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(71) Applicants:
- **National University Corporation Tohoku Unversity**
  Sendai Miyagi 980-8577 (JP)
- **Yamaha Hatsudoki Kabushiki Kaisha**
  Iwata-shi, Shizuoka 438-8501 (JP)

(72) Inventors:
- **YAOKAWA, Jun**
  Sendai-shi, Miyagi; 980-8577 (JP)
- **ANZAI, Koichi**
  Sendai-shi, Miyagi; 980-8577 (JP)
- **YAMADA, Youji**
  Iwata-shi, Shizuoka; 438-8501 (JP)

(74) Representative: **Grünecker, Kinkeldey,**
Stockmair & Schwanhäusser
Anwaltssozietät
Leopoldstrasse 4
80802 München (DE)

(54) SALT CORE FOR CASTING

(57) An expendable salt core (2) is formed into the shape of a water jacket (6) by, e.g., die casting using a salt of bromine and at least one of sodium and potassium, and a salt of carbonic acid and at least one of sodium and potassium. The expendable salt core (2) is formed to contain at least one of potassium and sodium as a cation, and bromine and carbonic acid as anions. For example, the expendable salt core (2) is formed by casting using a melt obtained by melting a salt mixture of sodium bromide and sodium carbonate.

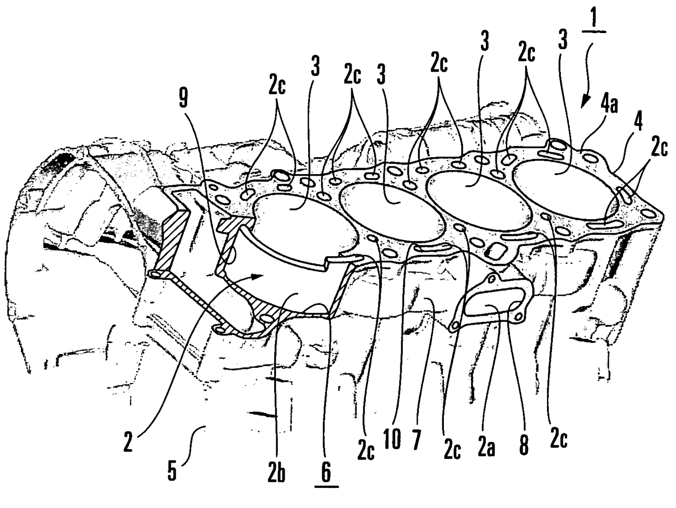

FIG. 1

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Description

Technical Field

[0001] The present invention relates to a water soluble expendable salt core for casting.

Background Art

[0002] As is known well, casting such as aluminum high pressure die casting (HPDC) is a technique that injects a molten aluminum alloy into a metal mold at high speed under a high pressure to cast a near-net-shape structure. In this casting, when molding a cast product having a hollow structure, e.g., a water cooling water jacket in the closed-deck type cylinder block of an internal combustion engine, an expendable core is used. The expendable core used in such a case must have a strength that can withstand a high pressure and high temperature because it may be subject to a large impact or impulse force fluctuation upon collision of a molten metal injected from the gate at high speed mold filling and because a high static compressive casting pressure is applied until solidification completion. After casting, the expendable core is removed from the cast product. When the cast product has a complicated internal structure, if a generally used phenol resin bonded sand core is used as the expendable core, it is not easy to remove. In contrast to this, a water soluble expendable salt core is available as the expendable core that can be removed by dissolution with, e.g., high-temperature water (reference 1: Japanese Patent Laid-Open No. 48-039696, reference 2: Japanese Patent Laid-Open No. 50-136225, and reference 3: Japanese Patent Laid-Open No. 52-010803).

[0003] The expendable salt core as described above is formed by using a salt mixture of, e.g., sodium carbonate (Na_2CO_3), potassium chloride (KCl), and sodium chloride (NaCl), melting these components, and molding. Hence, a high static compressive casting pressure resistance is obtained, and workability and stability of dimension accuracy in casting are improved.

Disclosure of Invention

Problems to be Solved by the Invention

[0004] When an expendable fused salt core is formed by melting a salt and casting, however, the formation of a shrinkage cavity, micro-porosity, small heat crack, and the like would be caused in the salt core due to a change in volume such as solidification shrinkage occurring in the solidification process. It is therefore not easy to mold the expendable fused salt core conforming to the mold precisely. In this manner, with the prior art, an expendable fused salt core cannot be manufactured easily by casting using a molten salt.

[0005] The present invention has been made to solve the above problems, and has as its object to facilitate manufacture of a water soluble expendable salt core for casting which is formed of a salt cast product obtained by molding after melting salts such as sodium and potassium and has a sufficient strength.

Means of Solution to the Problem

[0006] An expendable salt core for casting according to the present invention is formed of a molten salt containing bromine ions, carbonate ions, and at least one of sodium ions and potassium ions. For example, the molten salt is preferably formed of sodium ions, bromine ions, and carbonate ions. In this case, in the molten salt, the molar ratio of carbonate ions in all the anions is preferably 30 mol%. Alternatively, in the molten salt, the molar ratio of carbonate ions in all the anions is preferably 50 mol% to 80 mol%.

[0007] The molten salt may be formed of potassium ions, bromine ions, and carbonate ions, and the molar ratio of carbonate ions in all the anions may be 30 mol%, or 50 mol% to 90 mol%. Alternatively, the molten salt may be formed of sodium ions, potassium ions, bromine ions, and carbonate ions. The melting temperature of the molten salt may fall within a range of 600°C to 680°C. The molar ratio of potassium ions in all the cations may be 50 mol% to 90 mol%, and the molar ratio of carbonate ions in all the anions may be 40 mol% to 80 mol%.

[0008] A plurality of granular crystals are preferably formed in the parent phase in a dispersed state. The granular crystals are preferably formed of carbonate ions and at least one of sodium ions and potassium ions.

Effect of the Invention

[0009] According to the present invention, the expendable salt core for casting is formed of a molten salt containing at least one of sodium ions and potassium ions, bromine ions, and carbonate ions. Hence, a water soluble expendable salt core for casting which is formed of a salt cast product obtained by melting and molding salts such as sodium and potassium can be manufactured easily to have a sufficient strength.

Brief Description of Drawings

[0010]

Fig. 1 is a perspective view of a cylinder block which is cast using an expendable salt core for casting according to an embodiment of the present invention;
Fig. 2 is a graph showing the bending strengths of bending test pieces;
Fig. 3 is a graph showing the bending strengths of bending test pieces;
Fig. 4 is a phase diagram showing the bending strengths of bending test pieces as well as the relationship among the cationic ratio of potassium ions vs. sodium ions, the anionic ratio of carbonate ions vs. bromine ions, and the liquidus temperature;
Fig. 5 is an SEM photograph of a solidification structure in an expendable salt core;
Fig. 6 is an SEM photograph of a solidification structure in an expendable salt core;
Fig. 7 is an SEM photograph of a solidification structure in an expendable salt core;
Fig. 8 is an SEM photograph of a solidification structure in an expendable salt core;
Fig. 9A is a view showing the state of a test piece used for bending strength measurement;
Fig. 9B is a partial sectional view showing the state of the test piece used for bending strength measurement; and
Fig. 10 is a view for explaining bending strength measurement.

Best Mode for Carrying Out the Invention

[0011] The embodiment of the present invention will be described hereinafter with reference to the drawings. First, how an expendable salt core for casting according to the embodiment of the present invention is used will be described with reference to Fig. 1. Fig. 1 is a partially cutaway perspective view of a closed-deck type cylinder block which is cast using the expendable salt core for casting according to the present invention. Referring to Fig. 1, reference numeral 1 denotes a closed-deck type cylinder block which is made of an aluminum alloy and cast using an expendable salt core 2 as an expendable salt core for casting according to the present invention. The cylinder block 1 is part of a water cooling 4-cycle 4-cylinder engine for a motorcycle which is molded into a predetermined shape by high pressure die casting (HPDC).

[0012] The cylinder block 1 shown in Fig. 1 integrally has four cylinder bores 3, a cylinder body 4 having the cylinder bores 3, and an upper crank case 5 extending downward from the lower end of the cylinder body 4. A lower crank case (not shown) is attached to the lower end of the upper crank case 5. The upper crank case 5, together with the lower crank case, rotatably, axially supports a crank shaft (not shown) through a bearing.

[0013] The cylinder body 4 is a so-called closed-deck-type cylinder body, and has a water jacket 6 which is formed in it using the expendable salt core 2. The water jacket 6 is formed to include a cooling water passage forming portion 7, cooling water inlet port 8, main cooling water passage 9, and communication passage 10. The cooling water passage forming portion 7 projects on one side of the cylinder body 4 and extends in the direction in which the cylinder bores 3 line up. The cooling water inlet port 8 is formed in the cooling water passage forming portion 7. The main cooling water passage 9 is formed to communicate with a cooling water distribution passage (not shown) formed in the cooling water passage forming portion 7 and cover all the cylinder bores 3. The communication passage 10 extends upward in Fig. 1 from the main cooling water passage 9 and opens to a mating surface 4a with respect to a cylinder head (not shown) at the upper end of the cylinder body 4.

[0014] The water jacket 6 described above supplies cooling water flowing in from the cooling water inlet port 8 to the main cooling water passage 9 around the cylinder bores through the cooling water distribution passage, and guides the cooling water from the main cooling water passage 9 to a cooling water passage in the cylinder head (not shown) through the communication passage 10. Since the water jacket 6 is formed in this manner, the cylinder body 4 is covered with the ceiling wall (the wall that forms the mating surface 4a) of the cylinder body 4 except that the communication passage 10 of the water jacket 6 opens to the mating surface 4a at the upper end to which the cylinder head is connected. Hence, a closed-deck-type arrangement is formed.

[0015] The expendable salt core 2 to form the water jacket 6 has a shape identical to that obtained by integrally connecting the respective portions of the water jacket 6. In Fig. 1, the cylinder body 4 is partly cut away to facilitate understanding of the shape of the expendable salt core 2 (the shape of the water jacket 6).

[0016] The expendable salt core 2 according to this embodiment is formed from a molten salt obtained by melting a salt mixture of a salt of bromine and at least one of sodium and potassium and a salt of carbonic acid and at least one of sodium and potassium. The expendable salt core 2 is formed into the shape of the water jacket 6 by, e.g., die casting. The components of the expendable salt core 2 will be described later in detail. Note that the expendable salt core 2 can be formed by a casting method other than die casting, e.g., gravity casting. In formation of the expendable salt core 2 which employs die casting, first, a mixture consisting of a plurality of salts (to be described later) is melted by heating to obtain a melt. Then, the melt is injected into an expendable salt core forming metal mold under a high pressure and solidified. After solidification, the obtained expendable salt core 2 is taken out from the mold.

[0017] As shown in Fig. 1, in the expendable salt core 2, the passage forming portion 2a which forms the cooling water inlet port 8 and the cooling water distribution passage, an annular portion 2b which surrounds the four cylinder bores 3, and a plurality of projections 2c extending upward from the annular portion 2b are formed integrally. The projections 2c form the communication passage 10 of the water jacket 6. As is conventionally known, the expendable salt core 2 is supported at a predetermined position in the metal mold (not shown) by a core print (not shown) during casting, and is removed by dissolution with hot water or vapor after casting.

[0018] To remove the expendable salt core 2 after casting, the cylinder block 1 may be dipped in a dissolution tank (not shown) which contains dissolving liquid consisting of, e.g., hydrochloric acid and hot water. When dipping the cylinder block 1 in the dissolving liquid, the passage forming portion 2a and the projections 2c exposed to the mating surface 4a, of the expendable salt core 2 come into contact with the dissolving liquid and dissolve. The dissolved portions expand gradually until all the portions dissolve finally. In this core removing process, to promote dissolution of the expendable salt core 2 left in the water jacket 6, hot water or vapor may be sprayed under a pressure from a hole. In the expendable salt core 2, in place of the projections 2c, a core print may be inserted in portions where the projections 2c are to be formed.

[0019] If hydrochloric acid is used in the process of removing the expendable salt core 2 from the cylinder block 1 as a cast product, carbon dioxide gas foams. The foam provides a stirring function and promotes dissolution effectively. As the expendable salt core 2 contains potassium carbonate and sodium carbonate, when it dissolves in water, the resultant water exhibits alkaline. This alkali state poses problems such as corrosion of the cylinder block 1 as an aluminum cast product. Regarding this problem, corrosion of the cylinder block can be prevented by adding hydrochloric acid to control pH to near 7.

[0020] The expendable salt core 2 will be described. The expendable salt core 2 according to this embodiment is formed to at least contain at least one of potassium and sodium as cations and bromine as anions. In other words, the expendable salt core 2 is formed of a molten salt of bromine ions and at least one of sodium ions and potassium ions. The expendable salt core 2 is formed to also contain carbonic acid as anions.

[0021] For example, the expendable salt core 2 is formed by casting using a melt (molten salt) obtained by melting a salt mixture of sodium bromide and sodium carbonate. Alternatively, the expendable salt core 2 is formed by casting using a melt obtained by melting a salt mixture of potassium bromide and potassium carbonate. Alternatively, the expendable salt core 2 is formed by casting a melt obtained by melting a salt mixture of potassium bromide and sodium carbonate. Alternatively, the expendable salt core 2 is formed by casting a melt obtained by melting a salt mixture of sodium bromide and potassium carbonate. Alternatively, the expendable salt core 2 is formed by casting using a melt obtained by melting a salt mixture of at least three members of potassium bromide, sodium bromide, sodium carbonate, and potassium carbonate. Alternatively, the expendable salt core 2 is formed by casting using a melt obtained by melting a salt mixture of at least four members of potassium bromide, sodium bromide, sodium carbonate, and potassium carbonate.

[0022] In addition to at least one of potassium ions and sodium ions as cations and bromine and carbonate ions as anions, the expendable salt core 2 may contain other ions. For example, the expendable salt core 2 main contain, in addition to bromine ions and carbonate ions as anions, other anions such as sulfuric acid ions, nitric acid ions, and chlorine ions.

[0023] In the above description, casting is performed using a melt obtained by melting a salt mixture. However, the present invention is not limited to this. For example, the expendable salt core 2 may be manufactured by die casting which performs casting using a solid-liquid coexisting melt such as a semi-solidified melt. For example, a mixture (salt mixture) of the plurality of slats described above may be melted by heating to obtain a melt. Then, the temperature of the melt may be decreased to set the melt in the semi-solidified (solid-liquid coexisting) state. The melt in the semi-solidified state may be injected into a metal mold for an expendable salt core under a high pressure and solidified. After solidification, the resultant product may be taken out from the metal mold, thus fabricating the expendable salt core 2.

[0024] The expendable salt core 2 (expendable salt core for casting) according to the embodiment described above employs a bromide. When compared to an expendable salt core which is formed of chloride salts without using a bromide, the solidification shrinkage ratio is small, and shrinkage cavities do not form easily. A bromide has a lower latent heat of fusion than a chloride. With the expendable salt core 2 containing bromine, a melting energy can be reduced more when compared to an expendable salt core that does not contain bromine. A bromide has larger water solubility than a chloride. Hence, the expendable salt core 2 containing bromine dissolves more in an equivalent amount of water than the expendable salt core not containing bromine, so that it can be removed more quickly. In this manner, with the expendable salt core 2 according to this embodiment, a water soluble expendable salt core for casting formed of a salt cast product obtained by melting and molding salts such as sodium and potassium can be manufactured more easily.

[0025] Tables 1 and 2 and Fig. 2 show a change in bending strength (measurement value) occurring when the anionic ratio of bromine ions to carbonate ions is changed in an expendable salt core manufactured by melting a salt mixture of sodium bromide and sodium carbonate. This refers to cases in which the molten salt to form the expendable salt core is formed of sodium ions, bromine ions, and carbonate ions. Table 1 shows the measurement results (maximum bending loads) of the bending strengths of the fabricated test pieces, and Table 2 shows the measurement results (maximum bending strengths) of the bending strengths of the fabricated test pieces. Tables 1 and 2 are identical except that representations of the measurement results are different. The concentration of each ion is measured according to the analysis method determined by the rules of ion chromatograph analysis of JIS standard K0127. As shown in Tables 1 and 2 and Fig. 2, expendable salt cores in which a concentration YCO_3^{2-} of carbonate ions in all the cations is 30 mol% to 80 mol% exhibit high bending strengths exceeding a bending strength of 13.9 MPa. Particularly, expendable salt cores with YCO_3^{2-} of 50 mol% to 80 mol% exhibit higher bending strengths.

[0026]

Table 1

Sample Number	Cation Ratio mol%	Anion Ratio mol%		Liquidus Temperature °C	Molding Temperature °C	Bending Load N	
	XNa^+	YBr^-	YCO_3^{2-}			1st Time	2nd Time
1	100	100	0	747	757	393	377
2	100	90	10	710	720	2078	1590
3	100	80	20	680	690	2413	1028
4	100	70	30	650	660	2652	2266
5	100	60	40	648	658	2139	1664
6	100	50	50	705	715	3750	3224
7	100	40	60	735	745	4115	3078
8	100	30	70	772	782	3239	2938
9	100	20	80	807	817	3053	2672
10	100	10	90	837	847	1919	1605
Reference	100	0	100	856	866	347	219

[0027]

Table 2

Sample Number	Cation Ratio mol%	Anion Ratio mol%		Liquidus Temperature °C	Molding Temperature °C	Bending Strength MPa	
	XNa^+	YBr^-	YCO_3^{2-}			1st Time	2nd Time
1	100	100	0	747	757	3.3	3.1
2	100	90	10	710	720	17.3	13.2
3	100	80	20	680	690	20.1	8.6
4	100	70	30	650	660	22.1	18.9
5	100	60	40	648	658	17.8	13.9
6	100	50	50	705	715	31.2	26.9
7	100	40	60	735	745	34.3	25.7
8	100	30	70	772	782	27.0	24.5
9	100	20	80	807	817	25.4	22.3
10	100	10	90	837	847	16.0	13.4
Reference	100	0	100	856	866	2.9	1.8

[0028] Tables 3 and 4 and Fig. 3 show a change in bending strength (measurement value) occurring when the anion ratio of bromine ions to carbonate ions is changed in an expendable salt core manufactured by melting a salt mixture of potassium bromide and potassium carbonate. This refers to cases in which the molten salt to form the expendable salt core is formed of potassium ions, bromine ions, and carbonate ions. Table 3 shows the measurement results (maximum bending loads) of the bending strengths of the fabricated test pieces, and Table 4 shows the measurement results (maximum bending strengths) of the bending strengths of the fabricated test pieces. Tables 3 and 4 are identical except that representations of the measurement results are different. The concentration of each ion is measured according to the analysis method determined by the rules of ion chromatograph analysis of JIS standard K0127. As shown in Tables 3 and 4 and Fig. 3, expendable salt cores in which the concentration YCO_3^{2-} of carbonate ions in all the cations is 60 mol% to 80 mol% exhibit high bending strengths exceeding a bending strength of 16.0 MPa.

[0029]

Table 3

Sample Number	Cation Ratio	Anion Ratio mol%		Liquidus Temperature °C	Molding Temperature °C	Bending Load N	
	Xk^+	YBr^-	YCO_3^{2-}			1st Time	2nd Time
1	100	100	0	734	744	346	323
2	100	90	10	704	714	1390	1288
3	100	80	20	674	684	828	724
4	100	70	30	634	644	1839	1492
5	100	60	40	680	690	1275	754
6	100	50	50	731	741	1747	1359
7	100	40	60	774	784	2504	2075
8	100	30	70	811	821	2666	1924
9	100	20	80	838	848	2837	1358
10	100	10	90	867	877	1757	1638
Reference	100	0	100	901	911	451	394

[0030]

Table 4

Sample Number	Cation Ratio mol%	Anion Ratio mol%		Liquidus Temperature °C	Molding Temperature °C	Bending Strength MPa	
	Xk^+	YBr^-	YCO_3^{2-}			1st Time	2nd Time
1	100	100	0	734	744	2.9	2.7
2	100	90	10	704	714	11.6	10.7
3	100	80	20	674	684	6.9	6.0
4	100	70	30	634	644	15.3	12.4
5	100	60	40	680	690	10.6	6.3
6	100	50	50	731	741	14.6	11.3
7	100	40	60	774	784	20.9	17.3
8	100	30	70	811	821	22.2	16.0
9	100	20	80	838	848	23.6	11.3
10	100	10	90	867	877	14.6	13.6
Reference	100	0	100	901	911	3.8	3.3

[0031] Tables 5, 6, and 7 show a change in bending strength (measurement value) occurring when the anion ratio of bromine ions to carbonate ions is changed in an expendable salt core manufactured by melting a salt mixture of sodium bromide, potassium bromide, potassium carbonate, and sodium carbonate. This refers to cases in which the molten salt to form the expendable salt core is formed of sodium ions, potassium ions, bromine ions, and carbonate ions. The following Tables 5, 6, and 7 show the measurement results (maximum bending strengths) of the bending strengths of the fabricated test pieces. The concentration of each ion is measured according to the analysis method determined by the rules of ion chromatograph analysis of JIS standard K0127, in the same manner as described above.

[0032]

Table 5

Sample Number	Cation Ratio mol%		Anion Ratio mol%		Liquidus Temperature °C	Molding Temperature °C	Bending Strength MPa	
	XNa^+	XK^+	YBr^-	YCO_3^{2-}			1st Time	2nd Time
1	50	50	80	20	635	645	0.77	2.39
2	40	60	80	20	650	660	1.78	2.28
3	30	70	80	20	665	675	5.13	8.15
4	20	80	80	20	680	690	10.58	10.77
5	10	90	80	20	675	685	14.18	12.42
6	80	20	70	30	630	640	0.87	0.48
7	60	40	70	30	635	645	3.83	1.07
8	50	50	70	30	630	640	6.46	6.80
9	40	60	70	30	650	660	12.54	15.96
10	30	70	70	30	660	670	13.93	14.60
11	20	80	70	30	655	665	13.15	13.34
12	10	90	70	30	660	670	13.75	12.56
13	80	20	60	40	660	670	8.00	6.95
14	70	30	60	40	660	670	8.28	8.81
15	60	40	60	40	655	665	10.26	9.71
16	50	50	60	40			7.08	
17	40	60	60	40	635	645	10.01	9.34
18	30	70	60	40	635	645	13.56	16.54
19	20	80	60	40	625	635	12.64	11.66
20	10	90	60	40	620	630	6.66	6.89

[0033]

Table 6

Sample Number	Cation Ratio mol%		Anion Ratio mol%		Liquidus Temperature °C	Molding Temperature °C	Bending Strength MPa	
	XNa^+	XK^+	YBr^-	YCO_3^{2-}			1st Time	2nd Time
21	90	10	50	50	705	715	11.53	12.09
22	80	20	50	50	700	710	10.43	9.66
23	70	30	50	50	690	700	14.32	8.10
24	60	40	50	50	655	665	13.32	13.15
25	40	60	50	50	615	625	14.25	12.38

(continued)

Sample Number	Cation Ratio mol%		Anion Ratio mol%		Liquidus Temperature °C	Molding Temperature °C	Bending Strength MPa	
	XNa^+	XK^+	YBr^-	YCO_3^{2-}			1st Time	2nd Time
26	30	70	50	50	615	625	7.26	6.86
27	20	80	50	50	610	620	15.31	17.21
28	10	90	50	50	665	675	14.48	17.86
29	90	10	40	60	730	740	11.32	13.14
30	80	20	40	60	720	730	12.77	12.87
31	70	30	40	60	700	710	7.83	10.00
32	60	40	40	60	660	670	11.25	14.08
33	50	50	40	60	630	640	11.97	9.49
34	40	60	40	60	605	615	13.90	13.90
35	30	70	40	60	620	630	17.73	15.28
36	20	80	40	60	660	670	10.65	17.58
37	10	90	40	60	715	725	16.10	16.41

[0034]

Table 7

Sample Number	Cation Ratio mol%		Anion Ratio mol%		Liquidus Temperature °C	Molding Temperature °C	Bending Strength MPa	
	XNa^+	XK^+	YBr-	YCO_3^{2-}			1st Time	2nd Time
38	60	40	30	70	670	680	8.96	10.45
39	50	50	30	70	640	650	15.84	27.79
40	40	60	30	70	635	645	17.31	14.44
41	30	70	30	70	660	670	16.95	15.88
42	20	80	30	70	690	700	17.57	15.38
43	10	90	30	70	760	770	20.46	17.81
44	90	10	20	80	790	800	7.04	8.2
45	80	20	20	80	760	770	7.06	7.61
46	70	30	20	80	720	730	6.7	6.82
47	60	40	20	80	685	695	7.43	6.08
48	50	50	20	80	660	670	21.3	23.44
49	40	60	20	80	675	685	18.06	16.14
50	30	70	20	80	715	725	12.09	13.28
51	20	80	20	80	758	768	8.6	9.28

[0035] Fig. 4 shows the relationship (phase diagram of Na-K-Br-CO_3 system) among the cation ratio of potassium ions, the anionic ratio of carbonate ions, and the melting temperature (liquidus temperature). This corresponds to the results of the above Tables 2, 4, 5, 6, and 7. The largest circles represent test pieces that exhibit an average bending strength exceeding 20 MPa. The second largest circles represent test pieces that exhibit an average bending strength of 15 MPa to 20 MPa. The third largest circles represent test pieces that exhibit an average bending strength of 10 MPa to 15 MPa. The smallest circles represent test pieces that exhibit an average bending strength of 0 MPa to 10 MPa. Fig.

4 also shows the liquidus temperature of NaBr when K^+ is 0 mol% and CO_3^{2-} is 0 mol%, the liquidus temperature of KBr when Na^+ is 0 mol% and CO_3^{2-} is 0 mol%, the liquidus temperature of Na_2CO_3 when K^+ is 0 mol% and Br^- is 0 mol%, and the liquidus temperature of K_2CO_3 when Na^+ is 0 mol% and Br^- is 0 mol%. In Fig. 4, thick lines represent eutectic lines.

[0036] As shown in Tables 5, 6, and 7 and Fig. 4, when the molten salt is formed of sodium ions, potassium ions, bromine ions, and carbonate ions, a high bending strength exceeding a bending strength of 16.0 MPa is obtained with an expendable salt core in which a concentration XK^- (molar ratio) of potassium ions in all the cations is 50 mol% to 90 mol% and the concentration YCO_3^{2-} (molar ratio) of carbonate ions in all the anions is 40 mol% to 80 mol% with the melting temperature falling within a range of 600°C to 680°C. From the viewpoints of durability of the mold that forms the core and the process cost necessary to form the core, the melting temperature of the molten salt may be set to approximately 680°C at maximum.

[0037] The observation results with a scanning electron microscope (SEM) of the solidification structures of the expendable salt cores described above will be described. Fig. 5 is an SEM photograph of the solidification structure of an expendable salt core fabricated using a molten salt in which the concentration of potassium ions in all the cations is 50 mol% and the concentration of carbonate ions in all the anions is 70 mol%. The expendable salt core fabricated from the molten salt with this composition exhibits a bending strength of 20 MPa or more, as shown in Fig. 4, thus providing a very high strength. In this expendable salt core, as shown in Fig. 5, a state is observed in which a plurality of granular crystals are evenly dispersed in the parent phase. The composition of the granular crystal portion observed in this manner was analyzed by an energy-dispersive X-ray spectroscopic analyzer. The concentration of potassium ions in all the cations was 32 mol%, and the concentration of carbonate ions in all the anions was 100 mol%.

[0038] Fig. 6 is an SEM photograph of the solidification structure of an expendable salt core fabricated using a molten salt in which the concentration of potassium ions in all the cations is 60 mol% and the concentration of carbonate ions in all the anions is 70 mol%. The expendable salt core fabricated from the molten salt with this composition exhibits a bending strength of 15 MPa to 20 MPa, as shown in Fig. 4, thus providing a high strength. In this expendable salt core, as shown in Fig. 6, a state is observed in which a plurality of granular crystals are evenly dispersed in the parent phase. The composition of the granular crystal portion observed in this manner was analyzed by the energy-dispersive X-ray spectroscopic analyzer. The concentration of potassium ions in all the cations was 42 mol%, and the concentration of carbonate ions in all the anions was 100 mol%.

[0039] Fig. 7 is an SEM photograph of the solidification structure of an expendable salt core fabricated using a molten salt in which the concentration of potassium ions in all the cations is 40 mol% and the concentration of carbonate ions in all the anions is 70 mol%. The expendable salt core fabricated from the molten salt with this composition exhibits a bending strength 0 MPa to 10 MPa, as shown in Fig. 4, and does not provide a very high strength. In this expendable salt core, as shown in Fig. 7, comparatively large dendrites are observed in the parent phase. The composition of the dendrite portion observed in this manner was analyzed by the energy-dispersive X-ray spectroscopic analyzer. The concentration of potassium ions in all the cations was 22 mol%, and the concentration of carbonate ions in all the anions was 100 mol%.

[0040] From the above description, to obtain an expendable salt core with a higher strength, a plurality of granular crystals need to be formed in the parent phase in a dispersed manner. The granular crystals and dendrites observed by the SEM described above are crystals (primary crystals) which are formed first in the cooling process of the molten salt, and have comparatively high melting temperatures. After primary crystals are formed, the portion containing eutectic mixtures having a comparatively low melting point solidifies to form parent phase portions around the primary crystals. If the primary crystals formed in the parent phase of eutectic mixtures in this manner are not large dendrites but smaller granular crystals, the obtained expendable salt core may provide a high strength.

[0041] The above discussion often holds true for composition ratios other than those shown in Figs. 5, 6, and 7. For example, an expendable salt core formed of sodium ions, bromine ions, and carbonate ions and not containing potassium ions exhibits a high bending strength when the concentration of carbonate ions in all the anions is 30 mol% or falls between 50 mol% to 80 mol%. Of this molar ratio range, when the concentration of carbonate ions is 60 mol%, a state is also observed in the solidification structure of the expendable salt core in which a plurality of granular crystals are dispersed in the parent phase.

[0042] As is known well, NaBr is a fragile substance that causes cleavage fracture. With NaBr, only a low bending strength of less than 10 MPa is obtained, as described above. In contrast to this, when a carbonate is added to form the salt mixture, the solidified structure is formed of NaBr and Na_2CO_3, thus providing a higher bending strength. An expendable salt core having a high strength can be obtained not only by simply adding a carbonate, but also by selecting a composition in which a crystal structure having a comparatively high melting point is formed in the parent phase having a comparatively low melting point. As primary crystals are mixed in the parent phase, progress of cracks and the like may be interfered with, providing a high strength. If the primary crystals are large dendrites, cracks tend to progress. If the primary crystals are smaller granular crystals, a higher strength can be obtained as described above.

[0043] Measurement of the bending strength will be described. To measure the bending strength, a prismatic test piece with a predetermined size is fabricated. A load is applied to the test piece, and the bending load is obtained from the maximum load needed to break the test piece. Fabrication of the test piece will be described first. A rod-like test piece 901 as shown in Figs. 9A and 9B is formed using a predetermined metal mold. The employed metal mold is made of chrome molybdenum steel, e.g., SCM440H. Fig. 9A also shows riser portions 902 used when charging the metal mold with a melt. In measurement of the bending strength, the portions 902 are cut off. Fig. 9A is a side view, and Fig. 9B is a sectional view taken at the position b - b in Fig. 9A. The sizes indicated in Figs. 9A and 9B are design values of the metal mold.

[0044] To measure the bending strength of the rod-like test piece 901 fabricated in the above manner, first, as shown in Fig. 10, the test piece 901 is supported by two support portions 1001 arranged at the center of the test piece 901 at a gap of 50 mm from each other. In this support state, at the intermediate portion of the two support portions 1001, two load portions 1002 at a gap of 10 mm from each other apply a load to the test piece 901. The load to be applied to the test piece 901 is gradually increased. The maximum load needed to break the test piece 901 was the bending load shown in Tables 1 and 3.

[0045] A bending strength σ (MPa) can be obtained from a bending load P in accordance with an equation $\sigma = 3LP/BH^2$ where H is the length of the load direction in the section of the test piece, B is a length perpendicular to the load direction in the section of the test piece, and L is the distance from the support portions 1001 serving as fulcrums to the load portions 1002 where the load acts. Although the test piece 901 is formed by pouring the melt into the metal mold, it is difficult to form a test piece having a shape completely coinciding with the size true to the mold due to flow marks or shrinkage cavity. Therefore, the bending strength is calculated based on an approximation that the test piece has a rectangular section and that $H \approx 20$ mm, $B \approx 18$ mm, and $L = 20$ mm. Due to this approximation, the estimated strength is lower than the actual strength by approximately 0% to 20%. For example, it can be assumed that a test piece which is broken by a bending load of 1200N is stronger than an ideal test piece having a bending strength of 10 MPa.

Industrial Applicability

[0046] The present invention can be suitably used as a core in casting such as aluminum die casting.

Claims

1. An expendable salt core for casting,
   characterized by
   being formed of a molten salt containing bromine ions, carbonate ions, and at least one of sodium ions and potassium ions.

2. An expendable salt core for casting according to claim 1, **characterized in that**
   said molten salt is formed of sodium ions, bromine ions, and carbonate ions.

3. An expendable salt core for casting according to claim 2, **characterized in that**
   in said molten salt, a molar ratio of carbonate ions in all the anions is 30 mol%.

4. An expendable salt core for casting according to claim 2, **characterized in that**
   in said molten salt, a molar ratio of carbonate ions in all the anions is 50 mol% to 80 mol%.

5. An expendable salt core for casting according to claim 1, **characterized in that**
   said molten salt is formed of potassium ions, bromine ions, and carbonate ions, and a molar ratio of carbonate ions in all the anions is 30 mol%.

6. An expendable salt core for casting according to claim 1, **characterized in that**
   said molten salt is formed of potassium ions, bromine ions, and carbonate ions, and a molar ratio of carbonate ions in all the anions is 50 mol% to 90 mol%.

7. An expendable salt core for casting according to claim 1, **characterized in that**
   said molten salt is formed of sodium ions, potassium ions, bromine ions, and carbonate ions,
   a melting temperature of the molten salt falls within a range of 600°C to 680°C,
   a molar ratio of potassium ions in all the cations is 50 mol% to 90 mol%, and
   a molar ratio of carbonate ions in all the anions is 40 mol% to 80 mol%.

8. An expendable salt core for casting according to claim 1, **characterized in that**

a plurality of granular crystals are formed in a parent phase in a dispersed state.

9. An expendable salt core for casting according to claim 8, **characterized in that**
said granular crystals are formed of carbonate ions and at least one of sodium ions and potassium ions.

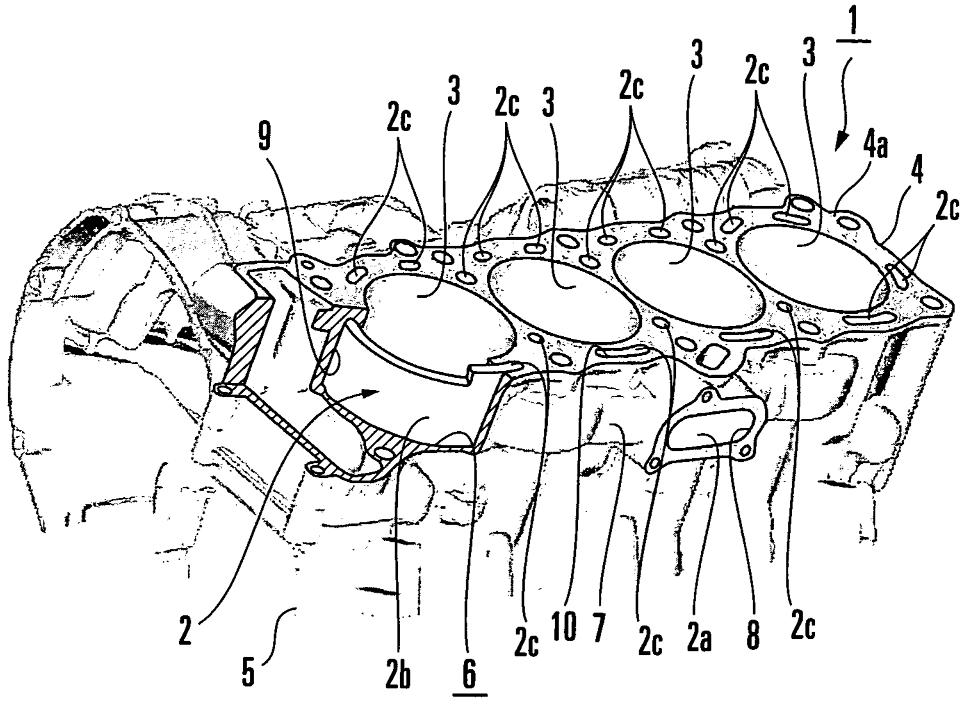
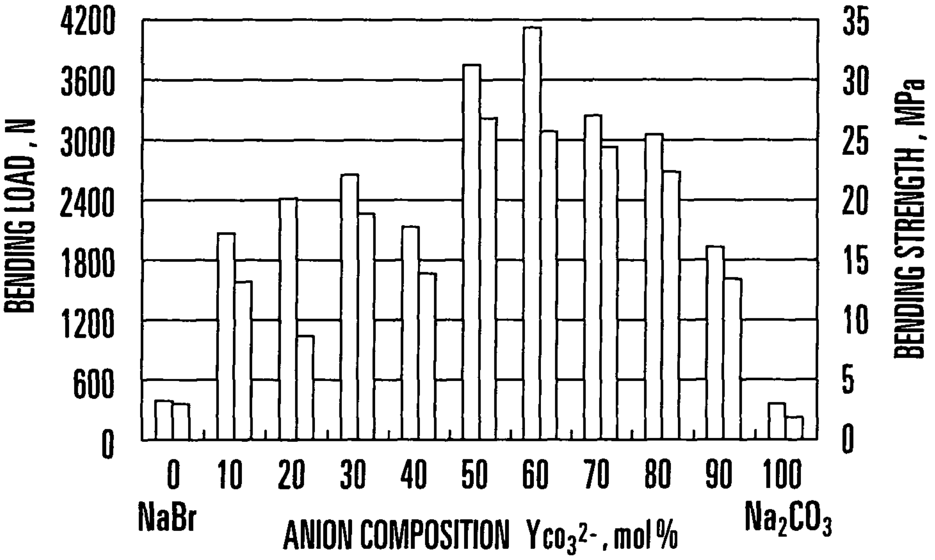


FIG. 1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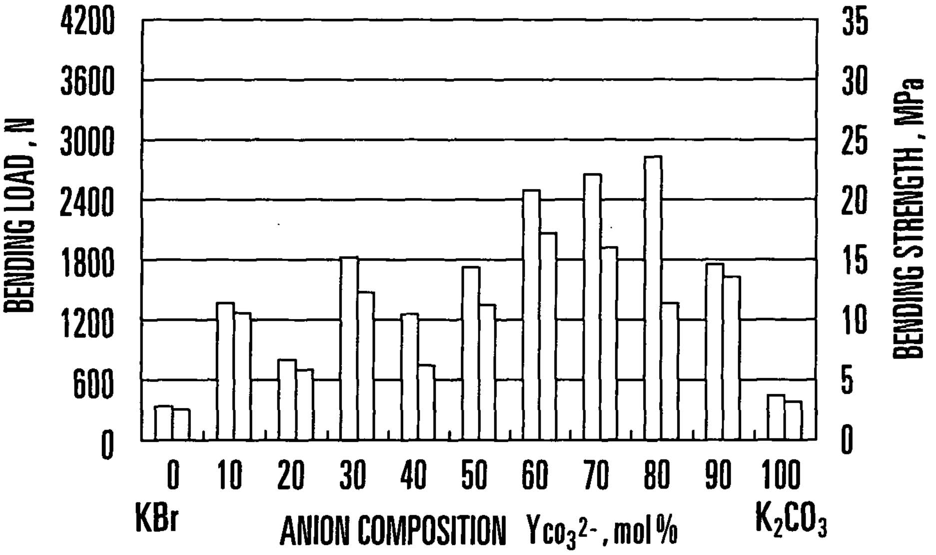
BENDING STRENGTH , MPa
0
10
20
30
40
50
60
70
80
90
100
NaBr
ANION COMPOSITION $Y_{CO_3^{2-}}$, mol%
Na_2CO_3

FIG. 2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20
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10
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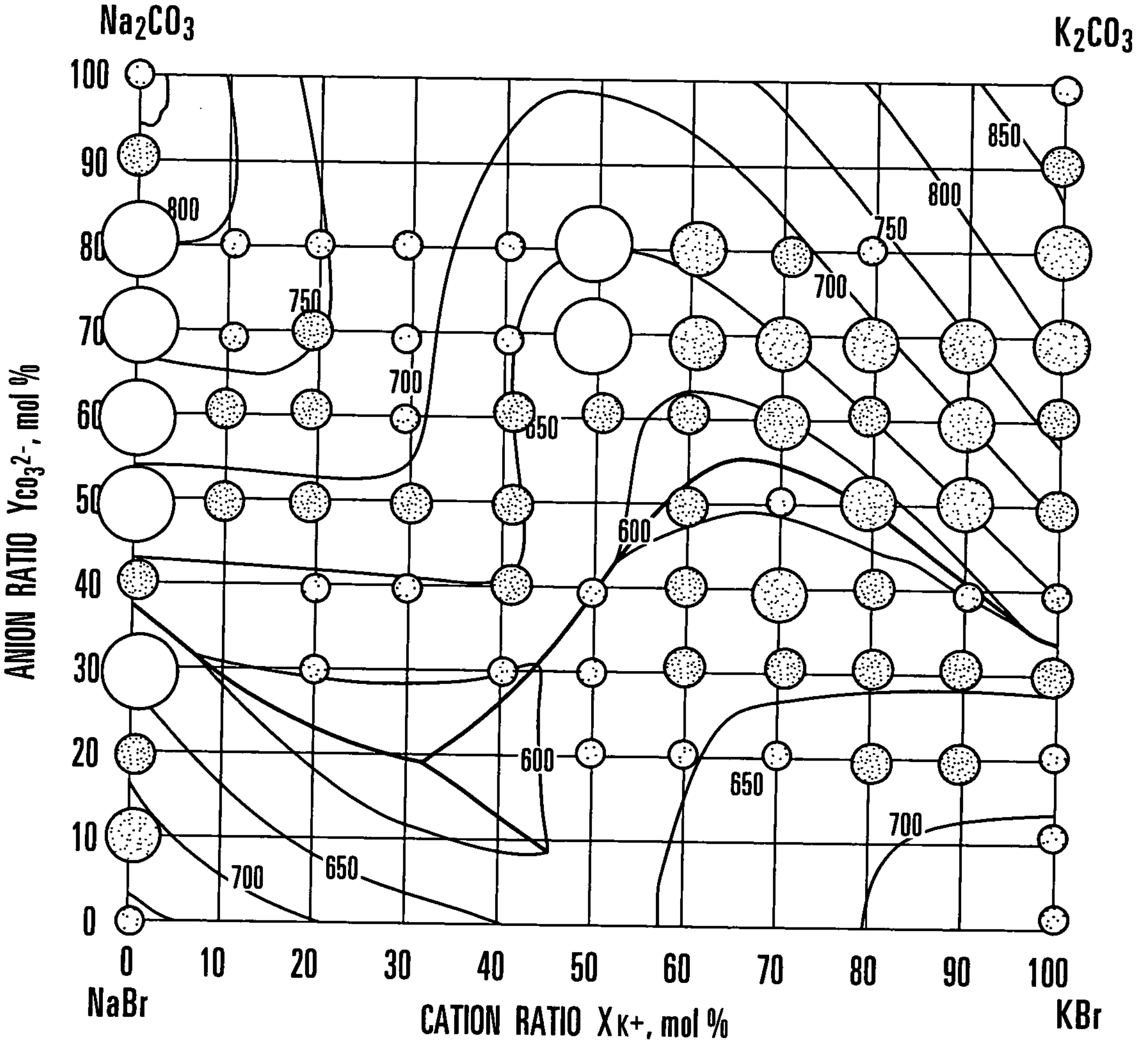
0
BENDING STRENGTH , MPa
0
10
20
30
40
50
60
70
80
90
100
KBr
ANION COMPOSITION $Y_{CO_3^{2-}}$, mol%
K_2CO_3

FIG. 3


Na_2CO_3
K_2CO_3
100
90
80
70
60
50
40
30
20
10
0
ANION RATIO $Y_{CO_3^{2-}}$, mol %
0
10
20
30
40
50
60
70
80
90
100
NaBr
KBr
CATION RATIO X_{K^+}, mol %
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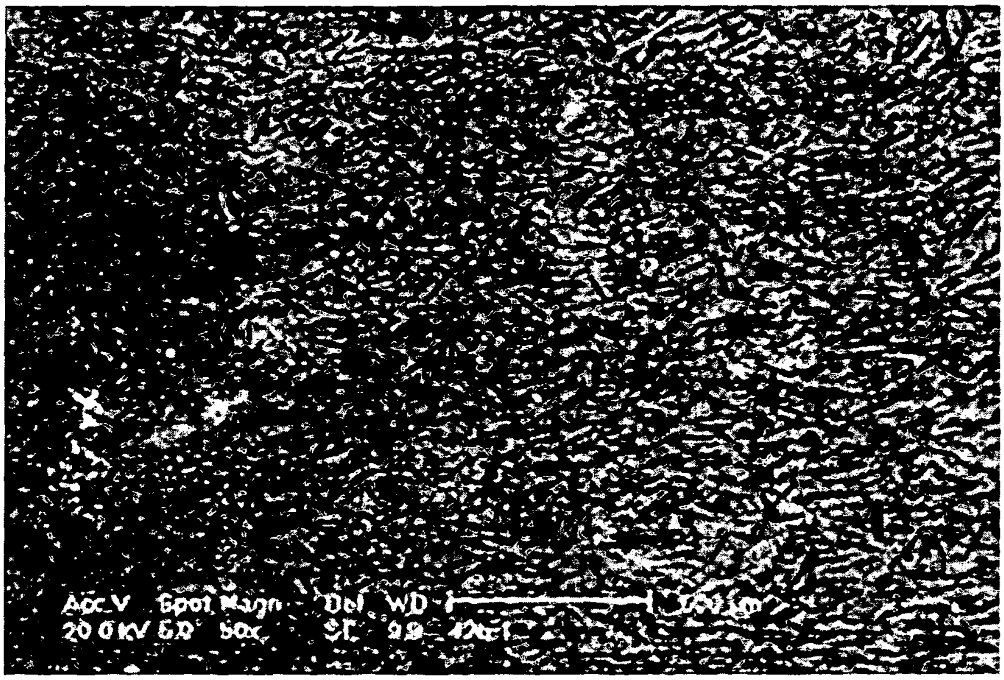
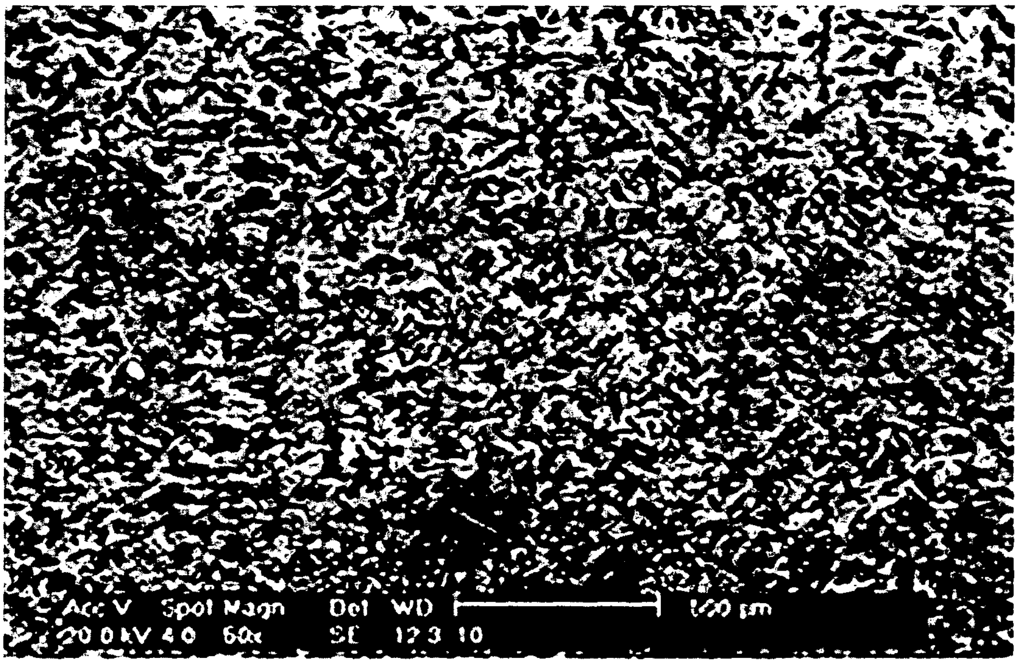
700
800
750
700

FIG. 4



$X_{K^+} = 50, Y_{CO_3^{2-}} = 70$

FIG. 5



$X_{K^+} = 60, Y_{CO_3^{2-}} = 70$

FIG. 6

$X_{K^+}=40, Y_{CO_3^{2-}}=70$

FIG.7

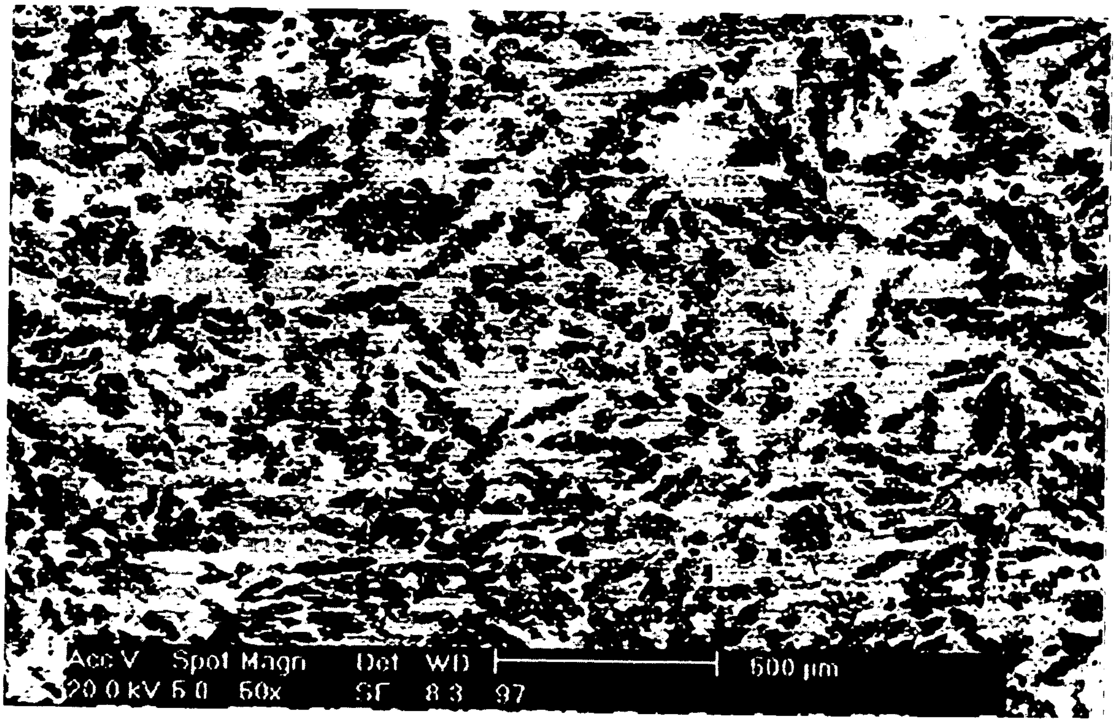


FIG.8

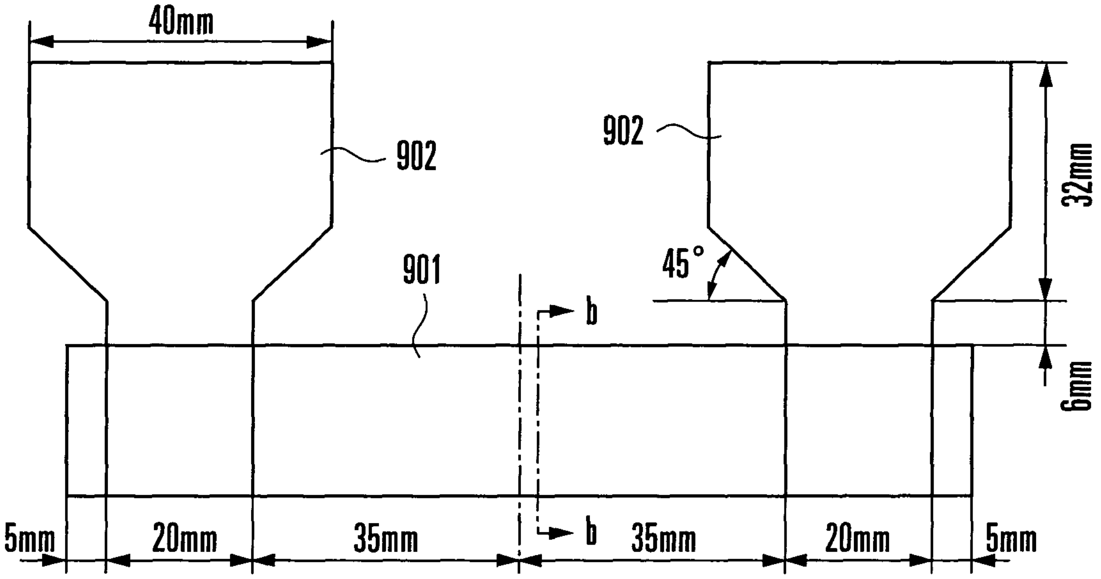


FIG. 9A

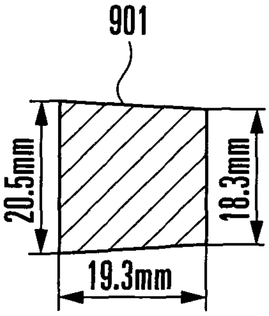


FIG. 9B

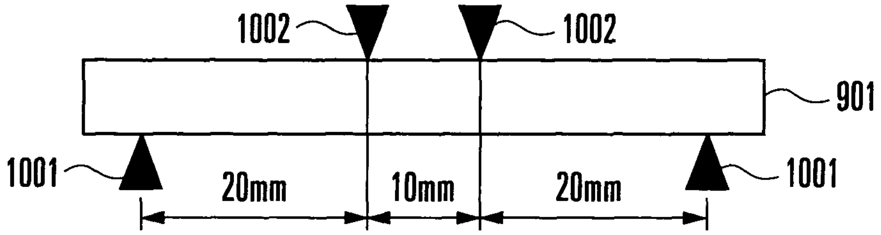


FIG. 10

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2007/060369

A. CLASSIFICATION OF SUBJECT MATTER
B22C9/10(2006.01)i, *B22C1/00*(2006.01)i

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)
B22C1/00-9/30

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	1996-2007
Kokai Jitsuyo Shinan Koho	1971-2007	Toroku Jitsuyo Shinan Koho	1994-2007

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	WO 2005/028142 A1 (Yamaha Motor Co., Ltd.), 31 March, 2005 (31.03.05), & EP 1674173 A1 & US 2006185815 A1	1-9
A	JP 48-39696 B1 (Toyo Kogyo Kabushiki Kaisha), 26 November, 1973 (26.11.73), (Family: none)	1-9

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
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"E" earlier application or patent but published on or after the international filing date
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"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
07 August, 2007 (07.08.07)

Date of mailing of the international search report
21 August, 2007 (21.08.07)

Name and mailing address of the ISA/
Japanese Patent Office

Facsimile No.

Authorized officer

Telephone No.

Form PCT/ISA/210 (second sheet) (April 2005)

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- JP 48039696 A **[0002]**
- JP 50136225 A **[0002]**
- JP 52010803 A **[0002]**