



Europäisches Patentamt
European Patent Office
Office européen des brevets



(11) **EP 0 747 494 B2**

(12) **NEW EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention
of the opposition decision:
24.08.2005 Bulletin 2005/34

(51) Int Cl.7: **C22C 21/02**

(45) Mention of the grant of the patent:
13.03.2002 Bulletin 2002/11

(21) Application number: **96108948.9**

(22) Date of filing: **04.06.1996**

(54) **A1-based composite material having adhesion resistance property and process for producing the same**

Verbundwerkstoff auf Aluminiumbasis mit Klebrigbeständigkeit und das Herstellungsverfahren

Matériau composite à base d'aluminium, ayant une propriété de résistance à l'adhésion, et procédé pour sa production

(84) Designated Contracting States:
DE FR GB

(30) Priority: **06.06.1995 JP 13974095**

(43) Date of publication of application:
11.12.1996 Bulletin 1996/50

(73) Proprietor: **Toyota Jidosha Kabushiki Kaisha
Aichi-ken (JP)**

(72) Inventors:
• **Nukami, Tetsuya c/o Toyota Jidosha K.K.
Aichi-ken (JP)**
• **Suganuma, Tetsuya c/o Toyota Jidosha K.K.
Aichi-ken (JP)**
• **Okochi, Yukio c/o Toyota Jidosha K.K.
Aichi-ken (JP)**

(74) Representative: **TBK-Patent
Bavariaring 4-6
80336 München (DE)**

(56) References cited:

EP-A- 0 141 501	EP-A- 0 526 079
EP-A- 0 592 665	JP-A- 1 025 935
JP-A- 58 003 946	US-A- 3 895 941
US-A- 5 234 514	US-A- 5 253 625

- **DATABASE WPI Section Ch, Week 8707 Derwent Publications Ltd., London, GB; Class M26, AN 87-045608 XP002011236 & JP-A-62 001 839 (SKY ALUMINIUM KK) , 7 January 1987**
- **DATABASE WPI Section Ch, Week 9201 Derwent Publications Ltd., London, GB; Class M22, AN 92-003616 XP002011237 & JP-A-03 257 128 (TOKAI CARBON KK) , 15 November 1991**
- **DATABASE WPI Section Ch, Week 8531 Derwent Publications Ltd., London, GB; Class M22, AN 85-188088 XP002011238 & JP-A-60 118 367 (SUMITOMO ELEC IND KK) , 25 June 1985**

EP 0 747 494 B2

DescriptionBACKGROUND OF THE INVENTION5 Field of the Invention

[0001] The present invention relates to an Al (aluminum)-based composite material having adhesion resistance property and a process for producing the same. The present invention can be applied to an Al-based member which includes a reinforced portion formed by the Al-based composite material at a part thereof at least. The present invention can be applied to, for example, a sliding material, at the concrete, a ring-shaped portion having wear resistance property and being provided with a piston ring groove whose sliding conditions are severe among pistons used in an engine.

Description of the Related Art

15 **[0002]** Taking a piston used in an engine as an example, the prior art of Al-based composite material will be explained. In recent years, an engine has been improved its performance and rising of piston temperature has been unavoidable. Accordingly, there has been developed a technique utilizing an Al-based composite material at pistons.

20 **[0003]** A publication "Iron and Steel" (Association of Iron and Steel, the September number 1989, page 376) discloses a technique in which an Al-based composite material produces a ring-shaped portion having wear resistance property which forms a ring groove which maintains a piston ring in a piston. Based on this conventional technique, reinforced materials: such as titanate whiskers; carbon fibers; alumina fibers; alumina-silica fibers; NiAl₃ particles are used, and Al alloy (JIS ACBA) is impregnated in this reinforced material by high pressure casting so that the ring-shaped portion having wear resistance property is formed.

25 **[0004]** By using the ring-shaped portion having wear resistance property and which is formed by the above-mentioned Al-based composite material, it is possible to reduce its weight and to improve adhesion resistance property compared with the ring-shaped portion having wear resistance property and being made of niresist cast iron. However, as the performance of engines has been advanced in recent years, it has been expected to improve adhesion resistance property more.

30 **[0005]** JP-A-3-257 128 and JP-A-60-118 367 disclose Al-based composite materials wherein a compact is formed and impregnated with molten Al under pressure. An Al matrix having primary crystal Si particles and eutectic Si particles dispersed therein, is not described.

35 **[0006]** JP-A-62-1839 discloses a wear resistance aluminum alloy rolled sheet comprising an Al matrix wherein grains over 0.2 microns of Al-Si eutectic particles, Si primary crystals and other intermetallic compounds are included. Si particles are included in an amount ranging from approximately 9.7 to 18.3 % by volume. Effects of this kind of Al composite material on the continuity of the Al matrix are not mentioned.

40 **[0007]** US-A-5,234,514 discloses a hypereutectic aluminum-silicon casting alloy having a refined primary silicon particle size and a modified silicon phase in the eutectic. The primary crystal silicon particles may have an average particle size of less than 30 μm. According to the casting method used in this reference an Al molten metal containing a large amount of Si is solidified having a large degree of heat energy. Therefore, a rapid solidification cannot be obtained. As the solidification speed is low, rapid cooling speed cannot be achieved. As a result, primary Si particles tend to have a comparatively large particle size. Therefore, the problem of improving the adhesion resistance property of an Al-based composite material cannot be sufficiently solved.

45 **[0008]** EP-A-0526079 and EP-A-0592665 disclose hyperventectic Al-Si alloys which are prepared by atomizing molten Al alloy, the resulting alloy contains well-refined primary Si particles by addition of a refiner.

SUMMARY OF THE INVENTION

50 **[0009]** The present invention has been developed in view of the above-mentioned problems. It is a primary object of the present invention to provide an Al-based composite material in which parting property of Al matrix is improved, and also, in which adhesion resistance property is improved more so that the Al-based composite material can be suitable to be used as a sliding member whose adhesion resistance property is improved and whose sliding conditions are severe. It is also an object of the present invention to provide a process for producing the above-mentioned Al-based composite material.

55 **[0010]** The present inventors earnestly carried out development about Al-based composite materials. The present inventors found that if continuity of Al matrix is parted finely by Si particles, continuity of Al matrix is suppressed and transferring of Al components to the mating side is effectively suppressed so that adhesion resistance property in the Al-based composite materials is improved. By paying attention to this viewpoint, the present inventors completed the present invention.

[0011] Namely, according to a first aspect of the present invention, an Al-based composite material having adhesion resistance property comprises:

[0012] Al matrix including primary crystal Si particles whose mean particle diameter is not more than 20 μm (microns) and eutectic Si particles;

5 wherein the overall amount of said Si particles fall in a range of from 20 to 36% by volume and said Al-based composite material is obtained by impregnation of Al molten metal or Al alloy molten metal into pores of a powder compound having Si particles. Al matrix means aluminum alloy or aluminum metal.

[0013] An Al-based composite material having adhesion resistance property according to a second aspect of the present invention comprises:

10 **[0014]** Al matrix including: first Si particles whose mean particle diameter is in an amount of 3 to 10 μm (microns); second Si particles which are made of eutectic Si and whose mean particle diameter is not more than 1 μm (micron); and third Si particles whose mean particle diameter is in an amount of 20 to 60 μm (microns),

15 wherein the total amount of the first and second Si particles fall in a range of from 20 to 40% by volume and the third Si particles fall in a range of from 1 to 6% by volume and said Al-based composite material is obtained by impregnation of Al molten metal or Al alloy molten metal into pores of a powder compound having Si particles.

[0015] An Al-based composite material having adhesion resistance property according to a third aspect of the present invention comprises:

20 Al matrix including primary crystal Si particles whose mean particle diameter is not more than 20μm and eutectic Si particles; and

Fe alloy fine pieces dispersed in the Al matrix having a mean particle size in the range of from 10 to 80μm;

25 wherein the total amount of the Si particles and the Fe alloy fine pieces fall in a range of from 20 to 74% by volume and the amount of said Si particles falls in the range of from 8 to 33% by volume.

[0016] An Al-based composite material having adhesion resistance property according to a fourth aspect of the present invention comprises:

30 Al matrix including primary crystal Si particles whose mean particle diameter is not more than 20 μm and eutectic Si particles; and

Fe alloy micro pieces having a mean particle size in the range of from 10 to 80 μm; and ceramic particles dispersed in the Al matrix having a mean particle diameter in the range of from 1 to 80 μm;

35 wherein the total amount of the Si particles, the Fe alloy micro pieces and ceramic particles falls in a range of from 25 to 73% by volume; the total amount of the ceramic particles falls in a range of from 2 to 10% by volume, and the total amount of said Si particles (including primary crystal Si and entectic Si) falls in the range of from 20 to 36 % by volume.

40 **[0017]** In an Al-based composite material having adhesion resistance property according to a fifth aspect of the present invention in the third or fourth aspect of the present invention, the hardness of Fe alloy micro pieces is not less than Hv 250.

[0018] In an Al-based composite material having adhesion resistance property according to a sixth aspect of the present invention in the first, third or fourth aspect of the present invention, the mean particle diameter of the primary crystal Si particles falls in the range of from 3 to 10 μm (microns).

45 **[0019]** A process for producing an Al-based composite material according to a seventh aspect of the present invention comprises the steps as defined in any of claims 7 to 9.

50 **[0020]** According to the first aspect of the present invention, the mean particle diameter of the primary Si particles included in the Al matrix is not more than 20 μm (microns) and the primary Si particles are very minute; and also these Si particles are included in a large amount ranging from 20 to 36% by volume; so that the parting property of parting the continuity of Al matrix by using these Si particles is improved. Accordingly, even if the sliding condition are severe, transferring of Al components of the Al matrix to a mating side is effectively suppressed so that the adhesion resistance property thereof is improved.

55 **[0021]** Furthermore, Si particles take pavement effect on Al matrix so that the wear resistance property thereof is also secured. The Si particles generally are primary crystal Si particles and eutectic Si particles which were crystallized at the time when Al-Si molten metal is solidified.

[0022] According to the second aspect of the present invention, the first, second and third Si particles, all of which have different particle diameters, are included in the Al-based composite material so that the parting of Al matrix by using Si particles is improved more. Accordingly, transferring of Al components of the Al matrix to a mating member

is effectively suppressed and adhesion resistance property thereof is improved. Generally, the first Si particles whose particle diameter is minute and the second Si particles whose particle diameter is extremely minute can be supplied in crystallizing phenomenon during the atomizing of powder particles constituting the powder compact. The third Si particles whose particle diameter is larger than that of the first Si particles can be supplied in crystallizing phenomenon of Al molten metal which is impregnated in the powder compact.

[0023] According to the second aspect of the present invention, the ratio of Si particles can be changed in response to the kinds of Al-based composite materials. For example, the upper limit of the total amount of the first Si particles and the second Si particles can be set to be 35% or 30% or up to 40% by volume; and the lower limit of the total amount the first Si particles and the second Si particles can be set to be 23% or 27% by volume. The upper limit of the third Si particles can be set to be 6% by volume and the lower limit of the third Si particles can be set to be 1 % by volume.

[0024] According to the third aspect of the present invention, not only Si particles but also Fe alloy micro pieces are added. Therefore, the parting of Al matrix is secured more and the adhesion resistance property is improved. Not only Si particles but also Fe alloy micro pieces can be expected to take pavement effect and to improve the wear resistance property thereof. As Fe alloy micro pieces, they may be selected from shapes such as particles and fibers. When the Fe alloy micro pieces are in the shape of particles, the mean particle diameter may fall in the range of from 10 to 80 μm (microns). As the composition of Fe alloy micro pieces, as shown in the preferred embodiments mentioned later, Fe-Cr alloy, Fe-Mo alloy or stainless steel (SUS) may be adopted. In Fe alloy micro pieces, carbon as a carbide producing element may be included.

[0025] According to the fourth aspect of the present invention, not only Si particles but also Fe alloy micro pieces and ceramic particles are added. Therefore, the parting of Al matrix is secured more and the adhesion resistance property is improved. The hardness of Fe alloy micro pieces and ceramic particles are higher compared with that of Al matrix, so that Fe alloy micro pieces and ceramic particles can be expected to obtain pavement effect and wear resistance property thereof can be secured. As ceramic particles, oxide, nitride or carbide may be employed. The mean particle diameter of ceramic particles falls in the range of from 1 to 80 μm (microns), especially from 3 to 50 μm (microns).

[0026] According to the fifth aspect of the present invention, Fe alloy micro pieces of more than Hv250 are used so that wear resistance property thereof is advantageously secured. In response to the using conditions of the Al-based composite material, as Fe alloy micro pieces, it may be selected from the group consisting of Fe alloy micro pieces whose hardness is more than Hv300, Hv 400, Hv500 Hv600 and Hv700.

[0027] According to the sixth aspect of the present invention, the minute primary crystal Si particles whose mean particle diameter is in an amount of 3 to 10 μm (microns), so that the parting of Al matrix by Si particles is easily secured and adhesion resistance property thereof is improved.

[0028] At the surface of Al powder particles, oxide films easily exist. When the Al powder particles are bonded integrally each other, the oxide films existing on the surface of Al powder particles produce harmful effects. With regard to this, according to the seventh aspect of the present invention, even if the oxide films exist on the surface of Al powder particles constituting a powder compact, the residual of oxide films on the surface of particles can be easily reduced and avoided. The oxide films are assumed to be destroyed by the pressure at the time high pressure casting. The existence of oxide films, which exist at the boundary of between the solidified portion of Al molten metal impregnated in the powder compact by the high pressure casting and the Al powder particles constituting the powder compact, is suppressed or avoided. Therefore, after the high pressure casting, as shown in Figure 2 mentioned later, matrix structure having no boundary or less boundary can be obtained. The pressure at the time of the high pressure casting may be set from about 500 atmosphere to 1500 atmosphere. According to the process of the seventh aspect of the present invention, the Al-based composite materials in the first to sixth aspects of the present invention can be produced.

[0029] According to the first aspect of the present invention, a large amount of minute Si particles are included so that the parting property in which Si particles part the continuity of the Al matrix is improved. Accordingly, the transferring of the Al matrix to a mating member is effectively suppressed and adhesion resistance property is improved.

[0030] According to the second aspect of the present invention, a large amount of the first Si particles, second Si particles and third Si particles, all of which are minute and have different particles diameters, are included. Accordingly, the parting of Al matrix by using Si particles is improved more and therefore, adhesion resistance property thereof is improved.

[0031] According to the third aspect of the present invention, not only Si particles but also Fe alloy micro pieces are added. Therefore, the parting of Al matrix is secured more and the adhesion resistance property is improved. The hardness of Fe alloy micro pieces are higher compared with that of the Al matrix, the wear resistance property is also secured.

[0032] According to the fourth aspect of the present invention, not only Si particles but also Fe alloy micro pieces and ceramic particles are added. Therefore, the parting of Al matrix is secured more and the adhesion resistance property is improved. The hardness of Fe alloy micro pieces and ceramic particles are higher compared with that of Al matrix, Fe alloy micro pieces and ceramic particles can be expected to secure wear resistance property.

[0033] According to the fifth aspect of the present invention, Fe alloy micro pieces of more than Hv250 so that the above-mentioned effect is obtained and furthermore, wear resistance property thereof is advantageously secured.

[0034] According to the sixth aspect of the present invention, the minute primary crystal Si particles whose mean particle diameter is in an amount of 3 to 10 μm (microns), so that the parting of Al matrix by primary crystal Si particles is easily secured and adhesion resistance property thereof is improved.

[0035] According to the seventh aspect of the present invention, even if the oxide films exist on the surface of Al powder particle, the oxide films are easy to be destroyed. As a result, the existence of oxide films, which exist at the boundary of between the solidified portion of Al molten metal impregnated by the high pressure casting and the Al powder particles constituting the powder compact, is suppressed or avoided. Therefore, Al matrix structure having no boundary or less boundaries is obtained so that not only adhesion resistance property of the Al-based composite material but also the strength thereof are improved.

[0036] According to the above-mentioned first to seventh aspects of the present invention, the present invention is advantageously applied to the sliding member whose sliding conditions are severe, for example, a region for forming a piston ring (top ring) groove of a diesel engine or a gasoline engine.

BRIEF DESCRIPTION OF THE DRAWINGS

[0037] A more complete appreciation of the present invention and many of its advantages will be readily obtained as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings and detailed specification, all of which forms a part of the disclosure:

Figure 1 is a block diagram showing typically the state in which adhesion resistance property is investigated;

Figure 2 is an electron microscope photograph showing metallographic structure of Al-based composite material;

Figure 3 is a block diagram showing the configuration for defining a parting coefficient;

Figure 4 is a graph showing the relation between mean particle diameter of primary crystal Si particles and the adhesion area; and

Figure 5 is a cross sectional view showing typically the application example to a piston.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0038] Having generally described the present invention, a further understanding can be obtained by reference to the specific preferred embodiments which are provided herein for purposes of illustration only and are not intended to limit the scope of the appended claims.

First Preferred Embodiment

[0039] In a First Preferred Embodiment, Al-Si powder (atomized powder, made by Toyo Aluminium Kabushiki Kaisha, mean particle diameter 50 μm (microns)) comprising the composition of Al-38wt%Si; and Fe-Cr powder (crushed powder, made by Fukuda Metal Corporation, mean particle diameter 60 μm (microns), including 7.4wt%C) comprising the composition of Fe-63wt%Cr are used. In the former Al-Si powder, primary crystal Si particles (mean particle diameter 10 μm (microns)) and eutectic Si particles of less than sub-micron (that is, less than 1 μm (micron)) are generated.

[0040] Initially, the mixed powder in which both of powder are mixed was inserted in a cavity of a metallic die for a forming green compact. After that, the mixed powder was pressed by metallic die compressing method so that a green compact having a predetermined porosity, that is a powder compact (size: diameter 100mm, length 10mm) was produced.

[0041] Furthermore, the powder compact was pinched by a ceramic-fiber compact (made by isolite Industry Co., Ltd., Vf7%, size: 100mm x 100mm x 5mm) equipped with a weight for preventing float, and furthermore, by preheating the powder compact at 350°C for 30 minutes and it was arranged in a part of a cavity (diameter 110mm, length 200mm) of a metallic mold for high pressure casting.

[0042] After that, Al molten metal (JIS-AC8A) at a temperature of 750°C was poured into the cavity of the metallic mold-die for high pressure casting method; the Al molten metal was impregnated in the pores at the inside of the powder compact by pressing by a plunger; that is, Al alloy was compounded by the high pressure casting so that a casting was molded.

[0043] The pressing pressure in the high pressure casting method falls in the range of from about 1200 to 1300

atmosphere. The target composition of AC8A in JIS standard is as follows: Si falls in the range of from 11 to 13wt%; Cu falls in the range of from 0.8 to 1.3wt%; and Mg falls in the range of from 0.7 to 1.3wt%. In the First Preferred Embodiment of the present invention, Si amount of Al molten metal which was actually impregnated is 12wt%.

[0044] From the above-mentioned casting, a specimen (NO.1) made from the Al-based composite material was picked out and T7 heat treatment (maintained for three hours at a temperature of 490°C, then warm water hardening was conducted) was conducted on it. Similarly, specimens No. 2 to No. 19 were obtained and in the same way, T7 heat treatment was conducted on them. The data concerning from No. 1 to No. 19 are shown in Table 1.

[0045] In table 1, when the Al-based composite material is set to be 100%, Vf(Al-Si) means % by volume in which the powder compact formed by Al-Si powder particles occupies. When the Al-based composite material is set to be 100%, Vf(Fe-Cr) means % by volume in which Fe-Cr particles occupy. When the Al-based composite material is set to be 100%, Vf(Si) means % by volume in which primary crystal Si particles and eutectic Si particles in the powder compact occupy.

[0046] Vf (Total) means the sum of Vf(Fe-Cr) and Vf(Si). When the Al-based composite material is set to be 100%, Vf (Total) means % by volume in which the sum of primary crystal Si particles and Fe-Cr particles in the powder compact occupy. Accordingly, in specimens (NO. 2, NO. 4 and the like) including no Fe-Cr particles, Vf (Total) means % by volume of Si particles when the Al-based composite material is set to be 100%.

[0047] When the Al-based composite material is set to be 100%, Vf(MMC) means % by volume in which the sum of Si particles and Fe-Cr particles in the powder compact and Si in the AC8A alloy impregnated and solidified occupy

[0048] For example, according to specimen No. 2 of Table 1, Vf(Al-Si) meaning the ratio of the powder compact is 50% by volume, and Vf(Si) meaning the ratio of primary crystal and eutectic Si particles is 21% by volume. Vf(MMC) including Si of Al molten metal impregnated is 28% by volume.

[0049] The adhesion resistance property of each of above-mentioned specimens (NO. 1 through NO.19) were evaluated. Namely, as shown typically in Figure 1, a testing machine comprising platforms 11 and 12 which are equipped with heaters 10 and which are facing each other. Considering the piston rings used in an engine, a nitride ring 13 made of Cr stainless steel including 17wt%Cr as a mating member is mounted on the platform 12; and furthermore, a specimen W (diameter 90 mm, thickness 10 mm) is maintained on the platform 11. In this state, the platform 12 was removed in the arrow Y1 direction in the reciprocating movement; the specimen W was beaten by the nitride ring 13 at 280°C, at a bearing pressure of 0.1MPa and for ten minutes; and after beating, the adhesion area at the specimen W was measured so that the adhesion resistance property was evaluated.

[0050] The results are shown in the column "ADHESION" of Table 1.

[0051] As shown in Table 1, specimen NO. 1 represents a comparative example in which the amount of Si particles (Vf(Si) = 17% by volume) is less. In specimen NO. 1 in this way, the adhesion was "YES".

[0052] Specimen NO. 2 (Vf(Si) : 21% by volume), specimen NO. 4 (Vf(Si) : 25% by volume) and specimen NO. 9 (Vf(Si) : 35% by volume) include no Fe-Cr particles, however, include a large amount of Si particles. Si particles, as mentioned above, are supplied from the atomized powder and Si particles comprises: the primary crystal Si particles whose mean particles diameter is 10 μm; and the eutectic Si particles of less than submicron diameter

[0053] In this way, based on specimens NO. 2, NO. 4 and NO. 9 which include a large amount of Si particles, the adhesion was "almost NO" as shown in Table 1. As is clear from this result, in the case when the large amount of minute Si particles are included, the parting property of Al matrix by Si particles is secured and it is found that the adhesion resistance property thereof is satisfactory.

[0054] As is clear from Table 1, in the other specimens, the adhesion was "NO" for they include both of minute Si particles and Fe-Cr particles.

[0055] Considering the specimen including both of Si particles and Fe-Cr particles, as shown in Table 1, in specimen NO. 3, Vf(Fe-Cr) meaning the amount including Fe-Cr particles is 4% by volume, and Vf(Si) meaning the amount including Si particles is 17% by volume. As a result, in specimen NO. 3, Vf(Total) meaning the sum of volume rates of Si particles and Fe-Cr particles is 21% by volume. In this way, in specimen NO. 3 including both of Si particles (mean particle diameter 10 μm (microns)) and Fe-Cr particles (mean particle diameter 60 μm (microns)), the adhesion was "NO".

[0056] As shown in Table 1, Vf(Total) of specimens NO. 3 and NO. 2 are 21% by volume in both cases. However, specimen NO. 3 including both of Si particles and Fe-Cr particles has more improved adhesion resistance property compared with that of specimen NO. 2 including Si particles but including no Fe-Cr particles.

[0057] As shown in Table 1, Vf(Total) of specimens NO. 4 and NO. 5 are 25% by volume in both cases. However, specimen NO. 5 including both of Si particles and Fe-Cr particles has more improved adhesion resistance property compared with that of specimen NO. 4 including Si particles but including no Fe-Cr particles.

[0058] This result means that including both of Si particles and Fe-Cr particles is effective to improve adhesion resistance property.

Table 1

No.	Vf(Al-Si)	Vf(Fe-Cr)	Vf(Si)	Vf(Total)	Vf(MMC)	ADHESION
1	40	0	17	17	25	YES
2	50	0	21	21	28	ALMOST NO
3	40	4	17	21	28	NO
4	60	0	25	25	30	ALMOST NO
5	50	4	21	25	31	NO
6	40	10	17	27	34	NO
7	40	13	17	30	36	NO
8	50	9	21	30	36	NO
9	85	0	35	35	37	ALMOST NO
10	80	5	33	38	40	NO
11	70	10	29	39	42	NO
12	60	15	25	40	43	NO
13	70	15	29	44	46	NO
14	60	20	25	45	48	NO
15	60	25	25	50	52	NO
16	40	40	17	57	60	NO
17	30	50	12	62	65	NO
18	20	60	8	68	71	NO
19	20	65	8	73	75	NO

[0059] Figure 2 shows a metallographic structure. As mentioned above, AC8A molten metal was impregnated in the powder compact comprising: Al-Si powder whose composition is Al-38wt%Si; and Fe-Cr powder whose composition is Fe-63wt%Cr and they were solidified so as to get the specimen. Figure 2 is the photograph in which the metallographic structure (no etch) of thus obtained specimen was observed by the electron microscope photograph (SEM) after the specimen was conducted T7 treatment. Concretely, Figure 2 shows the metallographic structure of specimen NO. 14. At the right bottom of the photograph, the reference length (10 μm (microns)) is shown.

[0060] In this metallographic structure, large and whitish particles which are square are seen to be Fe-Cr particles; and blackish and minute particles included in Al matrix are assumed to be the primary crystal Si particles.

[0061] Based on the reference length (10 μm (microns)) shown in the photograph (Figure 2), it is clear that the mean particle diameter of the primary crystal Si particles is not more than 10 μm (microns). In general, the hardness of Al matrix falls in the range of from about Hv110 to 150 at Al portions; and the hardness of Al matrix is about Hv200 if the Si particles are included. The hardness of the primary crystal Si particles falls in the range of from Hv800 to 1000. The hardness of Fe-Cr powder, in the state of the powder, is about Hv1600.

[0062] In the case when the Al alloy including a large amount of Si is molded by a die casting method, the mean particle diameter of the primary crystal Si particles grows so as to exceed to be 50 μm (microns) generally. Namely, in the die casting method, the solidifying speed is relatively low compared with that of the atomizing method so that, the mean particle diameter of the primary crystal Si particles at least falls in the range of from 40 to 50 μm (microns) at the minimum, and therefore, it is impossible to obtain the primary crystal Si particles whose mean particle diameter is not more than 20 μm (microns). In this case, the mean particle diameter of Si particles is large so that the distance between neighboring Si particles is departed. Namely, the parting property of Al matrix by the Si particles is not sufficient so that Al components are easy to be transferred to a mating member side, and therefore, satisfactory adhesion property is not obtained.

[0063] In this regard, according to the First Preferred Embodiment of the present invention, the atomized powder constituting the powder compact comprises: minute primary crystal Si particles whose mean particle diameter is 10 μm (microns); and the eutectic Si particles of less than submicron diameter (= 1 μm (micron) and less). Accordingly, even if Si content is as same as that in the case of Al alloy molded by the castings such as die casting, based on the First

Preferred Embodiment of the present invention, Si particles are minute so that the continuity of Al matrix is finely parted by Si particles in that amount and the parting property of Al matrix is improved. Therefore, the First Preferred Embodiment of the present invention advantageously reduces the transferring of Al components to a mating side and, therefore, the adhesion resistance property thereof is improved.

5 **[0064]** The definition of the parting property will be conducted as follows. Picking up a point in Al matrix, and a plurality of Si particles which exist around that point are linked by straight lines so as to form a figure; and the longest distance in that figure is understood to be the parting property. For example, as shown in Figure 3, an attention was given to an arbitrary point M in Al matrix; six Si particles around the point M, for example, were connected by straight lines so as to be supposed to draw a figure of a polygonal shape; and then the average value of the longest distance L1 in the inside of that figure can be defined as a parting coefficient.

10 **[0065]** According to the First Preferred Embodiment of the present invention, this parting coefficient can be set to be 10 μm (microns) and less. However in the case when the die casting method in which the primary crystal Si particles are crystallized from the Al molten metal is adopted, the parting coefficient is generally about 30 μm (microns) at the minimum so that in this case satisfactory parting property cannot be expected.

15 **[0066]** Also based on the First Preferred Embodiment of the present invention, even if the oxide films exist on the surface of the atomized powder particles constituting the powder compact, the oxide films are easy to be destroyed by the pressure at the time of the high pressure casting. As a result, it is suppressed or avoided that the oxide films exist between the boundary of the solidified portion of Al molten metal impregnated in the powder compact by the high pressure casting and the atomized powder particles constituting the powder compact. Therefore, as shown in metallographic structure concerning Figure 2, there are no boundary or extremely less boundary in Al matrix structure so that the strength of the Al-based composite material is improved.

Second Preferred Embodiment

25 **[0067]** In a Second Preferred Embodiment of the present invention, as in the same way as that of the First Preferred Embodiment, powder whose composition is Al-38wt%Si (made by Toyo Aluminium Kabushiki Kaisha, atomized powder, mean particle diameter is 50 μm (microns) and mean particle diameter of the primary crystal Si particles is 10 μm (microns)) was used. Then the powder compact (size: diameter 100 mm, length 10 mm) was produced by a metallic die compressing method. Furthermore, in the same way as that of the First Preferred Embodiment, the powder compact was pinched by a ceramic (kaowool) compact equipped with a weight for preventing float; and by preheating the powder compact at 350°C for 30 minutes, it was arranged in a cavity of a metallic mold-die.

30 **[0068]** After that, instead of Al molten metal of AC8A used in the First Preferred Embodiment, Al molten metal including more Si compared with those of AC8A, that is Al molten metal whose composition is Al-25wt%Si was used. This Al molten metal (850°C) was poured into the cavity of the metallic mold-die; then this Al molten metal was impregnated and solidified in the pores of the powder compact by the high pressure casting; so that Al alloy was compounded and a casting was molded by this. The pressure at the time of the high pressure casting falls in the range of from 1200 to 1300 atmosphere.

35 **[0069]** From the above mentioned casting, a specimen (NO. 20) was derived. The shape factors of this specimen are shown in Table 2. In the case of this specimen, primary crystal first Si particles whose particle diameters are small; eutectic Si particles which are not more than submicron (= 1 micron) diameter; and primary crystal third Si particles whose particle diameters are large are dispersed.

40 **[0070]** That is to say, in the atomized powder constituting the powder compact, at the time of atomizing treatment, the primary crystal Si particles (= the first Si particles) whose mean particle diameter is small to be 10 μm (microns) and the eutectic Si particles (= the second Si particles) which are not more than submicron diameters, namely, not more than 1 μm (micron) are generated. Furthermore, when Al molten metal impregnated in the powder compact is solidified, the primary crystal Si particles (= third Si particles) whose mean particle diameters are 20 to 60 μm (microns) are crystallized.

45 **[0071]** In this Second Preferred Embodiment of the present invention, when the Al-based composite material was set to be 100 %, the sum volume of the first Si particles whose mean particle diameters are 10 μm (microns) and the second Si particles which are not more than submicron diameters amounted to be about 25% by volume; and the third Si particles whose mean particle diameters are 20 to 60 μm (microns) was 2 to 3% by volume.

50 **[0072]** T7 heat treatment was conducted to the specimen (NO. 20) and adhesion resistance property was evaluated as in the same way as that in the First Preferred Embodiment. The test results are shown in Table 2. As shown in the column of "ADHESION" in Table 2, it was found that adhesion was not generated.

55

Table 2

No.	Vf(Al-Si)	Vf(Fe-Cr)	Vf(Si)	Vf(Total)	Vf(MMC)	ADHESION
20	60	0	25	25	36	NO

[0073] A large number of pores are included in the inside of the powder compact and this specimen has the structure of three-dimensional grating. If the Al molten metal is forced to be impregnated to the above-mentioned powder compact, Al molten metal is forced to be contact with a grating surface of the three-dimensional grating structure of the powder compact. Furthermore, Al molten metal gets in contact with in the inside of the powder compact three-dimensionally so that between the powder compact and the Al molten metal, area of heat-transfer surface is increased. Accordingly, the solidifying speed of Al molten metal is increased and when the primary crystal Si particles are crystallized from the Al molten metal, it is advantageous to prevent the primary crystal Si particles from growing. Therefore, it is possible to control the mean particle diameter of the third Si particles, which are crystallized from the Al molten metal impregnated in the powder compact, to be 20 to 60 μm (microns) so as to be small. Also in this sense, the parting of Al matrix by Si particles can be secured.

Third Preferred Embodiment

[0074] In a Third Preferred Embodiment, the same type of test as that of Table 1 concerning the First Preferred Embodiment was conducted except that instead of Fe-Cr powder having the composition of Fe-63wt%Cr used in the First preferred Embodiment, Fe-63wt%Mo powder (made by Fukuda Metals. Ltd., crushed powder, mean particle diameter 60 μm (microns)) was used. In this case the same tendency was obtained with regard to the adhesion resistance property. The hardness of Fe-Mo particles is about Hv1000, however, after high pressure casting and T7 treatment were conducted, it was found that the hardness of the Fe-Mo particles is decreased to be Hv600 to 750.

[0075] Also the same type of test as that of Table 1 concerning the First Preferred Embodiment was conducted, except that SUS316 short fibers (made by Aisin Seiki Co., Ltd., average length: 700 μm (microns), mean particle diameter: 100 μm (microns) as Fe alloy fine pieces was used as the substitute for Fe-Cr powder used in the First Preferred Embodiment to establish a Reference Example outside the scope of the claims. In this case, also, there was found the similar tendency of adhesion resistance property. When the SUS316 short fibers were used, molding limit was 75% by volume.

[0076] The same type of test as that of Table 1 concerning the First Preferred Embodiment was conducted, except that the mixed powder (mixed ratio is 2 : 1 in volume ratio) of Fe-Mo powder and SKD61 powder (made by Mitsubishi Steel Mfg. Co., Ltd., mean particle diameter : 60 μm (microns)) was used as the substitute for the Fe-Cr powder used in the First Preferred Embodiment. In this case, also, the similar tendency of adhesion resistance property was found.

[0077] The same type of test as that of Table 1 concerning the First preferred Embodiment was conducted, except that the mixed powder (mixed ratio is 1 : 1 in volume ratio) of Fe-Cr powder and the above-mentioned Fe-Mo powder was used as the substitute for Fe-Cr powder used in the First Preferred Embodiment. In this case, also, the similar tendency of adhesion resistance property was found.

[0078] As a Comparative Example, a specimen was molded in the same configuration as that of the First Preferred Embodiment, except that SKD61 powder (made by Mitsubishi Steel Mfg. Co., Ltd., mean particle diameter 60 μm (microns), Hv500 to 600) was independently used. The same type of test as that of the above-mentioned was conducted to the specimen concerning this Comparative Example. After the high pressure casting and T7 treatment were conducted to this Comparative Example, the hardness of SKD61 powder particles in the specimen was measured. There was found that hardness, which originally falls in a range of from Hv500 to 600, was greatly reduced to be about Hv200, so that it was found that hardness in the Comparative Example is soft compared with the hardness (more than Hv400) of the other powder particles. Accordingly, the hardness of Fe powder particles dispersed in the Al-based composite material in the state after treatments of high pressure casting and T7 treatment preferably amounts to HV250 and more .

Fourth Preferred Embodiment

[0079] In a Fourth Preferred Embodiment, Al-Si powder having the composition of Al-38wt%Si was used in 80% by volume ratio. Furthermore, the same type of test as that of the First Preferred Embodiment was conducted so as to evaluate adhesion resistance property, except that the Al_2O_3 particles (made by Showa Denko K.K., mean particle diameter 10 μm (microns)) as ceramic particles were used only in 5% by volume as the substitute for Fe-Cr powder used in the First Preferred Embodiment. Also in this case, it was found that no adhesion was generated.

[0080] The same type of test as that of the First Preferred Embodiment was conducted so as to evaluate adhesion resistance property, except that mullite particles (made by Showa Denko K.K., mean particle diameter 10 μm (microns))

as ceramic particles were used in only 5% by volume as the substitute for Fe-Cr powder used in the First Preferred Embodiment. Also in this case, it was found that no adhesion was generated.

[0081] The same type of test as that of the First Preferred Embodiment was conducted so as to evaluate adhesion property, except that SiC particles (made by Showa Denko K.K., mean particle diameter 10 μm (microns)) as ceramic particles were used only in 5% by volume as the substitute for Fe-Cr powder used in the First Preferred Embodiment. Also in this case, it was found that no adhesion was generated.

[0082] The same type of test as that of the First preferred Embodiment was conducted so as to evaluate adhesion resistance property, except that Si_3N_4 particles (made by Electric Chemical Co., Ltd., mean particle diameter 15 μm (microns)) as ceramic particles were used only in 5% by volume as the substitute for Fe-Cr powder used in the First Preferred Embodiment. Also in this case, it was found that no adhesion was generated.

[0083] Furthermore, the same type of test as that of the First Preferred Embodiment was conducted so as to evaluate adhesion property, except that $9\text{Al}_2\text{O}_3 \cdot 2\text{B}_2\text{O}_3$ particles (made by Shikoku Chemical Industry Co., Ltd., mean particle diameter 10 μm (microns)) as ceramic particles were used only in 5% by volume as the substitute for Fe-Cr powder used in the First Preferred Embodiment. Also in this case, it was found that no adhesion was generated.

[0084] Moreover, the same type of test as that of the First Preferred Embodiment was conducted so as to evaluate adhesion resistance property, except that TiC particles (made by Kyoritz Refractories Co., Ltd., mean particle diameter 10 μm (microns)) were used only in 5% by volume. Also in this case, it was found that no adhesion was generated.

[0085] The rate of the above-mentioned ceramics particles are not limited to the above-mentioned ratios, however, depending on the kinds of the Al-based composite material, the above-mentioned ceramics particles can be properly adjusted in the range of 2 to 10% by volume. The sum of Si particles, ceramics particles Fe alloy micro pieces can be adjusted in the range of from 25 to 73% by volume so as to secure adhesion resistance property.

[0086] Based on references, in general, the hardness of each of particles are mentioned as follows: the hardness of Al_2O_3 particles amount to about Hv1800; the hardness of mullite particles amount to about Hv1000; the hardness of SiC particles amount to about Hv2900; the hardness of Si_3N_4 particles amount to about Hv2300; and the hardness of TiC particles amount to about Hv1800.

Fifth Preferred Embodiment

[0087] In a Fifth Preferred Embodiment, Al-Si powder having the composition of Al-38wt%Si in which mean particle diameter varies in 3 μm , 10 μm and 15 μm . Except that Si is included only in 30% by volume, the specimen was produced under the same conditions as those of the specimen of NO. 4 in the First Preferred Embodiment; and the test was conducted so as to evaluate adhesion resistance property of that specimen. The test results are shown in Figure 4. As is understood from characteristic line X of Figure 4, when the mean particle diameter of the primary crystal Si particles is 15 μm (microns), the adhesion area thereof is not more than 9.5 mm^2 ; and when the mean particle diameter of the primary crystal Si particles is 10 μm (microns), the adhesion area thereof is not more than 7.5 mm^2 .

[0088] When the mean particle diameter of the primary crystal Si particles is relatively large to be 25 μm (microns), the adhesion area thereof generally exceeds 25 mm^2 . Accordingly, the mean particle diameter of the primary crystal Si particles is set to be not more than 20 μm (microns), the adhesion resistance property of the Al-based composite material is improved. Based on the characteristic line X of Figure 4, when the mean particle diameter of the primary crystal Si particles is not more than 10 μm (microns), it is clear that it is preferable to improve the adhesion resistance property.

(Application Example)

[0089] Figure 5 shows an application example. In this example, the present invention is applied to a piston used for a diesel engine. This piston 5 comprises: a piston body 50 having a piston head 50a and a cavity 50b; a reinforced portion 51 b which is connected to the piston head 50a side in the piston 50 and which is in ring shaped. This reinforced portion 51 is composed of the above-mentioned Al-based composite material. Namely, the Al-based composite material constituting the reinforced portion 51 is selected from the group consisting of the Al-based composite material concerning Claims 1 through 7.

[0090] Cited as an example, the Al-based composite material constituting the reinforced portion 51 comprises Al matrix including the primary crystal Si particles and the eutectic Si particles whose mean particle diameter is not more than 20 μm (microns); and when the Al-based composite material constituting the reinforced portion 51 is set to be 100%, Si particles amount to 20 to 36% by volume.

[0091] At the outer periphery portion of this reinforced portion 51, a top ring groove 52 was formed by a cutting work method by the use of a cutting tool. At the top ring groove 52, a top ring is provided and when a diesel engine is driven, that is, in the state of high temperature, a groove forming surface of the top ring groove 52 and the top ring slide each other. In this application example, adhesion resistance property at the reinforced portion 51 made of the Al-based

composite material was found to be satisfactory.

(Additional Remarks)

5 **[0092]** The following technical ideas can be seized from the above-mentioned Preferred Embodiments.

- o A sliding material which was molded in a way in which Al molten metal is impregnated, by the high pressure casting, to the powder compact which is non-sintered compact formed by Al-Si powder including the primary crystal Si particles so as to be solidified.
- 10 o An Al-based member which is equipped with a reinforced portion composed of Al-based composite material in at least one part, wherein
 the Al-based composite material comprising Al matrix including the primary crystal Si particles whose mean particle diameter is not more than 20 μm (microns) and the eutectic Si particles; and when the Al-based composite material is set to be 100%, Si particles amount to 20 to 36% by volume, and said Al-based composite material is
 15 obtained by impregnation of Al molten metal or Al alloy molten metal into pores of a powder compact having Si particles.
- o An Al-based member which is equipped with a reinforced portion composed of Al-based composite material at a part thereof at least, wherein
 the Al-based composite material is molded by one of the Al-based composite material concerning Claims 2
 20 through 7.

[0093] Having now fully described the present invention, it will be apparent to one of ordinary skill in the art that many changes and modifications can be made thereto without departing from the spirit or scope of the present invention as set forth herein including the appended claims.

25 **[0094]** An Al alloy piston comprises a piston body and a reinforced portion forming a piston groove. The reinforced portion is composed of Al-based composite material. Namely, Al molten metal (AC8A) forming the piston body was impregnated to the powder compact which is non-sintered compact so as to be solidified so that the reinforced portion was formed. The powder compact is made by compressing atomized powder having the primary crystal Si particles whose mean particle diameter is 10 μm (microns). To the powder compact Fe-Cr powder particles may be added.
 30 Accordingly, the present invention provide Al-based composite material whose adhesion resistance property is improved and the process for producing the same.

Claims

35 **1.** An Al-based composite material having adhesion resistance property, said Al-based composite material is **characterized in that** it comprises:

40 Al alloy or Al metal matrix including primary crystal Si particles whose mean particle diameter is not more than 20 μm and eutectic Si particles;

wherein the overall amount of said Si particles falls in the range of from 20 to 36 % by volume and said Al-based composite material is obtained by impregnation of Al molten metal or Al alloy molten metal into pores of a powder compact having Si particles.

45 **2.** An Al-based composite material having adhesion resistance property, said Al-based composite material is **characterized in that** it comprises:

50 Al alloy or Al metal matrix including:

first Si particles whose mean particle diameter is in the range of 3 to 10 μm; second Si particles which are made of eutectic Si and whose mean particle diameter is not more than 1 μm; and third Si particles whose mean particle diameter is in the range of 20 to 60 μm,

55 wherein the total amount of said first and second Si particles fall in the range of from 20 to 40 % by volume and the amount of said third Si particles falls in the range of from 1 to 6 % by volume, and said Al-based composite material is obtained by impregnation of Al molten metal or Al alloy molten metal into pores of a powder compact having Si particles.

3. An Al-based composite material having adhesion resistance property, said Al-based composite material is **characterized in that** it comprises:

Al alloy or Al metal matrix including primary crystal Si particles whose mean particle diameter is not more than 20 μm and eutectic Si particles; and Fe alloy micro pieces dispersed in said Al matrix having a mean particle size in the range of from 10 to 80 μm ;

wherein the total amount of said Si particles and said Fe alloy micro pieces falls in a range of from 20 to 74 % by volume and the amount of said Si particles falls in the range of from 8 to 33 % by volume.

4. An Al-based composite material having adhesion resistance property, said Al-based composite material is **characterized in that** it comprises:

Al alloy or Al metal matrix including primary crystal Si particles whose mean particle diameter is not more than 20 μm and eutectic Si particles; and Fe alloy micro pieces having a mean particle size in the range of from 10 to 80 μm ; and ceramic particles dispersed in said Al matrix having a mean particle diameter in the range of from 1 to 80 μm ;

wherein the total amount of said Si particles, said Fe alloy micro pieces and ceramic particles falls in the range of from 25 to 73% by volume; the total amount of said ceramic particles falls in the range of from 2 to 10% by volume, and the total amount of said Si particles falls in the range of from 20 to 36% by volume.

5. An Al-based composite material having adhesion resistance property according to Claim 3 or 4, wherein the hardness of Fe alloy fine pieces is not less than Hv 250.

6. An Al-based composite material having adhesion resistance property according to Claim 1, 3 or 4, wherein the mean particle diameter of primary crystal Si particles falls in the range of from 3 to 10 μm (microns).

7. A process for producing an Al-based composite material according to claim 1, said process comprising steps of:

forming a powder compact having pores by using aluminum-based alloy powder including primary Si particles whose mean particle diameter is not more than 20 μm and eutectic particles; and impregnating Al molten metal into said pores of said powder compact, wherein said Al-based composite material is prepared to include an overall amount of said Si particles in the range of from 20 to 36 % by volume.

8. A process for producing an Al-based composite material according to claim 3, said process comprising steps of:

forming a powder compact having pores by using aluminum-based alloy powder including primary Si particles whose mean particle diameter is not more than 20 μm and eutectic particles, and Fe alloy micro pieces having a mean particle size in the range of from 10 to 80 μm ; and impregnating Al molten metal into said pores of said powder compact, wherein said Al-based composite material is prepared to include a total amount of said Si particles and said Fe alloy micro pieces in the range of from 20 to 74 % by volume and to include an amount of said Si particles in the range of from 8 to 33 % by volume.

9. A process for producing an Al-based composite material according to claim 4, said process comprising steps of:

forming a powder compact having pores by using aluminum-based alloy powder including primary Si particles whose mean particle diameter is not more than 20 μm and eutectic particles, Fe alloy micro pieces having a mean particle size in the range of from 10 to 80 μm and ceramic particles having a mean particle diameter of from 1 to 80 μm ; and impregnating Al molten metal into said pores of said powder compact, wherein said Al-based composite material is prepared to include a total amount of said Si particles, said Fe alloy micro pieces and ceramic particles in the range of from 25 to 73 % by volume and to include an amount of said ceramic particles in the range of from 2 to 10 % by volume.

Patentansprüche

1. Adhäsionwiderstandsfähiges Verbundmaterial auf Aluminiumbasis, wobei das Verbundmaterial auf Aluminiumbasis **dadurch gekennzeichnet ist, dass** es folgendes umfasst:

Al-Legierung oder Al-Metallmatrix, die Primärkristall-Siliziumteilchen, deren durchschnittlicher Teilchendurchmesser nicht mehr als 20 µm beträgt, und eutektische Siliziumteilchen einschließt,

wobei die Gesamtmenge an Siliziumteilchen in dem Bereich von 20 bis 36 Vol.-% liegt und das Verbundmaterial auf Aluminiumbasis durch Imprägnieren von Al-Metallschmelze oder Al-Legierungsmetallschmelze in Poren eines Pulverpresslings mit Siliziumteilchen erhalten wird.

2. Adhäsionwiderstandsfähiges Verbundmaterial auf Aluminiumbasis, wobei das Verbundmaterial auf Aluminiumbasis **dadurch gekennzeichnet ist, dass** es folgendes umfasst:

Al-Legierung oder Al-Metallmatrix, die folgendes einschließt:

erste Siliziumteilchen, deren durchschnittlicher Teilchendurchmesser im Bereich von 3 bis 10 µm liegt, zweite aus eutektischem Silizium hergestellte Siliziumteilchen, deren durchschnittlicher Teilchendurchmesser nicht mehr als 1 µm beträgt, und dritte Siliziumteilchen, deren durchschnittlicher Teilchendurchmesser in dem Bereich von 20 bis 60 µm liegt,

wobei die Gesamtmenge der ersten und zweiten Siliziumteilchen in dem Bereich von 20 bis 40 Vol.-% und die Menge der dritten Siliziumteilchen in dem Bereich von 1 bis 6 Vol.-% liegt und das Verbundmaterial auf Aluminiumbasis durch Imprägnieren von Al-Metallschmelze oder Al-Legierungsmetallschmelze in Poren eines Pulverpresslings mit Siliziumteilchen erhalten wird.

3. Adhäsionwiderstandsfähiges Verbundmaterial auf Aluminiumbasis, wobei das Verbundmaterial auf Aluminiumbasis **dadurch gekennzeichnet ist, dass** es folgendes umfasst:

Al-Legierung oder Al-Metallmatrix, die Primärkristall-Siliziumteilchen, deren durchschnittlicher Teilchendurchmesser nicht mehr als 20 µm beträgt, und eutektische Siliziumteilchen einschließt und; In der Al-Matrix dispergierte Fe-Legierung-Mikrostücke mit einer durchschnittlichen Teilchengröße im Bereich von 10 bis 80 µm;

wobei die Gesamtmenge der Siliziumteilchen und der Fe-Legierung-Mikrostücke in dem Bereich von 20 bis 74 Vol.-% liegen und die Menge der Siliziumteilchen in dem Bereich von 8 bis 33 Vol.-% liegt.

4. Adhäsionwiderstandsfähiges Verbundmaterial auf Aluminiumbasis, wobei das Verbundmaterial auf Aluminiumbasis **dadurch gekennzeichnet ist, dass** es folgendes umfasst:

Al-Legierung oder Al-Metallmatrix, die Primärkristall-Siliziumteilchen, deren durchschnittlicher Teilchendurchmesser nicht mehr als 20 µm beträgt, und eutektische Siliziumteilchen einschließt, und Fe-Legierung-Mikrostücke mit einer durchschnittlichen Teilchengröße in dem Bereich von 10 bis 80 µm; und in der Al-Matrix dispergierte Keramikeilchen mit einem durchschnittlichen Teilchendurchmesser in dem Bereich von 1 bis 80 µm;

wobei die Gesamtmenge der Siliziumteilchen, der Fe-Legierung-Mikrostücke und der Keramikeilchen in dem Bereich von 25 bis 73 Vol.-% liegen, die Gesamtmenge an Keramikeilchen in dem Bereich von 2 bis 10 Vol.-% liegt und die Gesamtmenge an Siliziumteilchen in dem Bereich von 20 bis 36 Vol.-% liegt.

5. Adhäsionwiderstandsfähiges Verbundmaterial auf Aluminiumbasis nach Anspruch 3 oder 4, wobei die Härte der Fe-Legierung-Feinstücke nicht weniger als Hv 250 beträgt.

6. Adhäsionwiderstandsfähiges Verbundmaterial auf Aluminiumbasis nach Anspruch 1, 3 oder 4, wobei der durchschnittliche Teilchendurchmesser der Primärkristall-Siliziumteilchen in dem Bereich von 3 bis 10 µm (Mikrons) liegt.

7. Verfahren zur Herstellung eines Verbundmaterials auf Aluminiumbasis nach Anspruch 1, wobei das Verfahren

folgende Schritte umfasst:

Ausbilden eines Pulverpresslings mit Poren durch Verwendung von Legierungspulver auf Aluminiumbasis, das Primär-Siliziumteilchen mit einem durchschnittlichen Teilchendurchmesser von nicht mehr als 20 µm und eutektische Teilchen einschließt, und Imprägnieren von Al-Metallschmelze in die Poren des Pulverpresslings, wobei das Verbundmaterial auf Aluminiumbasis hergestellt wird, um eine Gesamtmenge an Siliziumteilchen in dem Bereich von 20 bis 36 Vol.-% einzuschließen.

8. Verfahren zur Herstellung eines Verbundmaterials auf Aluminiumbasis nach Anspruch 3, wobei das Verfahren folgende Schritte umfasst:

Ausbilden eines Pulverpresslings mit Poren unter Verwendung von Legierungspulver auf Aluminiumbasis, das Primär-Siliziumteilchen mit einem durchschnittlichen Teilchendurchmesser von nicht mehr als 20 µm und eutektische Teilchen, und Fe-Legierung-Mikrostücke mit einer durchschnittlichen Teilchengröße in dem Bereich von 10 bis 80 µm einschließt, und Imprägnieren der Al-Metallschmelze in die Poren des Pulverpresslings, wobei das Verbundmaterial auf Aluminiumbasis hergestellt wird, um eine Gesamtmenge an Siliziumteilchen und Fe-Legierung-Mikrostücke in dem Bereich von 20 bis 74 Vol.-% einzuschließen und um eine Menge der Siliziumteilchen in dem Bereich von 8 bis 33 Vol.-% einzuschließen.

9. Verfahren zur Herstellung eines Verbundmaterials auf Aluminiumbasis nach Anspruch 4, wobei das Verfahren folgende Schritte umfasst:

Ausbilden eines Pulverpresslings mit Poren durch Verwendung von Legierungspulver auf Aluminiumbasis, das Primär-Siliziumteilchen mit einem durchschnittlichen Teilchendurchmesser von nicht mehr als 20 µm und eutektische Teilchen, Fe-Legierung-Mikrostücke mit einer durchschnittlichen Teilchengröße in dem Bereich von 10 bis 80 µm und Keramikteilchen mit einem durchschnittlichen Teilchendurchmesser von 1 bis 80 µm einschließt, und Imprägnieren der Al-Metallschmelze in die Poren des Pulverpresslings, wobei das Verbundmaterial auf Aluminiumbasis hergestellt wird, um eine Gesamtmenge an Siliziumteilchen, an Fe-Legierung-Mikrostücke und Keramikteilchen in dem Bereich von 25 bis 73 Vol.-% einzuschließen und um eine Menge an Keramikteilchen in dem Bereich von 2 bis 10 Vol.-% einzuschließen.

Revendications

1. Un matériau composite à base d'Al doté d'une propriété de résistance à l'adhésion, ledit matériau composite à base d'Al étant **caractérisé en ce qu'il** comprend une matrice en Al, sous forme métal ou en alliage d'Al comprenant des particules de cristaux primaires de Si dont le diamètre particulaire moyen n'excède pas 20 µm et des particules de Si eutectique ; dans lequel la quantité totale des particules se situe dans une fourchette allant de 20 à 36 % en volume et ledit matériau composite à base d'Al est obtenu par imprégnation d'un alliage d'Al fondu sous forme métal ou d'un alliage d'Al fondu sous forme métal dans des pores d'un comprimé de poudre ayant des particules de Si.

2. Un matériau composite à base d'Al ayant des propriétés de résistance à l'adhésion, ledit matériau composite à base d'Al étant **caractérisé en ce qu'il** comprend une matrice en Al, sous forme métal, ou en alliage d'Al comprenant :

- des premières particules de Si dont le diamètre particulaire moyen est dans une fourchette de 3 à 10 µm,
- des deuxièmes particules de Si qui sont faites de Si eutectique et dont le diamètre particulaire moyen est inférieur à 1 µm, et
- des troisièmes particules de Si dont le diamètre particulaire moyen est dans une fourchette de 20 à 60 µm,

dans lequel le montant total desdites premières et deuxièmes particules de Si tourne dans la fourchette de 20 à 40 % en volume et le montant des troisièmes particules de Si est dans la fourchette de 1 à 6 % en volume, et ledit matériau composite à base d'Al est obtenu par imprégnation d'Al fondu sous forme métal ou d'un alliage d'Al fondu sous forme métal dans des pores d'un comprimé de poudre ayant des particules de Si.

3. Un matériau composite à base d'Al doté d'une propriété de résistance à l'adhésion, ledit matériau composite à base d'Al étant **caractérisé en ce qu'**il comprend :

5 une matrice en Al, sous forme métal ou en alliage d'Al comprenant des particules de cristaux primaires de Si dont le diamètre particulaire moyen n'excède pas 20 µm et des particules de Si eutectique ; et des microfragments d'alliage de Fe dispersés dans ladite matrice en Al ayant un diamètre particulaire moyen allant de 10 à 80 µm, et **en ce que** la quantité totale des particules de Si et des microfragments d'alliage de Fe se situe dans une fourchette allant de 20 à 74 % en volume et la quantité totale desdites particules de Si se situe dans une fourchette allant de 8 à 33 % en volume.

4. Un matériau composite à base d'Al doté d'une propriété de résistance à l'adhésion, ledit matériau composite à base d'Al étant **caractérisé en ce qu'**il comprend :

15 une matrice en Al, sous forme métal, ou en alliage d'Al comprenant des particules de cristaux primaires de Si dont le diamètre particulaire moyen n'excède pas 20 µm et des particules de Si eutectique ; des microfragments d'alliage de Fe ayant un diamètre particulaire moyen allant de 10 à 80 µm et des particules de céramique ayant un diamètre particulaire moyen allant de 1 à 80 µm, dispersées dans la matrice d'Al, et **en ce que** la quantité totale desdites particules de Si desdits microfragments d'alliage de Fe et desdites particules de céramique se situe dans une fourchette allant de 25 à 73 % en volume ; la quantité totale desdites particules de céramique se situe dans une fourchette allant de 2 à 10 % en volume et la quantité totale desdites particules de Si se situe dans une fourchette allant de 20 à 36 % en volume.

5. Un matériau composite à base d'Al doté d'une propriété de résistance à l'adhésion selon la revendication 3 ou 4, dans lequel la dureté des microfragments de l'alliage de Fe n'est pas inférieure à 250 Hv.

6. Un matériau composite à base d'Al doté d'une propriété de résistance à l'adhésion selon la revendication 1, 3 ou 4, dans lequel le diamètre particulaire moyen des particules de cristaux primaires de Si se situe dans la fourchette allant de 3 à 10 µm (microns)

7. Un procédé de fabrication d'un matériau composite à base d'Al selon la revendication 1, ledit procédé comprenant les étapes consistant à :

35 former un comprimé de poudre ayant des pores en utilisant la poudre d'alliage à base d'aluminium comprenant des particules de Si primaires dont le diamètre particulaire moyen n'excède pas 20 µm et des particules eutectiques ; et imprégner d'Al fondu, sous forme métal, lesdits pores dudit comprimé de poudre, ledit matériau composite à base d'Al étant préparé pour inclure une quantité totale desdites particules de Si dans une fourchette allant de 20 à 36 % en volume.

8. Un procédé de fabrication d'un matériau composite à base d'Al selon la revendication 3, ledit procédé comprenant les étapes consistant à :

45 former un comprimé de poudre ayant des pores en utilisant la poudre d'alliage à base d'aluminium comprenant des particules de Si primaires dont le diamètre particulaire moyen n'excède pas 20 µm et des particules eutectiques, et des microfragments d'alliage de Fe ayant un diamètre particulaire moyen allant de 10 à 80 µm, imprégner d'Al fondu, sous forme métal, lesdits pores dudit comprimé de poudre, ledit matériau composite à base d'Al étant préparé pour inclure une quantité totale desdites particules de Si et des microfragments d'alliage de Fe dans une fourchette allant de 20 à 74 % en volume et pour inclure une quantité totale desdites particules de Si dans une fourchette allant de 8 à 33 % en volume.

9. Un procédé de fabrication d'un matériau composite à base d'Al selon la revendication 4, ledit procédé comprenant les étapes consistant à :

55 former un comprimé de poudre ayant des pores en utilisant la poudre d'alliage à base d'aluminium comprenant des particules de Si primaires dont le diamètre particulaire moyen n'excède pas 20 µm et des particules eutectiques, et des microfragments d'alliage de Fe ayant un diamètre particulaire moyen allant de 10 à 80 µm et des particules de céramique ayant un diamètre particulaire moyen allant de 1 à 80 µm,

EP 0 747 494 B2

imprégner d'Al fondu, sous forme métal, lesdits pores dudit comprimé de poudre,

5 dans lequel ledit matériau composite à base d'Al est préparé pour inclure une quantité totale desdites particules de Si et des microfragments d'alliage de Fe et de particules de céramique dans une fourchette allant de 25 à 73 % en volume et pour inclure une quantité totale desdites particules de céramique dans une fourchette allant de 2 à 10 % en volume.

10

15

20

25

30

35

40

45

50

55

FIG . 1

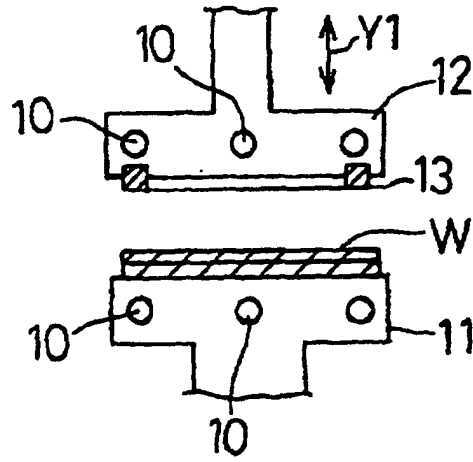


FIG . 2



FIG . 3

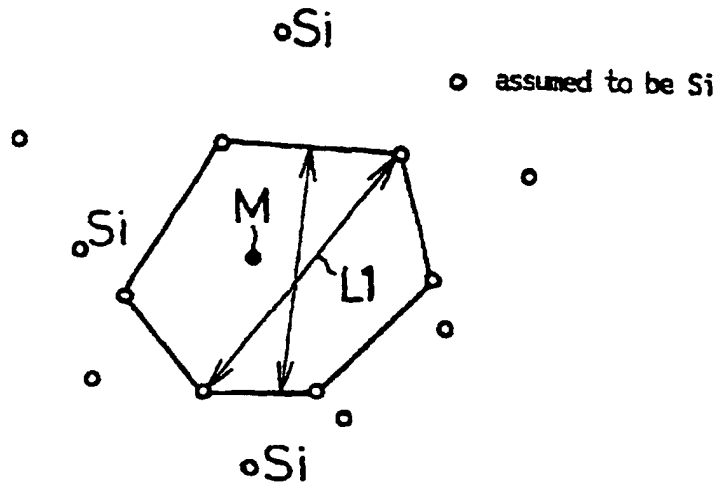


FIG . 4

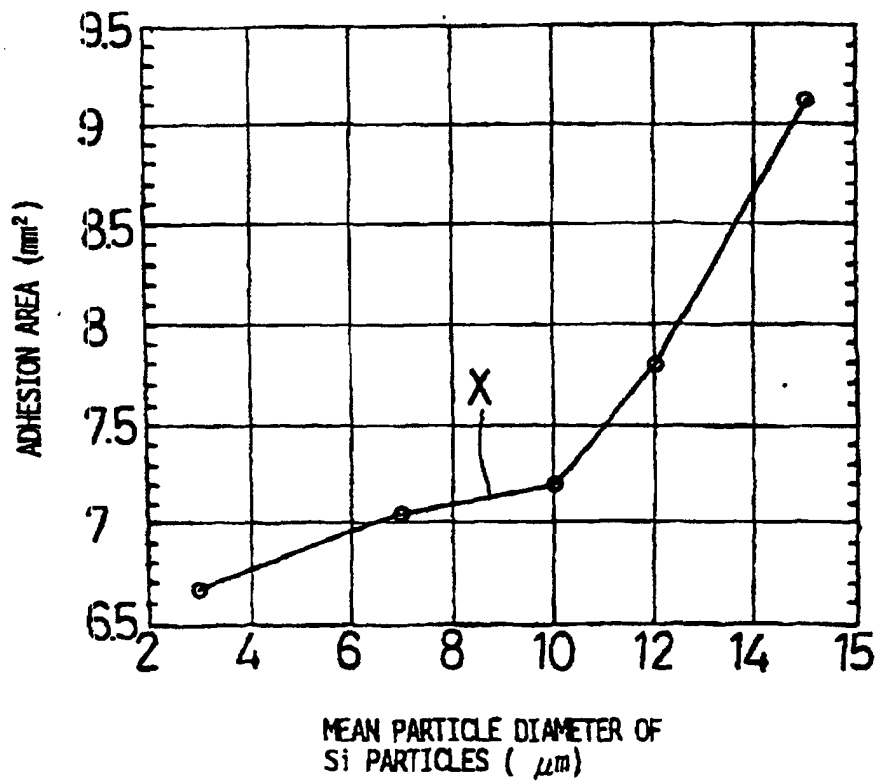


FIG. 5

