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420/546(22) PCT Filed: **Mar. 3, 2011**(57) **ABSTRACT**(86) PCT No.: **PCT/JP2011/054912**

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An aluminum alloy bearing includes dispersed Si particles amounting to 1.0 to 10.0 weight % of Si. In such aluminum alloy bearing, relative diffraction intensity of (111) plane of the Si particles is equal to or greater than 0.6.

TEST CONDITIONS	
WEAR TEST	
TESTING INSTRUMENT	WEAR TESTER
ROTATION SPEED	1500 rpm
TEST LOAD	20 MPa
TEST TIME	15 HOURS
	START 60 sec STOP 30 sec
LUBRICANT SUPPLY	1.5 ml/min
LUBRICANT	VG22
SHAFT MATERIAL	S55C
METHOD OF EVALUATION	MEASUREMENT OF WEAR AMOUNT

FIG. 1

TEST CONDITIONS	
SEIZURE TEST	
TESTING INSTRUMENT	SEIZURE TESTER
ROTATION SPEED	8200 rpm
TEST LOAD	INCREMENT BY 10MPa EVERY 10 MINUTES
LUBRICANT SUPPLY TEMPERATURE	100°C
LUBRICANT SUPPLY	75 ml/min
LUBRICANT	VG22
SHAFT MATERIAL	S55C
METHOD OF EVALUATION	SEIZURE LOAD IS DETERMINED WHEN: · TEMPERATURE OF BEARING BACK EXCEEDS 200 °C OR · SHAFT DRIVING BELT SLIPS BY TORQUE CHANGE

FIG.2

	RELATIVE DIFFRACTION INTENSITY OF (111) OF Si PARTICLE	RATE Dr OF DIFFRACTION INTENSITY	COMPONENT (mass%)					
			Al	Si	Sn	Cu	Mn	Zr
EXAMPLE 1	0.76	1.19	BALANCE	7.0	6.5	1.4		
EXAMPLE 2	0.75	1.15	BALANCE	6.0	5.5		0.1	
EXAMPLE 3	0.73	1.11	BALANCE	7.0	6.5			0.1
EXAMPLE 4	0.71	1.00	BALANCE	6.0	6.5	1.4		0.2
EXAMPLE 5	0.64	1.05	BALANCE	5.0	5.5		0.2	
EXAMPLE 6	0.62	1.19	BALANCE	4.0	6.0	1.2		0.1
EXAMPLE 7	0.62	1.21	BALANCE	4.0	6.0	1.2		0.1
COMPARATIVE EXAMPLE 1	0.53	1.03	BALANCE	4.0	6.0	1.2		0.1

MAXIMUM SPECIFIC LOAD WITHOUT SEIZURE (MPa)	WEAR AMOUNT (m)
110	9
100	9
100	11
110	10
100	12
100	14
90	14
70	18

FIG. 3

ALUMINUM ALLOY BEARING

TECHNICAL FIELD

[0001] The present invention relates to an aluminum alloy bearing with wear resistance and outstanding seizure resistance and to an aluminum alloy bearing which is suitable for engine bearings in internal combustion engine applications.

BACKGROUND

[0002] Wear resistance and seizure resistance have been required in engine bearings used in internal combustion engines. An aluminum alloy bearing configured by a metal backing, an aluminum bearing alloy layer, and an intermediate layer provided between them have been employed for meeting such requirements. Example of such aluminum bearing alloy layer is proposed in patent document 1 which teaches an aluminum alloy bearing (Al-Sn-Si bearing alloy) containing Si particles such that small Si particles and large Si particles are mixed in an suitable ratio to achieve improvement in both wear resistance and fatigue resistance.

RELATED ART

Patent Document

[0003] Patent Document 1: JP 2003-119530 A

SUMMARY OF THE INVENTION

Problems to be Overcome

[0004] Patent document 1 teaches improving fatigue resistance and wear resistance through the size of Si particles. In today's rigorous usage environment, bearings frequently suffer deformation typically originating from assembly misalignment and degraded housing strength which results from attempts to produce lighter and more compact housings. Deformed bearings are subjected to more frequent contact with the countershaft and thus, produce more heat. The heat may degrade the strength of the bearing material, which may lead to crack formation and consequently oil film ruptures, which in turn may cause seizures.

[0005] The present invention is based on the above described background and one object of the present invention is to provide an aluminum alloy bearing with good seizure resistance by preventing oil film ruptures originating from cracks formed by degraded material strength.

Means to Overcome the Problem

[0006] In one embodiment, an aluminum alloy bearing comprises dispersed Si particles amounting to 1.0 to 10.0 weight % of Si wherein a relative diffraction intensity of (111) plane of the Si particles is equal to or greater than 0.6 in order to achieve the above described objectives.

[0007] In one embodiment, the aluminum alloy bearing further includes a bearing surface, and a bearing interior portion located at a portion deeper in a thickness direction than the bearing surface, wherein ratio Dr of a diffraction intensity of (111) plane of the Si particles in the bearing surface to a diffraction intensity of (111) plane of the Si particles in the bearing interior portion is $0.8 \leq Dr \leq 1.2$.

[0008] In one embodiment, the aluminum alloy bearing according to either of foregoing embodiments includes one or more of:

[0009] (a) one or more elements selected from the group of Cu, Zn, and Mg amounting to a total of 0.1 to 7.0 weight %;

[0010] (b) one or more of Mn, V, Mo, Cr, Co, Fe, Ni, and W amounting to a total of 0.01 to 3.0 weight %, and

[0011] (c) one or more elements selected from the group of B, Ti, and Zr amounting to a total of 0.01 to 2.0 weight %.

Effect of the Invention

[0012] According to one embodiment, good seizure resistance was obtained by configuring the relative diffraction intensity of (111) plane of the Si particles representing the crystal orientation of the Si particles in Miller indices to 0.6 or greater. One solution to prevent seizures while obtaining wear resistance is avoiding oil film ruptures caused by cracks formed by degradation in material strength. The degradation in material strength may be prevented through reduced friction coefficient and consequently reduced friction heat. Thus, the crystal orientation of the Si particles was optimized, more specifically, the relative diffraction intensity of (111) plane of the Si particles was increased to reduce the friction coefficient and consequently the heat produced by the friction caused by the contact between the Si particles and the countershaft. As a result, crack formation originating from degraded material strength is prevented to prevent oil film ruptures, which in turn improve the seizure resistance.

[0013] The relative diffraction intensity of (111) plane of Si particles is given by:

[0014] relative diffraction density of (111) plane = $P1 / (P1 + P2 + P3 + P4)$

where,

[0015] $P1$ = Peak X-ray diffraction intensity of (111) plane;

[0016] $P2$ = Peak X-ray diffraction intensity of (220) plane;

[0017] $P3$ = Peak X-ray diffraction intensity of (311) plane; and

[0018] $P4$ = Peak X-ray diffraction intensity of (331) plane.

Other peak intensities such as (400) plane, (511) plane, and (440) plane exhibit low intensities that overlap with the background, and thus, are not considered since they contain large margins of error.

[0019] When the aluminum alloy containing dispersed Si particles is rolled, stress is applied to the Si particles dispersed in the Al matrix. The inventors utilized this fact to arrive at the manufacturing process flow which is later described. For example, the inventors have conceived of a method of configuring the relative diffraction intensity of the (111) plane of the Si particle to 0.6 or greater by producing an initial billet by continuous casting in which the size of the crystal grains of the Al matrix ranges between 30 to 50 μm and rolling the billet so that the crystal grains are destroyed. Any known methods other than continuous casting may be employed as long as the size of the crystal grains ranging between 30 to 50 μm can be obtained. The destruction of the crystal grains is defined as a state in which the crystal grain boundaries are excessively dense and hence cannot be distinguished from one another in the cross sectional sample of the microstructure obtained by etching.

[0020] The Si particles have a cleavage face on their (111) plane. Thus, when stress is applied to the Si particles by the rolling, (111) plane of Si is presumed to increase with effi-

ciency. Because the Si particles are inherently very hard, exhibiting a hardness of approximately 1000 HV, and the roughness of the cleavage face is sufficiently smooth as compared to the surface roughness of the finished product, friction coefficient is reduced to consequently reduce the friction heat, thereby preventing crack formation originating from degraded material strength, which in turn prevents oil film ruptures.

[0021] When the relative diffraction intensity of (111) plane of the Si particles is less than 0.6, the magnitude of reduction of the friction heat is significantly small, though the lapping of the countershaft and improvement of wear resistance exerted by the Si particle containing aluminum bearing alloy taught in patent document 1 can be achieved.

[0022] Further, according to one embodiment, the ratio Dr of the diffraction intensity of (111) plane of the Si particles in the bearing surface to the diffraction intensity of (111) plane of the Si particles in the bearing interior portion is configured to range between $0.8 \leq \text{Dr} \leq 1.2$.

[0023] The aluminum alloy bearing is repeatedly deformed through continuous use. In the presence of a large difference in internal stress between the bearing surface and the bearing interior portion, a large relative internal stress is produced between the two, causing a concentration of strain energy. When additional strain energy produced by deformation is further added to exceed the tolerable limit of the aluminum alloy bearing, it may cause formation of cracks in the aluminum alloy bearing. In contrast, by rolling the aluminum alloy bearing such that variation in the length taken along the direction orthogonal to the thickness direction is minimized, the difference of internal stress between the bearing surface and the bearing internal portion can be reduced.

[0024] That is, crack formation can be avoided to improve seizure resistance by rolling the aluminum alloy bearing such that the difference in the amount of dimensional variance between the bearing surface and the bearing interior portion is minimized. From the perspective of bearing performance, the bearing interior portion is preferably located relatively closer to the sliding surface contacting the counter element than to the thicknesswise center of the aluminum alloy bearing such that the dimensional variance between the bearing surface and the bearing interior portion is minimized especially in the portion relatively closer to the sliding surface. The bearing interior portion may be located substantially at the thicknesswise center of the aluminum alloy bearing. When rolled to a state exhibiting minimum dimensional variance, ratio Dr of the diffraction intensity of (111) plane of the Si particles in the bearing surface to the diffraction intensity of (111) plane of the Si particles in the bearing interior portion approximates 1. When ratio Dr of the diffraction intensities ranges between $0.8 \leq \text{Dr} \leq 1.2$, it is an indication that the aluminum alloy bearing has been rolled to a state exhibiting small dimensional variance, meaning that the difference of internal stress between the bearing surface and the bearing interior portion is minimized. Thus, tolerance to seizures, in other words, seizure resistance can be improved by controlling ratio Dr of the diffraction intensities.

[0025] Aluminum alloy bearing may be laminated with steel backing and in some cases with other elements in order to exert high bearing performance. When the aluminum alloy bearing is made of such composite material, the later described manufacturing method is particularly effective.

[0026] In order to control ratio Dr of the diffraction intensities, differential speed rolling may be employed in which

the upper working roll and the lower working roll are spun at different speeds. The friction coefficient may be controlled in the rolling through adjustments in the surface roughness of the bearing material or the working rolls. Internal stress applied to the aluminum alloy bearing can be controlled through control of dimensional variance which is carried out, for example, by differential speed rolling and by adjustments in the surface roughness. Thus, the rolling not only allows appropriate stress to be applied to the Si particles, but also allows the difference of internal stress between the bearing surface and the bearing interior portion of the aluminum alloy bearing to be minimized.

[0027] Further, according to one embodiment, the strength and heat resistivity of the Al matrix may be improved by selectively incorporating the various types of the aforementioned metallic elements grouped by (a), (b), and (c).

BRIEF DESCRIPTION OF THE DRAWINGS

[0028] FIG. 1 A chart indicating the wear test conditions.

[0029] FIG. 2 A chart indicating the seizure test conditions.

[0030] FIG. 3 A chart indicating the test results of EXAMPLES and COMPARATIVE EXAMPLE.

EMBODIMENTS OF THE INVENTION

[0031] Aluminum alloy bearing 1 of the present invention is manufactured as follows. First, an initial billet was formed by a continuous caster such that the size of the crystal grains within the Al matrix measured 30 to 50 μm . Then, the billet is rolled repeatedly to a predetermined thickness with an elongation of $\times 2$ to $\times 8$ and the crystal grains are destroyed at least once to obtain an aluminum bearing alloy sheet. In the rolling step, the upper and the lower working rolls are spun at different speeds, such that the lower working roll is spun faster by 2% compared to the upper working roll. Alternatively or additionally, the surface of the starting material is coarsened to increase the friction coefficient during the rolling to reduce the difference in the internal stress between the material surface and the predetermined location of the material interior while increasing the internal stress applied to the aluminum bearing alloy sheet. As a result, greater amount of internal strain can be given to the aluminum bearing alloy sheet to allow the crystal grains to be destroyed with greater efficiency. Annealing may be carried out during the rolling to eliminate strains for suppressing breakage.

[0032] Then, aluminum bearing alloy sheet 1 rolled to a predetermined thickness was roll bonded with a steel backing to obtain a bimetal. An aluminum sheet serving as a bonding layer may be inserted between the aluminum bearing alloy sheet and the steel backing in the roll bonding. Then, annealing was carried out after the roll bonding for bonding enhancement and eliminating strain. If required, heat treatments such as a solution heat treatment may be carried out to strengthen the aluminum bearing alloy sheet. The bimetal may be further rolled. Then, the obtained bimetal is machined into a semi-cylindrical form to obtain a semi-cylindrical bearing.

[0033] The produced semi-cylindrical bearing was measured for the peak strength of Si particles through X-ray diffraction. The semi-cylindrical bearing was further screened through wear and seizure tests. The conditions employed in the wear test are indicated in FIG. 1 and the conditions employed in the seizure test are indicated in FIG. 2. The wear test executes the start and stop cycle to drive a

frequent contact with the countershaft and obtain a measurement of wear amount (μm) for evaluation of wear resistance. The seizure test applies load on the inner surface of the bearing and the maximum specific load (MPa) tolerable without seizing within the predetermined test time was obtained for evaluation of seizure resistance.

[0034] As the result of the above described wear test and the seizure test carried out by the applicant, it was verified that a semi-cylindrical slide bearing in which the relative diffraction intensity of (111) plane of the Si particles was equal to or greater than 0.6 possessed sufficiently satisfactory wear resistance and seizure resistance. It was further verified that a semi-cylindrical slide bearing having the aforementioned ratio Dr ranging between $0.8 \leq Dr \leq 1.2$ also possessed sufficiently satisfactory wear resistance and seizure resistance. It was also verified that a semi-cylindrical slide bearing selectively containing the aforementioned metallic elements grouped by (a), (b), and (c) also possessed sufficiently satisfactory wear resistance and seizure resistance.

[0035] In contrast, it was verified that among the semi-cylindrical slide bearings in which the relative diffraction intensity of (111) plane of the Si particles were less than 0.6, some possessed satisfactory wear resistance but all possessed inferior seizure resistance. The results of evaluation will be explained based on FIG. 3.

[0036] EXAMPLES 1 to 7 were prepared as described above. COMPARATIVE EXAMPLE 1 was prepared in a similar manner with the exception of, but not limited to, the conventional rolling step which does not destroy the crystal grains.

[0037] First, EXAMPLE 7 is compared with COMPARATIVE EXAMPLE 1 to consider the impact of the relative diffraction intensity of (111) plane of the Si particles on wear resistance and seizure resistance. In EXAMPLE 7, the relative diffraction intensity of (111) plane of the Si particles was 0.62. EXAMPLE 7 further showed wear amount of $14 \mu\text{m}$ and the maximum specific load without seizing was 90 MPa. In contrast, in COMPARATIVE EXAMPLE 1, the relative diffraction intensity of (111) plane of the Si particles was 0.53. The relative diffraction intensity of (111) plane of the Si particles of an ordinary sample is 0.51 and is closer to the relative diffraction intensity of COMPARATIVE EXAMPLE 1. COMPARATIVE EXAMPLE 1 further showed wear amount of $18 \mu\text{m}$ and the maximum specific load without seizing was 70 MPa. It can be understood from the comparison of EXAMPLE 7 and COMPARATIVE EXAMPLE 1 that when the relative diffraction intensity of (111) plane of the Si particles is equal to or greater than 0.6 with errors considered, the wear resistance as well as the seizure resistance are improved. As described above, it was verified that EXAMPLES 1 to 7 in which the relative diffraction intensity of (111) plane of the Si particles is equal to or greater than 0.6 exhibited improvement in wear resistance and seizure resistance as compared to COMPARATIVE EXAMPLE 1.

[0038] It was further verified that the relative diffraction intensity of (111) plane of the Si particles being equal to or greater than 0.7 was preferable especially for improving wear resistance.

[0039] Next, EXAMPLES 6 and 7 were compared to consider the impact of ratio Dr of the diffraction intensities on seizure resistance. In EXAMPLE 6, ratio Dr of a diffraction intensity of (111) plane of the Si particles in the bearing surface to a diffraction intensity of (111) plane of the Si particles in the bearing interior portion was $Dr=1.19$. In EXAMPLE 6, the maximum specific load without seizing was 100 MPa. In contrast, in EXAMPLE 7, ratio Dr of a diffraction intensity of (111) plane of the Si particles in the bearing surface to a diffraction intensity of (111) plane of the Si particles in the bearing interior portion was $Dr=1.21$. In EXAMPLE 7, the maximum specific load without seizing was 90

MPa. It can be understood from the comparison of EXAMPLE 6 and EXAMPLE 7 that seizure resistance is improved when ratio Dr is equal to or less than 1.2.

[0041] In FIG. 3, ratio Dr of diffraction intensity is calculated by $Dr = \text{diffraction intensity of (111) plane of the Si particles in the bearing surface} / \text{diffraction intensity of (111) plane of the Si particles in the bearing interior portion}$.

[0042] It was thus verified that by defining ratio Dr of the diffraction intensities to range between $0.8 \leq Dr \leq 1.2$, seizure resistance was improved. It can be further verified from FIG. 3 that Dr is preferably equal or greater than 1.00 and equal to or less than 1.19.

[0043] Further, the strength and the heat resistivity of the Al matrix can be improved by incorporating various types of metallic elements.

1. An aluminum alloy bearing comprising:
 - dispersed Si particles amounting to 1.0 to 10.0 weight % of Si, wherein a relative diffraction intensity of (111) plane of the Si particles is equal to or greater than 0.6.
2. The aluminum alloy bearing according to claim 1, further comprising a bearing surface, and a bearing interior portion located at a portion deeper in a thickness direction than the bearing surface, wherein ratio Dr of a diffraction intensity of (111) plane of the Si particles in the bearing surface to a diffraction intensity of (111) plane of the Si particles in the bearing interior portion is $0.8 \leq Dr \leq 1.2$.
3. The aluminum alloy bearing according to claim 1 including one or more of:
 - (a) one or more elements selected from the group of Cu, Zn, and Mg amounting to a total of 0.1 to 7.0 weight %,
 - (b) one or more of Mn, V, Mo, Cr, Co, Fe, Ni, and W amounting to a total of 0.01 to 3.0 weight %, and
 - (c) one or more elements selected from the group of B, Ti, and Zr amounting to a total of 0.01 to 2.0 weight %.
4. The aluminum alloy bearing according to claim 2 including one or more of:
 - (a) one or more elements selected from the group of Cu, Zn, and Mg amounting to a total of 0.1 to 7.0 weight %,
 - (b) one or more of Mn, V, Mo, Cr, Co, Fe, Ni, and W amounting to a total of 0.01 to 3.0 weight %, and
 - (c) one or more elements selected from the group of B, Ti, and Zr amounting to a total of 0.01 to 2.0 weight %.

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