CHROMIUM FOR WEAR RESISTANCE

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This invention relates to chromium wearing surfaces, i.e., surfaces subject to friction, and especially cylinder bores.

It is known that by providing a surface layer of chromium on the cylinder bores of engines, pumps, air compressors and the like, the rate of wear of the bore can be greatly reduced as the chromium layer is extremely hard and is also highly resistant to corrosion.

The chromium layer can be deposited electrolytically on the cylinder bore, and owing to the hardness of the chromium it is desirable that the deposited chromium should be of such a form and thickness that a minimum of mechanical finishing of the surface is required. It is also desirable that the finished surface of the chromium should not be too smooth; a highly polished chromium surface is liable to pick up under working conditions, that is, to be torn away from the surface of the cylinder bore.

According to my invention a cylinder bore is provided with a layer or coating of chromium in the surface of which are formed numerous small grooves, pits or depressions. Under working conditions oil is retained in these and there is no tendency for the chromium to pick up. Further, such a finely irregular chromium surface permits the piston rings to grind the chromium layer sufficiently to form a close fit between the rings and cylinder early in their life, despite the extreme hardness of chromium as a metal, and also permits the face of a chromium layer to be worked reasonably readily, for example, for finishing closely to size.

In a preferred method of forming these grooves, pits or depressions a layer of chromium of the desired thickness or of slightly more than the required thickness is deposited electrolytically on the cylinder bore by the process described in Patent No. 2,048,378 employing an aqueous chromic acid bath or solution as described therein and an anode of circular cross-section and of a diameter only slightly less than that of the cylinder bore; it is not essential however that the plate of chromium be produced in the manner described in that patent. The current is then reversed for a short time so that the bore becomes the anode. The result of this treatment is that a certain amount of the chromium is removed from the surface, and the surface of the chromium after treatment is covered with small grooves, pits or depressions which under examination with a low-powered microscope have the appearance of cracks in the surface.

The appearance of the surface and the effective area of the grooves, pits or depressions relative to the total area of the surface depend to a certain extent on the length of the treatment with reversed current and the current density employed, and after a prolonged treatment the surface may have the appearance of an open grain cast iron.

The treatment of the chromium with reversed current, i.e., with current flowing in such a direction that the chromium serves as an anode, may be carried out in the same bath as the deposition of the chromium but preferably it is carried out in a separate bath to avoid spoiling the solution. The solution in the second bath is preferably a chromic acid solution as used in the first bath, but various other acid or alkaline solutions such as a 20% caustic soda solution may be employed.

Experiments have shown that a suitable surface can be obtained by treating a smooth chromium deposit with a reversed current of from 150 to 450 ampere-minutes per square decimeter.

In addition to their function of retaining oil the grooves, pits or depressions in the surface of the chromium reduce the effective area of the surface which is in contact with a piston or other member working in the cylinder bore and so reduce friction. Further, the reduction in the effective surface area facilitates any honing or grinding of the surface which may be subsequently carried out to bring it exactly to size as there is less chromium to remove.

As a certain amount of chromium is removed when the surface is treated with a reversed current it is desirable in depositing the chromium initially on a cylinder bore to deposit a layer of chromium of such thickness that the internal diameter of the bore is approximately one thousandth of an inch under the required finished diameter.

To avoid excessive removal of chromium from the deposited layer at the ends of the cylinder bore when the current is reversed, cylindrical extensions having the same diameter as the cylinder bore may be temporarily secured to the ends of the cylinder block or liner in alignment with the bore.

If desired the surface of the chromium layer after deposition may be lightly honed to remove any projections or high spots before the chromium is treated with the reversed current.

A chromium surface in accordance with my invention is particularly adapted for use in the cylinder bores of engines having aluminum pistons and can be applied to cylinder blocks, barrels or
liners of cast-iron, steel or any other metal on which chromium can be deposited electrolytically, and it can also be applied to other cylindrical bores.

The subject matter claimed herein was claimed initially in my copending application Serial No. 270,018, filed April 25, 1939, on which Patent No. 2,314,604 was issued March 29, 1943, and of a part of which this present application is a continuation. All claims to that subject matter were removed from that application on the ground that such subject matter is separate and distinct from the method or process of the claims retained in that application.

While the invention is described above as particularly applicable to cylinders for engines, pumps, compressors and the like, it can be applied to chromium or otherwise chromium-faced wearing members of other kinds, that is to say members tending to wear by frictional contact with co-operating members, where the retention of lubricating oil between the contacting members is desirable, or where the chromium is liable to be picked up, or which require honing to size, etc.

Briefly, as appears above, my preferred method of producing, for example, an engine cylinder or cylinder liner of my invention, the chromium being on the interior cylindrical wall of the cylinder or liner, is to take a cylinder block or liner of cast iron or of other metal suitable for the foundation and have a bore that is somewhat oversize, and plate the bore with chromium electrolytically until the diameter of the bore is less than the diameter desired when finished; then apply the reverse current treatment, that is to say, subject the chromium plate to the electric current in such a direction that the exposed face of the chromium is an anode while in an electrolytic bath capable of removing chromium from the surface with the passage of the current, until the exposed surface or face of the chromium is well pitted or porous; and then hone the so treated surface of the chromium to the size desired, and at least usually to a depth short of the bottoms of the grooves or pores resulting from the current, and usually using first a rough hone and then a finer one to finish. Wearing members other than cylinders can be produced by the same process in a manner that will be understood from the above. It will be understood of course that the chromium need not be piled or perforated completely through, e.g., to any underlying metal forming a foundation for the chromium; preferably at least the grooves, pits or depressions extend only part way through the chromium. Within the term "honing" and the like as here used, I include abrasive actions. In some instances or for some purposes it may not be necessary to hone the porous surface as initially produced, e.g., as produced by the anodic current action, or it may be produced as a chromium faced article that is readily treated further, or it may be sufficient to abrade or smooth the initial porous surface only slightly so as to, for example, merely remove minor projecting or high spots.

The accompanying drawings illustrate the type of article that results from this process which I prefer, and are representative generally of the article of my invention. Fig. 1 is a highly magnified view of a typical face or exposed surface of the chromium on which no honing has been done, looking directly at the face. Fig. 2 is a magnified view of a cross-section of an article having such a surface or face. Figs. 3 and 4 are magnified views of a typical surface or face, and a cross-section, after a material amount of honing. In the drawings forming part of the patent application, the magnification of Fig. 1 is about 500 diameters and the magnifications of Figs. 2, 3, and 4 are about 100 diameters.

In Figs. 2 and 4, the numeral 1 indicates a foundation metal carrying an electropate 2 or 3 of chromium. In Figs. 1 and 3 only the chromium is shown of course.

Speaking generally, the chromium face of an article of my invention contains a great many small depressions which in a face view (looking perpendicularly at the face of the chromium) appear as 4 and 5 except in the case when depressions of the form of 4 are so numerous that they cannot be distinguished one from another in a face view. The bottoms of some or all of these depressions 4 and 5 may be irregular, the irregularities being of microscopic dimensions but sufficiently large to be measurable under a magnification of 100 diameters. Figs. 3 and 4, for example, these major depressions 4 and 5 may have smaller depressions in their bottoms, Figs. 3 and 4, and in some instances and especially those 5 after honing, may have projections extending upwardly from their bottoms and forming smaller cavities. At least some of these major depressions 4 and 5 (whether individually distinguishable in a face view or not) are more than about 0.00015 inch and less than about 0.004 inch in width, and few if any are more than about 0.0125 inch in width. Preferably at least some of them are less than 0.004 inch in width and the widest are between about 0.0002 inch and about 0.0125 inch in width. Preferably in any instance the narrowest of the major number of the major depressions such as 4 and 5 that are observable under a magnification of 500 diameters, is between about 0.0003 inch and about 0.004 inch in width, and the widest of such major number is between about 0.0003 inch and about 0.0125 inch in width. With the depressions or major depressions 4 and 5 of such widths the grooves, pits or depressions of the chromium face or surface are of capillary size and hence tend strongly to retain lubricating oil supplied to them. The depressions 4 and 5 may occupy anything more than six percent of the total area of the working face, thus exposing adequate metal without much danger of local overheating.

Preferably the major number of the depressions are more than 0.0002 inch deep.

Prior to any honing that may be done or when the face has been only relatively slightly abraded, and provided that the facially-apparent depressions 4 are not too numerous, a microscopic view of sufficient magnification looking perpendicularly at the face of the chromium, Fig. 1, shows these depressions 4 as narrow cracks or crevices distributed over the face, each extending as a more or less straight or slightly curved line, with few if any exceptions of lengths many times greater than their average widths, the crevices or cracks extending in many different directions and crossing each other to form a network or networks of crevices, and which in such a case would be evident from the appearance of the network of crevices are of microscopic dimensions. However the cracks or crevices such as 4 may be so numerous that individually they are indistinguishable one from another in a face view such as Fig. 1.

In such a case a microscopic view looking directly at an unabraded or a slightly abraded face is of the nature to be expected of such a struc-
ture, for example a conglomerate of metal at different levels, or exceedingly small areas of metal in focus and irregularly distributed throughout a depressed area in the midst of which other metallic areas, points or ridges may appear as blurs. According to my invention the cracks or crevices (regardless of whether or not they are so few in number as to be individually distinguishable in a face view as in Fig. 1) include some that are more than about 0.00015 inch and less than about 0.00125 inch in width. Preferably the widest of them is between about 0.00035 inch and 0.0009 inch in width, and more preferably the widest of them is between 0.0004 inch and about 0.0009 inch in width. Most preferably in any instance the major number of the cracks or crevices that are observable at a magnification of 500 diameters, are of various widths, the narrowest of that major number is between about 0.0003 inch and about 0.00009 inch in width and the widest is between about 0.0004 inch and about 0.0009 inch in width. The number of the cracks or crevices as counted by the number of those obtained from the examination of 500 diameters that, per inch, cross a straight line, the average of a number of such counts being taken in any case, may be anywhere from about 400 per inch to such a number (usually above 1000 per inch) that the crevices merge into each other to such an extent as to be indistinguishable one from another; preferably I provide more than about 500 per inch. The cracks or crevices may occupy anywhere from six per cent to substantially one hundred percent of the total area of the face, depending on the porosity desired. In any instance the crevices may be of various depths, and the depths of at least the major number of them (as measurable in a magnified cross-section such as Fig. 2) may be anything greater than about 0.00015 inch; preferably I make the depths of the deepest of them between about 0.0017 inch and about 0.0035 inch; more preferably I make the depths of at least the major number of those that are observable at a magnification of 500 diameters, about between 0.0002 inch and about 0.0035 inch. The number of the cracks or crevices produced by passing current through the chromium with the anode as described above, the widths of the widest of those cracks or crevices at the end of such operation, and the percent of the total area of the face treated occupied by the cracks or crevices, depend on the number of ampere-minutes per unit of area employed in that operation, generally speaking, e.g., as a rule 300 ampere-minutes per square decimeter produces both more crevice and crevices of greater widths, and causes the crevices to occupy a greater part of the total area of the face, than 150 ampere-minutes per square decimeter, and so on until the number and widths of the cracks or crevices become so great relative to each other that they occupy the whole face and the cracks or crevices are no more distinguishable one from another. However, at times at least the depths of the deepest crevices directly resulting from such current operations, as seen in cross-sectional views, does not seem to be very great in comparison with the amount of energy used in the operation; in any case however the needed depths are readily achieved.

After a more or less thorough honing the structure described above assumes the form illustrated in Figs. 3 and 4. As shown representatively in Fig. 3, a microscopic view looking perpendicularly at the face or exposed surface of the chromium shows this face to consist of, primarily, a plane area or areas of metal and the more or less uniformly distributed major depressions 5 mentioned before and which extend below the level of the plane area or areas 6. Additionally, much smaller or minor pits or depressions may be distributed more or less throughout the metal area or areas as may be seen in the upper right-hand quarter of Fig. 3 where the focus is sharper. I use the term "plane" area here in the sense of tooling, or finished, or relatively smooth, rather than in the sense of wholly flat, since in fact they may be curved, e.g., where the face of the internal cylindrical wall of an engine cylinder. The minor pits or small depressions referred to above appear to be composed in whole or in part of remnants of some of the smaller or minor grooves, pits or depressions of the form of the article of Figs. 1 and 2, and may be so minute in size and shallow that they appear to be collected along lines such as those of the cracks or crevices 4 although at other times such disposition may be hard to observe. For the most part at least, these minor pits or depressions are generally elongated (although the differences between their respective lengths and widths may be greatly less than the differences between the lengths and widths of the respective cracks or crevices 4), and desirably are of higher irregular shapes as seen in a face view such as Fig. 3.

Generally speaking, and other things being the same, the greater the degree of porosity given to the chromium face prior to honing, the greater is the percentage of the total surface that is occupied by major depressions such as 5, the greater their lengths, and the greater their lengths relative to their average widths, and the more they tend to be connected one with another and to divide the plane metal areas into the form of isolated islands. The greater the honing in any instance the greater the number of the cracks or crevices produced by passing current through the chromium with the anode as described above, the widths of the widest of those cracks or crevices at the end of such operation, and the percent of the total area of the face treated occupied by the cracks or crevices, the smaller is the percentage of the total face area occupied by major depressions such as 5, and the less the porosity of the face of the chromium.

The maximum width of at least some of the depressed areas 5 may be more than about 0.00015 inch and less than about 0.004 inch. Preferably at least some of them are less than about 0.004 inch in maximum width and the widest of them are between about 0.002 inch and about 0.0125 inch in maximum width; and preferably, the narrowest of them are between about 0.0001 inch and about 0.004 inch in width. Preferably the depressed areas 5 occupy between six per cent and seventy-five per cent of the total operating area of the face, dependent on the conditions such as the load to be borne and the degree of porosity desired for oil retention. Usually I make the facially-apparent depressions 5 between about 0.00006 inch (preferably about 0.00015 inch) and about 0.005 inch in depth; they may be of various depths.

It will be understood of course that my invention is not limited to the matter as specifically described above nor to the particular structures illustrated in the drawings except as appears in the claims hereafter.
I claim:
1. A wearing member having a wearing surface consisting of chromium and a body formed of another material, and in which wearing surface are grooves, pits or other depressions which, in number, size and depth, are at least of the order of the grooves, pits or other depressions which result from treating an electropolished chromium surface to a reversed current for from 150 to 450 ampere-minutes and then honing to finish.
2. A member having a surface to operate in wearing contact with another member, said surface consisting substantially of chromium in which there are small grooves, pits or depressions at least equal in number, size, depth and distribution, to the number, size, depth and distribution of the grooves, pits or depressions which result from passing a current through a chromium plated surface, in an electrolyte, and in such a direction that the chromium is an anode, until about 150 ampere-minutes of electricity per square decimeter of the surface has passed through the surface and thereafter honing the surface to finish.
3. A member having a wearing surface consisting substantially of chromium and a body formed of another material, and in which wearing surface there are small grooves, pits or depressions of at least the number, size, depth and distribution of the grooves, pits or depressions which result from passing a current through a chromium plated surface, in an electrolyte, and in such a direction that the chromium is an anode, until about 150 ampere-minutes of electricity per square decimeter of the surface has passed through the surface and thereafter honing the surface to finish.
4. A member having a surface to engage in moving contact with another member, said surface of the first mentioned member consisting of chromium and the body of said first mentioned member being formed of another material, and there being in the exposed surface of the chromium grooves, pits or other depressions to contain lubricant, the distribution, number, size and depth of said grooves, pits or depressions being at least as great approximately as the distribution, number, size and depth of those grooves, pits or depressions which result from passing a current through an electropolished chromium surface, in an electrolyte, and in such a direction that the chromium is an anode, until from about 150 to about 450 ampere-minutes of electricity per square decimeter of the surface has passed through the surface and thereafter honing the surface to finish.
5. A cylinder of which the bore is coated with a layer of chromium in the surface of which are numerous small grooves, pits or depressions adapted to retain oil, the number, size, depth and distribution of said grooves, pits and depressions being at least equal to substantially the number, size, depth and distribution of the grooves, pits or depressions produced by treating a chromium plated surface, in an electrolyte, to a current, with the chromium as an anode, until about 150 ampere-minutes of electricity per square decimeter of the surface has passed through the surface to finish.
6. A wearing member having a face of chromium to operate in frictional contact with another wearing member, there being a multitude of small depressions in said face and the bottoms of at least many of said depressions being irregular, the irregularities of such bottoms being of microscopic dimensions but of sufficient size to be measurable under a magnification of 100 diameters.
7. A wearing member having a face of chromium to operate in frictional contact with another wearing member, there being in said face a multitude of depressions at least some of which, as observable looking directly at the face, are more than about 0.00015 inch and less than about 0.004 inch in width.
9. A wearing member having a face of chromium to operate in frictional contact with another wearing member, there being in said face a multitude of depressions of various widths, and, as observable looking directly at the face, at least some of said depressions being less than about 0.004 inch in width and the widest being between about 0.0002 inch and about 0.0125 inch in width.
10. A wearing member having a face of chromium to operate in frictional contact with another wearing member, there being in said face a multitude of depressions of various widths and of which the narrowest of the major number observable looking directly at the face at a magnification of 500 diameters is between about 0.00003 inch and 0.004 inch in width and the widest of said major number is between about 0.0003 inch and about 0.0125 inch in width.
11. A wearing member having a face of chromium to operate in frictional contact with another wearing member, there being in said face a multitude of depressions of various widths and of which the narrowest of the major number observable looking directly at the face at a magnification of 500 diameters is between about 0.00003 inch and 0.004 inch in width and the widest of said major number is between about 0.0003 inch and about 0.0125 inch in width.
12. The subject matter of claim 11 characterized by the fact that the said depressions in the face occupy more than six percent of the total area of the face.
13. The subject matter of claim 11 characterized by the fact that the major number of said depressions are more than 0.0002 inch deep.
14. An article of manufacture having a face of chromium in which there are crevices extending in many directions and which are so numerous that any areas standing between the crevices are of microscopic dimensions.
15. An article of manufacture having a face of chromium in which there are individually distinguishable crevices extending in many directions and crossing each other to form a network and which are so numerous that the areas standing between the crevices are of microscopic dimensions.
16. An article of manufacture having a face of chromium in which there are crevices extending in many directions, and at least many of the said crevices being so narrow that, in face view, they are individually indistinguishable.
17. A wearing member having a face of chromium to operate in frictional contact with another wearing member, there being in said face a multitude of depressions having the form of crevices at least some of which are more than about 0.00015 inch and less than about 0.000125 inch in width.
18. A wearing member having a face of chromium to operate in frictional contact with another
other wearing member, there being in said face a multitude of depressions having the form of crevices the maximum width of the widest of which is between about 0.0004 inch and about 0.001 inch in width.

19. A wearing member having a face of chromium to operate in frictional contact with another wearing member, there being in said face a multitude of depressions having the form of crevices of various widths, and of which the narrowest of the major number observable at a magnification of 500 diameters is between about 0.00003 and about 0.00009 inch in width and the widest is between about 0.0004 and about 0.0009 inch in width.

20. The subject matter of claim 19 characterized by the fact that said crevices occupy between six percent and about one hundred percent of the total area of the face.

21. The subject matter of claim 19 characterized by the fact that the major number of said crevices are between about 0.0002 inch and about 0.0035 inch deep.

22. A wearing member having a face of chromium to operate in frictional contact with another wearing member, said face being composed primarily of interspersed plane and major depressed areas, at least many of said major depressed areas having projections rising from their bottoms and forming small cavities.

23. A wearing member having a face of chromium to operate in frictional contact with another wearing member, said face being composed primarily of interspersed plane and major depressed areas, at least some of the major depressed areas being more than about 0.00015 inch and less than about 0.004 inch in maximum width.

24. A wearing member having a face of chromium to operate in frictional contact with another wearing member, said face being composed primarily of interspersed plane and major depressed areas, at least some of the major depressed areas being less than about 0.004 inch in maximum width and the widest being between about 0.002 inch and about 0.0125 inch in maximum width.

25. A wearing member having a face of chromium to operate in frictional contact with another wearing member, said face being composed primarily of interspersed plane and major depressed areas, the major depressed areas being of various widths, the narrowest of them being between about 0.0001 inch and about 0.004 inch in maximum width, and the widest of them being between about 0.002 inch and about 0.0125 inch in maximum width.

26. The subject matter of claim 22 characterized by the fact that the said major depressed areas occupy between six percent and seventy-five percent of the total area of the face.

27. The subject matter of claim 22 characterized by the fact that at least the larger number of said major depressions are between about 0.0001 inch and about 0.003 inch deep.

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