

March 27, 1973

ARINOBU HAMADA ETAL
METHOD FOR INCREASING WEAR RESISTANCE OF A RUBBING
SURFACE OF ALUMINUM ALLOY ARTICLES
Filed April 13, 1971

3,723,209

FIG. 1

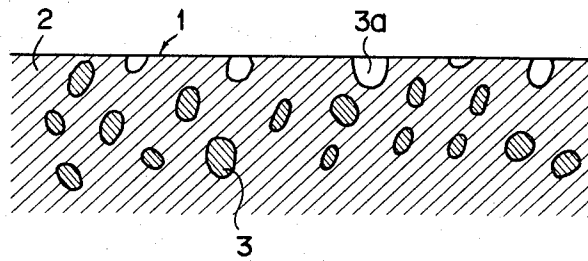
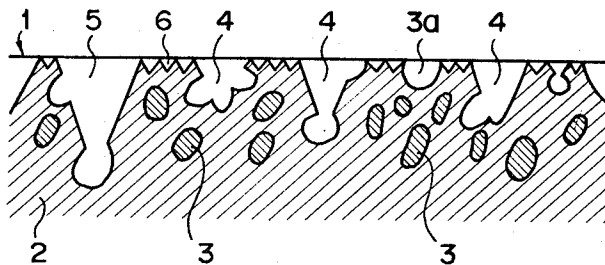


FIG. 2



INVENTOR

Arinobu Hamada

BY Yuuji Ohnishi

Tanehisa Sekiguchi

Remou, Palmer & Estabrook

1

3,723,209

METHOD FOR INCREASING WEAR RESISTANCE OF A RUBBING SURFACE OF ALUMINUM ALLOY ARTICLES

Arinobu Hamada and Yuuji Ohnishi, Kawasaki, and Tanehisa Sekiguchi, Tokyo, Japan, assignors to Showa Denko K.K., Tokyo, Japan

Filed Apr. 13, 1971, Ser. No. 133,562

Claims priority, application Japan, Dec. 25, 1970,

45/117,495

Int. Cl. C23f 1/00; F02f 7/00; F16j 11/00

U.S. Cl. 156-6

14 Claims

ABSTRACT OF THE DISCLOSURE

A method for effectively increasing wear resistance of a rubbing surface of aluminum alloy articles which comprises machining said rubbing surface of a cast aluminum alloy article in which there are dispersed fine particles of magnesium silicide or lead dichloride homogeneously so as to expose some of said particles on the rubbing surfaces, and washing out the exposed silicide or dichloride from the surface layer with an inorganic acid solution so as to leave fine exposed hollows in the rubbing surface layer as oil pools.

This invention relates to a method of increasing wear resistance of a rubbing surface of articles made of aluminum alloys, and especially of the inside surface of engine cylinder or its liner made of Al-Si-Mg alloy.

Recently active researches have been made for utilizing aluminum alloys as internal combustion engine materials with the purpose of supplying light weight engines. However, since such alloys have been too poor in wear resistance to be used for the inside surface of cylinder or its liner, the inside surface thereof has been reinforced by a cast iron liner inserted therein so the weight of the engine inevitably increases. Also, studies have been made for providing a porous chromium electroplating on the surface of aluminum alloys, but the process therefor is too complicated to be of practical use.

A method for enhancing wear resistance of a rubbing surface of hypereutectic silicon aluminum alloy is disclosed in U.S. Pat. 3,333,579. Said method comprises preferentially removing aluminum metal from a surface layer of a hypereutectic silicon aluminum alloy article by a mechanical or chemical process to expose particles of silicon protruding above the surrounding alloy surface, and then mechanically polishing the protruding silicon surface. However, this method is applicable only to hypereutectic silicon aluminum alloy. Since the amount of silicon exposed on the surface varies depending on the degree of removal of aluminum, quality control of the resulting surface condition is extremely difficult. Further, delicate techniques are required for smoothing the exposed silicon protrusions.

The object of this invention is to provide a rubbing surfaces on aluminum alloy articles that possess excellent wear resistance by means of a method which can be carried out easily and effectively.

This object may be attained according to this invention by a process which comprises the steps of dispersing fine particles of magnesium silicide or lead dichloride in a

2

melted aluminum alloy, casting the melted alloy into a shaped article, polishing a rubbing surface of said article to expose some of the dispersed particles thereon, and removing the substance of the exposed particles out of the rubbing surface layer by washing it with an inorganic acid solution to leave fine exposed hollows as oil pools in the rubbing surface layer.

Other important objects and advantageous features of the invention will be apparent from the following description and accompanying drawing, wherein specific embodiments of the invention are set forth in detail.

FIG. 1 is an enlarged schematic sectional view of rubbing surface layer in the basic embodiment of the present invention; and

FIG. 2 is another enlarged schematic sectional view of rubbing surface layer in another modified embodiment of the present invention.

In the following description, all parts and percentages are by weight unless otherwise indicated.

In the method of this invention, an Al-Si-Mg alloy containing 5 to 30% silicon and 3 to 15% magnesium can be used as the casting metal. Other similar alloys containing several percents of other element or elements, e.g., copper, in addition to the above-mentioned elements can be used for the same purpose. In the course of producing these alloys, fine particles of magnesium silicide Mg_2Si are formed when the magnesium content is sufficient, and they exit uniformly dispersed in the alloy as seen in FIG. 1 as the numeral 3. The diameter of such particles is approximately between 5 and 100 microns.

When the surface of a shaped article, such as an engine cylinder or its liner, manufactured by casting the above-mentioned alloy is finished by mechanical polishing, a smooth rubbing surface 1 as shown in FIG. 1 is formed, and some of the fine particles 3 of magnesium silicide existing in the surface layer 2 are exposed in the surface. When the exposed particles are removed by a chemical treatment, there remain numerous fine hollows 3a on the surface layer 2. By utilizing these hollows as oil pools, wear resistance of the rubbing surface is remarkably improved.

For the chemical washing of the surface, an aqueous solution of inorganic acid, such as nitric acid, chromic acid, sulfuric acid, hydrochloric acid or phosphoric acid, in suitable concentration is used. When using an oxidizing acid, the surface of the aluminum alloy is passivated by this washing, and the alloy itself does not dissolve in the above-mentioned washing agent. When using non-oxidizing acid, the surface of the aluminum alloy dissolves slightly in the washing solution. However, as the dissolving velocity of magnesium silicide is much larger than that of the aluminum alloy, there occurs no problem about this matter. There may exist some other particles of silicon metal or other intermetallic compound which are exposed on the surface other than magnesium silicide. (These metals are omitted from the drawing.) These metals do not dissolve in the washing agent either. The necessary time of this washing varies in accordance with the kind and concentration of acid used.

In order that the fine hollows in the rubbing surface be effective as oil pools, the total surface area of the exposed hollows must occupy 5 to 50% of the whole area of the rubbing surface.

3

Further, the fine hollows must be of an adequate size range. According to the experimental results, it has been made clear that, when the size of the hollows is in the range of 10 to 50 microns in diameter, the most adequate lubrication can be achieved. It also has been found that within the above-mentioned proportion range of silicon and magnesium in the aluminum alloy, satisfactory results are obtained.

In another embodiment of this invention, lead dichloride is used as the substance for the fine particles dispersed in the metal matrix instead of magnesium silicide. In this case, any aluminum metal can be used as the casting metal.

In this embodiment, an aluminum alloy is melted, and 2 to 10% of fine particles of lead dichloride ($PbCl_2$) is added to the melt at a temperature lower than $800^\circ C.$, and the melt is stirred well so as to effect uniform dispersion of the added particles. Since the density of lead dichloride is greater than that of aluminum alloys, the melt must be thoroughly stirred, otherwise the particles will settle. It must be noticed that lead dichloride is reduced to metallic lead by decomposition when it is heated at a temperature of $800^\circ C.$ or more. Further, when the additive amount of lead dichloride is less than 2%, the increasing effect of wear resistance is not noticeable. On the other hand, when the amount of lead dichloride added is more than 10%, the excess lead dichloride over 10% will settle down in the bottom part of vessel. The size of the dispersed particles is approximately 30 microns.

The melted aluminum alloy containing dispersed lead dichloride particles is cast into a shaped article, and the rubbing surface thereof is made smooth by polishing, whereby the rubbing surface, in which some of fine lead dichloride particles are exposed, is prepared as in the case of the first embodiment of this invention. In this case, the particles also are represented by 3 in FIG. 1. This surface is washed with the same kind of aqueous solution of inorganic acid as aforesaid, or else with hot water of about $60^\circ C.$, and lead dichloride forming the particles is removed from the surface layer, dissolving in the washing liquor. Thus oil pools are formed in the same way as in the first embodiment.

As a third embodiment of this invention, a method which combines the feature of this invention with a known technique is provided. There are known methods for improving cylinder and ring surfaces which have been proposed in the prior art. One of them comprises cross-hatching and honing the contact surface of cylinders and piston rings made of cast iron, but such method has not been used effectively for those made of aluminum alloy. However, when such method is combined with the method of the present invention, wear resistance of the rubbing surface of aluminum alloy is markedly improved.

FIG. 2 shows the aspect of such combination. First of all, the rubbing surface 1 of an article made of an aluminum alloy is honed with a rough grade grind-stone on the bias. Thus, there are formed numerous parallel grooves 4 of medium size which have depth of 10 to 20 microns. In some cases, cross-hatched screw grooves 5 as large grooves, approximately 20 microns in depth, may be provided on the rubbing surface by means of a lathe or other machine tool. Further, when desired, grooves of small size 6 which have a depth of 5 to 7 microns may be provided in a direction different from the previously provided medium size grooves by means of a fine grade grind-stone. The angle between the grooves and the cross section of the cylinder is, for instance, 40° for the medium size grooves and 60° for the small size grooves, and the effect is more remarkable when the angle of the small grooves is greater than that of the medium size grooves.

These grooves are communicated with the minute spaces occupied by the dispersed particles 3 of magnesium silicide or lead dichloride which are produced in accordance with the above-mentioned feature of this invention. Thus prepared surface layer is washed with any of the above-men-

4

tioned leaching agent, and the substance filled in the exposed particles and connected particles with the grooves is removed and oil pools with enlarged and transformed void space as shown in FIG. 2 are provided. As explained in U.S. Pat. 3,333,579, these grooves are ineffective when they alone are provided on the rubbing surface of an engine cylinder made of aluminum alloy, but the grooves communicated with the fine hollows as above can improve the wear resistance of the rubbing surface.

This invention can be worked in a following modified form, too. When a machined rubbing surface is treated with an inorganic acid solution which contains a water-soluble salt of a metal, the ionization tendency of which is smaller than that of aluminum, not only the exposed magnesium silicide or lead chloride particles are removed, but also the metal of the added salt deposits on all the surface and the inside surface of hollow and grooves. The salts suitable for this purpose are water-soluble salts of Fe, Zn, Mn, Mo, Pb, Sn, B, etc. Preferred concentration of such a salt in a leaching solution is 10 to 50% or thereabout. The hollows and grooves having the thus formed porous metallic deposit have improved, resulting in further increased wear resistance of the rubbing surface.

According to this invention, wear resistance of the rubbing surface of aluminum alloy articles can be increased by a very simple process. Significance of this invention is especially great in the field of manufacturing engine cylinders or liners of aluminum alloy.

The process of the present invention will be more fully understood with reference to the following specific examples.

EXAMPLE 1

Cylinder sleeves of the automobile were cast using an alloy consisting of 20% Si, 5% Mg, 4% Cu and Al remainder. The microscopic examination of the machined inside surface thereof showed that the average diameter of the exposed particles of Mg_2Si was 20 microns, and total area of the surface of the exposed particles was about 30% of the whole surface area. By washing the inside surface of the cylinders with a 25% aqueous solution of nitric acid for 20 minutes, almost all exposed magnesium silicide was removed.

These sleeves were fitted to an automotive gasoline engine of forced air-cooling type. The engine characteristics were: 2 cylinders, 4 cycles, inner diameter 62.5 mm., stroke 57.8 mm., total displacement 354 cc., and compression ratio 8.5. With respect to this automobile, a continuous running bench test was carried out under the conditions of 7500 r.p.m., full load, and 200 hours (10 hours per day). After the test was finished, average abrasion of the cylinders was 17 microns, and neither scuffing nor scoring was observed on the cylinder surfaces. This aluminum alloy cylinder is never inferior to the conventional cast iron cylinder or chromium-plated porous cylinder.

EXAMPLE 2

To the melt of a high silicon aluminum alloy consisting of 20% Si, 4% Cu, 1% Mg, 1% Fe, 1% Mn and Al remainder, 5% of fine powder of $PbCl_2$ was added and the melt was stirred well at $800^\circ C.$, and then cylinder sleeves of the automobile were cast from this melt. The castings were soaked in hot water of $80^\circ C.$ for 30 minutes, and the machined inner surface thereof was furnished with a numerous number of minute hollows which have openings on the surface. Microscopic examination revealed that the average diameter of these hollows was 25 microns, the average depth was 20 microns, and the total surface area of these hollows was 20% of the whole surface.

These sleeves were fitted to the same automobile as used in Example 1, and the same test was carried out with respect to these cylinders. After the test was finished, the average abrasion of the cylinders was 18 microns,

5

and neither scuffing nor scoring was observed on the cylinder surfaces.

EXAMPLE 3

Cylinder liners for an automobile were cast with a high silicon aluminum alloy consisting of 20% Si, 4% Cu, 6% Mg, 2% Mn and Al remainder, and the inside surfaces were finished to predetermined dimensions. On the surfaces there existed numerous exposed particles of Mg_2Si under the same condition as in Example 1.

In the inside surfaces of these liners, a plurality of medium size grooves about 20 microns in depth were provided by honing with 120J grit stone in the direction at 40° to the cross section of the liner, and further a plurality of small grooves about 7 microns in depth were provided by honing with 600J grit stone in the direction at 60° to the cross section of the liner and crossing the medium size grooves. Thereafter the inside surfaces were finished by light lapping.

Thus prepared grooved rubbing surfaces of the liners were treated with a 25% aqueous solution of nitric acid for 20 minutes, and washed with water.

These liners were fitted to the automobile gasoline engine as described in Example 1 and a continuous running bench test was carried out under the same conditions. After the test was finished, the average abrasion of the cylinder liners was 15 microns, and neither scuffing nor scoring was observed on the rubbing surface.

EXAMPLE 4

The inner surface of the cast cylinder sleeves prepared in Example 2 was further provided with a plurality of the medium size grooves 10 to 20 microns in depth in the direction at 40° to the cross section of the sleeve by honing with 200J grit stone, and further with a plurality of small grooves 6 to 7 microns in depth in the direction at 60° to the cross section of the sleeve, and crossing the medium size grooves by honing with 600J grit stone, and then the inside surface was finished with light lapping.

Thus prepared grooved sliding surfaces of the sleeves were soaked in hot water of 80° C. and thereafter were washed with water.

The sleeves were fitted to an automotive gasoline engine of water-cooling type. The engine characteristics were: 4 cylinders, 4 cycles, inner diameter 70.0 mm., stroke 76.0 mm., total displacement 1,169 cc. and compression ratio 8.6. With respect to this automobile, a continuous running bench test was carried out under the conditions of 5500 r.p.m., full load, and 200 hours (8 hours per day). After the test was finished, the average abrasion of the cylinder was 13.5 microns, and neither scuffing nor scoring was observed on the rubbing surface.

EXAMPLE 5

Engine liners were made by repeating the operations of Example 3 except that a 25% aqueous solution of nitric acid containing 20% of ferric nitrate was used as the leaching solution. Honing and lapping were applied in the same way.

These liners were fitted to the automotive gasoline engine as in Example 1, and the same running bench test was carried out. After the test was finished, the average abrasion of the liners was 11.5 microns, and neither scuffing nor scoring was observed on the rubbing surface.

For the purpose of comparison, with respect to ordinary cast iron liners, on the surface of which honed grooves were provided, the same test was carried out, and the results showed the average abrasion was 20.5 microns.

What is claimed is:

1. A method of increasing wear resistance of a rubbing surface of an aluminum alloy article which comprises: providing a molten metal alloy consisting essentially of 5 to 30 weight percent silicon, 3 to 15 weight per-

6

cent magnesium and the remainder aluminum containing dispersed therein particles of magnesium silicide in the size range between about 10 to 50 microns in diameter,

casting said molten metal alloy containing said dispersed particles into a shaped article,

polishing a rubbing surface of the resulting cast alloy article to expose in the rubbing surface at least some of said dispersed particles, and

removing exposed particles of magnesium silicide from said rubbing surface by dissolving them with an inorganic acid solution to leave exposed hollows in said rubbing surface to provide oil pools during rubbing action on said surface, the total surface area of said exposed hollows being between about 5 to 50 percent of the whole area of said rubbing surface.

2. A method of increasing wear resistance of a rubbing surface of an aluminum alloy article which comprises:

dispersing particles of lead dichloride of about 10 to 50 microns diameter uniformly in a molten aluminum alloy in an amount between about 2 to 10 percent by weight based upon the weight of said alloy,

casting said molten alloy containing said dispersed particles into a shaped article,

polishing a rubbing surface of the resulting cast alloy article to expose in the rubbing surface at least some of said dispersed particles, and

removing exposed particles of lead dichloride from said rubbing surface by dissolving them with a solvent selected from the group consisting of water heated to a temperature of 60 to 80° C. and an inorganic acid solution to leave exposed hollows in said rubbing surface to provide oil pools during rubbing action on said surface, the total surface area of said exposed hollows being between about 5 to 50 percent of the whole area of said rubbing surface.

3. The method according to claim 1 wherein, in the removing step, said inorganic acid is selected from the group consisting of nitric acid, chromic acid, sulfuric acid, hydrochloric acid and phosphoric acid.

4. The method according to claim 2 wherein, in the removing step, said inorganic acid is selected from the group consisting of nitric acid, chromic acid, sulfuric acid, hydrochloric acid and phosphoric acid.

5. The method according to claim 2 wherein, in the step of dispersing, the dispersing temperature is lower than 800° C.

6. The method according to claim 1 wherein, after the step of polishing, the polished rubbing surface is honed to form numerous grooves connected to some dispersed particles in the surface layer of the shaped article.

7. The method according to claim 2 wherein, after the step of polishing, the polished rubbing surface is honed to form numerous grooves connected to some of dispersed particles in the surface layer of the shaped article.

8. The method according to claim 6 wherein the depth of the grooves is 5 to 20 microns.

9. The method according to claim 7 wherein the depth of the grooves is 5 to 20 microns.

10. The method according to claim 1 wherein, in said removing step, said inorganic acid solution contains an added metal salt, whose component metal has smaller ionization tendency than that of aluminum, to produce a thin deposit layer of said metal on the surface of exposed hollows.

11. The method according to claim 10 wherein the component metal of the metal salt is the one selected from the group consisting of Fe, Zn, Mn, Mo, Ni, Pb, Sn and B.

12. The method according to claim 2 wherein, in said removing step, an inorganic acid solution is used that contains an added metal salt, whose component metal has smaller ionization tendency than that of aluminum, to produce a thin deposit layer of said metal on the surface of exposed hollows.

7

13. The method according to claim 12 wherein the component metal of the metal salt is the one selected from the group consisting of Fe, Zn, Mn, Mo, Ni, Pb, Sn and B.

14. The method of claim 6 wherein, in said removing step, said inorganic acid solution contains an added metal salt of a metal selected from the group consisting of Fe, Zn, Mn, Mo, Ni, Pb, Sn and B to produce a thin deposit layer of said metal on the surfaces of grooves and hollows in said rubbing surface of the aluminum alloy article.

5

10

8

References Cited

UNITED STATES PATENTS

2,558,286	6/1951	Albertson	-----	123—193	C
3,333,579	8/1967	Schockley et al.	-----	123—193	C

JACOB H. STEINBERG, Primary Examiner

U.S. Cl. X.R.

123—193 CP: 117—50