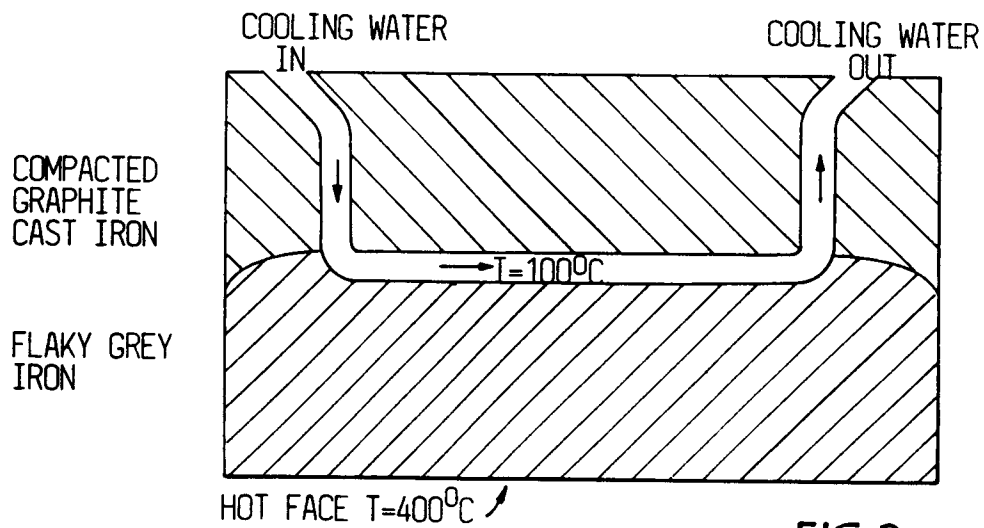


FIG. 2

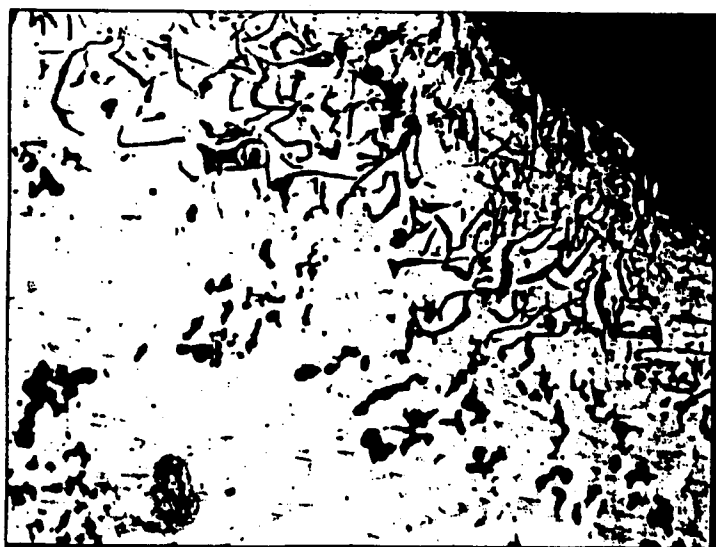


FIG. 3A



FIG. 3B