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Aluminium alloy matrix composite for internal combustion engines.

(57)

An aluminium alloy matrix composite for internal combustion engine is disclosed, which is strengthened by porous metal 3 containing chromium, and oil pockets 12, 13, 14, 22, 23 are formed on the exposed surface 11 by lapping or etching, thereby improving wear resistance and lubricancy.

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ALUMINUM ALLOY MATRIX COMPOSITE FOR INTERNAL COMBUSTION ENGINES

The present invention relates to an aluminum alloy matrix composite for internal combustion engines, comprising a porous metal composed with an aluminum alloy, which is suitable to be used for sliding portions in internal combustion engines.

A cylinder block made of an aluminum alloy for internal combustion engines has many advantages such that the weight of the engine can be reduced remarkably as compared with a cylinder block, for example, made of cast iron, it has good heat dissipation, and noises can be decreased by reducing a gap between the cylinder block and a piston made of aluminum alloy. Accordingly, use of cylinder blocks made of aluminum alloy have been increased more and more.

A bore in a cylinder made of an aluminum alloy in which a piston is reciprocated has been strengthened to improve of the wear resistance, generally, by the following three methods:

- (1) improvement for the aluminum alloy itself,
- (2) surface treatment applied to the bore of the cylinder,
- (3) composite strengthening for the aluminum alloy with ceramic fibers or particles.

However, each of the foregoing methods involve the following drawbacks.

A typical example for (1) above is an aluminum alloy A390 of high Si content available from Reynolds Co., which is widely used mainly in Europe. In this alloy, the wear resistance is improved by floating hard primary crystals of Si particles, but the high Si aluminum alloy has poor castability and poor machinability, which leads to increase the production cost.

Further, there has also been proposed an alloy comprising aluminum alloy and graphite particles dispensed therein for the improvement of the lubricancy. Since the mechanical strength is reduced in this alloy due to mixing of graphite, it has been studied for the practical application of the alloy to use it only as a liner in the cylinder bore. The alloy is produced by a casting method or an extrusion method. In the casting method, since the surface of the graphite particles is treated by Ni plating or the like in advance in order to suppress the reaction between graphite and a molten aluminum alloy during casting, it increases the production cost. It is often difficult for the method to perform casting with uniform dispersion of the graphite particles. In the extrusion method, an aluminum powder and a graphite powder are extruded and sintered, but this method has not yet been put to practical use since it involves a problem that the graphite is extended in the extruding direction to deteriorate the wear resistance.

The surface treatment as described in (2) above includes Cr plating, or Ni dispersion plating in which hard fine particles such as SiC or TiB are dispensed in Ni plating. It is often used for cylinders made of aluminum alloy in 2-cycle engines. However, when applying the surface treatment to a large cylinder block such as in 4-cycle gasoline engines, the cylinder block has to be dipped into a plating bath after the portions other than those applied with plating are masked. Since the masking operation is difficult and increases the cost, this is not suitable to mass production.

The typical example of the method of composite strengthening for the aluminum alloy as described in (3) above, is a method of strengthening with inorganic fibers such as Al_2O_3 fibers, or a method of strengthening by dispersing inorganic particles such as silicon nitride into a molten aluminum alloy and then applying die casting (Japanese Patent Application No. 149166/1985). However, since fine and hard inorganic fibers or particles are present in the aluminum alloy cylinder which is strengthened by the above-mentioned method, they cause abrasion to a piston ring or a piston during use, therefore, the method has not yet been put to practical use. In addition, Japanese Patent Applications No. 102802/1986, No. 141130/1986 and No. 38542/1988 propose the use of a combination of Al_2O_3 - SiO_2 fibers or Al_2O_3 fibers and C fibers as the strengthening material and the protection to the opposite sliding portions with plating or flame spraying in order to improve the wear resistance and the scuffing resistance. In a case of an aluminum alloy composite material using hard composite strengthening material such as inorganic fibers, since the hard fibers which are scatteringly protruded in the aluminum alloy composite material scratch the opposite sliding members to cause abrasion, both of the members have to be selected and combined, taking the properties of the opposite members to each other into consideration.

The object of the present invention is to provide an aluminum alloy matrix composite for internal combustion engines capable of preventing injuries such as abrasion to opposite sliding members and capable of improving the wear resistance and the scuffing resistance of the composite.

In order to achieve said object of the present invention, there is provided an aluminum alloy matrix composite for internal combustion engines, which is strengthened by a porous metal; and in an exposed surface of which at least a part of the aluminum alloy is scratched a little more than parts of the porous metal by lapping so that fine oil

pockets are formed in the exposed surface, the porous metal containing chromium of 10 to 55 weight %, preferably 15 to 55 weight %, and the volumetric ratio of the porous metal being within a range of 6 to 30 volume %, preferably 8 to 20 volume %.

According to another feature of the present invention, there is provided an aluminum alloy matrix composite for internal combustion engines, which is strengthened by a porous metal; and in an exposed surface of which at least a part of the aluminum alloy is removed a little more than parts of the porous metal by etching so that fine oil pockets are formed in the exposed surface, the porous metal containing chromium of 10 to 55 weight %, preferably 15 to 55 weight %, and the volumetric ratio of the porous metal being within a range of 6 to 30 volume %, preferably 8 to 20 volume %.

The porous metal is preferably obtained by compressing a raw porous metal in one direction, the raw porous metal having 85 to 98 volume % in porosity.

The porous metal is preferably embedded in the aluminum alloy mainly by means of squeeze casting.

The porous metal as the composite strengthening material preferably comprises material, preferably iron or nickel harder than the aluminum alloy.

The aluminum alloy is, preferably, Al-Cu series alloy, Al-Cu-Si series alloy, Al-Si series alloy, Al-Si-Mg series alloy, Al-Si-Cu series alloy, Al-Si-Cu-Mg series alloy, Al-Cu-Ni-Mg series alloy, Al-Mg series alloy or Al-Si-Cu-Ni-Mg series alloy.

Since the aluminum alloy is composed with the porous metal, it is possible to apply composite strengthening only for a required portion by forming the porous metal into an objective shape.

If the volumetric ratio of the porous metal is less than 6 volume %, since the ratio of the composite strengthening material in the aluminum alloy matrix composite is reduced, the effect of improving the wear resistance of the composite member is reduced. On the contrary, if the volumetric ratio is more than 30 volume %, penetrating property of the aluminum alloy into the porous metal is reduced upon composition.

The chromium content necessary for the porous metal is within a range of 10 to 55 weight %. The formation of brittle intermetallic compounds can be suppressed upon composition of the aluminum alloy and the porous metal thereby increasing the strength at the boundary between the aluminum alloy and the porous metal if the chromium content is more than 10 weight %. If the brittle intermetallic compound is formed, cracks may possibly occur at the portion of the intermetallic compound. Further, in the porous metal the hardness is

increased by containing chromium, thereby improving the wear resistance of the composite portion. However, if chromium content is more than 55 weight %, the wear resistance is not improved so much. Since the hardness is lower than that of the inorganic fibers or particles, there is no possibility of damage to the opposite sliding portion or the like.

The porous metal and the aluminum alloy are exposed in the surface of the aluminum alloy matrix composite strengthened by the porous metal. Since the aluminum alloy is softer than the porous metal containing chromium, at least a part of a region of the aluminum alloy is scratched a little more than parts of the porous metal by lapping, thereby forming fine recesses, pits or grooves.

Alternatively, at least a part of a region of the aluminum alloy is removed a little more than parts of the porous metal by etching, thereby forming fine recesses or pits.

Since the recesses, pits or grooves constitute oil pockets for the lubricant used in an internal combustion engine, it is possible to effectively store the lubricant on the surface.

Reference will now be made, by way of example, to the accompanying drawings in which:

Fig. 1 is a vertical cross sectional view for a bore portion of a cylinder block for internal combustion engines made of an aluminum alloy matrix composite according to the present invention;

Fig. 2 is an enlarged plan view of a portion of the surface of a cylinder bore portion constituted with the aluminum alloy matrix composite;

Fig. 3 is an enlarged plan view of a portion illustrating pits and grooves formed as oil pockets by lapping on the surface of the cylinder bore portion shown in Fig. 2;

Fig. 4 is an enlarged perspective view of a portion illustrating pits and grooves formed as oil pockets;

Fig. 5 is a cross sectional view illustrating recesses, pits and grooves formed as oil pockets;

Fig. 6 is a graph illustrating the specific wear amount for each of the materials in Examples 1, 2 and Comparative examples 1 to 4 measured by the wear test;

Fig. 7 is a graph illustrating the normalized wear amount by that measured in Comparative Example 1 for each rotor portions of the wear tester, said each rotor portions being used for each of the materials in Examples 1, 2 and Comparative Examples 1 to 4 upon the wear test;

Fig. 8 is a cross sectional view illustrating recesses formed as oil pockets by etching on the surface of the cylinder bore shown in Fig. 2;

Fig. 9 is a cross sectional view illustrating pits formed as oil pockets;

Fig. 10 is a cross sectional view illustrating recesses and pits formed as oil pockets;

Fig. 11 is a graph illustrating the specific wear amount for each of the materials in Examples 3, 4 and Comparative Examples 1 to 4 measured by a wear test;

Fig. 12 is a view illustrating the normalized wear amount by that measured in Comparative Example 1 for each of the rotor portions of the wear tester, said each of rotor portions being used for each of the materials in Examples 3, 4 and Comparative Examples 1 to 4 upon the wear test; and

Fig. 13 is a vertical cross sectional view of a cylinder liner in a example for application.

The present invention will now be explained by way of preferred embodiments with reference to the drawings, with the understanding that the present disclosure is not intended to limit the invention to the embodiments.

In a first embodiment, a cylinder bore, in which the wear resistance and the scuffing resistance in the cylinder body of an internal combustion engine are required, is constituted with an aluminum alloy matrix composite according to the present invention.

At first, as previously proposed by the present inventors in Japanese Patent Application No. 149220/1989, a plate-like raw porous metal with 85 to 98 volume % in porosity is compressed preferentially in one direction into a porous metal sheet with 6 to 30 volume %, preferably, 8 to 20 volume % of volumetric ratio V_f . The porous metal has the function of strengthening material in the composite material. The wear resistance of the composite material is improved as much as the increased volumetric ratio of the porous metal by compressing the raw porous metal. If the volumetric ratio of the porous metal is less than 6 volume %, there is less effect for improving the wear resistance. On the other hand, if it exceeds 30 volume %, the porous metal is not easily composited with the aluminum alloy. When the porous metal is compressed preferentially in one direction, the diameter of the pores in the porous metal observed in the direction of the compression does not substantially change as compared with the diameter before compression. Accordingly, the penetrability of the molten aluminum alloy into the porous metal does not substantially change as compared with that of using the raw porous metal. A method of uniform compression of the raw porous metal with hydrostatic pressure is not preferred since the volumetric ratio is increased. Since the porous metal is preferably harder than the aluminum alloy in view of wear resistance, the porous metal consists of iron, nickel or the like.

The porous metal sheet is molded into a cylin-

drical shape so as to form a cylinder bore, then chromium is diffused into the cylindrical porous metal to a content from 10 to 55 weight %.

When porous metal of iron or nickel is brought into reaction with aluminum upon composition, brittle intermetallic compounds are formed at the boundary between them. When the composited aluminum alloy material is used, for example, in a piston of an internal combustion engine, the piston undergoes thermal cycles of heating and cooling for a long period of time, and cracks may possibly occur at the portion of the brittle intermetallic compounds. The present inventors have disclosed in Japanese Patent Application No. 222239/1988 that the formation of the brittle intermetallic compound can be suppressed by using a porous metal whose surface is treated by chroming or the like to depth of 0.001 mm or more so that the porous metal contains more than 10 weight %, preferably, more than 15 weight % chromium. By containing upto 55 weight % chromium the hardness of the porous metal can be increased to improve the wear resistance of the porous metal.

The cylindrical porous metal body is set to a die for casting a cylinder block. Then, when the cylinder block is casted by squeeze casting, a molten aluminum alloy is penetrates into the porous metal.

Fig. 1 is a cross sectional view of a bore portion of a cylinder block 1 made of an aluminum alloy prepared as described above, in which a cylinder bore 2 is strengthened by a porous metal 3. When the cylinder block 1 is thus manufactured, the cylinder bore 2, in which a piston (not illustrated) is reciprocated to cause wear or scuffing, can be strengthened by the porous metal 3. In addition, the composition to strengthen the bore 2 can be performed simultaneously with the manufacture of the cylinder block 1, and only the bore 2 in which wear resistance is required can be constituted with the porous metal 3 while most of other portions may be constituted with an aluminum alloy 4. Accordingly, it can be manufactured easily and the material cost is not too expensive. In this case, since the squeeze casting method is used, strength of the aluminum alloy is improved and the casting defects are decreased.

A surface finishing is applied to the cylinder bore 2. Fig. 2 is an enlarged view for the metal structure of the cylinder bore surface 11. In Fig. 2, dotted areas show a region of the porous metal 3, and blank areas show a region of the aluminum alloy 4 as a matrix. It can be seen, on the surface 11 of the aluminum alloy matrix composite, that the porous metal 3 is present like islands in the aluminum alloy 4 and the aluminum alloy 4 is like a small island in a relatively large porous metal 3.

Lapping treatment is performed on the cylinder

bore surface 11 by applying a lapping agent to the cylinder bore surface 11, the lapping agent generally consisting of a slurry which is prepared from a suspension of hard fine particles such as SiC in liquid such as oil. Fig. 3 and Fig. 4 show an enlarged view for a portion of the surface 11 and an enlarged perspective view for a portion after the lapping, respectively. As shown in Figs. 3 and 4, pits 13 and grooves 14 are formed preferentially in the region of the aluminum alloy 4, because the composite material comprises heterogeneous phases each having different hardness, i.e., the porous metal 3 and the aluminum alloy 4, and the hardness of the region of the aluminum alloy is smaller than that of the region of the porous metal 3. That is, the Vickers hardness of the porous metal consisting of nickel diffused with chromium by more than 20 weight % is about from 250 to 300 (as measured by micro Vickers hardness tester), while the Brinell hardness of the aluminum alloy, for example, AC8A specified by JIS is about 100 (about 115 when converted as Vickers hardness). A lapping shoe made of cast iron FC15 as specified in JIS is pressed and slid against the bore surface 11 at a pressure of 0.2 kg/cm² under the conditions of 100 rpm of rotation and 100 mm strokes. At the same time, a lapping agent of a slurry in which Si particles of about 400 mesh are mixed in a lubricant having 1200 cs of viscosity is dropped between the surface of the shoe and the bore surface 11. When the Si particles are rolled at the surface 11 and rub the surface 11, a portion of the region of the aluminum alloy 4 is scratched to form pits 13 each having 1 to 10 μ m depth. Subsequently, the surface 11 is slightly polished by means of a shoe made of cork or rubber to eliminate burrs which have been formed at the periphery of the aluminum alloy, thereby to form pits 13 each having 1 to 4 μ m depth, the pits being dispersed uniformly in the region of the aluminum alloy 4. At the same time, the surface 11 is scratched with SiC particles in one direction over a relatively long distance, thereby to form grooves 14.

While the above-mentioned lapping conditions can be varied appropriately, it is desirable that the pressure of the shoe is within a range of 0.05 to 1.0 kg/cm², for forming the pits 13 and/or grooves 14 preferentially to the region of the aluminum alloy 4. A pressure greater than 1.0 kg/cm² is not desired since many pits or grooves are also formed in the region of the porous metal 3.

If lapping is applied for a relatively long period of time (about 0.5 to 3 minutes) under a relatively low shoe pressure, the region of the aluminum alloy 4 is entirely concaved by scratching. Fig. 5 shows a cross sectional view of the thus lapped surface 11. As shown in Fig. 5, since the region of

the aluminum alloy 4 is scratched a little more than the region of the porous metal 3, the region of the aluminum alloy 4 is entirely concaved on the surface 11 shown in Fig. 2 to form a recess 12 and the region of the porous metal 3 is relatively protruded. The pits 13 and the grooves 14 are left at the surface of the region of the aluminum alloy 4 in the recess 12. The recess 12 has a depth d of about 0.2 to 2.0 μ m.

For smoothing the reciprocal movement of the piston in the cylinder bore 2, lubricant forms oil films between the bore surface 11 and the surface of the piston. The lubricant can be effectively stored in the recesses 12, pits 13 and the groove 14, which have the function of oil pockets to maintain the oil films satisfactorily. As a result, lubricancy and scuffing resistance can be improved in the gaps.

In particular, when the composite material of the aluminum alloy 4 and the porous metal 3 is used for the cylinder bore, since scuffing occurs in the regions of the soft aluminum alloy 4, it is preferred that the region of the aluminum alloy 4 is entirely concaved as shown in Fig. 5, and it is more preferred that the pits 13 and/or grooves 14 are present in the recess 12 because the effect of storing the lubricant is further improved.

The hard particles of 200 to 800 mesh are preferably used for the lapping. Coarse particles greater than 200 mesh are not preferred since the depth and the size of the pit or the groove are too great, which increases the consumption amount of the lubricant. Fine particles of less than 800 mesh are not preferred since the performance of forming pits or grooves is reduced. In the case that SiC particles 17 of hard grains are slightly embedded as small lumps into the aluminum alloy 4 as shown in Figs. 3 and 4 upon lapping, as the size of the hard particles is larger, abrasion given to the piston (opposite sliding member) is increased. In addition, the pressure of the shoe in the lapping is preferably less than 1.0 kg/cm² since the amount of the embedded hard particles is reduced as the shoe pressure is lower. The hard particles having 400 to 800 mesh are particularly preferred for the same reasons as described above.

The aluminum alloy matrix composite in the first embodiment will now be explained referring to Examples 1, 2 and Comparative Examples 1 to 4.

Example 1

After compressing a sheet material of 5 mm thickness made of a raw porous metal comprising nickel (Ni Cermet #6, manufactured by Sumitomo Denko) in one direction into 3 mm thickness, the porous metal sheet was molded into a cylindrical

shape of about 100 mm inner diameter. Then, chromium was diffused into the cylindrical porous metal by chroming to have a content of 35 weight %.

Then, the cylindrical porous metal body was set to a die in which a molten aluminum alloy (Al-Si-Cu-Ni-Mg series alloy) AC8A (Cu: 0.8 to 1.3 wt.%, Si: 11.0 to 13.0 wt.%, Mg: 0.7 to 1.3 wt.% and Ni: 0.8 to 1.5 wt.%) as specified according to JIS was poured at a temperature of 760 °C and under a pressure of 700 kg/cm² to prepare a hollow cylindrical aluminum alloy matrix composite with the volume ratio of the porous metal of about 10 volume %. After applying so-called T6 treatment specified by JIS to the hollow cylindrical body, slight grinding treatment was applied to the inner surface of the hollow cylindrical body. Subsequently, the hollow cylindrical body was set to a lapping device, and a shoe made of an extremely soft cast iron (F15C specified by JIS) was pressed to the inner surface of the hollow cylindrical body under a pressure adjusted to 0.12 kg/mm² while applying a tapping agent constituting of a slurry in which SiC particles of 600 mesh were mixed into a lubricant having 1200 cs of viscosity. Then, lapping was applied for 2 minutes under the conditions of 100 rpm of rotation and 100 mm of stroke. Successively, the shoe was replaced with one made of rubber and a lapping finishing was performed (without using the lapping agent) under a pressure of 0.2 kg/cm² for 30 sec., whereby recess 12 each having about 0.2 to 0.5 μm depth were formed over the entire regions of aluminum alloy 4 mainly, and a number of pits 13 and grooves 14 each having 2 to 3 μm depth were formed at the surface of the recess 12.

Comparative Example 1

A hollow cylindrical body of the same shape as that in Example 1 was prepared by using cast iron having flaky graphite (C: 3.1 wt.%, B: 0.06 wt.%, Si: 2.0 wt.%, Mn: 0.7 wt.%, P: 0.3 wt.%, Fe: balance), and plateau honing was applied to the inner surface to a roughness of 2 to 3 μm.

Comparative Example 2

A hollow cylindrical body of the same shape as that in Example 1 was prepared by casting with an aluminum alloy (Si: 17 wt.%, Cu: 4.5 wt.%, Mg: 0.5 wt.%, Al: balance) such that Si primary crystals of 50 to 70 μm were uniformly dispersed. After applying T6 treatment to the hollow cylindrical body, slight grinding was applied to the inner surface of the hollow cylindrical body. Then, the surface was

finished by honing to a roughness of less than 0.5 μm. Subsequently, the inner surface was electrolytically etched in a solution of sodium nitrate, by which Si particles were embossed about 1 μm from the inner surface.

Comparative Example 3

A hollow cylindrical body of the same shape as that in Example 1 was prepared by penetrating a molten aluminum alloy AC8A at a temperature of 760 °C under a pressure of 800 kg/cm into a cylindrical molding body of Al₂O₃-SiO₂ fibers (Al₂O₃ : 50%, volume ratio Vf: 9%, shot: less than 1%, manufactured by Nichias Co.). After applying T6 treatment to the hollow cylindrical body, slight grinding was applied to the inner surface of the hollow cylindrical body. Then, the surface was finished by honing to less than 1 μm roughness. Then, electrolytic etching was applied to the inner surface such that the portions of the aluminum alloy between the fibers the formed recesses of each having 2 μm depth.

Comparative Example 4

Si particles less than 3 μm were dispersed in Ni at about 3 weight % and Ni dispersion plating was applied to form a thickness of about 70 μm on the inner surface of a hollow cylindrical body made of an aluminum alloy AC8A (the same shape as in Example 1). Then, the inner surface was finished by honing to a surface roughness of 1 to 2 μm.

Example 2

In this Example 2, the same hollow cylindrical body was prepared under the same conditions and applied with the same treatment as those in Example 1 except for replacing the aluminum alloy in Example 1 with AC9B as specified by JIS.

Test pieces were cut out from each of the hollow cylindrical bodies in Examples 1, 2 and Comparative Examples 1 to 4 described above, and a wear test was carried out for the test specimens by using an Ohgoshi type Wear Tester. The rotor of the tester having the surface to be in sliding contact with the test specimen was made of the same cast iron as in Comparative Example 1. Pressed indents were formed by a pyramid shaped weight to the circumferential sliding surface of the rotor to be in sliding contact with the test specimen. The abrasion amount of the rotor itself was also measured by microscopically measuring the length of the diagonal line of the indent before and

after the wear test. The test conditions for the wear test were 570 m of friction distance, 0.12 m/sec. of friction speed, 1.9 kg of load, 3 cc/min. of the amount of dropping lubricant (SAECC grade #30). Fig. 6 and Fig. 7 show the results of the wear test for examples 1, 2 and Comparative Examples 1 to 4.

Fig. 6 shows the specific wear amount for each of the test specimens, and Fig. 7 shows the wear amount of the rotor measured in the wear resistance test for each of the test specimens, and normalized by the wear amount of the rotor measured in Comparative Example 1. From Figure 7, it can be seen the degree of injury given from each of the members in Examples 1, 2 and Comparative Examples 1 to 4 to the opposite sliding material. From Figs. 6 and 7, it can be seen that the specific wear amount was least in Comparative Example 3 (aluminum alloy strengthened by composing with Al_2O_3 - SiO_2 fibers) but greatest injury was given to the mating sliding member, because the fibers are extremely hard. It can also be seen that the material in Examples 1 and 2 according to the present invention showed wear resistance as comparable with that in Comparative example 1 (cast iron material) and Comparative Example 4 (Ni-dispersion placed material), which were actually used so far with satisfactory results and that the material in Example 1 was further improved with the wear resistance as compared with the material in Example 1.

In a second embodiment, oil pockets are formed by etching on the inner surface of the cylinder bore comprising the aluminum alloy matrix composite as described in the first embodiment.

Etching is applied to the cylinder bore surface 11 shown in Fig. 2. Impurities are present in the region of the aluminum alloy 4 to form a phase which is different from the matrix phase of aluminum alloy. The etching is adapted to selectively etch the objective phase. The etching method can generally be classified into a following three types depending on the phases to be etched:

- (a) : a method of applying etching over the entire region of the aluminum alloy 4,
- (b) : a method of etching to dissolve the phase of impurities such as Mg_2Si in the region of the aluminum alloy 4, and
- (c) : a combined method of (a) and (b) above.

In the method (a) above, an etching treatment is selected so as to etch the aluminum alloy 4 in preference to the chromium-containing porous metal 3. Such etching includes a chemical etching treatment using an NaOH solution or a mixed solution of H_3PO_4 and H_2SO_4 .

In the method (b) above, an etching treatment is selected so as to dissolve preferentially the phase of impurities, for example, Mg_2Si in the

aluminum alloy 4. Such etching includes a chemical etching treatment using an HNO_3 solution, Cr_2O_3 solution or CrO_3 solution.

In the combined method (c), the method (b) is preferably applied after applying the method (a).

Figs. 8 to 10 are cross sectional views for the cylinder bore surface 11 obtained by applying etching as described above.

Fig. 8 shows the surface 11 after applying the method (a) above, in which the region of the aluminum alloy 4 is etched more than the region of the porous metal 3. Thus, in the surface 11 shown in Fig. 2, the region of the aluminum alloy 4 is entirely concaved to form a recess 22, while the region of the porous metal 3 is relatively protruded. For instance, if the surface 11 is applied with etching for 4 min. with an aqueous solution containing 10 weight % of NaOH , the depth d' of the recess 22 is 1 to 4 μm . A desired depth d' can be formed in the recess 22 by properly setting etching conditions (etching solution, etching time, concentration, etc.). Oil films are formed with a lubricant between the bore surface 11 and a piston so as to smooth the reciprocal movement of the piston in the cylinder bore 2, and the lubricant can be effectively stored in the recess 22 thus formed in the bore surface 11. Since the recess 22 has the function of oil pockets thereby maintaining the oil films satisfactorily, lubricancy and scuffing resistance can be improved in the gap. If the depth d' of the recess 22 is excessively great, it is not preferred since the consumption amount of the lubricant is increased. Accordingly, the depth d' for the recess 22 is preferably about from 0.3 to 5 μm .

Fig. 9 shows the cylinder bore surface after applying the method (b) above, in which fine pits 13 are formed by dissolving impurities such as MgSi in the region of the aluminum alloy 4. For instance, by applying etching to the surface 11 for 5 min. with an aqueous solution containing 20 weight % of HNO_3 impurities in the aluminum alloy 3 can be removed by dissolving to form a lot of fine pits 23. Since a great number of impurities are present in the aluminum alloy 4, a number of pits 23 are formed. The depth d' of the pit is about 1 to 8 μm , which will depend on the size of the impurities. The pits 23 have also the function as the oil pockets for the lubricant.

Fig. 10 shows the cylinder bore surface 11 after applying the method (c) above, in which a recess 22 is formed to the surface 11 and, subsequently, the pits 23 are formed on the surface of the region of the recess 22 of the aluminum alloy 4. Formation of both of the recess 22 and the pits 23 on the surface 11 are preferred since the effect as oil pockets for the storing the lubricant is further increased.

Although chemical etching is applied in the

foregoing case, electrolytic etching may also be used.

Description will now be made to Examples 3 and 4 for the aluminum alloy matrix composite according to the second embodiment.

Example 3

After compressing a sheet material of 5 mm thickness made of a raw porous metal comprising nickel (Ni Cermet #6, manufactured by Sumitomo Denko) in one directions into 3 mm thickness, the porous metal sheet was molded into a cylindrical shape of about 100 mm inner diameter. Then, chromium was diffused into the cylindrical porous metal by chroming to be a content of 35 weight %.

Then, the cylindrical porous metal body was set to a die in which a molten aluminum alloy AC8A as specified according to JIS was poured at a temperature of 760 °C and under a pressure of 700 kg/cm² to form a hollow cylindrical aluminum alloy matrix composite with the volume ratio of the porous metal about 10 volume %. After applying a so-called T6 treatment as specified by JIS to the hollow cylindrical body, slight grinding was applied to the inner surface of the hollow cylindrical body. The surface was finished by honing. Then, by applying etching to the inner surface such that it was immersed for 2 min. in an aqueous solution containing 10 weight % of NaOH, recesses 22 each having 0.5 to 1.5 μm depth $\bar{d}$ were formed on the inner surface.

Example 4

In this example 4, the same hollow cylindrical body was prepared under the same conditions and applied with same treatment as those in Example 3 except for replacing the aluminum alloy in Example 3 with AC9B specified by JIS.

Test pieces were cut out from each of the hollow cylindrical bodies in Examples 3 and 4, and a wear test was carried out for the test specimens in the same methods as those in Examples 1, 2 by an Ohgoshi type wear tester.

Figs. 11 and 12 show the results of the wear test for Examples 3 and 4 in comparison with the results of Comparative Examples 1 to 4.

Fig. 11 shows a specific wear amount for each of the test specimens and Fig. 12 shows the normalized wear amount of the rotor measured in the wear tester for each of the test specimens by being normalized with the wear amount of the rotor measured in Comparative Example 1.

From Figs. 11 and 12, it can be seen that each of the materials in Examples 3 and 4 is further

improved with the wear resistance like that in Examples 1 and 2.

Fig. 13 shows an application example in which the aluminum alloy matrix composite according to the present invention is applied to a cylinder liner 15. The cylinder liner 15 is made of an aluminum alloy 4 composed with a cylindrically shaped porous metal 3 by the method as described above. The inner surface 11 constitutes the cylinder bore 2, and by applying the same fabrication as that described above, recesses 12, 22 and/or pits 13/23 are formed as oil pits on the inner surface 11. The cylinder liner 15 is fit into the cylinder bore and then secured by means of shrinkage fit or expansion fit. Since the cylinder block for the internal combustion engine can be manufactured with a cylinder liner 15 by an inexpensive casting method such as low pressure casting or die casting without the process such as plating, production cost can be reduced. If the aluminum alloy composite is made of an aluminum alloy of high Si content, the wear resistance of the cylinder liner 15 can further be improved.

Since the present invention has the constitution as described above, the aluminum alloy matrix composite for internal combustion engines according to the present invention can provide the advantages as described below:

(1) Since the porous metal is used as the material for strengthening, only those portions suffering from remarkable wear can be strengthened. It is possible to select an optimum aluminum alloy in view of the characteristics of internal combustion engine.

(2) Since porous metal having an appropriate volume ratio is used, wear resistance of the aluminum alloy matrix composite can be improved by the porous metal, and composition with the aluminum alloy can be conducted with no troubles.

(3) Since the porous metal of an appropriate chromium content is used, brittle intermetallic compounds formed upon composition between the porous metal and the aluminum alloy can be suppressed to improve the strength at the boundary between the porous metal and the aluminum alloy, as well as the hardness of the porous metal can be increased to improve the wear resistance of the composite. In addition, since the hardness is less than that of inorganic fibers or particles as the conventional composite material, there is less possibility of damage, for example, to opposite sliding portions.

(4) Since oil pockets capable of storing the lubricant in the internal combustion engine are formed, the lubricancy and the scuffing resistance at the portions formed with the oil pockets can be improved.

Claims

1. An aluminium alloy matrix composite for internal combustion engines, characterised in that the composite is strengthened by a porous metal 3; and in an exposed surface 11 of which at least a part of the aluminium alloy 4 is scratched a little more than parts of the porous metal 3 by lapping so that fine oil pockets 12, 13, 14 are formed in the exposed surface 11, the porous metal 3 containing 10 to 55% weight of chromium, and the volumetric ratio of the porous metal 3 being within a range of 6 to 30% by volume.

2. An aluminium alloy matrix composite according to claim 1, characterised in that the porous metal 3 is obtained by compressing a raw material in one direction, the raw porous metal having 85 to 98% by volume in porosity.

3. An aluminium alloy matrix composite according to claim 1 or claim 2, characterised in that the porous metal 3 comprises iron or nickel.

4. An aluminium alloy matrix composite according any one of claims 1, 2 or 3, characterised in that the volumetric ratio of the porous metal 3 is within a range of 8 to 20% by volume.

5. An aluminium alloy matrix composite according to any one of the preceding claims, characterised in that the chromium content of the porous metal 3 is within a range of 15 to 55% by weight.

6. An aluminium alloy matrix composite according to any one of the preceding claims, characterised in that chromium is diffused into the porous metal 3 by means of chroming.

7. An aluminium alloy matrix composite according to any one of the preceding claims, characterised in that the porous metal 3 is embedded in the aluminium alloy 4 mainly by means of squeeze casting.

8. An aluminium alloy matrix composite according to any one of the preceding claims, characterised in that the oil pockets comprise a recess 12 formed on the exposed surface 11 of the aluminium alloy 4.

9. An aluminium alloy matrix composite according to any one of claims 1 to 7, characterised in that the oil pockets comprise grooves 14 and pits 13 formed on the exposed surface 11 of the aluminium alloy 4.

10. An aluminium alloy matrix composite according to any one of the preceding claims, characterised in that a pressure of a shoe used for lapping is within a range 0.05 to 1.0 kg/cm², the shoe being pressed and slid against the exposed surface 11 to which fine ceramic particles suspended by liquid are added.

11. An aluminium alloy matrix composite according to claim 10, characterised in that the ceramic particle has a grain size of 200 to 800 mesh.

12. An aluminium alloy matrix composite according to any one of the preceding claims, characterised in that pits 23 are formed on the surface of the recess 22 by etching impurities on the aluminium alloy 4.

13. An aluminium alloy matrix composite according to any one of the preceding claims, characterised in that the aluminium alloy 4 comprises an alloy selected from the group consisting of Al-Cu series alloy, Al-Cu-Si series alloy, Al-Si series alloy, Al-Si-Mg series alloy, Al-Si-Cu series alloy, Al-Si-Cu-Mg series alloy, Al-Cu-Ni-Mg series alloy, Al-Mg series alloy and Al-Si-Cu-Ni-Mg series alloy.

14. An aluminium alloy matrix composite according to any one of the preceding claims, characterised in that the composite is used for internal combustion engines.

15. An internal combustion engine using an aluminium alloy matrix composite according to any one of claims 1 to 13.

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FIG. 1

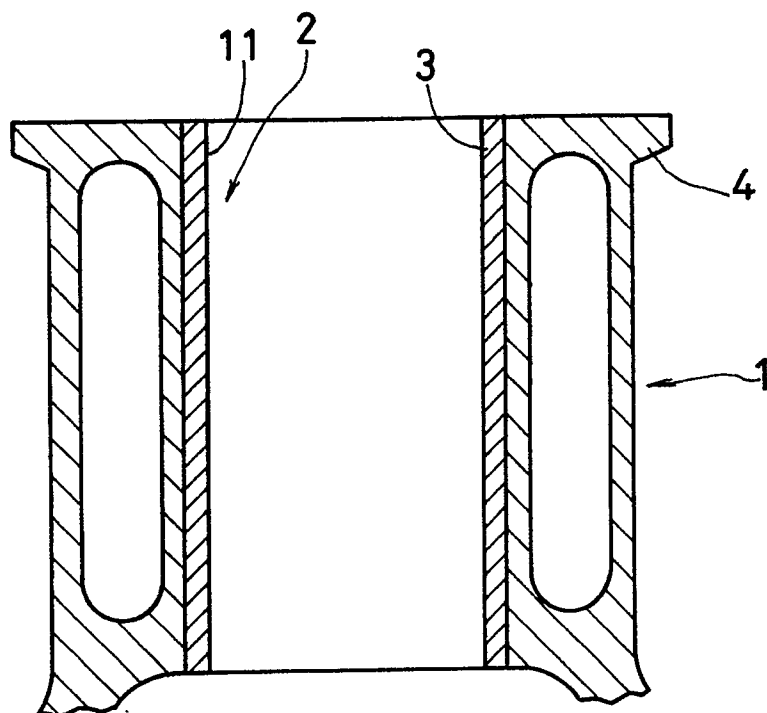


FIG. 2

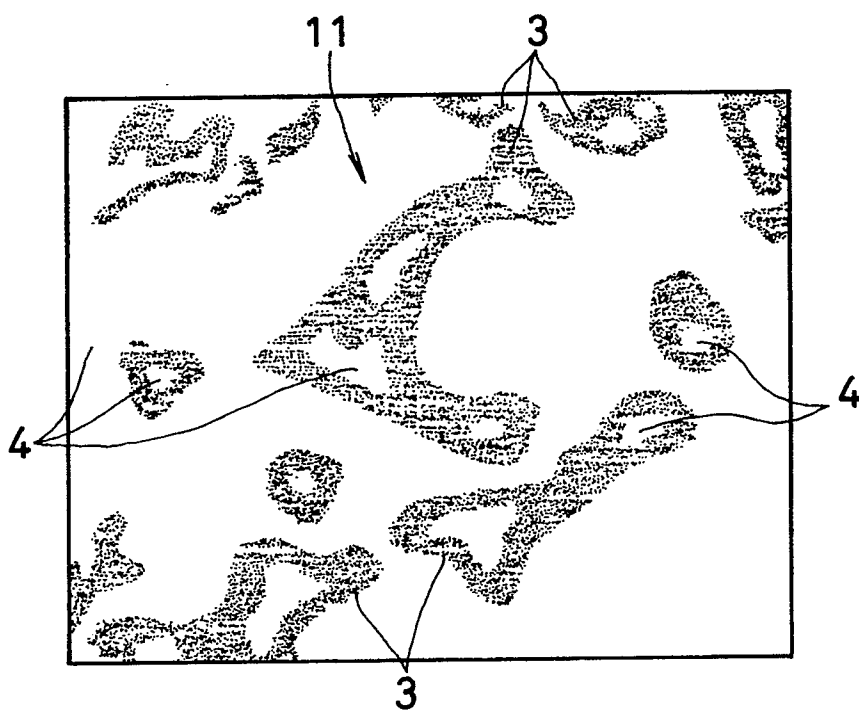


FIG. 3

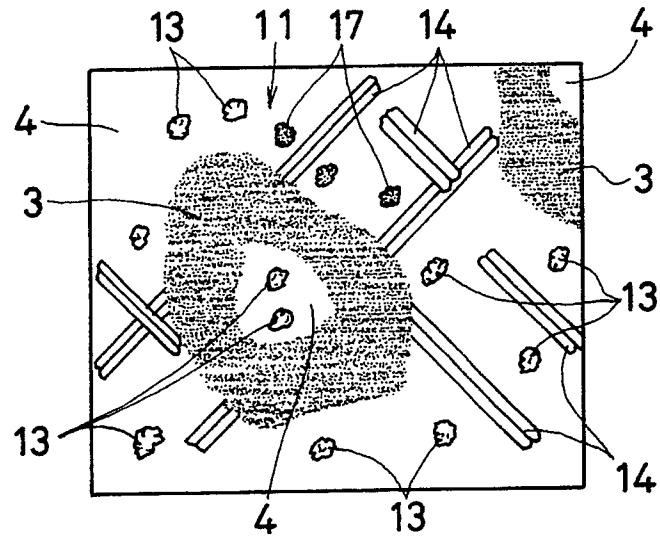


FIG. 4

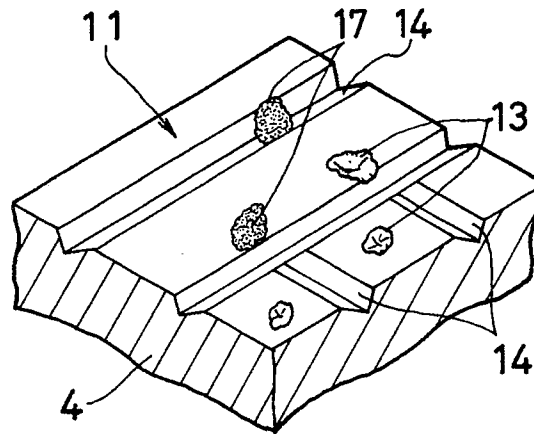


FIG. 5

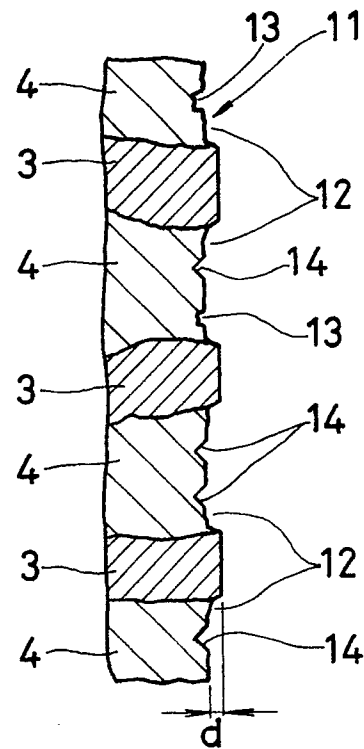


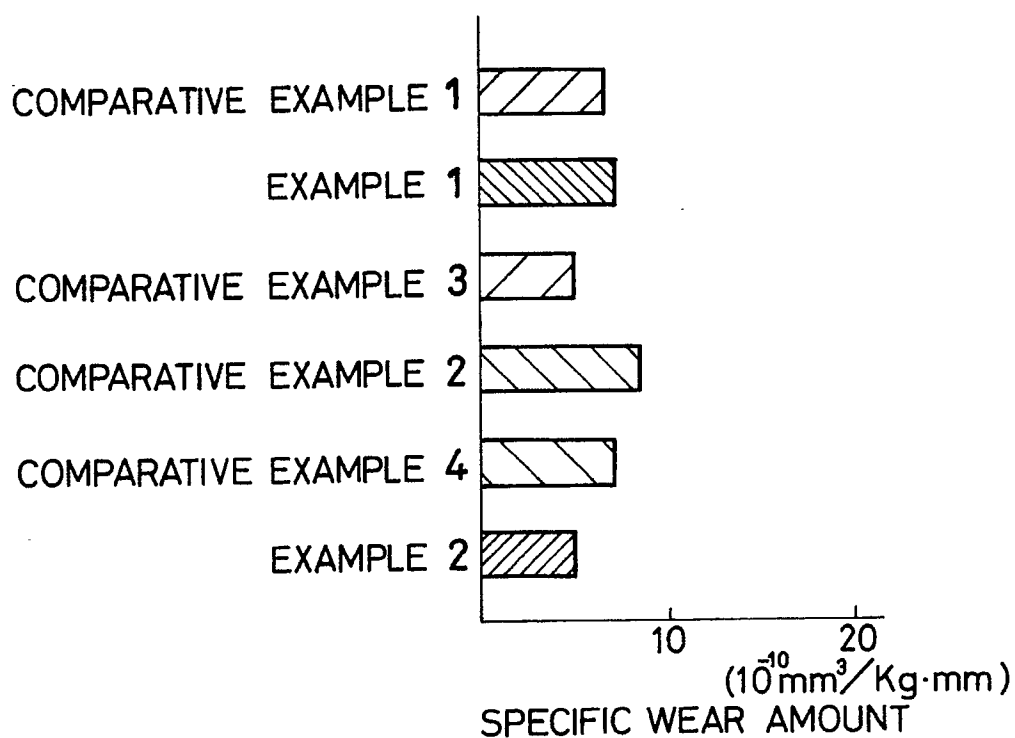
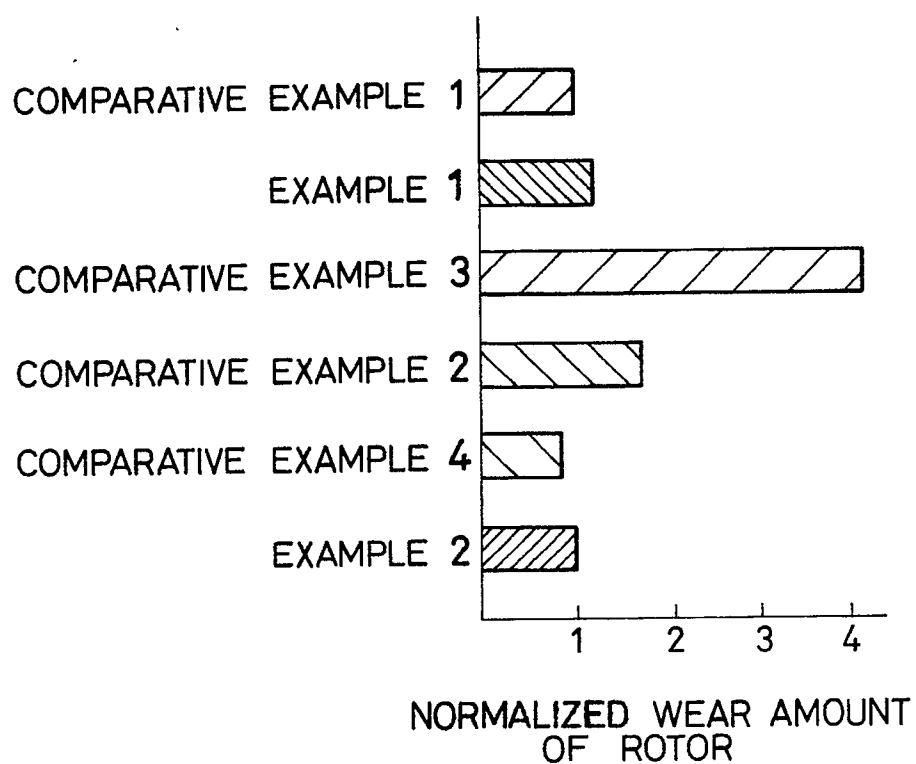
FIG. 6**FIG. 7**

FIG. 8

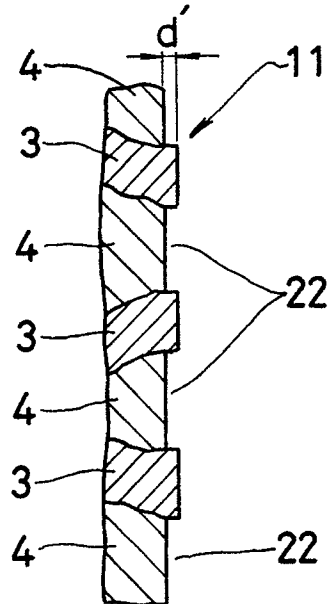


FIG. 9

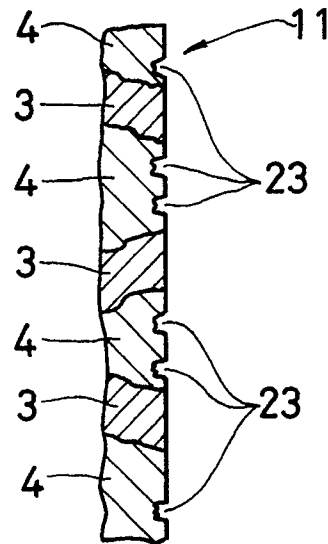


FIG. 10

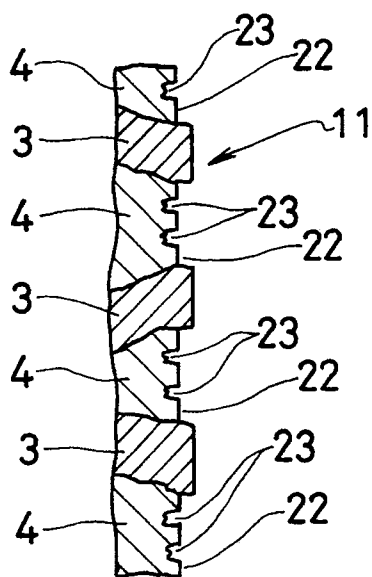


FIG. 13

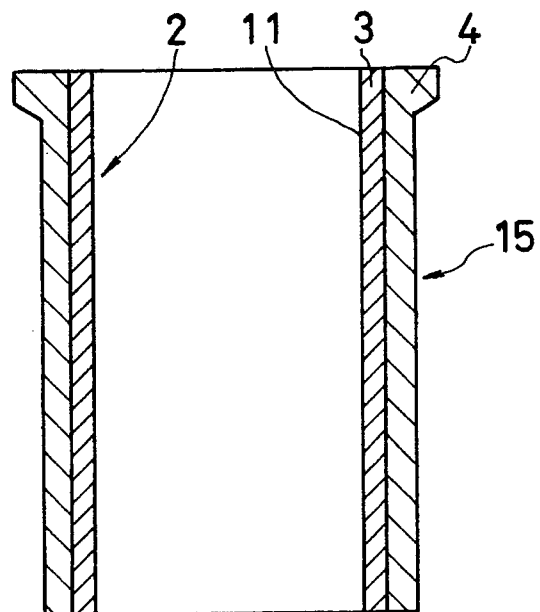
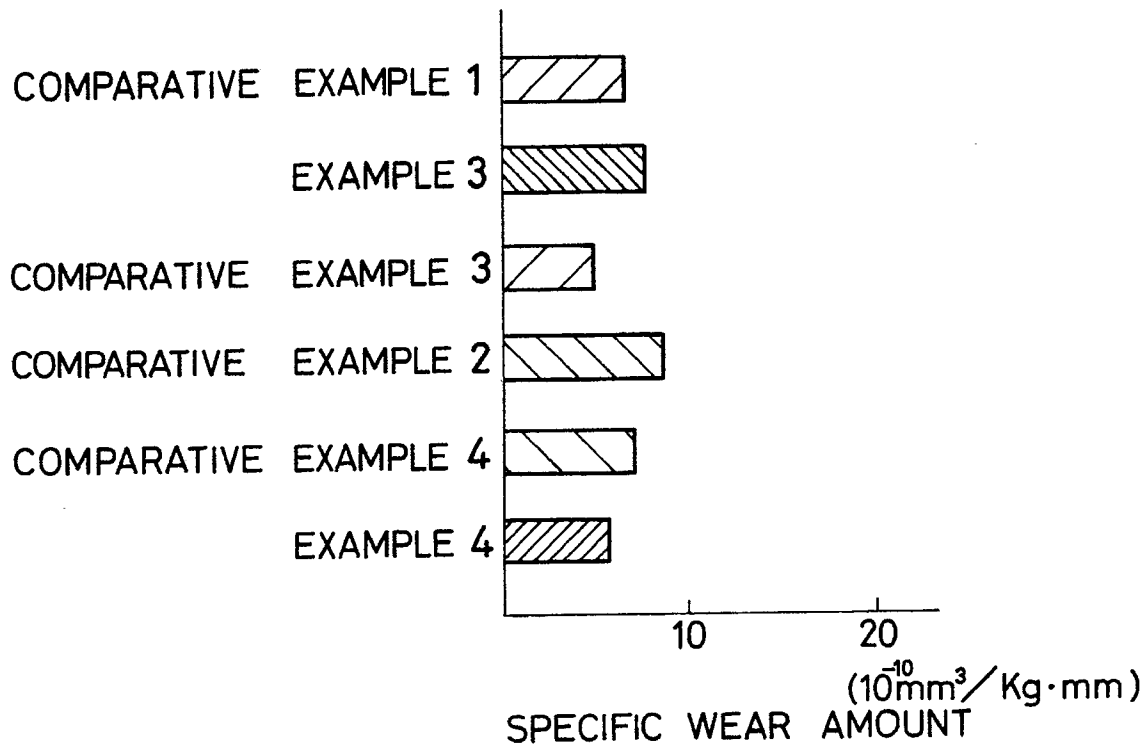


FIG. 11**FIG. 12**