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• **Hirukawa, Ryoji****Kawagoe-cho, Mie-gun Mie 5108121 (JP)**(54) **PROCESS FOR PRODUCING CAST METAL ACCORDING TO EVAPORATIVE PATTERN CASTING**

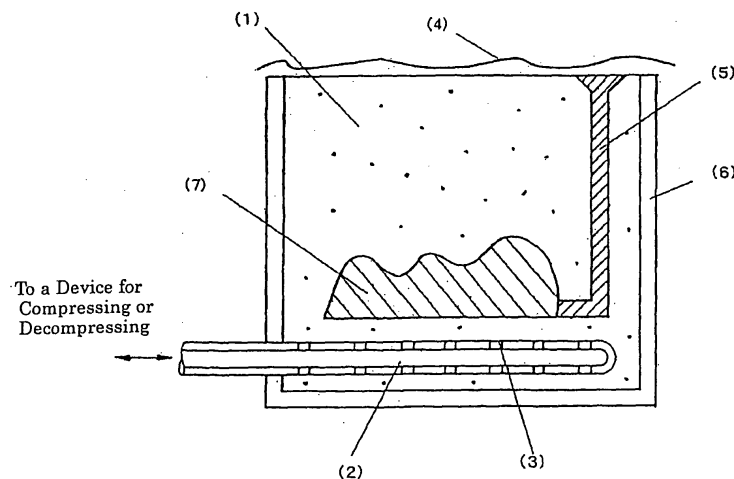
(57) These inventions are intended to provide a method for manufacturing castings which have no defect and which have good quality.

These inventions have a constitution which includes a step for pouring molten metal into a mold, wherein the

molten metal has a temperature range from 1,250 to 1,330 °C, and a step for reducing pressure in a mold.

Further, these inventions include a step for increasing the pressure in the mold through a ventilator channel after the step for reducing the pressure in the mold is carried out.

Fig. 4

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Description

Technical Field

[0001] These inventions relate to a method for manufacturing cast iron, such as gray cast iron or ductile cast iron. Particularly, they provide a method for manufacturing castings with improved quality and increased production efficiency by using a foam pattern.

Background of the Inventions

[0002] It is well known to use a method for manufacturing castings by using a foam pattern in order to produce cast iron products, such as deformed fittings.

[0003] For the method for manufacturing the castings by using a foam pattern, first the portion of the product of the pattern made from foamed resin is coated with a mold wash. Next, patterns for a runner, a sprue, a pouring cup and a feeder are formed by foaming resin and then coating them with the mold wash. Then these foam patterns are assembled and are buried in molding sand. When molten metal is poured in the pouring cup, since the foamed resin patterns has decomposed and then gas is generated by the heat of the molten metal, the molten metal can flow into the pattern made from the foamed resin through the runner and the gate. The molten metal can decompose the patterns made from the foamed resin by its heat and generate gas. Accordingly, the space for the pattern is filled with the molten metal. Then, as the molten metal in the space of the pattern is solidified, the castings can be manufactured.

[0004] For this method for manufacturing foundry products by using a foam pattern, generally the method that uses foundry sand that includes a binder, such as a fran resin, is called a "full mold casting." In contrast, the method that uses molding sand that does not include any binder is called a "lost-foam casting."

[0005] For example, the method for manufacturing castings by using a foam pattern is used to manufacture water pipes and other items, since the cost of equipment for this method is low. When lost-foam casting, which uses molding sand that does not include any binder, is used, since there is less waste sand than in other methods, it is advantageous in this point.

[0006] However, when the method for manufacturing castings by using a foam pattern is used, since the molten metal is poured in a mold that includes the foam pattern, much gas is generated because of the decomposition of the foam pattern. Thus, the fluidity of the molten metal in the mold may decrease. To solve this problem, it is necessary to take measures to rise the temperature of the molten metal.

[0007] Further, as the temperature of the molten metal rise, then during the cooling process the shrinkage volume of the castings becomes larger than otherwise. Consequently, "shrinkage" is caused to appear on the castings. Accordingly, the shrinkage must be reduced by adding a feeder in the mold.

[0008] Further, when dry molding sand is used, since the temperature of the molten metal rise, it takes a longer time to cool the castings after pouring the molten metal into the mold. Thus, it is a problem in that it takes a long time from pouring the molten metal to releasing the mold.

Summary of the Invention

[0009] These inventions are intended to solve the problems of the prior art explained in the above paragraphs. The first purpose of these inventions is to provide a method for manufacturing castings which have no defect, such as a shrinkage, a cold shot or blow hole and which have good quality. Namely, for the method for manufacturing castings by using a foam pattern, this purpose is achieved by dropping the temperature of the molten metal without decreasing the fluidity of the molten metal in the mold.

[0010] The second purpose of these inventions is to provide a method for manufacturing castings with high productivity. This purpose is achieved by decreasing the time for cooling the foundry product after pouring the molten metal in the mold, by reusing the molding sand, by increasing the recovery of the molten metal, and by increasing the productivity of the mold.

[0011] To achieve the purposes explained in the above paragraphs, the invention of claim 1 is comprised of:

a method for manufacturing a castings by using a foam pattern, wherein the method uses dry sand and a foamed pattern as a lost pattern, the method comprising: a step for pouring molten metal into a mold, wherein the molten metal has a temperature range from 1250 to 1330 °C, and a step for pressure reduction in a mold.

[0012] This is accomplished by pouring the molten metal at a lower temperature than that in the conventional method. Namely, the molten metal is poured into the mold at a low temperature so that it is formed in a semi-solid state, which means a state wherein a solid and liquid state coexist. Consequently, it becomes possible to reduce the shrinkage of

the castings caused by the solidification shrinkage while cooling. Further, it is accomplished by reducing the pressure in the mold. Consequently, since the gas caused by the decomposition of the foamed pattern is suctioned from the mold, no blow holes can affect the castings. Further, the fluidity of the molten metal in the mold can be increased. Thus, it becomes possible to prevent the blow holes or the cold shut from being generated in the castings, and to provide a method for manufacturing them with a high quality.

[0013] Further, the invention of claim 2 is comprised of:

the method of claim 1, wherein the step for reducing the pressure in the mold is accomplished by decreasing the pressure in a ventilator channel. It is disposed at a lower part of the mold and is provided with holes connecting with the sand in the mold.

[0014] Based on this composition of the invention of claim 2, since the gas caused by the decomposition of the foamed pattern is suctioned from the mold, no gas bubbles affect the foundry products. Further, since the gas caused by the decomposition is suctioned from the lower part of the mold, the molten metal that is poured into the mold is drawn downward. Consequently, the fluidity of the molten metal in the mold can be improved.

[0015] The invention of claim 3 is comprised of:

the method of claim 2, wherein after the step for reducing the pressure in the mold, it further comprises a step for increasing the pressure in the mold, wherein the step is achieved by increasing the pressure in the ventilator channel.

[0016] Based on this composition of the invention of claim 3, since pressurized low-temperature air flows in the mold, it becomes possible to increase the speed at which the mold cools, which mold includes the molten metal. Thus, the time from when the molten metal begins to be poured into the mold to when the mold is releasing can be shortened. Consequently, the productivity for producing castings can be improved.

[0017] Further, the invention of claim 4 is comprised of:

the method of any of claims 1-3, wherein the vacuum pressure of the step for reducing the pressure of the mold is from 0.03 Mpa to 0.05 Mpa.

[0018] As explained in the above paragraph, by applying the vacuum pressure of 0.03 Mpa to 0.05 Mpa to the ventilator channel as the step for decreasing the pressure in the mold, the gas caused by the decomposition of the foamed pattern is best suctioned from the mold while the molten metal is being poured. Thus, no gas bubbles affect the foundry product, and so the fluidity of the molten metal in the mold can be improved.

[0019] Further, the invention of claim 5 is comprised of: the method of either claim 3 or 4, wherein the step for reducing the pressure in the mold is applied from when the molten metal begins to be poured and filled into the mold, and then wherein the step for increasing the pressure in the mold is applied when the temperature of the foundry product descends to the temperature of ferrite-pearlite transformation.

[0020] Based on this composition of the invention of claim 5, the time from when the molten metal begins to be poured into the mold to when the mold is releasing can be shortened, and the productivity of castings can be improved.

[0021] Further, the invention of claim 6 is comprised of:

the method of any of claims 1-5, wherein no binder sand is used to molding.

[0022] Based on this composition of the invention of claim 6, since the foundry sand can be reused, the productivity of castings can be improved.

[0023] Further, the invention of claim 7 is comprised of:

the method of any of claims 1-6, wherein the material of the foamed pattern is a PMMA (polymethylmethacrylate), and wherein the material has its volume increased by 40-50 times, by being foamed.

[0024] Based on this composition of the invention of claim 7, the rigidity of the foamed pattern can be increased so as to withstand a load applied to a mold. Further, it is possible to make a foamed pattern generating less gas caused by the decomposition and less residue and to manufacture high quality castings.

[0025] Further, the invention of claim 8 is comprised of:

the method of any of claims 1-7, wherein the entire all or a part of the surface of the foamed pattern is coated with a mold wash having a bending strength of more than 15 Kg/cm².

[0026] Based on this composition of the invention of claim 8, it is possible to prevent a reaction between the sand and the molten metal, to further improve the rigidity of the foamed pattern, and to manufacture high quality castings.

[0027] Further, the invention of claim 9 is comprised of:

the method of any of claims 1-8, wherein no feeder is used in the mold.

[0028] By using no feeder in the mold, it is possible to improve the yield ratio of the molten metal and the productivity of the castings.

[0029] Further, the invention of claim 10 is comprised of:

the method of any of claims 1-9, wherein the foamed pattern that includes a runner, a gate, and a portion of a product, is integrally made, or separately formed, and then is assembled by adhering them.

[0030] Based on this composition of the invention of claim 10, since it is possible to improve the productivity of the mold, it is also possible to improve the productivity of castings.

[0031] By these compositions of the inventions explained in the above paragraphs, by the method for manufacturing the castings by using the foam pattern it is possible to reduce the temperature of the molten metal without decreasing its fluidity in the mold. Thus, it is possible to provide a method for manufacturing castings which have no defects, such as a shrinkage, a cold shut, or blow holes, and which are of good quality.

[0032] Further, since it becomes possible to decrease the time for cooling the castings after pouring the molten metal in the mold, to reuse the sand, to increase the ratio of the yield of the molten metal, and to increase the productivity of the mold, it is possible to provide a method with high productivity for castings.

Description of the Preferred Embodiments

[0033] For the steps for manufacturing castings, the temperature of a molten metal while pouring it into a mold affects the quality and the costs of manufacturing castings. For the conventional steps for manufacturing castings, the temperature of the molten metal while pouring it into a mold is high, namely, about 1,450 °C. Generally, however, the temperature of molten metal affects the shrinkage of foundry products when the molten metal is solidified, affects the fluidity of the molten metal in the mold, affects the degree of the decomposition of a foamed pattern, and affects the electrical power required to melt the metal.

[0034] If the pouring temperature is high, the shrinkage in castings becomes greater than otherwise when the molten metal is solidified. Conventionally, a feeder is disposed at the castings to prevent the surface sink. If molten metal which is in a half-solidified state, namely, in a semi-solid state, is poured into the mold, the thermal shrinkage of castings substantially equals that of its expansion. This expansion is caused by graphite deposition during solidification. Thus, since these effects cancel each other out, it is possible to prevent the shrinkage. The semi-solid state is defined as the state in which cementite that is in a liquid state and martensite that is in a solid state are mixed, at the step when the state of the cast iron changes from a liquid state to a solid state.

[0035] Further, if the molten metal that is in the semi-solid state is poured into the mold, it is not necessary to heat the molten metal up to the temperature that is used in the conventional manufacturing process. Thus, the electrical power necessary for heating can be reduced.

[0036] However, if the pouring temperature is low, since then the viscosity of the molten metal increases, the fluidity of it decreases. Thus, since it becomes difficult for the molten metal to run through the entire mold, this difficulty is liable to cause a flaw, such as a cold shut.

[0037] Further, if the pouring temperature is low, the rate of the decomposition of a foamed pattern decreases, or a residue of it is generated. Thus, this problem is liable to cause defects.

[0038] Because of the aspects explained above, to manufacture high quality castings at low costs, it is necessary to control the temperature of the molten metal to maintain it within the range of the transition temperature of the semi-solid state, and to take countermeasures to prevent harmful effects that could be caused by a lower temperature of the molten metal while it is being poured into the mold.

[0039] It is important to clarify the conditions to control the temperature of the molten metal while it is being poured into the mold so that the condition of the semi-solid state at the gate of the mold can be maintained. Thus, analyses while pouring the molten metal were made to clarify the conditions.

[0040] As shown in Fig. 1, the analyses while pouring the molten metal were made by using a device that simulates the runner portion of the actual mold. Namely, the device is provided with a metal pipe having a wall made from a refractory material, and with a foamed resin (a foamed pattern) in the hollow part of the pipe. The molten metal is poured through the pipe. The molten metal that goes through the pipe falls into a tank of water disposed under the outlet port of the pipe. The analyses were made to evaluate whether the molten metal was formed in the semi-solid state at the

outlet port of the pipe (this location corresponds to the gate of the mold) by metallographic observation of samples (test pieces) that solidified in the tank of water.

[Table 1]

[0041]

Table 1: Relationship Between the Temperature and a Semi-solid State of the Molten Metal

Temperature of the Molten Metal (°C)	Semi-solid State
1400	×
1350	×
1330	○
1300	○
1280	○
1250	○
1230	○

[0042] Table 1 shows the results of the analyses of the poured molten metal. Fig. 2 shows a photomicrograph of the metallographic structure of the test piece. The mark "○" in Table 1 denotes that the molten metal formed in a semi-solid state. The mark "×" in Table 1 denotes that the molten metal did not form in a semi-solid state.

[0043] For the analyses of the poured molten metal, they were made by varying the temperature of the molten metal that was poured into the pipe from 1,230 to 1,400 °C. At more than 1,350 °C, no metallographic structure that became partially formed in the solid state at the location just before falling into the tank of water could be found. However, when the molten metal had a temperature of 1,330 °C, a metallographic structure that became partially in solid state was able to be found. When the molten metal had a temperature of 1,230 to 1300 °C it formed in a mixed solid state and liquid state at the location just before it falls into the tank of water. Thus, it was proven that the semi-solid state could be achieved in the mold by pouring the molten metal at a temperature within a range of 1,230 to 1,330 °C.

[0044] Next, deformed fittings made from ductile cast iron were experimentally manufactured by varying the manufacturing conditions. Two types of the deformed fittings were experimentally manufactured. One was a straight duct-type deformed fitting having a nominal diameter of 8 inches and a thickness of 3.5 mm, as shown in Fig. 3 (weight of 5.5 Kg/one). The other was a straight duct-type deformed fitting having a nominal diameter of 10 inches and thickness of 5 mm, as shown in Fig. 3 (weight of 11 Kg/one).

[0045] For this experimental manufacturing, the deformed fittings were manufactured by varying the temperature of the molten metal that was poured into the mold from 1,230 to 1,400 °C. Further, while pouring the molten metal into the mold, two types of pressure conditions were applied. Namely, in one case, while pouring the molten metal into the mold, the pressure in the mold was decreased. In the other case, it was not decreased.

[0046] First, below is explained the method for manufacturing the deformed fittings without decreasing the pressure in the mold.

[0047] The foamed pattern having a shape of a deformed fitting, which pattern is used to form the mold, is made by foaming a polymethylmethacrylate resin (PMMA). For the steps for making the foamed pattern, it is desirable to reduce the density of the pattern by increasing the ratio of the volume of the resin after foaming compared to before foaming in order to generate less gas caused by the decomposition and less residue. However, if the foamed pattern were to be made by increasing the ratio of the volume of the resin after foaming compared to before foaming too much, since the density and the rigidity of the pattern would also be reduced too much, the foamed pattern would become deformable. Consequently, it would become difficult to manufacture castings having a high dimensional accuracy. Thus, it is desirable to set the volume of the resin after foaming to be 40-50 times greater than that before foaming.

[0048] Then, the surface layer of the foamed pattern is formed by coating it with a mold wash (facing material). This mold wash is used to prevent the sand from reacting to the molten metal, to improve the rigidity of the foamed pattern, and to reinforce it. To achieve these purposes, it is desirable to use a mold wash having a strength of more than 15 Kg/cm². The concentration of the mold wash affects the quantity of the blow holes generated in the castings. It is desirable to set the concentration of the mold wash at about 70 Baume.

[0049] When the foamed patterns are made, it is possible to independently form the portion of the product of the pattern, the patterns of the runner portion, the gate portion, the portion for pouring the molten metal, and the portion for pressurizing the portion of the product. It is also possible to integrally make all parts of the foamed pattern, such as the

patterns of castings, the runner, the gate, pouring cup, and feeder. Then the foamed patterns are coated with the mold wash. It is also possible to independently form the patterns of all portions, to assemble them by adhering them together, and then to coat them with the mold wash.

[0050] Next, the mold is made by using the foamed pattern coated with the mold wash. "Thera Beads 400" (a brand name), which is molding sand made from artificial ceramics, is used as the sand for the mold. Since the sand does not include a binder, and since there is less waste foundry sand generated from fractures than by other methods, it can be reused as the sand. Thus, this sand has an advantage in this point.

[0051] After making a mold that includes the foamed pattern, the molten metal is poured into the mold. The material of the molten metal is FCD45 (spheroidal graphite cast iron). When castings is manufactured by using the mold containing the foamed pattern, at the same time that the molten metal is poured into the mold, the foamed pattern is decomposed by the heat of the molten metal. Then, the molten metal flow into every corner of the mold. The gas caused by the decomposition diffuses through the molding sand, which has some permeability to air, and is discharged from the mold to the outside of it.

[0052] Over time the molten metal poured in the mold is gradually cooled and changed from the liquid state to the solid state.

[0053] When the temperature of the castings drops down sufficiently, the mold is releasing. Then, the manufacturing steps of the deformed fitting are completed by removing it from the molding sand.

[0054] Second, below is explained the method for manufacturing the deformed fittings while reducing the pressure in the mold.

[0055] In the method for manufacturing the deformed fitting, the steps after pouring the molten metal into the mold differ from those in the method of manufacturing it without reducing the pressure or not. Namely, as shown in Fig. 4, in the method for manufacturing the deformed fitting while reducing the pressure, the step for decreasing the pressure in the mold is accomplished by decreasing the pressure in a ventilator channel (2), which is disposed at the lower part of the mold (1), at the same time that the molten metal is poured into the mold containing the foamed pattern.

[0056] The ventilator channel (2) has a plurality of holes (3) to contact with the foundry sand in the mold. One end of the ventilatory channel (2) is connected to a device (not shown in the Figs.) named a vacuum pump.

[0057] If the pressure in the ventilator channel (2) is decreased by the device for decompression, the air in the foundry sand and the gas caused by the decomposition of the foamed pattern made from a resin are drawn through voids between the sand.

[0058] For the suction of the decomposition gas, it is desirable to continue decreasing the pressure in the ventilator channel (2) until the molten metal poured into the mold can be solidified. Further, to avoid directly drawing out the sand, but to draw out all the decomposition gas, it is desirable to set the pressure in the mold within the range of 0.03 Mpa to 0.05 Mpa.

[0059] When the temperature of the deformed fitting is sufficiently dropped, the mold is released. Then, the steps of manufacturing the deformed fitting are completed by removing from the sand.

[0060] In the above paragraphs, it is explained that the ventilator channel (2) is disposed at the lower portion of the mold. However, the location of the ventilator channel (2) is not limited to this configuration. It can also be disposed at the sides or upper portion of the mold. Further, a flask having a plurality of vent holes can be used. Such a flask is disposed at the periphery of the mold. It is also possible to decompress the outside the flask.

[0061] As shown in Fig. 4, if the ventilator channel (2) is disposed at the lower portion of the mold, then when the molten metal is poured into it while the pressure in the ventilator channel (2) is being decreased, the molten metal is drawn downward. Thus, it is less likely that the molten metal will swash in the mold, and so the surface of the molten metal in the mold will gradually and stably ascend. Thus, the molten metal can be prevented from possibly including air or gas bubbles.

[0062] Further, if a heat-resistant plastic film (4) is placed on top of the mold, since the air which flows through the sand is decreased, it is possible to effectively draw out the decomposition gas.

[0063] Below, the results of the trial manufacture of the deformed fittings based on the method explained above are shown. [Table 2]

Table 2: The Experimental Result of the Deformed Fittings Having Nominal Diameters of 8 Inches and 10 Inches

Temperature of the Molten Metal (°C)	8 Inch Deformed Fittings (Thickness: 3.5 mm)		10 Inch Deformed Fittings (Thickness: 5 mm)	
	With Decompression	Without Decompression	With Decompression	Without Decompression
1400	○	○	○	○
1380	○	○	○	○

(continued)

Temperature of the Molten Metal (°C)	8 Inch Deformed Fittings (Thickness: 3.5 mm)		10 Inch Deformed Fittings (Thickness: 5 mm)	
	With Decompression	Without Decompression	With Decompression	Without Decompression
1350	○	Δ	○	Δ
1330	○	Δ	○	Δ
1300	○	×	○	Δ
1280	○	×	○	Δ
1250	○	×	○	×
1230	Δ	×	Δ	×

[0064] Table 2 shows the results of the trial manufacture of a straight duct-type deformed fitting having a nominal diameter of 8 inches and a thickness of 3.5 mm and a straight duct-type deformed fitting having a nominal diameter of 10 inches and a thickness of 5 mm.

[0065] These deformed fittings are manufactured by varying the temperature of the molten metal and the pressure in the ventilator channel (2). The marks of "○", "Δ", and "×" in Table 2 denote the results of the evaluation for foundry products produced by the deformed fittings. The mark "○" means that the product produced by the deformed fittings has no defects, such as a cold shut caused by the fluidity of the molten metal or blow holes caused by including the decomposition gas caused by foam pattern, and has a high quality. The mark "Δ" means that while there are not any problems with the fluidity of the molten metal, the castings has blow holes in it. The mark "×" means that there are also some problems with the fluidity of the molten metal.

[0066] It was found that it was necessary to reduce the pressure in the mold in order to manufacture a castings having a high quality, by reducing the temperature of the molten metal.

[0067] From Tables 1 and 2 it is seen that to manufacture castings especially having a thin wall, and having high quality, by pouring molten metal into the mold in a semi-solid state, it was found that it was necessary to control the temperature of the molten metal to within the range of 1,250-1,330 °C and to lower the pressure in the mold. In addition, it is possible to eliminate the feeder of the mold and then to improve the ratio of the yielded molten metal by pouring the molten metal into a mold when it is in the semi-solid state.

[0068] Fig. 5 shows the measurements of the strength of the castings shown in Table 2. They can be manufactured by decompressing or not decompressing the mold while the molten metal is being poured.

[0069] From Fig. 5, one can see that the strength of the castings is improved by reducing the pressure in the mold while pouring the molten metal into the mold. One can also see that the strength of the castings is improved by pouring the molten metal into the mold in the semi-solid state.

[0070] As well as the trial manufacturing of the castings as explained in the above paragraphs, the deformed fittings were trial manufactured by causing the castings to cool by further raising the pressure of the mold after lowering it.

[0071] The steps for manufacturing castings by applying a step for compressing a mold after a step for decompressing it are substantially similar to those applying only a step for decompressing a mold, except for one step. Namely, the step for compressing the ventilator channel (2) in the mold after reducing the pressure in it while pouring the molten metal is applied to the method for manufacturing castings, instead of the step for just reducing the pressure in the ventilator channel (2).

[0072] For this method for manufacturing the castings, at the same time that the molten metal is poured into the mold containing the foamed pattern, the decompression of the mold is achieved by reducing the pressure in the ventilator channel (2) disposed at the lower portion of the mold (1). The decompression is continued until all the molten metal has been poured into the mold. After pouring the molten metal, the pressure in the ventilator channel (2) is increased to above the atmospheric pressure. By increasing the pressure in the ventilator channel (2), room-temperature air is fed in the voids between the sand from the ventilator channel (2). And then, an air flow is formed. It becomes possible to increase cooling rate of the castings by that flow of air. For this method for manufacturing the castings, if a heat-resistant plastic film (4) is placed on top of the mold, it is desirable to begin to reduce the pressure in the ventilator channel (2) to more than the atmospheric pressure after removing the plastic film (4), so that the air in the mold can flow easily.

[0073] The ventilator channel (2) may be compressed until the temperature of the castings drop down sufficiently. It may also be compressed until the temperature of the castings drop down to below the temperature of ferrite-pearlite transformation, and then the pressure in the ventilator channel (2) may be reduce to the atmospheric pressure. By this method, the cooling rate of castings can be effectively increased. Further, wasted use of the energy necessary to

compress the ventilator channel (2) can be reduced.

[0074] From the results of the trial manufacture of the deformed fittings by further compressing the mold after decompressing it in order to cause the castings to cool, it is seen that while it took 30 minutes from pouring the molten metal to release the mold when the step for compressing the mold to cause the castings to cool was not applied, it took just 15 minutes from pouring the molten metal to release the mold when the step was applied. Thus, improving the productivity of the castings was achieved.

Brief Descriptions of the Drawings

[0075]

[Fig. 1] Fig. 1 shows a device used for analyzing molten metal being poured to clarify which temperature causes the metal to be in a semi-solid state in the mold.

[Fig. 2] Fig. 2 shows a photomicrograph of the metallographic structure of the test piece that is made by the analysis of the molten metal being poured to clarify which temperature of the molten metal causes the metal to be in the semi-solid state.

[Fig. 3] Fig. 3 shows a photograph of a deformed fitting. It is trial manufactured cast iron.

[Fig. 4] Fig. 4 shows the constitution of the device for compressing or decompressing the mold.

[Fig. 5] Fig. 5 shows the measurements of the strength of the castings which are manufactured by decompressing or not decompressing the mold while pouring the molten metal.

Claims

1. A method for manufacturing castings by using dry sand and a foamed pattern as a lost-form pattern, the method comprising:

a step for pouring molten metal into a mold, wherein the molten metal has a temperature from 1,250 to 1,330 °C, and
a step for reducing pressure in a mold.

2. The method of claim 1, wherein the step for reducing the pressure in the mold is accomplished by decreasing the pressure in a ventilator channel that is disposed at a lower part of the mold and that is provided with holes communicating with sand in the mold.

3. The method of claim 2, wherein, after the step for decreasing the pressure in the mold, it further comprises:

a step for increasing the pressure in the mold, wherein the step is accomplished by increasing the pressure in the ventilator channel.

4. The method of any of claims 1-3, wherein the pressure of the vacuum in the step for reducing the pressure of the mold is from 0.03 Mpa to 0.05 Mpa.

5. The method of either claim 3 or 4,
wherein the step for reducing the pressure in the mold is applied from when the molten metal begins to be poured into the mold to when the molten metal has been poured, and
wherein the step for increasing the pressure in the mold is applied from when the molten metal has been poured to when the temperature of the castings descends to the temperature of ferrite-pearlite transformation.

6. The method of any of claims 1-5, wherein no binder is mixed with the sand used for molding.

7. The method of any of claims 1-6, wherein the material of the foamed pattern is a PMMA (poly methyl methacrylate), and wherein the material has its volume increased 40-50 times by being foamed.

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8. The method of any of claims 1-7, wherein the entire surface or a part of the surface of the foamed pattern is coated with a mold wash having a bending strength of more than 15 Kgf/cm².

9. The method of any of claims 1-8, wherein no feeder is disposed in the mold.

10. The method of any of claims 1-9,
wherein the foamed pattern that includes a runner, a gate, and a casting, is integrally made, or
wherein the foamed pattern that includes a runner, a gate, and a castings, is separately formed, and then is assembled
by adhering them.

Fig. 1

A Device Used for Analyzing Molten Metal Being
Poured to Clarify Which Temperature of It Causes
the Metal to Be in a Semi-Solid State in the Mold

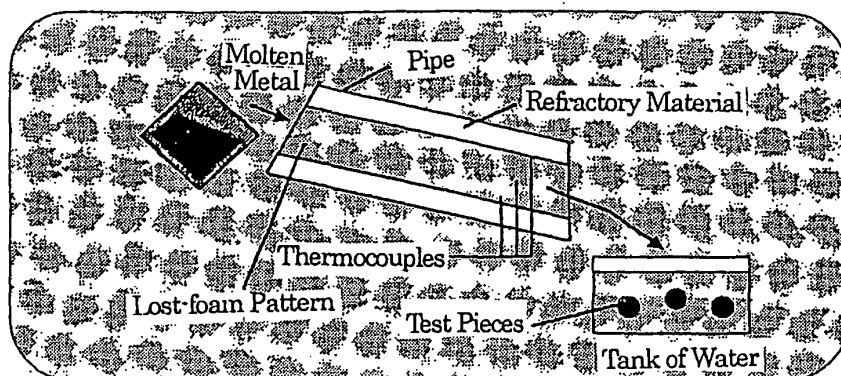


Fig. 2

A Photomicrograph of the Metallographic
Structure of the Test Piece

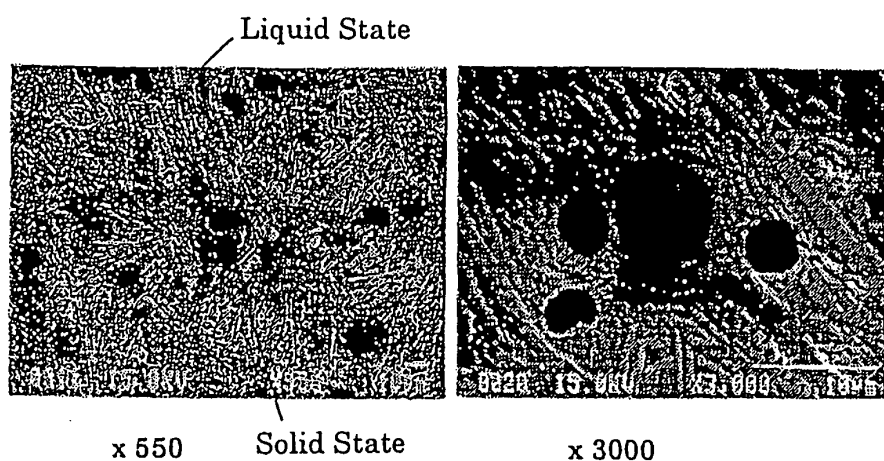


Fig. 3

Photographs of a Deformed Fitting

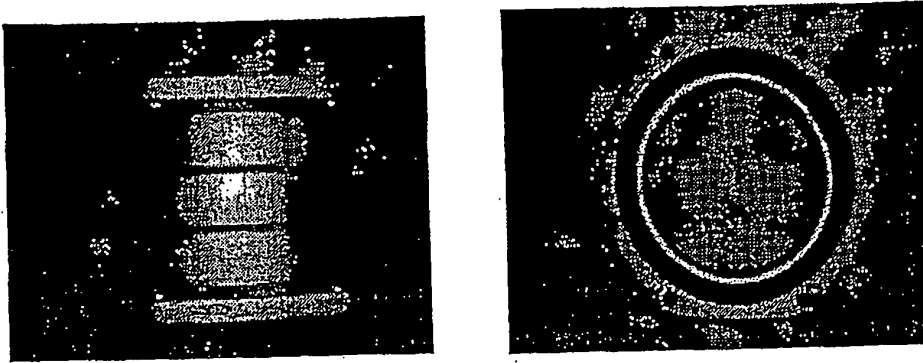


Fig. 4

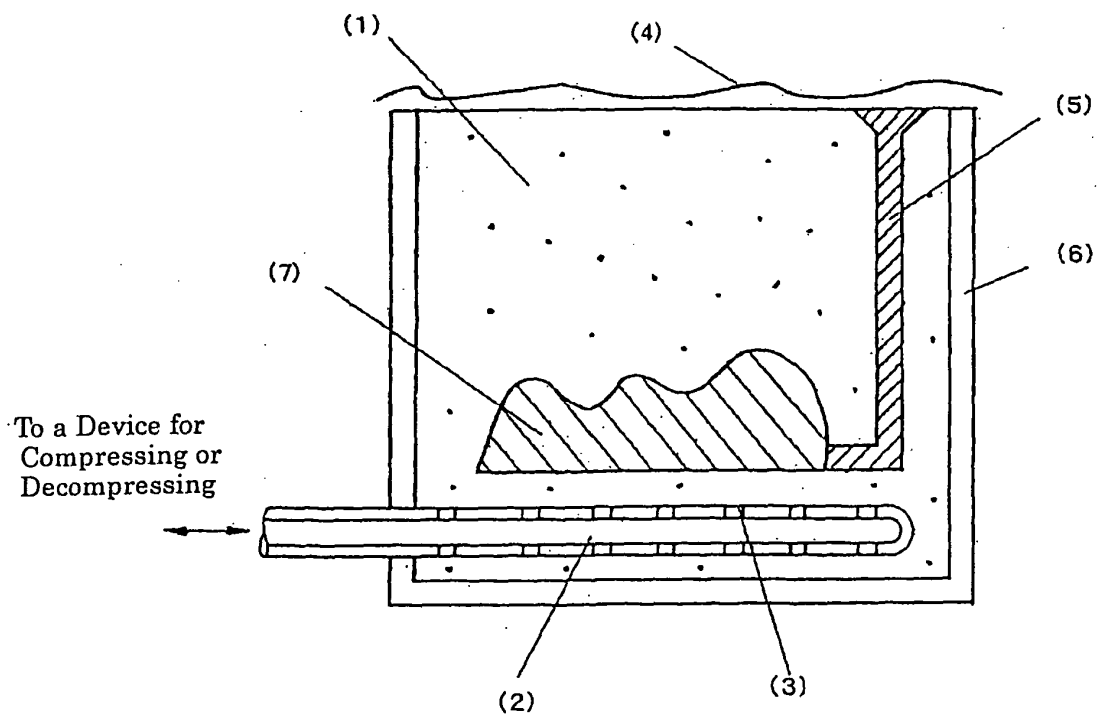
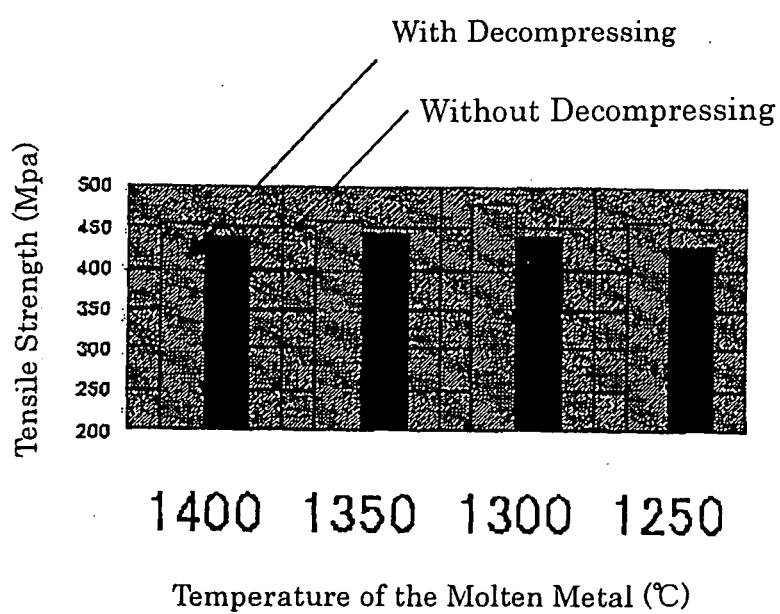


Fig. 5

Measurements of the Strength of the Castings Which Are Manufactured by Decompressing or Not Decompressing the Mold While Pouring the Molten Metal



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2005/022785

A. CLASSIFICATION OF SUBJECT MATTER B22C9/04 (2006.01)		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED		
Minimum documentation searched (classification system followed by classification symbols) B22C5/00-25/00		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2006 Kokai Jitsuyo Shinan Koho 1971-2006 Toroku Jitsuyo Shinan Koho 1994-2006		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 52-5004 B2 (Mitsubishi Heavy Industries, Ltd.), 09 February, 1977 (09.02.77), (Family: none)	1-10
A	JP 3480263 B2 (Isuzu Motors Ltd.), 10 October, 2003 (10.10.03), (Family: none)	1-10
<input type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/> See patent family annex.		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 06 March, 2006 (06.03.06)		Date of mailing of the international search report 14 March, 2006 (14.03.06)
Name and mailing address of the ISA/ Japanese Patent Office		Authorized officer
Facsimile No.		Telephone No.

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