

Description**[Technical Field]**

[0001] The present invention relates to cast iron and a method of producing the same, and more particularly, to cast iron having an improved casting property and stable tensile strength and yield strength by controlling the contents of components added to iron, and a method of producing the cast iron. Cast iron according to the present invention corresponds to hypereutectic compacted graphite iron (CGI) cast iron that can be applied to the cylinder block of diesel engines with high output.

[Technical Field]

[0002] Recently, it is required to reduce the contents of environmental pollutants such as COx or NOx discharged from engines due to strictly enforced environmental regulation.

[0003] For diesel engines, it is necessary to increase the explosive pressure of the engines in order to reduce the exhaust amount of environmental pollutants such as COx or NOx. It needs to increase the strength of the cylinder block of the engines in order to increase the explosive pressure of the engines.

[0004] Cast iron is the material that is generally used for cylinder blocks in the related art, common grade cast iron is usually gray cast iron. The gray cast iron is called gray cast iron because carbon is decomposed and produced into graphite in casting and the surface shows gray.

[0005] In general, cast iron has differences in accordance with the shape, size, and distribution state of graphite contained in the base and the tensile strength of gray cast iron generally called cast iron is about 147.1 to 196.1MPa. The gray cast iron has a limit in use for the material of the cylinder block of engines having high explosive pressure, because the strength is low although a cast property, damping capacity, and thermal conductivity are excellent.

[0006] There is spherical graphite cast iron as cast iron produced by improving the properties of gray cast iron. The spherical graphite cast iron is cast iron of which the toughness is improved by changing graphite shown in common cast iron (gray cast iron) into a spherical structure from the original foliaceous structure. The spherical graphite cast iron is also called nodular cast iron or ductile cast iron. The spherical graphite cast iron has excellent abrasion resistance, heat resistance, corrosion resistance, has a higher modulus of elasticity than that of common gray cast iron, has a Brinell Hardness of even about 200, and also has a cutting property better than that of common cast iron having the same hardness.

[0007] However, the spherical graphite cast iron has high strength required for cylinder blocks, but has an insufficient casting property and low thermal conductivity to be produced in a complicate shape, such that it has a limit in use for cylinder blocks having complicated shapes.

[0008] Therefore, CGI (Compacted Graphite Iron) that has both the high strength and predetermined elongation of the spherical graphite cast iron while having the excellent casting property, damping capacity, and thermal conductivity of the gray cast iron is used as the next generation material for cylinder blocks.

[0009] The CGI cast iron may be produced by accurately controlling the content of magnesium (Mg) when tapping molten spherical graphite cast iron, which is produced by melting spherical graphite cast iron, into a ladle for carrying original molten metal produced by a furnace to another place.

[0010] It is necessary to accurately control the amount of magnesium and melting/tapping temperatures in order to ensure stable mechanical properties (tensile strength) in CGI cast iron, and for this purpose, an accurate control device, an experienced worker, and using high-quality pig iron with low contents of impurities are required. There is a problem in that poor quality and poor casting of CGI cast iron are frequently generated by differences in various requirements such as the content of magnesium, the tapping position, the tapping temperature, and the tapping speed, even under accurate control.

[Disclosure]**[Technical Problem]**

[0011] The present invention provides cast iron of which tensile strength and yield strength are controlled within the ranges of 500 to 600MPa and 350 to 450MPa, respectively, by controlling the contents of carbon (C), silicon (Si), manganese (Mn), copper (Cu), tin (Sn), and magnesium (Mg) with a range that ensures stable properties without causing poor casting.

[0012] An object of the present invention is to provide cast iron having stable properties and structure by accurately controlling the amount of magnesium (Mg). In particular, it is an object of the present invention to provide cast iron that can be applied to the cylinder block of high-output and high-power diesel engines.

[0013] Another object of the present invention is to establish a chemical composition and a production method which

make it possible to producing cast iron for a cylinder block that can be applied to high-output and high-power diesel engines by providing stable tensile strength and yield strength and appropriate hardness.

[Technical Solution]

[0014] The present invention provides a cast iron for use with cylinder block of an engine comprising carbon (C) of 3.65 to 3.75 wt%, silicon (Si) of 2.0 to 2.25 wt%, manganese (Mn) of 0.3 to 0.6 wt%, copper (Cu) of 1.2 to 1.4 wt%, tin (Sn) of 0.07 to 0.10 wt%, magnesium (Mg) of 0.008 to 0.018 wt%, phosphorus (P) of 0.04 wt% or less, sulfur (S) of 0.02 wt% or less, and the balance of ferrum (Fe), in the entire weight.

[0015] According to an exemplary embodiment of the present invention, tensile strength of the cast iron is 500 to 600MPa. Further, according to another exemplary embodiment of the present invention, yield strength of the cast iron is in the range of 350 to 450MPa. Meanwhile, a Brinell Hardness value (BHW) of the cast iron is 255 to 280.

[0016] According to an exemplary embodiment of the present invention, CE (Carbon Equivalent) of the cast iron is 4.35 to 4.5.

[0017] According to an exemplary embodiment of the present invention, nodularity of graphite produced by the carbon is 5 to 20% in the cast iron.

[0018] The present invention provides a method of producing cast iron, comprising: producing original molten cast iron by melting a cast iron material, which contains carbon (C) of 3.65 to 3.75 wt%, silicon (Si) of 2.0 to 2.25 wt%, manganese (Mn) of 0.3 to 0.6 wt%, phosphorus (P) of 0.04 wt% or less, sulfur (S) of 0.02 wt% or less, and the balance of ferrum (Fe), in the entire weight, in a furnace; providing copper (Cu) of 1.2 to 1.4 wt%, tin (Sn) of 0.07 to 0.10 wt%, and magnesium (Mg) of 0.008 to 0.018 wt% in a ladle that is a container for tapping the original molten cast iron melted in a furnace; producing molten cast iron by tapping the produced original molten cast iron with the ladle with copper (Cu) of 1.2 to 1.4 wt%, tin (Sn) of 0.07 to 0.10 wt%, and magnesium (Mg) of 0.008 to 0.018 wt%; determining the amount of magnesium to be added by checking the content of magnesium contained in the molten cast iron in the ladle; adding magnesium of which the amount to be added is determined to the molten cast iron in the ladle; and injecting the molten cast iron added with the magnesium into a mold.

[0019] In the present invention, CGI cast iron with stable mechanical properties is achieved by putting a predetermined amount of magnesium (Mg) and appropriate amounts of copper (Cu) and tin (Sn) into a ladle, which is a container for tapping an original molten cast iron melted in a furnace, tapping the original molten cast iron into the ladle, and crystallizing the graphite to be stable CGI.

[0020] According to an exemplary embodiment of the present invention, CE (Carbon Equivalent) is adjusted to be 4.35 to 4.5 in the original molten cast iron.

[0021] Further, according to an exemplary embodiment of the present invention, the tapping temperature of the original molten metal is adjusted to be 1520°C.

[0022] According to an exemplary embodiment of the present invention, it may be possible to inoculate magnesium by using a wire type of magnesium inoculant in the adding of magnesium.

[0023] In the cast iron according to the present invention, it is possible to estimate nodularity of graphite contained in cast iron from the content of magnesium contained in the molten cast iron and to estimate the range of strength according to the nodularity.

[0024] In the present invention, the content of magnesium may depend on the necessary strength and the content is 0.008 to 0.018 wt% to be applied to the cylinder block of high-output diesel engines.

[Advantageous Effects]

[0025] According to the present invention, it is possible to provide cast iron with tensile strength in the range of 500 to 600 MPa, yield strength in the range of 350 to 450 Mpa, and Brinell Hardness in the range of 255 to 280, by precisely controlling the amount of magnesium (Mg) and controlling the amounts of copper (Cu) and tin (Sn).

[0026] Since the cast iron according to the present invention has stable tensile strength and yield strength and appropriate hardness, the cast iron can be used to manufacture cylinder blocks that can be applied to high-output and high-power diesel engines.

[0027] According to the present invention, it is possible to produce CGI cast iron having a uniform structure and strength that is high enough to be used for the cylinder block of high-power diesel engines, by precisely controlling the amount of magnesium (Mg). Further, it is possible to produce CGI cast iron having various hardness and tensile strength by controlling the amount of copper (Cu) and tin (Sn) that is alloy elements.

[Description of Drawings]

[0028]

FIG. 1 is a graph illustrating the relationship between the content of magnesium (Mg) and nodularity of graphite.

FIG. 2 is a graph illustrating the relationship of nodularity of graphite, tensile strength, and yield strength.

FIG. 3 is a table showing the relationship between the content of magnesium (Mg) and tensile strength and a representative structure of cast iron (for reference, 1 MPa is 1N/mm²).

FIG. 4 is a view simply showing an example of a process of producing cast iron according to the present invention.

[Embodiments]

[0029] The present invention will be described in more detail with reference to detailed examples.

[0030] Cast iron according to the present invention contains carbon (c) of 3.65 to 3.75 wt%, silicon (Si) of 2.0 to 2.25 wt%, manganese (Mn) of 0.3 to 0.6 wt%, copper (Cu) of 1.2 to 1.4 wt%, tin (Sn) of 0.07 to 0.10 wt%, magnesium (Mg) of 0.008 to 0.018 wt%, phosphorus (P) of 0.04 wt% or less, sulfur (S) of 0.02 wt% or less, and the balance of ferrum (Fe), an the entire weight. The basic material of the cast iron is ferrum (Fe).

[0031] Next, the components and contents of the cast iron in the present invention are described.

1) Carbon (c) of 3.65 to 3.75 wt%

[0032] Carbon is added for crystallization of compacted graphite, and when the content of carbon in cast iron is less than 3.65 wt%, a chilling behavior is observed in a thin-walled part, and when it is above 3.75 wt%, graphite nodularity retraction and poor flow are generated. Therefore, the content of carbon is limited within 3.65 to 3.75 wt% in the present invention to prevent the defects in high-strength cylinder block having various thicknesses.

2) Silicon (Si) 2.0 to 2.25 wt%

[0033] Silicon maximizes the amount of crystallization of compacted graphite and increases strength of cast iron when being added at the optimum ratio with carbon. In the cast iron according to the present invention, when the content of silicon is less than 2.0 wt%, the amount of crystallization of compacted graphite decreases, and when it is above 2.25 wt%, ductility decreases, such that the content is set within 2.0 to 2.25 wt%.

3) Manganese (Mn) 0.3 to 0.6 wt%

[0034] Manganese is added to make graphite fine and stabilize pearlite, and in the cast iron according to the present invention, when the content of manganese is less than 0.3 wt%, hardness decreases, and when it is above 0.6 wt%, brittleness increases, such that the content is set within 0.3 to 0.6 wt%.

4) Copper (Cu) 1.2 to 1.4 wt%

[0035] Copper is an element for compacted graphitization and promote creation of pearlite and makes it fine, such that it is an element for ensuring strength. In the case iron according to the present invention, when the content of copper is less than 1.2 wt%, lack of strength is caused, but even if the content is above 1.4 wt%, there is no additional effect corresponding to the excessive amount. Therefore, the content of copper is set within 1.2 to 1.4 wt% in the present invention.

5) Tin (Sn) 0.07 to 0.10 wt%

[0036] Tins is a very strong element for promoting creation of pearlite and added to improve strength, similar to copper. In the cast iron according to the present invention, when the content of tin is less than 0.07 wt%, strength decreases and when it is added over 0.10 wt%, brittleness rapidly increases, such that the content is set within 0.07 to 0.10 wt%.

6) Magnesium (Mg) 0.008 to 0.018 wt%

[0037] Magnesium has function of graphite nodularity and promotes creation and growth of the nucleus of compacted graphite. In the cast iron according to the present invention, when the content of magnesium is less than 0.008 wt%, graphite becomes flaky, and when it is above 0.018 wt%, nodularity of graphite increases and poor retraction is caused, such that the content is limited within 0.008 to 0.018 wt%.

7) Phosphorous (P) 0.04 wt% or less

[0038] Phosphorous is also a kind of impurity naturally added from the air in the process of producing cast iron. Phosphorous stabilizes pearlite but when the content is above 0.04 wt%, brittleness rapidly increases and this is in association with poor retraction due to segregation. Therefore, in the cast iron according to the present invention, it is preferable to maintain the content of phosphorous at 0.04 wt% or less.

[0039] It is realistically difficult to make the content of phosphorous 0 in the raw material components of cast iron, and even if the content of phosphorous in the raw material components of cast iron is 0, phosphorous would be contained in the process of producing cast iron. Therefore, it is important to keep the content of phosphorous not more than 0.04 wt% in the present invention.

8) Sulfur (S) 0.02 wt% or less

[0040] Sulfur functions as a creation site of compacted graphite, but when the content is above 0.02 wt%, it is required to add more magnesium in order to create compacted graphite. That is, when the content of sulfur increases above a predetermined range, with the content is magnesium limited, compacted graphite becomes flaky. Therefore, it is necessary to maintain the content of sulfur at 0.02 wt% or less in the cast iron according to the present invention.

[0041] It is realistically difficult to make the content of sulfur 0 in the raw material components of cast iron, and even if the content of sulfur in the raw material components of cast iron is 0, sulfur would be contained in the process of producing cast iron. Therefore, it is important to keep the content of sulfur not more than 0.02 wt% in the present invention.

9) Ferrum (Fe)

[0042] Ferrum is the main substance of cast iron according to the present invention. The balance except for the components described above is ferrum.

[0043] According to an exemplary embodiment of the present invention, carbon equivalent is 4.35 to 4.5. In the cast iron according to the present invention, when the carbon equivalent is less than 4.35, the thin-walled part is chilled, and when it is above 4.5, retraction and poor flow is caused by excessive primary graphite, such that the content is limited within 4.35 to 4.5. The carbon equivalent (CE) is defined by $\text{carbon} + (\text{silicon} + \text{phosphorous}) \times 1/3$ and the value may be adjusted to control the properties and quality of the product.

[0044] According to an exemplary embodiment of the present invention, tensile strength of the cast iron is 500 to 600MPa and yield strength is 350 to 450MPa.

[0045] According to an exemplary embodiment of the present invention, in the cast iron, nodularity of graphite produced by the carbon is 5 to 20%.

[0046] A process of producing cast iron according to the present invention is described with reference to FIG. 4.

[0047] According to a method of producing cast iron of the present invention, original molten cast iron 110 is produced by melting a cast iron material containing carbon (C) of 3.65 to 3.75 wt%, silicon (Si) of 2.0 to 2.25 wt%, manganese (Mn) of 0.3 to 0.6 wt%, phosphorous (P) of above 0 and 0.04 wt% less, sulfur (S) of above 0 and 0.02 wt% or less, and the balance of ferrum (Fe), in the entire weight, in a furnace 100.

[0048] A ladle 200 with the other components 210 of copper (Cu) of 1.2 to 1.4 wt%, tin (Sn) of 0.07 to 0.10 wt%, and magnesium (Mg) of 0.008 to 0.018 wt% is prepared, in which the ladle 200 is a container for tapping the original molten cast iron melted in a furnace.

[0049] The molten cast iron 110 is produced by tapping the produced original molten cast iron with the ladle 200 with copper (Cu) of 1.2 to 1.4 wt%, tin (Sn) of 0.07 to 0.10 wt%, and magnesium (Mg) of 0.008 to 0.018 wt%.

[0050] According to an exemplary embodiment of the present invention, the tapping temperature can be adjusted to be 1,520°C.

[0051] Meanwhile, according to an exemplary embodiment of the present invention, the CE (Carbon Equivalent) may be adjusted to be 4.35 to 4.5 in the original molten cast iron.

[0052] The amount of magnesium to be added is determined by checking the content of magnesium contained in the molten cast iron in the ladle 200.

[0053] Since the original molten cast iron was carried to the ladle with the magnesium, a predetermined amount of magnesium is contained in the molten cast iron in the ladle. Nevertheless, the content of magnesium contained in the molten cast iron in the ladle is checked again to more precisely controlled the content of magnesium in consideration of loss of magnesium while carrying the ladle, and when it is determined that it needs to add magnesium, magnesium is added again.

[0054] According to an exemplary embodiment of the present invention, a thermal analysis system 300 may be used to check the content of magnesium.

[0055] Magnesium of which the amount to be added is determined is added to the molten cast iron in the ladle.

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According to an exemplary embodiment of the present invention, it may be possible to add magnesium, using a wire shape of magnesium 500.

[0056] Another inoculant that is generally used in a process of producing cast iron may be added with magnesium. For example, a silicon-based inoculant may be added. The silicon-based inoculant may be obtained from those on the market. The kind and content of the inoculant may be easily selected and determined by those skilled in the art, if necessary. Other inoculants may also be shaped in a wire type 500.

[0057] Cast iron is completed by injecting the molten metal with magnesium into a mold 400.

< Examples 1 to 10 and Comparative Examples 1 to 10 >

[0058] Cast iron according to Examples 1 to 10 and Comparative example 1 to 10 was produced in accordance with the composition in the following Table 1

[Table 1]

Unit: wt%									
Items	C	Si	Mn	Cu	Sn	Mg	P	S	Fe
Example 1	3.650	2.240	0.440	1.360	0.090	0.017	0.031	small	balance
Example 2	3.680	2.190	0.400	1.340	0.090	0.010	0.031	small	balance
Example 3	3.700	2.110	0.390	1.410	0.080	0.011	0.031	small	balance
Example 4	3.710	2.080	0.400	1.330	0.100	0.009	0.034	small	balance
Example 5	3.680	2.140	0.380	1.260	0.080	0.011	0.031	small	balance
Example 6	3.680	2.180	0.430	1.340	0.090	0.018	0.026	small	balance
Example 7	3.710	2.130	0.400	1.290	0.070	0.013	0.031	small	balance
Example 8	3.690	2.050	0.400	1.350	0.100	0.014	0.033	small	balance
Example 9	3.710	2.130	0.400	1.290	0.070	0.013	0.031	small	balance
Example 10	3.700	2.140	0.430	1.320	0.090	0.017	0.030	small	balance
Comparative Example 1	3.810	2.220	0.110	1.150	0.090	0.012	0.034	small	balance
Comparative Example 2	3.710	2.090	0.290	0.820	0.070	0.008	0.024	small	balance
Comparative Example 3	3.780	1.970	0.110	0.870	0.070	0.000	0.019	small	balance
Comparative Example 4	3.690	2.220	0.080	1.100	0.120	0.011	0.036	small	balance
Comparative Example 5	3.780	2.010	0.110	0.890	0.070	0.000	0.018	small	balance
Comparative Example 6	3.620	2.230	0.480	1.650	0.090	0.020	0.028	small	balance
Comparative Example 7	3.720	2.090	0.460	1.390	0.090	0.022	0.029	small	balance
Comparative Example 8	3.710	2.090	0.430	1.430	0.100	0.024	0.025	small	balance
Comparative Example 9	3.650	2.190	0.370	1.230	0.090	0.020	0.031	small	balance
Comparative Example 10	3.690	2.370	0.290	0.810	0.070	0.017	0.023	small	balance

[0059] First, in accordance with the composition in Table 1, original molten metal containing carbon (C), silicon (Si), Manganese (Mn), and phosphorous (P) was prepared. Sulfur (S) is an element that is unavoidably contained in the raw material of cast iron and the process of producing cast iron, such that it is not separately added but the content is maintained at 0.02 wt% or less.

[0060] The content of carbon was adjusted by measuring the CE by using a CE meter before tapping and temperature was fitted to 1,146°C with respect to TL (Liquidous Temperature), thereby preparing original molten metal.

[0061] A ladle was prepared by adding magnesium (Mg), copper (Cu), and tin (Sn) and the original molten metal was tapped to the ladle while the tapping temperature is uniformly maintained around about 1,520°C .

[0062] The amount of magnesium to be added in consideration of the content of magnesium that will be finally contained was determined by thermally analyzing the tapped original molten metal, the alloy amount of a wire type of magnesium

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was injected into a mold at 1,410°C after the alloy elements are adjusted.

[0063] Carbon equivalent (CE), tensile strength (TS), yield strength (YS), hardness (Hardness), and nodularity of the cast iron produced in accordance with the composition in Table 1 were measured and shown in Table 2. The hardness is Brinell Hardness and an HBW brinell hardness value.

[Table 2]

Items	C.E	Tensile strength (N/mm ²)	Yield strength (N/mm ²)	Hardness (HBW)	Nodularity (%)
Example 1	4.410	514.0	422.0	267.3	17.8
Example 2	4.420	521.0	342.5	259.5	8.5
Example 3	4.410	537.0	418.5	260.5	7.5
Example 4	4.410	550.8	418.8	273.3	11.6
Example 5	4.400	562.5	424.5	265.0	18.0
Example 6	4.420	570.0	434.0	271.3	19.9
Example 7	4.430	576.3	427.3	261.8	18.2
Example 8	4.380	579.5	441.8	279.0	14.4
Example 9	4.430	584.0	430.8	272.5	18.3
Example 10	4.420	584.8	438.3	269.0	21.1
Comparative Example 1	4.560	356.3	371.0	261.5	9.2
Comparative Example 2	4.410	412.5	345.8	244.3	17.5
Comparative Example 3	4.440	480.3	379.5	248.0	Impossible to measure
Comparative Example 4	4.440	480.7	372.0	256.7	5.1
Comparative Example 5	4.460	481.0	390.0	248.0	Impossible to measure
Comparative Example 6	4.370	602.8	443.8	275.3	22.0
Comparative Example 7	4.430	609.0	433.3	261.8	36.4
Comparative Example 8	4.420	629.0	442.5	273.8	29.7
Comparative Example 9	4.390	636.3	462.3	281.8	42.0
Comparative Example 10	4.490	654.3	448.0	266.0	59.3

[0064] As described above, it can be seen that in the cast iron according to the examples of the present invention the tensile strength was within 500 to 600 MPa(N/mm²), the yield strength was 350 to 450 MPa(N/mm²), and the HBW brinell hardness value was 255 to 280.

[0065] As described above, the cast iron according to the present invention has stable tensile strength and yield strength and appropriate hardness, such that the cast iron may be easily used to manufacture a cylinder block that can be applied to high-output and high-power diesel engines.

[0066] For reference, the result of observing the relationship between the nodularity of cast iron and the amount of magnesium was shown in FIG. 1. As shown in FIG. 1, it can be seen that nodularity was in the range of 5 to 20% in the CGI cast iron according to the present invention.

[0067] FIGS. 2 and 3 can be referred for the relationship between tensile strength and yield strength according to nodularity of the CGI cast iron produced as described above. As shown in FIGS. 2 and 3, it is possible to provide the cast iron of which the tensile strength and the yield strength are in the ranges of 500 to 600MPa and 350 to 450Mpa, respectively, with good quality of product.

Claims

1. A cast iron for use with a cylinder block of an engine comprising:

carbon (c) of 3.65 to 3.75 wt%;
 silicon (Si) of 2.0 to 2.25 wt%;
 manganese (Mn) of 0.3 to 0.6 wt%;
 copper (Cu) of 1.2 to 1.4 wt%;
 tin (Sn) of 0.07 to 0.10 wt%;
 magnesium (Mg) of 0.008 to 0.018 wt%;
 phosphorus (P) of 0.04 wt% or less;
 sulfur (S) of 0.02 wt% or less; and
 the balance of ferrum (Fe), an the entire weight

2. The cast iron of claim 1, wherein tensile strength is 500 to 600MPa.

3. The cast iron of claim 1, wherein yield strength is 350 to 450MPa.

4. The cast iron of claim 1, wherein carbon equivalent is 4.35 to 4.5.

5. The cast iron of claim 1, wherein nodularity of graphite produced by the carbon is 5 to 20%.

6. A method of producing cast iron, comprising:

producing original molten cast iron by melting a cast iron material, which contains carbon (C) of 3.65 to 3.75 wt%, silicon (Si) of 2.0 to 2.25 wt%, manganese (Mn) of 0.3 to 0.6 wt%, phosphorous (P) of above 0 and 0.04 wt% less, sulfur (S) of above 0 and 0.02 wt% or less, and the balance of ferrum (Fe), in the entire weight, in a furnace;

providing copper (Cu) of 1.2 to 1.4 wt%, tin (Sn) of 0.07 to 0.10 wt%, and magnesium (Mg) of 0.008 to 0.018 wt% in a ladle that is a container for tapping the original molten cast iron melted in a furnace;

producing molten cast iron by tapping the produced original molten cast iron with the ladle with copper (Cu) of 1.2 to 1.4 wt%, tin (Sn) of 0.07 to 0.10 wt%, and magnesium (Mg) of 0.008 to 0.018 wt%;

determining the amount of magnesium to be added by checking the content of magnesium contained in the molten cast iron in the ladle;

adding magnesium of which the amount to be added is determined to the molten cast iron in the ladle; and
 injecting the molten cast iron added with the magnesium into a mold.

7. The method of claim 6, wherein carbon equivalent in the original molten cast iron is 4.35 to 4.5.

8. The method of claim 6, wherein the tapping temperature is adjusted to be 1,520°C.

9. The method of claim 6, wherein magnesium is added by using a wire type of magnesium in the adding of magnesium.

Fig. 1

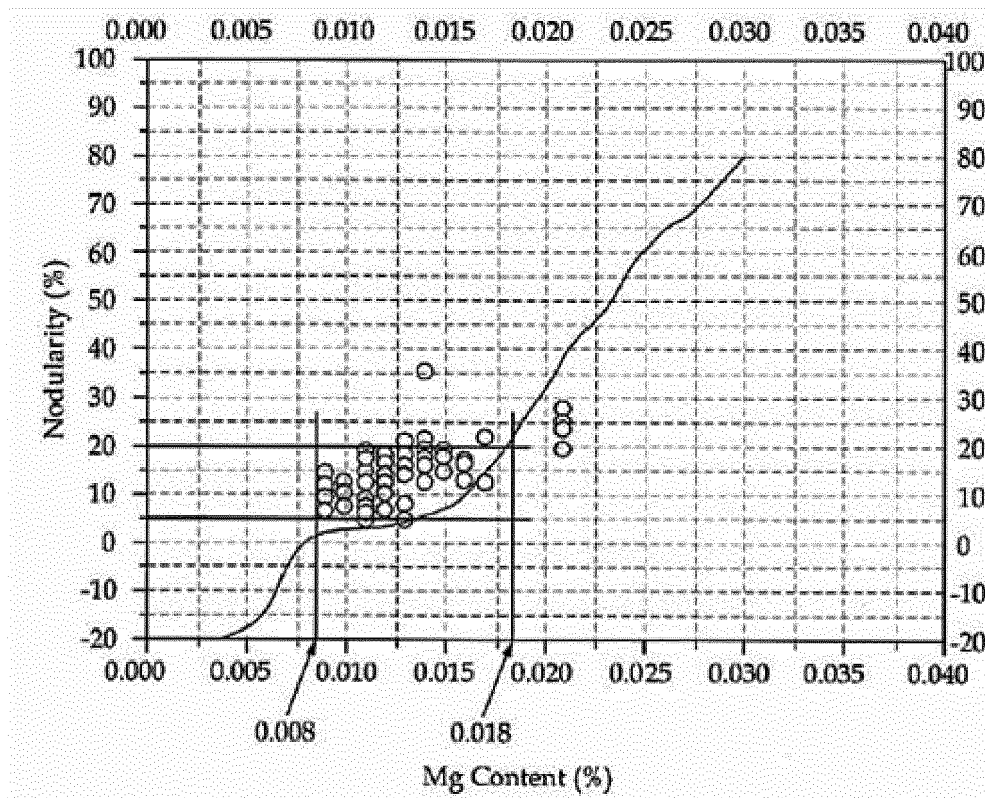


Fig. 2

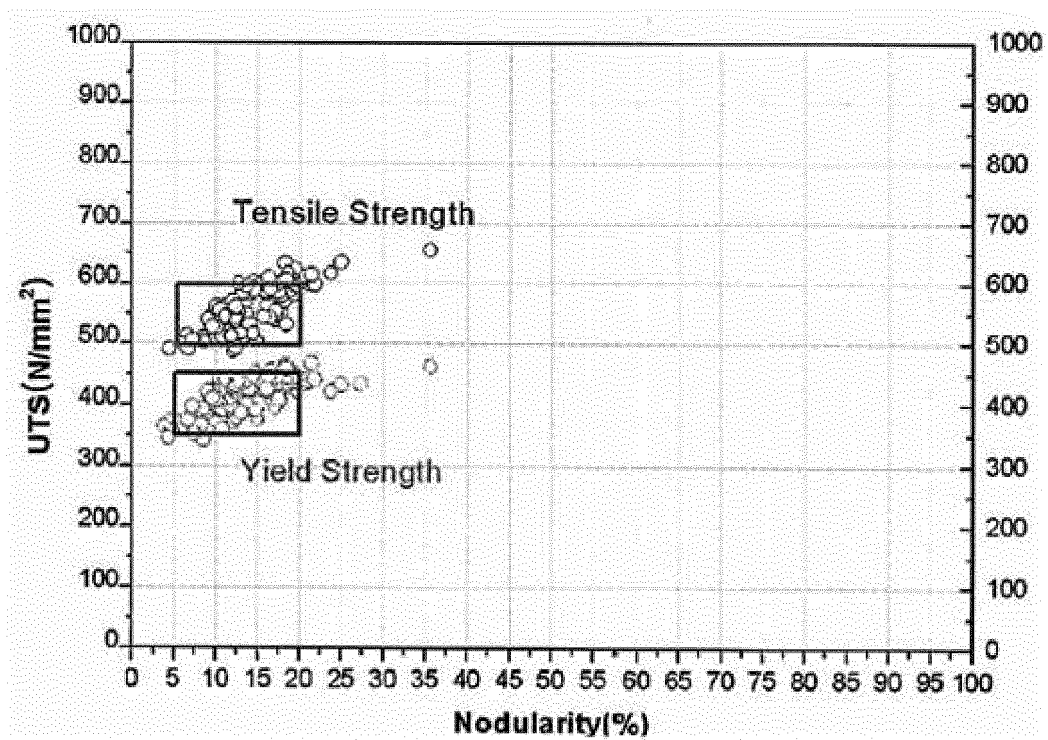


Fig. 3

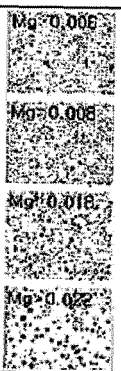
UTS (MPa) Mg wt. %	460	480	500	520	540	560	580	600	620	QUALITY OF PRODUCT	REPRESENTATIVE STRUCTURE
0.006	x	x	x	x	x	x	x	x	x	POOR	
0.008	●	●	●	x	x	x	x	x	x	GOOD	
0.010	●	●	●	●	x	x	x	x	x	GOOD	
0.012	●	●	●	●	●	●	x	x	x	GOOD	
0.014	●	●	●	●	●	●	●	x	x	GOOD	
0.016	●	●	●	●	●	●	●	x	x	GOOD	
0.018	●	●	●	●	●	●	●	●	x	GOOD	
0.020	●	●	●	●	●	●	●	●	●	POOR	
0.022	●	●	●	●	●	●	●	●	●	POOR	

Fig. 4

