

UNITED STATES PATENT OFFICE

2,248,530

METAL ARTICLE HAVING ANTIFRICTION SURFACE

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Cleveland, Waterbury, Conn.No Drawing. Application June 5, 1939,
Serial No. 277,498

14 Claims. (Cl. 308—241)

This invention relates to metal articles having antifriction surfaces; and it comprises a metal article, having a surface which is of chromium, said surface being covered with a multiplicity of depressions and prominences of a size sufficient to be visible to the naked eye and producing a matte appearance, the tops of the prominences forming a substantially smooth, plane surface, in combination and in frictional contact with a second surface which is in relative motion with respect to said chromium surface, the contact pressure between said surfaces being below that causing deformation of the second surface to such an extent that said second surface is caused to enter said depressions thereby increasing the friction therebetween; all as more fully hereinafter set forth and as claimed.

A number of distinctly different methods have been proposed in the art for the production of antifriction surfaces. For example bearing surfaces have been plated with metals, such as chromium, which possess a low coefficient of friction. In another method the bearing surfaces have been constructed of porous materials which are capable of retaining lubricants such as oils and supplying these lubricants to moving surfaces in contact therewith. In still another method crystals of hard materials, such as tungsten carbide, have been embedded in a softer metallic matrix, the harder crystals furnishing bearing points of great wear resistance. But of course the oldest and best known method of reducing the friction between any two surfaces is to polish the two surfaces to make them as smooth as possible. This method of reducing the friction between metal surfaces has been highly developed with the introduction of improved grinding and polishing methods designed to reduce surface irregularities to insignificant values. It is well recognized that smooth surfaces in general have coefficients of friction substantially below those of surfaces which have been roughened, for example by sand blasting.

We have discovered, however, the surprising fact that the coefficient of friction of a chromium plated surface can be substantially reduced by a sand blasting or other roughening operation performed either on the plated surface or on the metal surface prior to chromium plating. Best results are obtained when the surface is roughened to such an extent that it consists of a multiplicity of depressions and prominences of a size barely visible to the naked eye, producing a matte appearance. This type of surface can be produced in various ways. Sand blasting is prob-

ably the easiest and most satisfactory method but etching, engraving, knurling and any of the other mechanical methods of producing indentations of the desired type and size may be employed.

We have found that the indentations should be distributed as uniformly as possible over the surface. The size of the indentations may vary rather widely and the optimum size depends to some extent upon the type of surface with which the new surface is in frictional contact. With soft flexible or fibrous materials, for example, and in the absence of lubrication the indentations should be smaller and of less depth than in the case of hard metallic surfaces. But when lubrication is provided the friction is reduced by the new surface in contact with a soft fibrous packing, for example, even when the indentations are produced by blasting with coarse sand.

We have produced the indentations of our invention by blasting with an abrasive varying in size from 4 mesh to 150 mesh and have found that improved results are usually obtained over this entire range. The actual size of the indentations produced in this fashion may vary between about 0.004 to 0.185 inch in diameter, these indentations having depths roughly about half their diameters.

The finished surface should be free from all burrs which may be produced by the roughening operation. Burrs may be removed by a very light smoothing or polishing operation conducted either before or after chromium plating. Smoothing should not be carried to the point at which the roughening is substantially reduced, however. We have found that a light rubbing with 000 emery paper is sufficient for most purposes. When sand blasting is employed with sand having a size smaller than about 60 mesh it is usually not necessary to treat the surface for removal of burrs. The extremely fine burrs produced by sand of 60 mesh and finer are apparently removed in the usual cleaning operation prior to chromium plating. The presence of burrs is more objectionable when a soft fibrous material is used in contact with our antifriction surface than when a hard metal is used.

Our antifriction surface is useful either in the presence or absence of a lubricant. Lubrication, when possible, of course lowers the frictional resistance of our surface in the same way as it lowers the frictional resistance of smooth surfaces, although the presence of lubricant is by no means essential for the securing the advantages presented by our invention. However, when a lubricant,

such as a lubricating oil is employed between the surfaces, its effect in the reduction of friction is much more marked with our surface than with smooth surfaces. The apparent cause for this is the fact that the indentations of our surface pick up and retain the lubricant, feeding it to the two surfaces when and as required, thus producing a heavier and more uniform film of oil. If intermittent lubrication is employed our surface is greatly superior for the reason that the indentations form tiny pools of lubricant which tend to conserve and distribute the lubricant over the intervals between its application.

Our antifriction surface can be produced on any material which can be chromium plated. Among the materials which have been provided with this surface there can be mentioned steel, cast iron, brass, bronze, aluminum, monel and nickel-silver.

We have found that our antifriction surface is almost universally applicable. Our surface has a lower coefficient of friction against such widely different surfaces as metals, glass, rayon, cotton-textiles, plastics, leather, wood, paper, rubber, etc. In comparison with a chromium plated surface having a mirror finish, our new surface produces less friction when in contact with any of these materials under most conditions of operation. In fact the only limit to the applicability of our new surface, which we have discovered, is that the material in contact therewith must not be deformed sufficiently to enter the indentations. The extent of deformation depends upon the pressure between the two surfaces as well as upon the size of the indentations. We have found that there is apparently a critical pressure below which our surface reduces friction and above which there is no improvement over a polished chromium surface. In some cases, with the use of pressures above this critical value, we have found that our surface has a coefficient of friction which may be higher than that of a polished surface of chromium. For most practical purposes this critical pressure is exceeded only when pressure is applied to relatively soft materials, such as paper, which can be readily deformed under pressure. In a few industrial applications, however, such as wire drawing dies or punching and stamping dies, which are operating at extremely high pressures and on soft metals, such as copper, critical pressure may also be exceeded. This can be determined readily by an inspection of the surfaces of the worked metals to determine whether the indentations of our antifriction surface have left any imprint. The existence of a critical pressure can be demonstrated readily by a simple test in which our new surface is compared with a polished chromium plated surface. If the finger is rubbed lightly over these two surfaces it will be noted that the antifriction sur-

face will produce substantially less drag, whereas if the finger is pressed against these surfaces as it is rubbed across them, it will be noted that the roughened surface produces the greatest drag.

We have found that when two steel surfaces are in dry frictional contact, the roughening of one or of both of the surfaces, as by sand-blasting, substantially increases the frictional contact between them. But if two chromium plated and polished surfaces are in dry frictional contact and if one or both is roughened, in accordance with our invention, the coefficient of friction is substantially reduced. And if a steel surface is in frictional contact with a polished chromium surface the friction between these surfaces may be substantially reduced by roughening either or both of these surfaces. In the case of a steel surface in frictional contact with a chromium plated surface it is evidently much more advantageous to roughen the chromium plated rather than the steel surface for the reason that the former surface will retain its roughened characteristic for a period several times as long. A roughened steel surface subjected to frictional wear soon becomes smooth.

The cause for the reduced friction produced in our invention is not fully understood. From the theoretical standpoint there is a so-called law of friction which states that when an object is moved across a surface the force of friction is independent of the area of contact between the object and the surface. The roughening of our surface undoubtedly reduces the area of contact and it would be expected that, if the force required to move an object across our new surface should be measured and compared with that required to move the same object across a polished chromium surface, the two forces would be the same. This expected result is not obtained however since the force required in the case of our antifriction surface is substantially less. It is known, of course, that this so-called law of friction is only an approximation and that it is not valid in certain cases. But there appears to be no satisfactory theoretical explanation for the results obtained by the present invention.

Where a sheet or strip of material is passed over our new surface, that is, in those cases where the material must be lifted or separated from the surface, it might be expected that less adhesion would be produced owing to the fact that the indentations supply pockets of air which prevent any tendency to form a vacuum between the surfaces. But this effect does not account for the improved results secured in those cases in which this effect cannot be present.

We have tested our antifriction surface in a large number of practical industrial applications, some of which are listed in the following table:

Table I

Antifriction surface applied to—	Material contacted	Lubrication	Speed
Suction box covers.	Bronze wire mesh.	Water.	300-500 ft./min.
Thread guides.	Acetate and viscose rayon, containing zinc oxide.	None.	500 ft./min.
Hydraulic rams.	Rubber or fibre packing.	Water.	9 in./min.
Thrust bearing.	Steel.	Oil.	1250 R. F. M.
Pump plunger.	Fibre packing.	Water.	30 ft./min.
Shake rail shaft.	Bronze.	Oil.	200 cycles/min.
Fourdrinier wire guides.	Bronze wire.	Water.	300-500 ft./min.
Wire guide.	do.	None.	1000 ft./min.
Piston.	Steel.	Oil.	Variable.
Guide shoe.	Motion picture film.	None.	60 ft./min.
Mandrel.	Waxed paper.	do.	

In all of these cases the new surface has given longer wear and less friction than smooth chromium plated surfaces used previously to the present invention.

It should be noted that the speeds given in the above table are only approximate. The materials contacted with our new surface in the above list include bronze, steel, rayon, paper, rubber and fibre. The lubricants used include oil, water and soap, while in four cases no lubricant whatever was used, i. e. the surfaces were in substantially dry frictional contact. The surfaces tested were in relative motion at speeds ranging from about 9 inches per minute to 1000 feet per minute. And the pressures varied from comparatively light pressures, as in the case of the thread guides up to exceedingly heavy pressures in the case of the shake rail shaft and the thrust bearing.

In a specific example of our invention we tested our surface on the thread guides used in the textile industry. The usual steel guides were first sand blasted, using 120 mesh sand. This was followed by the application of a chromium plate having a thickness of 0.0025 inch. These guides were found to last more than twice as long as similar guides which were merely supplied with chromium plate with a bright finish and of the same thickness. It was noted that in this application of our invention the threads passing over the antifriction surfaces were substantially less frayed than in the case of the guides with a bright chromium finish. This was found due to reduced static electricity caused by the lower friction in the case of the roughened surfaces. The new surface was also found to permit the thread to quiver sideways as the latter passed over it, this quivering tending to spread the wear on the guides over a larger area.

In another industrial application we used our new surface on a so-called suction box cover. The conventional suction box cover, used in the Fourdrinier machine, is of bronze. It is in frictional contact with the Fourdrinier wire which passes over the cover and causes rather rapid wear. Suction box covers have, in the past, been chromium plated with a resultant increase in their life. But we have found that, if these covers are sand blasted with 12 mesh sand and then plated with chromium plate having a thickness of 0.007 inch, the Fourdrinier wire slides over these covers with much less friction and that their life is increased by approximately 175 per cent in comparison with covers carrying a bright chromium plate. The life of the Fourdrinier wire is, of course, also lengthened.

In another specific industrial application of our invention we sandblasted with 60 mesh sand a cast iron hydraulic ram, smoothed the surface with fine emery paper and then electrodeposited upon this surface a layer of chromium 0.005 inch thick. This ram has remained unaffected after eight months' service whereas a similar ram, likewise chromium-plated but with a smooth bright surface scored badly after three months' use.

One of the most important industrial applications of our antifriction surface is in the coating of the pistons and piston rings of internal combustion engines. Our surface retains an oil film even when the motor is idle over long periods of time and this is available for use at the exact point where it is most required to reduce friction. It is well recognized that the bulk of the piston wear in an automobile engine, for example, occurs during the interval between starting and the time the oil reaches and is distributed over the sur-

faces of the pistons and piston rings. The use of our new antifriction surface at these points ensures the presence of a film of oil over these surfaces at the very moment of starting. The lubricant is retained in the indentations by capillarity and is fed to the surface as required to maintain the desired oil film. The hardness of the chromium plate prevents any seizing or galling. A substantial reduction in wear results.

We have found it very difficult to obtain reliable and reproducible values for the coefficients of friction between our new surface and other materials. The results tabulated below were obtained in a series of tests made by constructing an inclined plane of steel, having a polished surface, and preparing a series of discs having a steel base but being provided with surfaces of the type mentioned in the first column of the table. These disc specimens were then placed on the inclined plane and the inclination of the plane was varied to determine the minimum angles at which the various specimens would continue to slide. The tangents of these minimum angles, which represent the coefficients of friction, are given in the table. In the second column the friction coefficients are given as determined before the specimen discs were chromium plated, while in the last column are tabulated the results obtained with chromium plated specimens.

Table II

Surface	Before chromium plating	After chromium plating
Polished.....	.260	.235
Sand blasted with 150 mesh sand.....	.250	.210
120 mesh sand.....	.200	.230
80 mesh sand.....	.200	.220
60 mesh sand.....	.200	.205
24 mesh sand.....	.200	.205
12 mesh sand.....	.200	.200

A similar series of tests were made to determine the coefficients of friction of the various specimens against polished chromium, these tests being made by chromium plating and polishing the surface of the inclined plane. The results obtained are tabulated in Table III.

Table III

Surface	Before chromium plating	After chromium plating
Polished.....	.200	.191
Sand blasted with 150 mesh sand.....	.176	.133
120 mesh sand.....	.205	.128
80 mesh sand.....	.186	.133
60 mesh sand.....	.191	.137
24 mesh sand.....	.176	.133
12 mesh sand.....	.181	.133

The data given in Tables II and III are believed to have more qualitative than quantitative significance and the figures in one table cannot be compared with those in the other table. But it is evident, from the results given in Table II, that the chromium plating of polished steel reduces the coefficient of friction against steel by approximately 10 per cent. In contrast to this, if a sand blasted steel surface is chromium plated to produce a surface within the present invention, the coefficient of friction is reduced by an amount averaging about 25 per cent. Table II, column 2, also shows that the friction between steel and steel is increased by sand blasting one of the steel surfaces, whereas column 3 shows that, if the specimens are sand blasted and chromium plated,

the sand blasting substantially reduces the friction against steel. Table III, column 2 shows that the sand blasting of steel specimens reduces the friction against polished chromium plating. Column 3 shows that a still larger reduction in friction is produced against polished chromium plate by sand-blasting the specimens and then chromium plating.

While we have described what we consider to be the best embodiments of our antifriction surface it is evident that various modifications can be made within the purview of this invention. In order to secure the benefits of our invention it is only necessary, when two surfaces are in frictional contact, that one be provided with indentations or pits of the type described and that one be chromium plated. In carrying out our invention we do not alter the shape of the object supplied with our antifriction surface nor the general contour of its surface. Usually we simply form upon the object a pitted surface and chromium plate it. We may lightly polish the pitted surface either before or after plating, but in no case do we polish enough to remove any appreciable portion of the pits. Sandblasting may be accomplished by any of the usual methods and by the use of any of the conventional abrasives such as ground chilled iron, carborundum, etc. The metal article carrying our antifriction surface may, of course, be of solid chromium. Sand-blasting alone is then required to produce our surface, although it is usually then necessary to lightly polish the surface to remove the burrs produced by the sand blasting. If a plating of chromium is employed it may have a depth ranging from about 0.001 to 0.01 inch. Any type of lubricant may be supplied to our antifriction surface. And the range of application of our invention is limited only by number of industrial uses for two surfaces in frictional contact in which at least one of the surfaces may be of a metal capable of being chromium plated. Other modifications of this invention which fall within the scope of the following claims will be immediately evident to those skilled in this art.

What we claim is:

1. The combination of an article, having an antifriction surface which is of chromium, said surface being covered with a multiplicity of indentations and prominences of a size sufficient to be visible to the naked eye and producing a matte appearance, the tops of the prominences forming a substantially smooth, plane surface, with a second article having a surface in frictional contact with said chromium surface, the said surfaces being in relative motion, the contact pressure between said surfaces being below that causing deformation of the second surface to such an extent that said second surface is caused to enter said indentations thereby increasing the friction therebetween.
2. The combination of claim 1 wherein the said second surface is of steel.
3. The combination of claim 1 wherein said second surface is of paper.
4. The combination of claim 1 wherein said second surface is a textile fibrous material.
5. The combination of claim 1 where the article having a chromium surface is a chromium plated piston.
6. The combination of claim 1 wherein the article having a chromium surface is a thread guide used in the textile industry.
7. The combination of claim 1 wherein the

article having a chromium surface is a hydraulic ram.

8. The combination of claim 1 wherein said indentations have diameters ranging from about 0.004 to 0.185 inch and depths of about half of these values.

9. The combination of two metallic articles having surfaces in relative motion and in frictional contact, at least one of said surfaces being of chromium and at least one being uniformly covered with a multiplicity of indentations of a size barely sufficient to be visible to the naked eye, producing a matte appearance, said indented surface being free from burrs, the contact pressure between said surfaces being below those causing said indentations to produce any imprint on the surface in contact therewith.

10. The combination of two metallic articles having surfaces in relative motion and in frictional contact, one of said surfaces being chromium plated and being uniformly covered with a multiplicity of indentations of a size barely visible to the naked eye, producing a matte appearance, said indented surface being free from burrs, the contact pressure between said surfaces being below those causing said indentations to produce any imprint on the surface in contact therewith.

11. An article having an antifriction surface which is of chromium, said surface being covered with a multiplicity of indentations of the character produced by blasting a metal surface with an abrasive having a size ranging from about 4 to 150 mesh followed by chromium plating to a thickness of about 0.001 to 0.01 inch, said surface being free from burrs, in combination with a second article having a surface in substantially dry frictional contact with said indented surface, the said surfaces being in relative motion, the contact pressure between said surfaces being below those causing deformation of the second surface to such an extent that said second surface is caused to enter said indentations thereby increasing the friction therebetween.

12. An article having a cylindrical, antifriction surface which is chromium plated, said surface being uniformly covered with a multiplicity of indentations in random arrangement having diameters ranging from about 0.004 to 0.185 inch and depths about half of the diameters, producing a matte appearance, said indentations being filled with lubricant in combination with a second article of metal having a smooth surface in relative motion with respect to said indented surface and in frictional contact therewith, the contact pressure between said surfaces being below that causing deformation of the second surface to such an extent that said second surface is caused to enter said indentations thereby increasing the friction therebetween.

13. The combination of an article, having an antifriction surface of chromium covered with a multiplicity of indentations and prominences of random arrangement and of a size barely sufficient to be visible to the naked eye and producing a matte appearance, the tops of the prominences forming a substantially smooth, plane surface, with a second article having a surface in substantially dry frictional contact with said chromium surface, the said surfaces being in relative motion, the contact pressure between said surfaces being below that causing deformation of the second surface to such an extent that said second surface is caused to enter said indentations thereby increasing the friction therebetween.

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14. The combination of an article, having an antifriction surface of chromium covered with a multiplicity of indentations and prominences of random arrangement and of a size barely sufficient to be visible to the naked eye and producing a matte appearance, the tops of the prominences forming a substantially smooth, plane surface, with a second article having a surface

of fibrous material in substantially dry frictional contact with said chromium surface, the said surfaces being in relative motion, the contact pressure between said surfaces being below that causing deformation of the fibrous material to such an extent that said material is caused to enter said indentations thereby increasing the friction therebetween.

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