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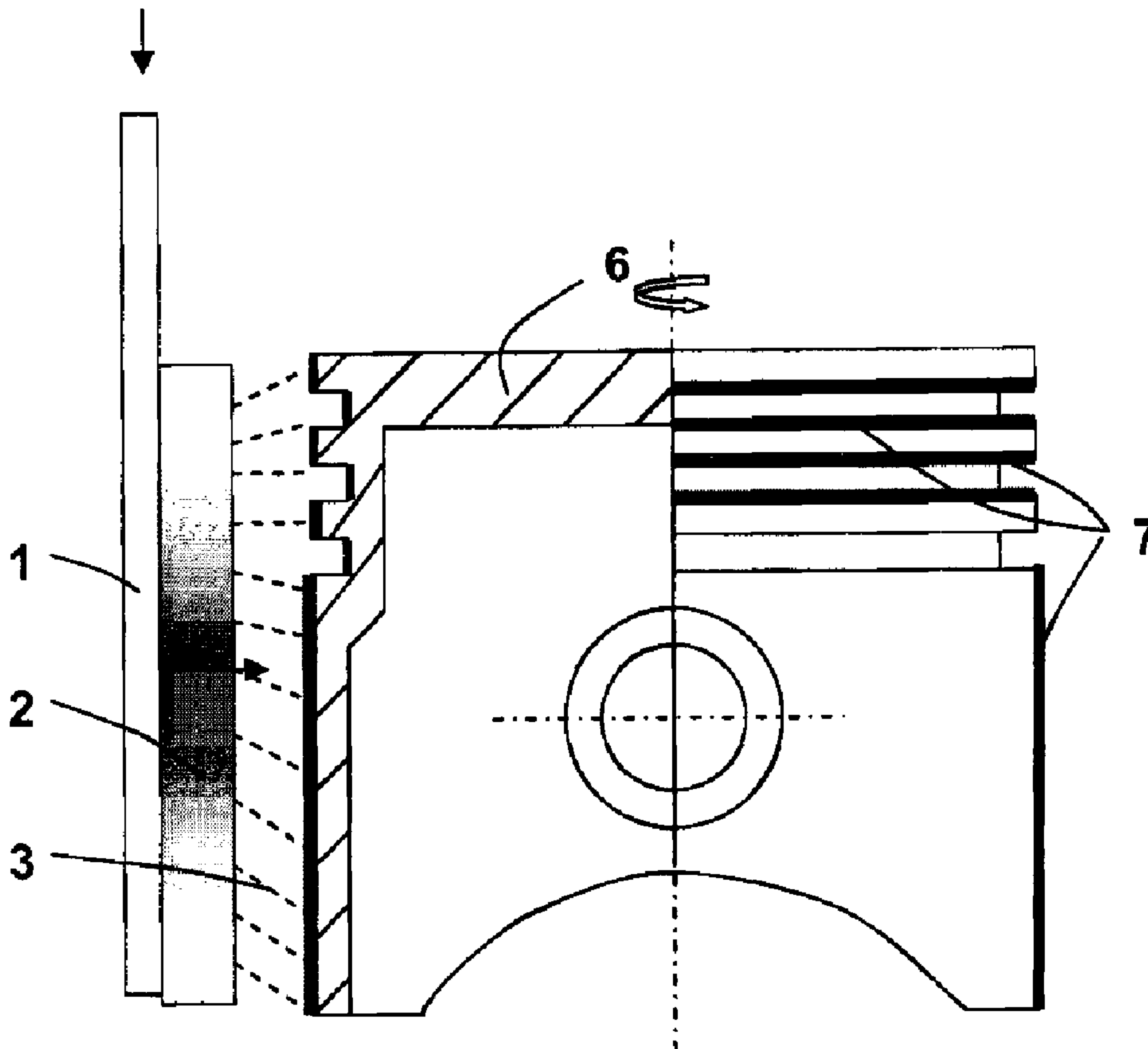
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(54) Titre : COUCHE D'OXYDE MINCE ET PROCEDE DE PROTECTION CONTRE L'USURE

(54) Title: THIN OXIDE COATING AND PROCESS



(57) Abrégé/Abstract:

This invention is involved in a thin oxide coating process on lightweight materials (Al-, Mg- and Ti-alloys). The oxide coating with dimples on its surface is synthesized by a high voltage anodizing process where an etching and plasma oxidation in an alkaline

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electrolyte may occur. The as-synthesized coating has the microstructure, mechanical and tribological property, thermal conductivity, and surface finish required for the applications of sliding contacts and wear in ambient and elevated temperature environment. The present invention can be particularly applied onto Al-Si alloys for wear and corrosion-wear protection of a sleeveless aluminum engine bore/piston system and parts used in alternative fuel vehicles.

THIN OXIDE COATING AND PROCESS FOR WEAR PROTECTION

ABSTRACT

This invention is involved in a thin oxide coating process on lightweight materials (Al-, Mg- and Ti-alloys). The oxide coating with dimples on its surface is synthesized by a high voltage anodizing process where an etching and plasma oxidation in an alkaline electrolyte may occur. The as-synthesized coating has the microstructure, mechanical and tribological property, thermal conductivity, and surface finish required for the applications of sliding contacts and wear in ambient and elevated temperature environment. The present invention can be particularly applied onto Al-Si alloys for wear and corrosion-wear protection of a sleeveless aluminum engine bore/piston system and parts used in alternative fuel vehicles.

THIN OXIDE COATING AND PROCESS

DESCRIPTIONS

TECHNICAL FIELD

This invention deals with surface modification of lightweight alloys for instance aluminum (Al), magnesium (Mg), and titanium (Ti) alloys. Particularly, the surface of an engine cylinder bore and piston, made of said aluminum-silicon (Al-Si) alloys, is deposited with a thin oxide or oxide which is prepared by use of a high voltage anodizing process where an etching and plasma process may occur. The present invention is suitable for wear and corrosion protections of lightweight metallic/alloy components, sleeveless engine bores and pistons of said Al-Si alloys.

BACKGROUND

The lightweight will improve fuel efficiency and reduce emission of vehicles. Al, Mg, and Ti alloys as weight-saving materials become increasingly important in the automotive, aerospace, and other industries. In particular, cast Al-Si alloys are being used in powertrain applications as lightweight components. There is a trend of development of sleeveless engines to further reduced weight. Some engines (such as Mercedes V6 Engine) use iron-coated light-weight Al pistons and high Si content Al-Si cylinder liners for low mass and reduced friction. Compared to an iron cylinder liner, the Al-Si liner reduces weight 0.5 kg (1.1 lb) per cylinder. Moreover, the reduction of number of parts by elimination of cylinder liners is a very effective way of cost saving.

However, there is another trend in usage of alternative fuels, for instances, biofuels such as E85 (85% ethanol and 15% gasoline) due to the pressure of shortening of fossil oils. Unfortunately, the ethanol is corrosive to Al-Si alloys and cast irons and is susceptible to corrosion problems. Thick iron-based, Ni-based, and oxide coatings may be the ones of the solutions. Those coatings need either pro- or post-treatments and/or honing, which may result in an extra cost. A number of coating processes are eliminated from automotive applications due to the sensitively increased process cost.

The auto parts industry is being squeezed from all sides by material prices and automakers seeking to reduce costs. There is a need to develop a new treatment process which can produce a hard but thin coating without a need of costly pro- and post-treatments. In this invention, the thin but hard oxide layer is prepared using an AC, DC or pulse DC power supply in an electrolyte which contacts, by spraying or immersing, components of lightweight alloys said Al-, Ti-, Mg-, and Al-Si alloys. The oxide layer has a thickness of usually 0.5 – 5 microns with hardness > 800 HV. The thin layer has a reasonably high thermal conductivity. No complicated post-treatment such as honing is needed for the surface finish.

The previous processes as described in patents (Patent No.: US 6,684,844 B1; Patent No.: US 6,365,028; and Patent No. US 5,884,600) intended to produce a very thick coating (up to hundreds of microns) that usually has a very rough surface. A complicated polishing/honing post-process is necessary if the coating is used for tribological

applications. Unlike the thick coating which also has a low thermal conductivity (i.e., an excellent thermal barrier property), the as-prepared thin coating in this invention has a smooth surface finish and high thermal conductivity. Thus, no complicated pre- and post-treatments before and after the invented coating process are necessary, which would significantly reduce the manufacturing cost. For instance, a thin coating (ideally 0.5-5 microns in thickness) synthesized on an Al engine bore/piston can withstand a mild and severe wear problem which may otherwise occur if there is no such coating on the Al engine bore and/or piston ring groove.

SUMMARY OF THE INVENTION

This invention is involved in development of a thin, hard oxide layer prepared under an AC, DC or pulse DC power in an alkaline electrolyte which contacts, by spraying, components of lightweight alloys said Al-, Ti-, and Mg-alloys. The oxide layer has a thickness of 0.5 – 5 microns with hardness > 800 HV. The thin layer has a smooth surface ($R_a < 0.8$ microns) and a reasonably high thermal conductivity. No complicated post-treatment such as honing is needed for the coating surface.

The invented process can be described as the following consequence steps:

Step 1. An electrolyte sprays to a surface of a lightweight alloy such as an Al-Si alloy as an example, and the surface is electrochemically etched when the alloy as an anode is connected with a power supply. As a result, the Al matrix surface is etched down by 0.3-3 microns and Si grains in the matrix are protruded from the surface with the exposed peak height of possible up to 3 microns.

Step 2. The etched Al matrix surface then grows with the formation of a thin oxide layer by plasma oxidation when the applied voltage increases, making the surface smoother. The surface consists of Al-O oxides in the Al matrix areas and Si-O oxides in the Si grain boundary regions. The dielectric plasma discharges on the oxide surface can be utilized to produce a number of dimples (dimple's size: 0.3-2 microns in diameter) on the surface that can be used as reservoirs of oil lubricants. With the increase of the oxide layer thickness, the Si regions will also perform plasma oxidation forming fused silica on their surfaces. The thin oxide layer thickness can be in the range of 0.5-5 microns.

Step 3. With the increase in treatment time, the whole sample surface covers with an Al-Si-O ceramic layer with a thickness of 5-10 microns. The surface becomes rougher, smoother, and then rougher again with the increase in treatment time up to 10 minutes.

The oxide layer thickness can be controlled by selection of the step above as the process ending. If the process terminates at Step 2, the oxide layer only has a thickness of 0.5-5 microns, and the surface roughness is less than 0.3-0.7 microns. There is no need for any post-treatment such as honing or polishing, which is beneficial in manufacturing cost-saving.

If the process ends at Step 3, the oxide layer thickness can be in range of 5-10 microns. Although slightly surface polishing is usually suggested to make the surface finish from

said Ra 1.0-1.5 microns to Ra 0.3-0.5 microns, no honing process is required, which can still significantly reduce the manufacturing cost.

The thin oxide layer can be applied on said sleeveless Al-Si engine bores and pistons and it can be efficient to battle a mild and severe engine wear.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a sectioned side view of electrolytic etching and plasma oxidation process for an internal surface.

Figure 2 is a side view of electrolytic etching and plasma oxidation process for an external surface.

Figure 3 is a schematic drawing of electrolytic etching and plasma oxidation procedure on surfaces of Al, Mg, and Ti alloys, where an Al-Si alloy is taken as an example for clear description purpose.

THE DETAILED DESCRIPTION OF THE INVENTION

As illustrated in Figure 1, a rotating hollow shaft (1) with at least one (ideally two to four) spraying head(s) (2) supplies an electrolyte (3) which is sprayed to an interior surface for instance a cylinder or engine block (4) bore (5). For a multiple number of cylinders/bores, the above spraying head is required for each of the cylinders/bores. Said, for a V8 engine which has eight cylinders/bores, eight above systems are needed.

As illustrated in Figure 2, a fixed hollow shaft (1) with one spraying head (2) supplies an electrolyte (3) which is sprayed to an exterior surface for instance a piston (6) and piston ring grooves (7) that can be fixed or rotating.

The oxide coating will form on the interior (for instance cylinder and engine bore) and exterior (for instance piston and piston ring groove) surfaces of a component as schematically shown in Figure 3, where the component of said an Al-Si alloy comprises primary Si grains distributed in the Al matrix.

As shown in Figure 3, the component is of said an engine bore and/or piston ring grooves which are connected to a DC, AC, or pulse DC power supply during the treatment in Figure 1 or Figure 2. The treatment process starts with a slightly etching process wherein the original surface (8) of said an Al-Si alloy is etched to some extent. The primary Si grains (9) are exposed from the aluminum matrix (10) and a new surface (11) forms. The surface finish is in a range of $Ra = 0.3-1.0$ microns

Then, a thin oxide coating (12) with a thickness of 0.5-5 microns is grown on the etched Al-Si alloy surface (11) and a new coated surface (13) forms. The new coated surface (13) consists of a thin Al oxide coating surface and exposed Si grain surfaces with Si-O oxides existing at the Si/Al boundary areas. A number of dimples (14) are formed on the Al

oxide surface areas. The thickness of the outward-grown part of the oxide layer from the etched surface (11) is in a range of one-third to half of the total coating thickness.

With an increase in the treatment time, the coating (12) thickness increases. The thickened oxide coating eventually covers the whole surface (15) without any exposition of Si grains. The entire surface (15) on the Al-Si alloy is an Al-Si-O oxide coating with a thickness of 5-10 microns.

Thus, this invention is involved in a surface modification process by which a thin, hard oxide layer is formed on a component of a lightweight alloy said Al-, Ti-, Mg-, and Al-Si alloy using a high voltage anodizing method. The component as an anode is connected to an AC, DC or pulse DC power supply. An alkaline electrolyte with a passivity property (pH 10-12) is used as the treatment solution which is applied to the component by a spraying or immersion method.

When the process starts, the surface of a lightweight alloy for instance an Al-Si alloy is electrochemically etched first by the alkaline solution. As a result, the Al matrix surface is etched down by 0.3-3 microns and Si grains in the matrix are exposed with a peak height of possible up to 3 microns.

The etched Al matrix surface then grows with the formation of a thin oxide layer by passivity activity and then plasma oxidation when the applied voltage increases, making the surface smoother. The plasma formation results from dielectric discharges on the oxide layer. The surface thus consists of Al-O oxides in the Al matrix areas and some Si-O oxides in the Si grain boundary regions. The dielectric plasma discharges on the oxide surface also cause a number of dimples on the surface (dimple's size: 0.3 – 2 microns in diameter) that can be favorably utilized as reservoirs of oil lubricants for reduction of friction and shear forces during a sliding wear.

The thin Al-O oxide layer thickness can be in the range of 0.5 - 5 microns. Ideally, the oxide layer has a thickness of 0.5 - 3 microns with hardness > 800 HV and surface roughness $R_a < 0.5$ -0.7 microns. The thin Al-O oxide layer has a mechanical property similar to the Si grains and the Si-O oxides (> 800 HV). The hard oxide layer protects the Al-Si alloy surface from scratching. The similar property on the surface between the original Al matrix and Si grain regions is critical to avoid the breaking and delaminating of the Si grains in and from the Al matrix during the sliding wear.

In addition, the thin, hard oxide layer on the lightweight component eliminates a metal-metal sliding contact and can withstand a higher heat impact than the lightweight alloy itself, which reduces the risk of adhesive or scuffing wear. The thin coating also has a reasonably high thermal conductivity that improves heat conductivity and lessens the cylinder bore distortion for a combustion engine.

Since the as-treated thin coating has a required mechanical, tribological property, and high thermal conductivity as well as smooth surface finish, no complicated post-treatments (polishing/honing) after the coating process are necessary, which would

significantly improve the lifetime of the lightweight component and also reduce the manufacturing cost.

The present invention will be further described with reference to the following examples.

Example 1

As shown in Figure 1, a rotating hollow shaft (1) with at least one (ideally two to four) spraying head(s) (2), which is connected to a high voltage power supply, supplies an electrolyte (3) which is sprayed to an interior surface for instance an Al-Si cylinder or engine block (4) bore (5). For a multiple number of cylinders/bores, the above spraying head is required for each of cylinders/bores. Said, for a V6 engine which has six cylinders/bores, six above systems are needed. The process can apply to sleeveless engine bores that are made of a cast Al-Si alloy with a low or high Si content.

When the process starts, the surface of a lightweight alloy for instance an Al-Si alloy is electrochemically etched first by the alkaline solution. The etched Al matrix surface then grows with the formation of a thin oxide layer by passivity activity and then plasma oxidation when the applied voltage increases, making the surface smoother. The dielectric plasma discharges on the oxide surface also cause a large number of dimples on the surface that can be favorably utilized as reservoirs of oil lubricants for reduction of friction and share forces during a sliding wear.

For instance, an as-prepared thin coating (ideally 0.5-3 microns in thickness) on interior surfaces said engine bores can eliminate a mild and severe wear problem which may otherwise occur if there is no such coating on them.

Example 2

As shown in Figure 2, a fixed hollow shaft (1) with one spraying head (2) supplies an electrolyte (3) which is sprayed to an exterior surface for instance an Al-Si piston (6) and piston ring grooves (7). The oxide coating forms on the piston exterior surface, particularly in the ring grooves.

For instance, an as-prepared thin coating (ideally 0.5-3 microns in thickness) on exterior surfaces said pistons and piston ring grooves can eliminate a mild and severe wear problem which may otherwise occur if there is no such coating on them.

Example 3

The thin oxide layer also has a high corrosion resistance, thus, the surface layer would protect the engine block bore, piston, and piston ring groove from corrosion caused by an alternative fuel such as E85 and biodiesel.

Example 4

The as-treated thin coating has a required mechanical, tribological property, and high thermal conductivity as well as smooth surface finish, thus, no complicated post-treatment (polishing/honing) after the coating process is necessary, which would

significantly improve the lifetime of the lightweight component and also reduce the manufacturing cost.

Example 5

The thin oxide coating can be applied on sleeveless engine bores made of an Al-Si alloy with a low or high Si content. The sleeveless engine bores will reduce the weight of an engine by elimination of cast iron cylinder liners. The possibility in elimination of cast iron cylinder, high Si content Al-Si alloy, or other Al alloy cylinder liners would also further save the material and manufacturing costs.

Example 6

The thin, hard oxide layer on a lightweight component eliminates a metal-metal contact during the sliding wear. Al-Si engine block bore surfaces coated with the thin oxide coating can withstand a higher heat impact than the bare Al-Si alloy bores. Therefore, the oxide coating would reduce the risk of adhesive or scuffing wear. The thin oxide coating on engine block bores also have a high thermal conductivity, similar to metallic cylinder bores, which would improve heat conductivity and lessens cylinder bore distortions.

CLAIMS

What is claimed is:

1. A process of forming an oxide coating on a surface of lightweight Al, Al-Si, Mg, and Ti alloys, which comprises an alkaline electrolyte being sprayed onto a surface of said alloys, an electrochemical etching of said surface of said alloys down by 0.3-3 microns, and a plasma oxidation of said surface to form an oxide coating on said alloys under an electrode voltage.
2. The process according to claim 1, wherein the oxide coating on said alloys has a coating thickness 0.5-5 micron, and the oxide coating has dimples.
3. The process according to claim 1 or 2, wherein the coated surfaces of said alloys have a mean surface roughness R_a less than 0.6 micron.
4. The process according to claim 1 or 2, wherein the coated surfaces of said alloys are engine block bores and pistons.
5. The process according to claim 1 or 2, wherein the coated surfaces of said alloys are interior and exterior surfaces which need protections from wear and corrosion.

Application number/numéro de demande: Q2556869

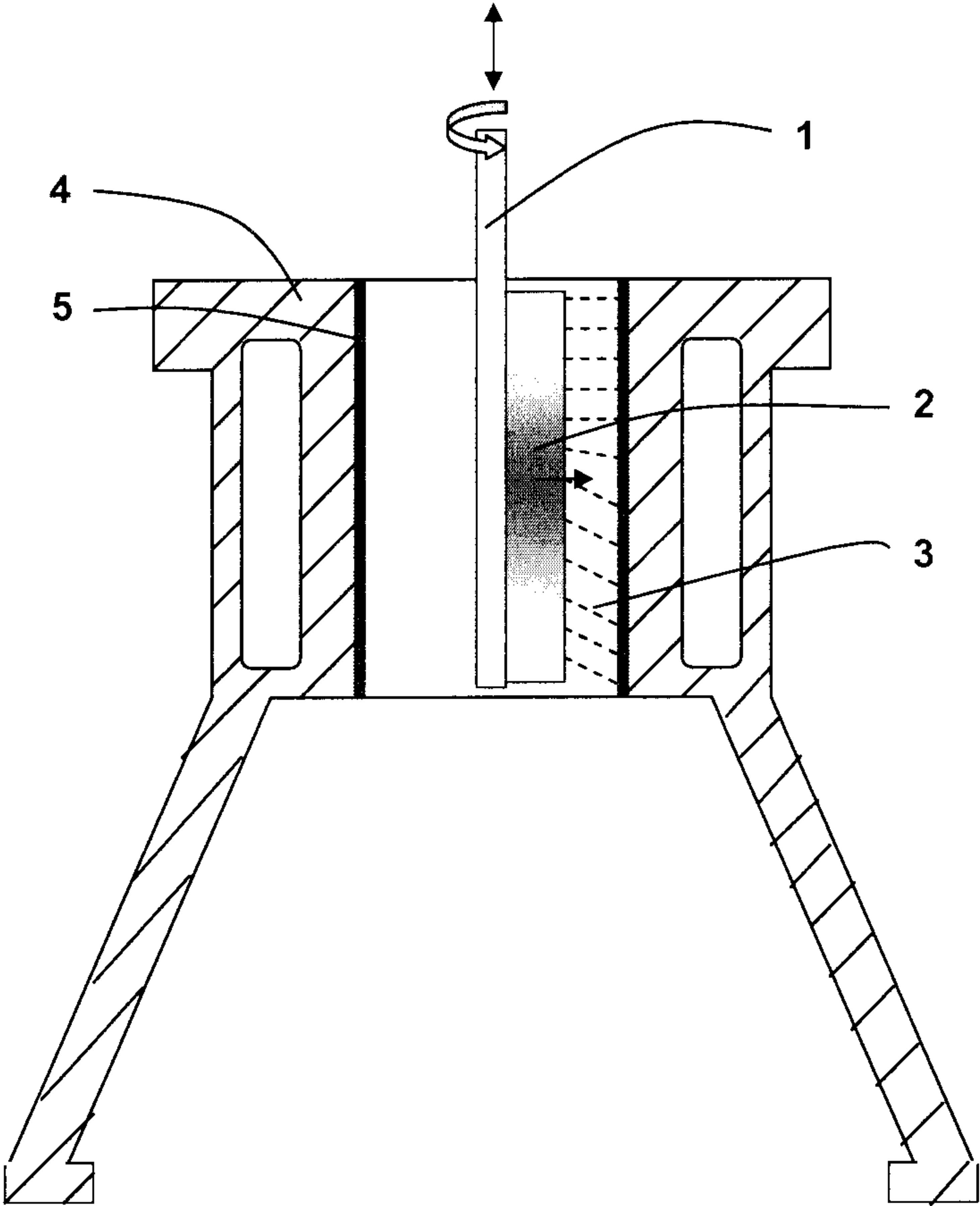
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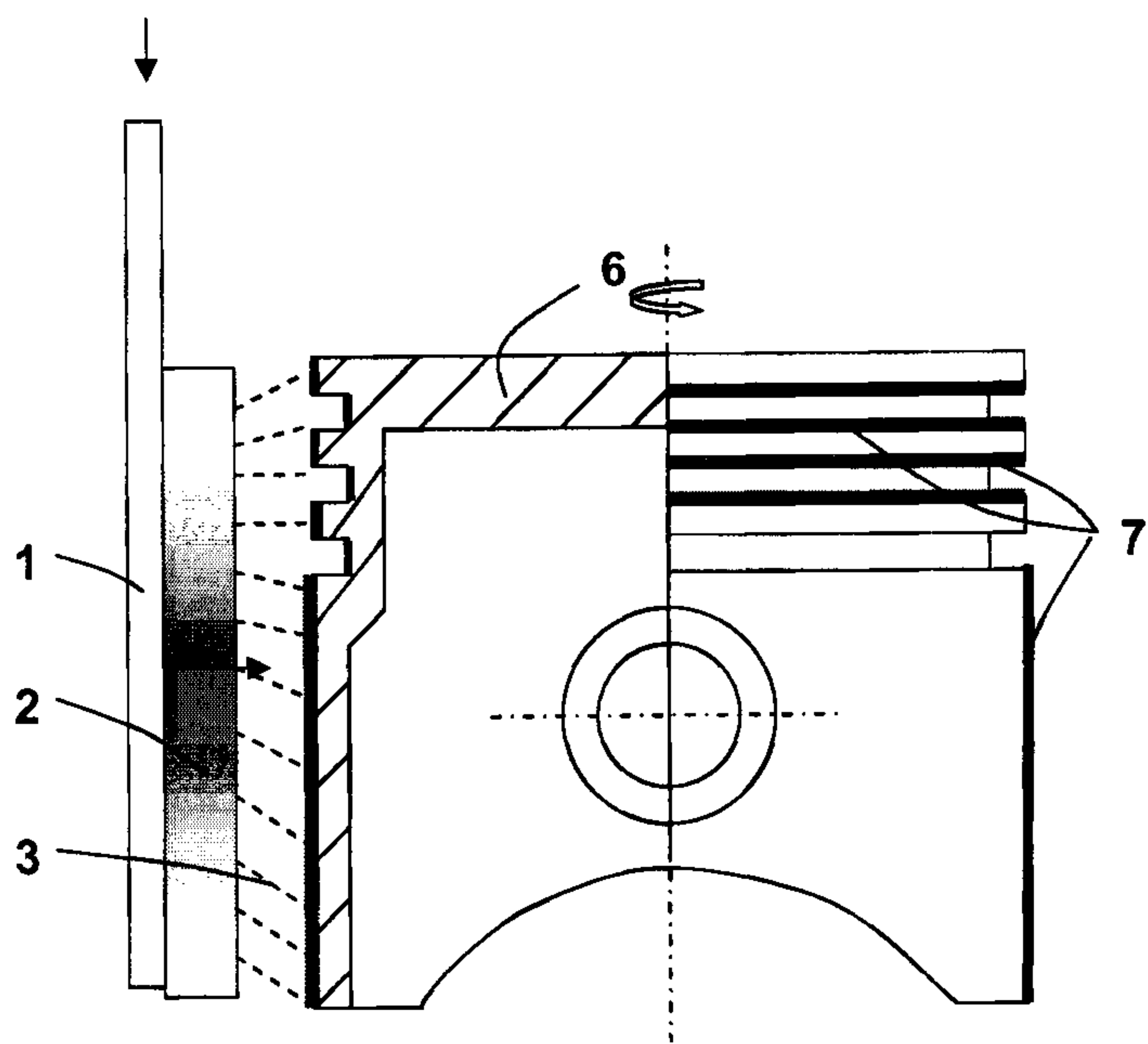
Unscannable items
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(Request original documents in File Prep. Section on the 10th Floor)

Documents reçus avec cette demande ne pouvant être balayés
(Commander les documents originaux dans la section de préparation des dossiers au
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DRAWINGS



Drawing 1



Drawing 2

