(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 3 290 130 A1**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
07.03.2018 Bulletin 2018/10

(51) Int Cl.:
B22C 1/02 $^{(2006.01)}$ ***B22C 1/22*** $^{(2006.01)}$
B22C 9/02 $^{(2006.01)}$

(21) Application number: **17185130.6**

(22) Date of filing: **07.08.2017**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
MA MD

(30) Priority: **29.08.2016 US 201615250690**

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(54) ANTI-VEINING ADDITIVE FOR SILICA SAND MOLD

(57) This invention relates generally to a composition for silica sand cores and molds suitable for use in the casting of metals. The sand core composition contains a binder and a uniformly dispersed anti-veining additive. The mixed metal oxides collapse into a visco-plastic state when the foundry mold/core is heated by the molten metal during casting. A change in state of the MMOx from solid to a visco-plastic at the casting high temperatures provides space and lubricity within the foundry shape sufficient to compensate for the thermally-induced physical expansion of the silica grains. Thereby avoiding the mechanical forces which cause cracks and fissures in the mold or core that produce veins and other surface imperfections associated with the high coefficient of thermal expansion of silica sand.

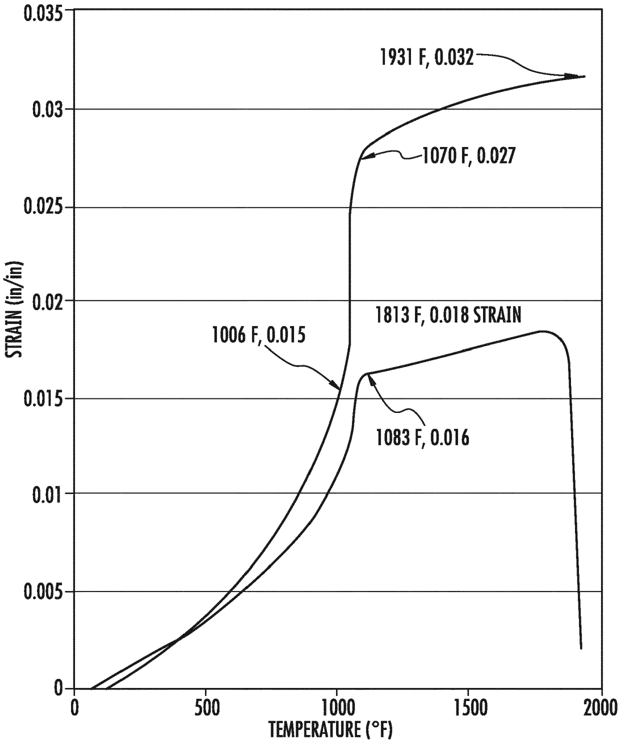

FIG. 1

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Description

FIELD OF THE INVENTION

[0001] The present invention relates to metal founding, and more particularly to a method of making a silica sand-based mold which improves the quality of metal castings by reducing veining defects. This invention relates to silica sand mold/core additives for controlling thermal expansion of sand mold/cores during metal casting operations.

BACKGROUND OF THE INVENTION

[0002] In a metal casting process, a cavity is first shaped in a mold. The mold inner cavity surface is the active surface and has a configuration corresponding to the exterior surface of the product desired to be manufactured. Molten metal is poured into the mold cavity and takes the shape of the cavity. As the metal cools it solidifies into a metal casting product having a shape corresponding to the mold cavity imprint.

[0003] Silica sand is commonly used for molds and cores because it is readily available and inexpensive in most of the world. A drawback of using silica sand is that it has a high coefficient of thermal expansion, including a high coefficient of thermal expansion at temperatures below the solidification temperatures of iron and steel.

[0004] The degree of thermal expansion for the typical bonded silica sand used in the North American foundry industry is typically in the range of about 1.3 to 1.6% of the original sand volume, with approximately 90% of that increase having occurred upon reaching temperatures of about 1200° F (649 degrees C).

[0005] As silica sand mold is heated by the molten metal during casting, layers of silica heat up expand, and they force the surface layer of the mold to move. When this happens, the surface layer (in the absence of suitable additions to the mold) cracks, these cracks open up, and metal runs into the cracks to produce veins on castings which are highly undesirable. When the molten metal solidifies, it leaves raised, narrow ridges on the surfaces of the cast part at those locations where the molten metal penetrated into small cracks and fissures. The resulting narrow ridges are referred to as "veins" and the phemonon as "veining". The veining may make it necessary to surface grind or machine away the projecting veins. Of course, such surface grinding or machining increases the casting cost.

[0006] Sand cores are shaped solid aggregates of sand which are used in foundries for making internal passages in castings. Sand cores are placed in a mold to define the internal recesses of the casting. They are surrounded by liquid metal during pouring and typically heat up more rapidly than molds which are almost always larger and have external surfaces exposed to the environment. When molten metal is poured into a mold or over the sand core, the rapid rise in temperature causes thermal expansion of the sand mass, and the surface of the sand mold and core is rapidly heated to the metal temperature, and it expands as it is heated. The expansion may cause pieces of the core to flake off, which leaves a rough surface finish, and thermal expansion produces cracks in the core. These cracks allow molten metal to penetrate the core and form fin-shaped imperfections on the interior surface (formed by core) of the casting which are known in the art as veins. Again, these veins project from the passages within the casting.

[0007] A photograph of a so-called step cone made with a Phenolic Urethane Cold Box (PUCB) resin bonded silica sand having no anti-veining additives is shown in Figure 3. The foundry casting was formed into a cylindrical silica mold having a centered, stepped, silica core. The casting illustrated in figure 3 is a photograph of half a step cone casting after a shakeout and being divided in two halves. The half shown in figure 3 is representative of both halves. As shown in figure 3 the casting half contains several deep veins in the smallest diameter section and the intermediate diameter section of the casting. The centered foundry core was made using bonded silica having an expansion coefficient illustrated by a first graphical curvilinear line shown in Figure 1 (the generally first steeper plot curvilinear line reaching a maximum of 0.032 in/in).

[0008] These veining defects, caused by uncontrolled core sand thermal expansion are most often partially controlled by anti-veining or expansion control agents. These agents are mixed uniformly with the silica sand and binder prior to the formation of the sand cores/molds with a pattern. Anti-veining or expansion control agents change the thermal coefficient of expansion of the sand core/mold to control cracking and reduce or eliminate the formation of veins

[0009] A wide variety of agents have been added to silica sand mixtures in an attempt to improve the properties of cores and molds by partially limiting veining and related expansion defects. These additives include starch based products, dextrin, fine ground glass particles, hydrated clays of many types, and cellulosic compounds.

[0010] Other materials. include pitch and coal dust of various kinds and compositions. For many years it was thought that ground sea coal found floating on the surface of the sea on the east side of England was the best material to use, and sea coal is still a commonly used term to describe various grades of pulverized coal. It was eventually found however that many kinds of coal could be used, preferably coal having a high volatile content when heated to 1500°F to 2000°F (815-1093 °C) As the volatile compounds are decomposed and evaporated, the coal particles shrink and this provides some room for the thermal expansion of the individual sand particles.

[0011] The important point is that these organic particulate materials decompose and shrink in volume as they are heated. This shrinkage provides some room for the silica grain expansion to occur without producing a stress so high that the surface of the mold cracks or spalls. The technical term for providing space into which silica grains can expand is "thermal strain accommodation".

[0012] These particulate materials, and other organic material used in the prior art provide some strain accommodation but most the prior art organic additives are brittle and do not plastically deform as the mold is heated. These organic materials often decompose and generate undesirable gas at metal pouring temperatures.

[0013] Iron oxides have also been used in foundries to improve sand cores and the quality of castings. Iron oxides proved to be advantageous in sand cores by reducing the formation of thermal expansion defects such as veining. Iron oxides in use include red iron oxide (Fe_2O_3), also known as hematite, black iron oxide (Fe_3O_4), known as magnetite, and yellow ochre. The most common method of employing such iron oxides is by adding approximately 1% to 3% iron oxides to the core sand during mixing. The mechanism by which iron oxides improve the surface finish is not clearly understood. One theory is that the iron oxides increase the plasticity of the sand core by forming sand grain interfaces which deform, or give, without fracturing, thereby preventing cracks in the core which can form veins. One variation on the use of iron oxide is to use hollow spherical oxide particles referred to as FINEOX ®. The hollow sphere shape gives even more strain accommodation as the sphere softens and is crushed by the expanding sand. The FINEOX ® iron oxide appears to function by softening and fluxing silica sand at temperatures around 2000^0F (1093°C).

[0014] A proprietary material made in several grades called VEINSEAL ® (Chesapeake Specialty Products, Inc. (Baltimore, MD) is marketed by several companies around the world. VEINSEAL ® products are primarily metallic elements which oxidize at elevated temperatures and expand to close up mold cracks. VEINSEAL is available in a variety of compositions to control expansion in metals with different section sizes and pouring temperature. While VEINSEAL ® does reduce veining, this material is considered to be relatively expensive in the casting industry.

[0015] The step-cone PUCB mold shown in figure 5 was made with the same bonded silica sand having the same expansion coefficient illustrated by the curvilinear line in Figure 1. An anti-veining additive of iron oxide FINEOX ® was uniformly blended into this PUCB step cone mold. As shown the metal step cone casting half illustrated in Figure 5 has fewer and less protruding veins on the surface of the smallest diameter and the intermediate diameter sections of the casting than Figure 3.

[0016] Glass has been employed as an additive to help reduce expansion defects of sand cores and molds during casting. US Patent Application Publication No. 2009/0095439 (Stotzel) refers to the addition of borosilicate glass and preferably borosilicate glass hollow microspheres having a softening point of less than 1500C and preferably within the range of 500 to 1000C. The '439 Glass publication disclose the borosilicate glass being used as an additive for higher temperature iron castings. US Patent 5,983,984 (Auderheide et al.) teaches the use of aluminosilicate glass in the form of microspheres.

[0017] US Patents Nos. 8122936 (Attridge et al.) and US 7,938,169 (Attridge et al.) disclose the combination of glass with iron oxide additives to reduce veining and other expansion defects. The iron oxide is believed to provide greater plasticity between grains of sand in the mold and thereby reduce mold cracking and it is also believed to assist in trapping gases released from the binder. US Patent 2008/0099180 (Weicker et al) discloses using combinations of anti-veining additives which may or may not include granules of glass.

[0018] Various other additives have been proposed for reducing the cracking of sand cores during casting. U.S. Pat. No. 5,911,269 discloses a method of making silica sand cores utilizing lithium-containing materials that provide a source of lithium oxide (Li_2O) to improve the quality of castings by reducing sand core thermal expansion and the veins resulting therefrom. The disclosed method of making sand cores comprises the steps of preparing an aggregate of sand core and a resin binder, and mixing into the aggregate a lithium-containing additive selected from a group consisting of alpha-spodumene, amblygonite, montebrasite, petalite, lepidolite, zinnwaldite, eucryptite and lithium carbonate in amounts to provide from about 0.001% to about 2% of lithium oxide. The use of such a method and lithium oxide-containing additives is described as reducing the casting defects associated with thermal expansion of silica, including the formation of veins in the cavity and improved surface finish.

[0019] In spite of the antiquity of the sand casting process and the vast amount of developmental work carried on in this field, there remains substantial room for improvement in silica sand properties to provide a casting with a superior surface finish.

SUMMARY OF THE INVENTION

[0020] It is an object of this invention therefore to provide a silica sand core and mold composition adapted to the production of cores and molds essentially free from the above-described undesirable properties using materials easily added to sand molds to improve the surface finish of the resulting products.

[0021] Another object is to provide an improved method of making silica sand molds and cores that are inexpensive.

[0022] This invention relates generally to silica sand cores and molds suitable for use in the casting of metals and to a composition for use in making same. The invention relates more specifically to silica sand core and mold compositions containing a binder and an anti-veining additive and to a method of making sand cores and molds therefrom.

[0023] The present invention relates to the use of mixed metal oxides as an anti-veining agent in silica sand molds to create shapes for casting metal parts. The additions are especially suitable for casting bronze, brass, gray iron, ductile iron and steels of various compositions. The mixed metal oxides collapse into a visco-plastic state when the foundry shape is heated by the molten metal during casting. With a sufficient concentration or volumetric quantity of MMOx distributed within the mold or core, the change in state of the MMOx from solid to visco-plastic at high temperatures provides space and lubricity within the foundry shape sufficient to compensate for the thermally-induced physical expansion of the silica grains. The net result is a minimum change in volume of the foundry shape during heating to 2200°F (1204 °C) thereby avoiding the mechanical forces which cause cracks and fissures in the mold or core that produce veins and other surface imperfections including rat tails, penetration, scabs, and other defects associated with the high coefficient of thermal expansion of silica sand.

[0024] Visco-plastic mixed metal oxides (MMOx compounds) can be added to the silica mold to melt and relieve the thermal expansion stress. The plasticity provides strain accommodation so cracks are not formed as the mold or core is heated. The volumetric quantity of the MMOx necessary to yield the physical volume sufficient to compensate for the physical expansion of the sand grains may be achieved by using a MMOx in the range of 2%-7% by weight of the total mold material weight. Still further objects will appear in the description which is to follow.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025]

Fig. 1 is a plot of superimposed thermal expansion curves for PUCB bonded silica sand and PUCB bonded silica sand with 4% MMOx anti-veining additive of the present invention,

Fig. 2 is a plot of a thermal expansion curve of an anti-veining MMOx additive of the present invention;

Fig. 3 is a photograph of step core castings of a PUCB bonded silica sand with no additives,

Fig. 4 is a photograph of step core castings of a PUCB bonded silica sand including 4% by weight a MMOx anti-veining additive of the present invention,

Fig. 5 is a photograph of step core castings of a PUCB bonded silica sand including an iron oxide additive of 4% by weight.

DETAILED DESCRIPTION OF THE INVENTION

[0026] An additive to foundry sand molding and core aggregates is used to produce sand cores and molds. The additive requires no carbon addition and is unreactive with most foundry sand binders. The additive produces a sand-based foundry molding and core aggregate which resists the formation of some of the defects commonly associated with the production of castings in silica sand-based molding and core aggregates. In particular, the additive improves the surface quality of castings by reducing thermal expansion defects, i.e. vein, in iron, steel, brass and bronze castings. In some instances it may be beneficial for use in aluminum castings, but in general, veins are not nearly as serious a problem in aluminum castings as they are in iron and steel castings.

[0027] The first curvilinear line in Figure 1 illustrates the coefficient of thermal expansion of a PUCB bonded silica sand. The phenolic urethane binder is the same binder employed throughout the North America foundry industry. PUCB bonded silica sand coefficient of expansion is plotted versus temperature in the graphical curvilinear line of Figure 1. No additives were included in the bonded silica sand, just silica and a phenolic urethane binder.

[0028] This PUCB bonded silica sand expansion data was obtained by placing a sample of the PUCB bonded silica sand in a holder, placing the holder in a dilatometer, and then heating the bonded silica sand to elevated temperatures. This curvilinear line represents the expansion of conventional quartz sand from 80°F (27°C) to about 1950°F (1065°C) The silica begins to transform from alpha quartz to beta quartz at about 1100°F (593°C), and the transformation to beta quartz is complete at about 1170°F (632°C). As the sand is heated to higher temperatures, the beta quartz continues to expand as illustrated.

[0029] The silica sand radically expands as it transforms from alpha to beta quartz. In this region, the sand has a very high coefficient of thermal expansion, with a value of about (0.027 in/in/°F), a value substantially greater than that of alpha quartz. This high expansion coefficient of beta quartz is a major factor causing molds and cores to split, crack, spall, and otherwise produce surface defects on castings.

[0030] The additive of the present invention may be utilized in conventional silica sand molds and cores including but not limited to PUCB cold box binders. Such mold and core aggregates are usually made from silica sand, with the sand grains being bound together by chemical means. Typically, the mold or core mixture may comprise between about 90% to about 99% of silica sand, less than 2% resin and about 3.0% to about 7% of an anti-veining additive of the present invention.

[0031] In a preferred embodiment of the present invention an anti-veining additive for eliminating expansion defects is to add a visco-plastic mixture of metal oxides (MMOx) to the mold. There are several inexpensive mixed metal oxides commercially available, and the composition of several suitable mixed materials of the present invention is presented in Table I. It is noted that the MMOx compounds have softening temperatures of about 1050°F (565.5°C) compared to iron oxide softening at a temperature of about 1780°F (971°C).

[0032] In the present invention, an amount of MMOx mixture of sufficient quantity to yield a sufficient amount of strain accommodation within the foundry shape to accept and compensate for the thermally-induced expansion of the silica sand grains is employed. The quantity of the MMOx mixture required is related in significant part to the amount of void volume or space between the silica sand grains.

[0033] When there is an insufficient volumetric quantity of MMOx mixed with the silica grains, very little or no significant anti-veining effect will be achieved. Thermally-induced MMOx plasticity and viscosity decreases combined with expansion pressure from the silica sand grains occurs at the elevated temperatures caused by molten metal.

[0034] The addition of mixed metal oxides to the sand in a quantity of approximately 4% by weight, drastically changes the expansion coefficient and actually causes core shrinkage to occur at the higher temperatures, (see the second curvilinear graphical line in Figure 1). In other preferred embodiments of the invention the amount of MMOx added into bonded silica sand is approximately within the range of 3%-5% by weight of the total weight of mold material (silica and phenolic urethane binder). In the following table the composition of preferred MMOx additive samples of the instant invention along with their corresponding softening temperature are provided:

TABLE 1

COMPOSITIONS & SOFTENING TEMPS OF SELECTED MIXED METAL OXIDES									
MMOx	(% Weight)								
Sample Name	Na	Al	Si	Ca	O_2	Mg	K	Fe	Softening Temp F
BG	9.7	1.3	47.0	13.8	27.1	--	--	--	1046
CPS	13.02	4.5	59.1	11.46	6	2.9	1.6	--	1099
GG	9.8	2.7	45.8	12.17	28.83	--	1.3	--	1069
SLC	11.31	1.8	58.3	16.2	10.5	0.6	1.1	--	1051
MCSG	9.98	3.2	46.7	9.88	27.39	2.77	--	--	1060
TG	9.6	0.45	48.3	11.5	23.88	2.22	--	3.98	1074

[0035] The MMOx addition is accomplished by adding a material selected from the group consisting of the Na, Al, Si, Ca, O_2, Mg, K, Fe. Eachof these materials are commercially available and for each MMOx mixture except for MCSG sample in table 1 the amount of Na, Al, Ca, Mg, or K never exceeds 17.0%. As seen in table 1, the amount of Silicon in the MMOx mixtures is between 40%-60%. Silicon is a very affordable and inexpensive additive as are the other materials in the MMOx mixtures: Na, Al, Ca, O_2, Mg, K, Fe.

[0036] In accordance with another preferred mixed metal oxide embodiment of the present invention: the amount of sodium (a) in the MMOx additive ranges between about 9.0%- 15.0% by weight, the amount of aluminum (Al) in the MMOx additive ranges between 0.3%- 5.0% by weight, the amount of silicon (Si) in the MMOx additive ranges between 40.0%- 60.0% by weight, the amount of calcium (Ca) in the MMOx additive ranges between 8.0%- 20.0% by weight, the amount of oxygen (O_2) in the MMOx additive ranges between 5.0%- 30.0% by weight, the amount of magnesium (Mg) in the MMOx additive ranges between 0.0%- 3.0% by weight, the amount of potassium (K) in the MMOx additive ranges between 0.0%- 2.0% by weight and the amount of iron (Fe) in the MMOx additive ranges between 0.0%-5.0% by weight.

[0037] It is understood by those skilled in the art of oxide formulations that in multicomponent oxide systems composition changes or even additions of new oxides can alter the softening temperature. Thus it is clear to those skilled in the art that minor changes in composition and compositions outside the ranges in Table I are within the scope of this patent. The critical feature of using mixed oxides is that the softening point can be controlled to values in the range of 1050°F (565.5°C) for the mixed oxides to 1900°F (1037°C) for the oxides of iron. Other oxide mixtures may be found with beneficial properties with variations in the ratios of the various oxides.

[0038] In accordance with another preferred present invention embodiment: the amount of Na in the MMOx additive ranges between 10.0%- 13.0% by weight, the amount of Al in the MMOx additive ranges between 0.1%- 3.0% by weight, the amount of Si in the MMOx additive ranges between 55.0%- 61.0% by weight, the amount of Ca in the MMOx additive ranges between 13.0%- 19.0% by weight, the amount of O_2 in the MMOx additive ranges between 5.0%- 15.0% by weight, the amount of Mg in the MMOx additive ranges between 0.1%- 1.0% by weight, the amount of K in the MMOx additive ranges between 0.5%- 1.5% and no iron oxide.

[0039] In one preferred SLC embodiment of the invention, see SLC sample in Table 1, the MMOx mixuture comprises approximately of the following: 11% sodium, 0.6% magnesium, 1.8% aluminum, 58% silicon, 1.1% potassium, 16.2 % calcium, 0.2% zinc and 10.5% oxygen. The mixture rate of thermal expansion vs temperature for the SLC mixture is plotted in the generally second curvilinear graphical line in Figure 1. The SLC sample mixture has a softening temperature of 1051°F (see Table 1). The mixture of bonded silica blended with the SLC additive converts completely to beta quartz at 1083°F and has a strain of 0.016 in/in/°F, the beta quartz continues to expand until it reaches a temperature of about 1815°F at a strain of 0.018 in/in/°F and then the strain starts decreasing until it reaches a value of near zero at 1930°F.

[0040] The addition of the SLC additive caused the expansion of beta quartz to drop to essentially zero at 1930°F (1055.4°C). The plasticity of the SLC at temperatures above 1900°F allows the sand to move slightly under the pressure of the molten metal and close any cracks that might have been formed at lower temperatures. The closed cracks prevent the formation of veins. The mechanical forces induced by thermal expansion of each silica sand grain on silica sand grains adjacent to it within the foundry shape is thereby avoided, and as a result, the cracks and fissures in the foundry shapes that allow metal penetration and cause veining in the cast part are avoided. The plasticity of the molten MMOx prevents spalling of the mold/core surface.

[0041] The SLC sample mixture described above was likewise used in a test trial casting step-cone similar to the silica sand step-cone of figure 3, and the silica sand step-cone with iron oxide additive of figure 5. Figure 4 is a photograph of a step-cone casting wherein the sand mold and sand core materials employed were PUCB bonded silica sand with the SLC mixture described immediately above and shown in table 1. This step-cone casting in figure 4 is seen to be essentially free of veins and any other objectionable surface defects.

[0042] This data shows that MMOx in the correct composition range provides sufficient lubricity for the sand to collapse on the surface and eliminate surface cracks so long as the pouring temperature of the metal is above 1950°F (1065.5°C). Bronze alloys are typically poured about 2200°F (1200 °C), gray cast-iron is typically poured about 2450°F (1343 °C, ductile iron is poured about 2550° F(1400 °C), and the steel alloys are typically poured about 2900°F (1593 °C).

[0043] The plasticity of the SLC mixture at temperatures above its softening temperature of 1050°F (565.5 °C) provides for the thermal strain accommodation in bonded silica sand molds/cores. The other MMOx additives in Table 1 have relatively similar softening temperatures. As shown in the table, the softening temperatures for each of the sample MMOxs falls within the range of 1045°F - 1075°F (563-579.4 °C).

[0044] Each of the other five listed MMOx additives (not the Fe_xO_y sample) listed in Table 1 were also tested by similarly blending the samples with phenolic urethane bonded silica sand in a so-called step cone casting as discussed above. Upon inspection, after shakeout and similarly dividing each and every one of the castings in half, no veins were visible in any of the casting formed with the MMOxs listed in Table 1.

[0045] In accordance with an additional preferred MMOx additive of the present invention the MMOx softening temperature ranges between 1,000°F- 1,110°F (538-593°C); in another preferred alternative the MMOx softening temperature ranges between 1,025°F - 1,085°F (552-585°C) ; and still yet in another preferred embodiment the MMOx softening temperature ranges between 1,040°F - 1,080°F (560-582°C).

[0046] In each preferred embodiments disclosed herein the MMOx mixture is distributed throughout the resulting foundry shape in such a manner that the idealized response described above is generally achieved throughout the foundry shape. The MMOx mixture is uniformly distributed throughout the matrix of silica sand sufficient to separate a significant number of silica sand grains so that the plasticity of the MMOx mixture yields adequate space to accept and compensate for the thermal expansion of the bonded silica sand.

[0047] The MMOx is not used in great quantity, in a preferred embodiment of the invention MMO_x comprises about 4.0-5.0% of the weight of the total material used in making the bonded silica sand mold/core. In another preferred embodiment MMO_x comprises about 3.0-6.0% of the weight of the total material used in making the bonded silica sand mold/core. Further the commercial price of the metals listed in Table 1 are relatively inexpensive so that the overall cost of the MMOx additive is small.

[0048] It is contemplated that the silica sand mold/core of the present invention may alternatively be bonded together with organic binders other than phenolic urethane. Binders such as shell, furan or alkyd may be substituted for the phenolic urethane binder. Still other organic binders for the silica sand mold of the present invention may be employed, including well-known hot box binders, well-known shell mold binders or other resin binders well-known in the industry.

[0049] It is further contemplated that the silica sand mold/core of the present invention may alternatively be bonded together with well-known inorganic binders in the industry, including but not limited to sodium silicate $Na_2(SO_2)_nO$.

[0050] While certain novel features of this invention have been shown and described, it is not intended to be limited to the details above, since it will be understood that various omissions, modifications, substitutions and changes in the forms and details of the can be made by those skilled in the art without departing in any way from the spirit of the present invention.

Claims

1. A bonded silica sand mold for use in manufacturing metal castings, the metal castings produced with said bonded silica sand mold are substantially free of surface veins, said mold comprising:

   an additive of mixed metal oxides.

2. The bonded silica sand mold as claimed in claim 1, wherein said additive mixed metal oxides comprise 6.0% by weight or less of said bonded silica sand mold.

3. The bonded silica sand mold as claimed in claim 1 or claim 2, wherein said additive of mixed metal oxides comprises at least two metals selected from the group consisting of Na, Al, Si, Ca, Mg, K, Fe, preferably at least four metals, and more preferably at least five metals from the group consisting of Na, Al, Si, Ca, Mg, K, Fe.

4. The bonded silica sand mold as claimed in any one of claims 1 to 3, wherein said additive of mixed metal oxides comprises of at least 40% by weight of silicon.

5. The bonded silica sand mold as claimed in any one of the preceding claims, wherein said additive of mixed metal oxides combined have a softening temperature of above at least 1,000 °F (540 °C).

6. The bonded silica sand mold as claimed in any one of the preceding claims, wherein said mold further comprising:

   an organic binder.

7. The bonded silica sand mold as claimed in any one of the preceding claims, wherein said additive of mixed metal oxides comprises between 1%-6% by weight of the bonded silica sand mold.

8. The bonded silica sand mold any one of the preceding claims, wherein the metal castings produced with said bonded silica sand mold are substantially free of surface veins, said mold comprising:

   an additive of mixed metal oxides, said mixed metal oxides comprising of at least two metals selected from the group consisting of Na, Al, Si, Ca, Mg, K, Fe;
   wherein said additive of mixed metal oxides comprises between 1%-6% by weight of the bonded silica sand mold.

9. The bonded silica sand mold as claimed in claim 8, wherein said Ca is at least 9% by weight of the mixed metal oxides.

10. The bonded silica sand mold as claimed in any one of claims 8 or 9, wherein said additive of mixed metal oxides combined have a softening temperature of above at least 563 °C (1,045 °F).

11. The bonded silica sand mold as claimed in any one of claims 8 to 10, wherein said mold is a phenolic urethane cold box mold.

12. Use of an anti-veining mixed metal oxides additive in a bonded silica sand mold according to any one of claims 1 to 11, said mixed metal oxides comprising of at least two, metals selected from the group consisting of Na, Al, Si, Ca, Mg, K, Fe.

13. The use of the anti-veining mixed metal oxides additive as claimed in claim 12, wherein said additive of mixed metal oxides in combination have a softening temperature of above at least 563 °C (1,045 °F).

14. Use of the anti-veining mixed metal oxides additive as claimed in claims 12 or 13, wherein said mixed metal oxides comprises of at least four metals selected from the group consisting of Na, Al, Si, Ca, Mg, K, Fe.

15. Use of the anti-veining mixed metal oxides additive as claimed in any one of claims 12 to 14, wherein said Na is at

least 9% by weight of said mixed metal oxides, and said Si is at least 40% by weight of said mixed metal oxides.

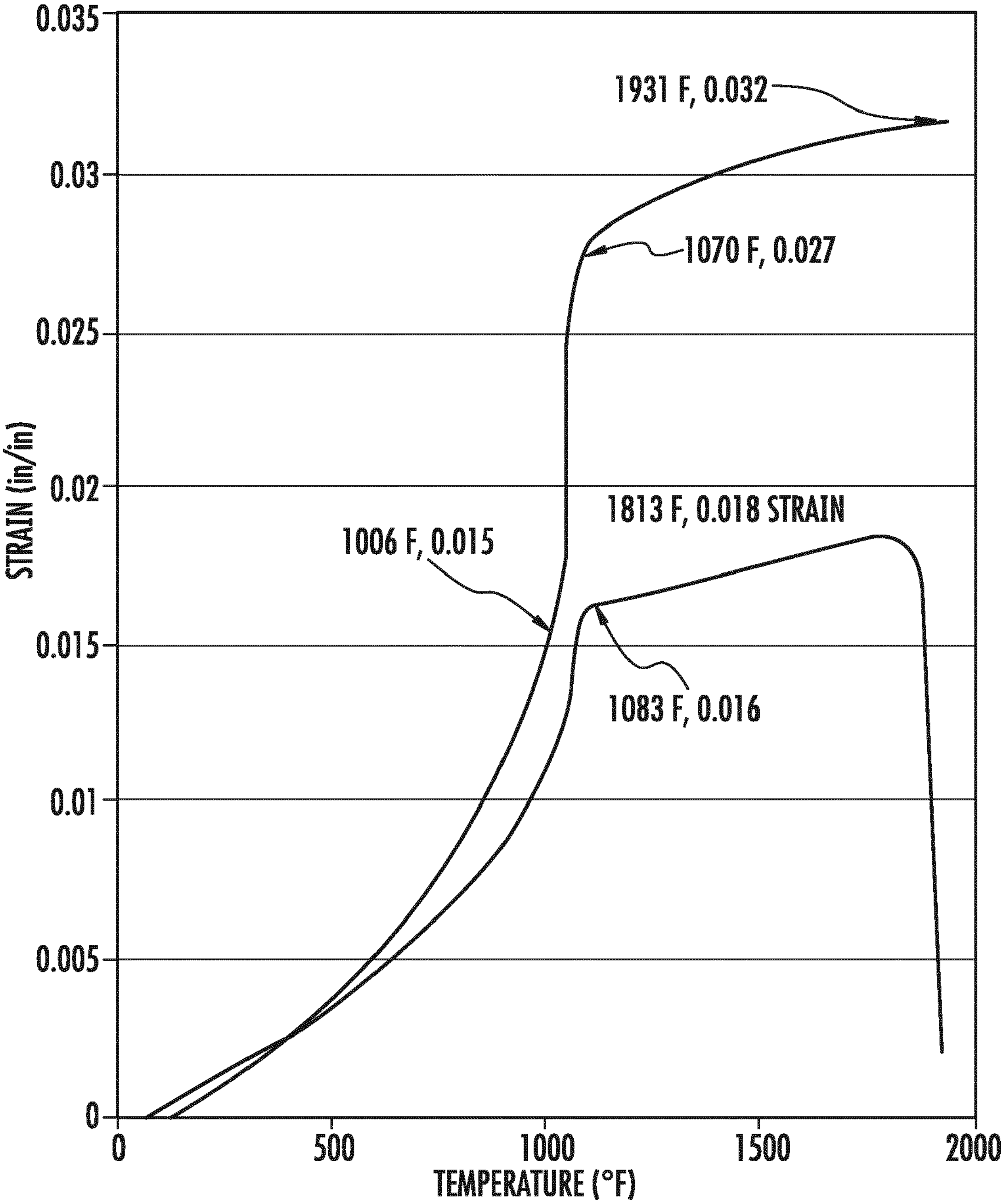
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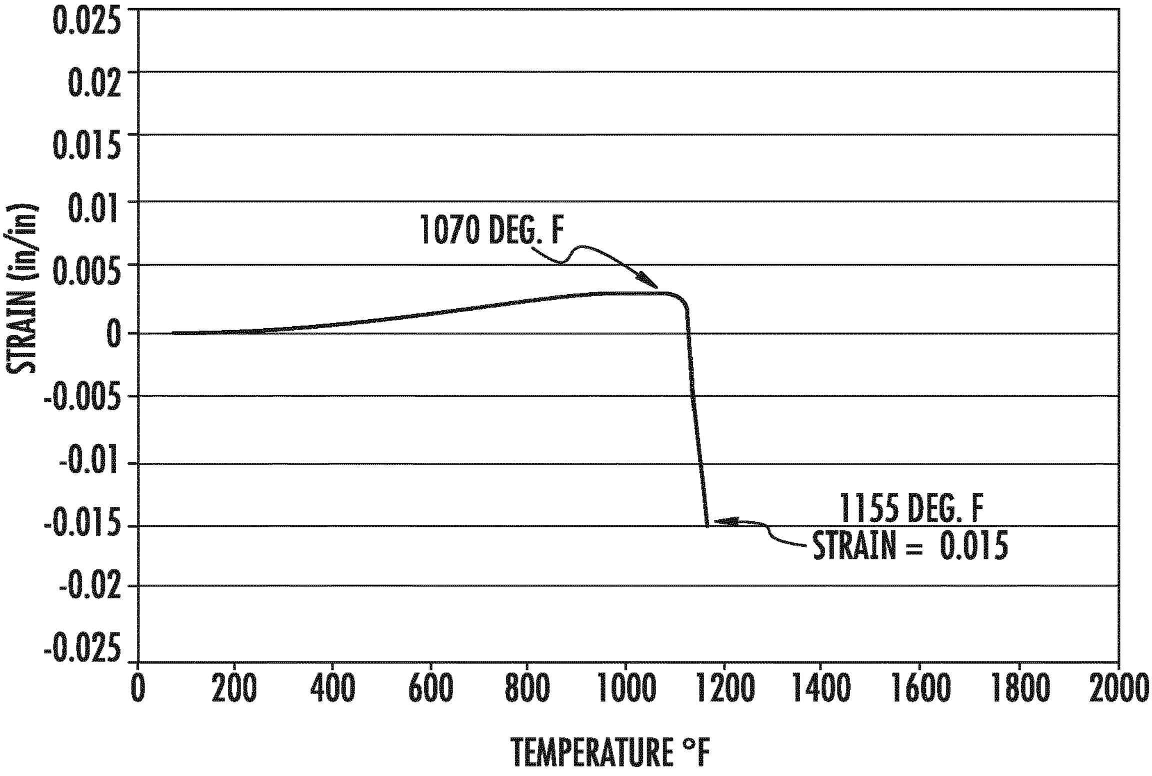
FIG. 1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1800
2000
TEMPERATURE °F

FIG. 2

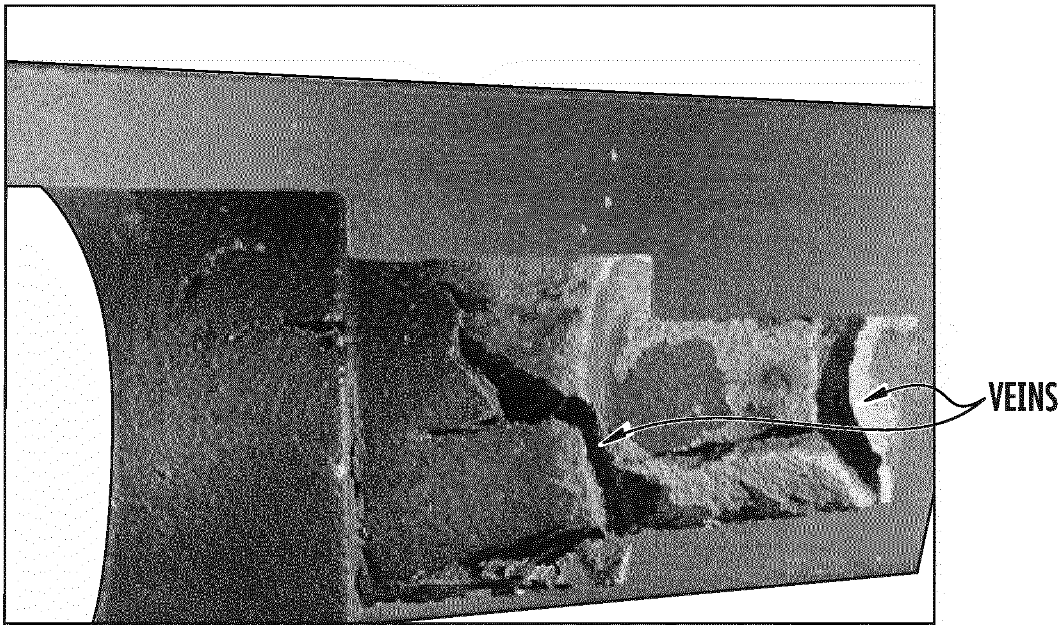

FIG. 3

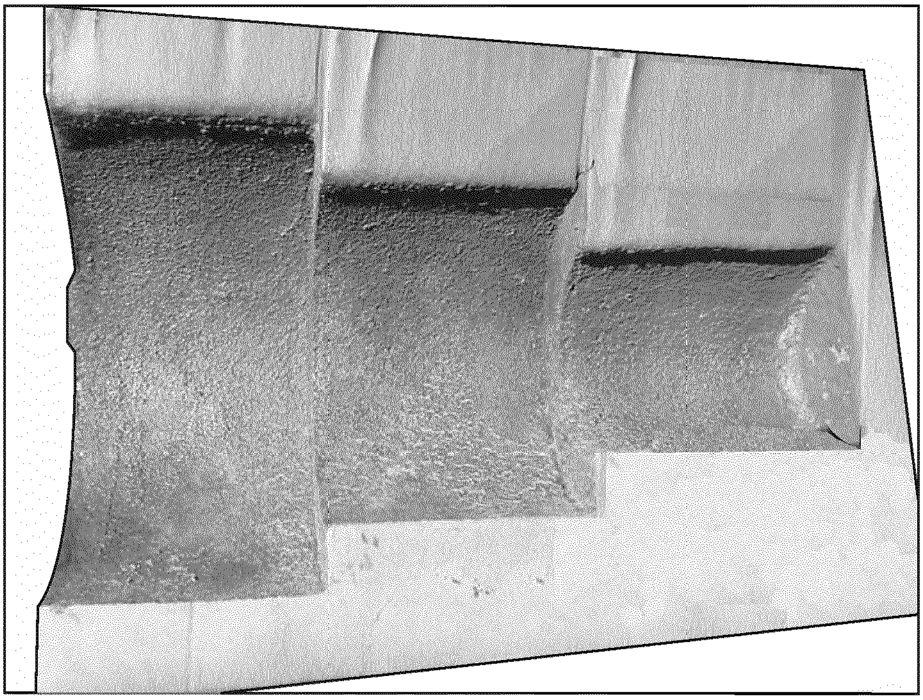

FIG. 4

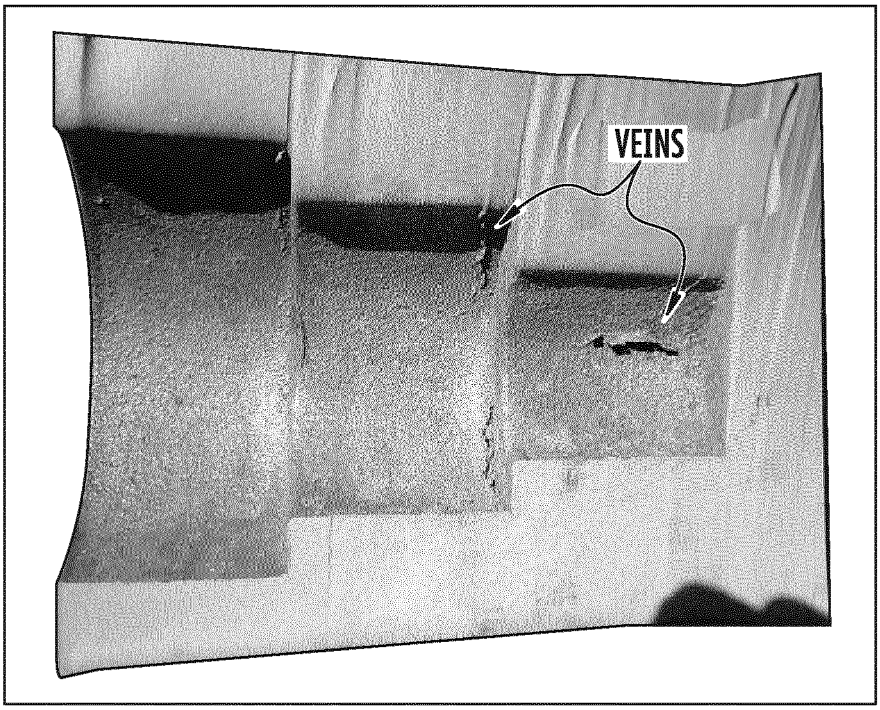

FIG. 5

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EUROPEAN SEARCH REPORT

Application Number
EP 17 18 5130

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The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	15 December 2017	Grave, Christian

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