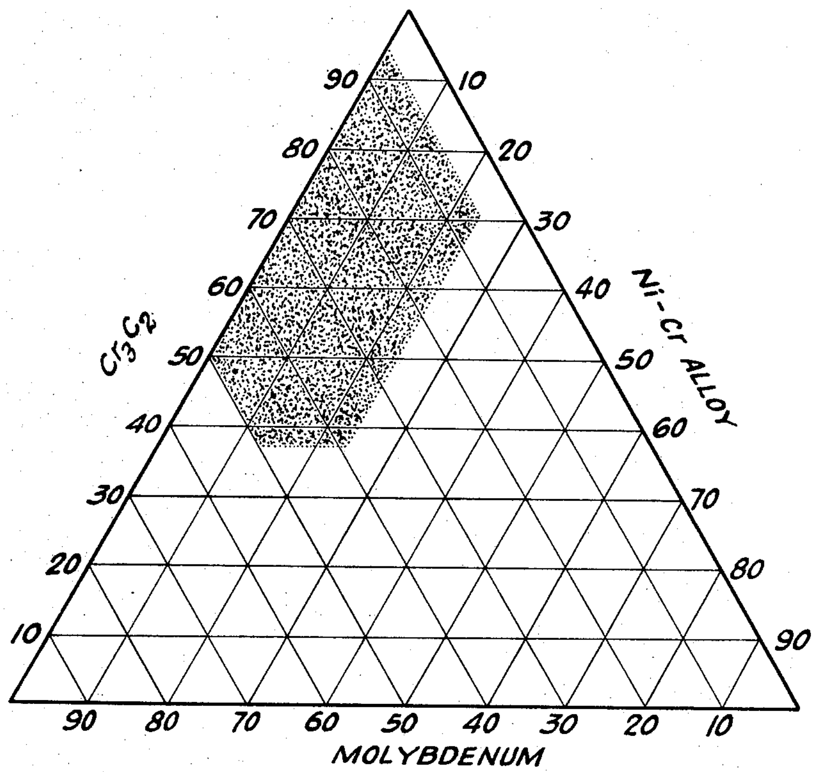
PISTON RING COATINGS FOR HIGH TEMPERATURE APPLICATIONS

Filed Nov. 7, 1967



INVENTOR.
GLENN F. HYDE &
JOHN E. CROMWELL
BY John P. Taylor
their Attorney

United States Patent Office

3,556,747

Patented Jan. 19, 1971

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3,556,747

PISTON RING COATINGS FOR HIGH TEMPERATURE APPLICATIONS

Glenn F. Hyde, Timonium, and John E. Cromwell, Baltimore, Md., assignors to Koppers Company, Inc., a corporation of Delaware

Filed Nov. 7, 1967, Ser. No. 681,153

Int. Cl. B32b *15/00*

U.S. Cl. 29—198 **5 Claims**

ABSTRACT OF THE DISCLOSURE

A coating for piston rings which can be used in internal combustion engines such as diesel engines at temperatures about 700° F. comprises a mixture of chromium carbide and molybdenum which may also include a minor portion of a nickel-chromium alloy. The composition is applied to the piston ring with a plasma-arc gun to bond the composition to the base material.

BACKGROUND OF THE INVENTION

Piston rings used in internal combustion engines have been coated with a variety of materials which generally fall into two major classifications: (1) corrosion-resistant break-in coatings whose purpose is to improve shelf life and run-in capabilities of the ring itself; and (2) wear-resistant coatings whose purpose is to increase the useful operating life of the piston ring. The wear-resistant coatings which have been applied to piston rings include predominantly chrome plate and to a lesser extend molybdenum-sprayed coatings. Both materials provide good wear-resistance at ring temperatures below 500° F.

The operating performance requirements of internal combustion engines, particularly diesel engines, however, have been steadily increasing in severity including the operating temperatures. However, a problem has arisen because the chrome-plated and molybdenum-coated piston rings heretofore used do not perform well when heated to temperatures exceeding about 500° F. Engines today develop combustion temperatures of approximately 1000° F. which subjects the piston rings to temperatures on the order of 700° F.

The chromium plate is sensitive to such high temperatures and will soften and, therefore, lose much of its abrasive resistance. On the other hand, the molybdenum coating loses its abrasive wear resistance at high temperatures from oxidation. Such oxidation forms an oxide lamella within the coating which reduces its cohesive strength leading to eroding or loss of the coating an engine service. The threshold of oxidation for molybdenum begins at about 500° F. However, a molybdenum coating retains its desirable wear properties at high temperature provided that the formation of an oxide lamella can be prevented.

Quite surprisingly, we have found a coating material having a high threshold of oxidation thereby enabling its use at temperatures exceeding 700° F. and without loss of wear-resistance and without degradation. The coating material, furthermore, is not susceptible to large changes in wear-resistance when run under non-lubricated conditions.

SUMMARY OF THE INVENTION

In accordance with the invention, a wearing member having a wearing surface to operate in contact with another member at elevated temperatures is provided; the wearing surface comprising a chromium carbide-molybdenum composition sprayed thereon to provide a wear-resistant coating suitable for operation at temperatures above 700° F. under both lubricated and nonlubricated conditions. The composition can include a third component, a nickel-chromium alloy, in minor amounts as well.

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BRIEF DESCRIPTION OF THE DRAWING

The figure is a triangular graph illustrating the range of the constituents of the alloy.

DETAILED DESCRIPTION

As mentioned above, the wear surface of the invention is obtained by applying a composition comprising chromium carbide and molybdenum to the surface of the wearing member. In one embodiment, the composition also contains a nickel-chromium alloy as a bonding material.

The composition is applied to the wearing member by flameplating with a plasma-arc gun as is well known in the art. Briefly, the plasma flame, having a temperature of about 32,000° F. is produced by applying electrical energy to a gas mixture (such as a 5:1 nitrogen-hydrogen mixture) which disassociates the gas molecules to an atom stage which then ionize to produce free electrons and charged ions. The electrical energy absorbed by ionization is converted to heat energy by deionization of the gas. The particulate composition is directed into the plasma flame by a carrier gas, such as nitrogen. The particles are propelled by the gas escaping through the nozzle of the gun as a stream of molten particles. The nozzle is aimed at the surface to be coated so that the molten particles impinge thereon. A mechanical and atomic bond is produced at the interface between the work piece and the coating particles.

The composition, therefore, is a physical mixture of powders or particles. The size of the particles can vary from about 100 to 5 microns. Preferably, the particle size is about 50 to 20 microns. The particle size range can be readily ascertained by screening the particles in accordance with ASTM Test B–214. Those particles passing through a No. 140 sieve (105 microns) yet retained by a 5-micron sieve comprise the operable particle range. The preferred particle range (20–50 microns) is that retained by a No. 325 sieve (44 microns) or passed through this sieve, but retained on a 20-micron sieve.

The molybdenum component of the composition comprises molybdenum having a 99% purity; it still may contain trace amounts of carbon or iron. The range of this component in the composition of this invention may vary from 5–50%, but, preferably, is 20–40%. The range is graphically depicted in the figure which shows the make up of the composition taking into account the maximum and minimum amounts of each component. The molybdenum component provides excellent wear compatibility to the composition, particularly in regard to its antiscuff and antiwelding properties. The molybdenum component may also act as a bonding material for the composition.

The chromium carbide component is a carbide having the formula Cr_3C_2. It must be 98+ percent pure; the impurities may include minor amounts of iron or silicon. A typical analysis of the chromium carbide showed Cr_3C_2, 98.75%, free carbon, 0.2%, iron, 0.7%, and silicon, 0.1%. The chromium carbide is used in amounts which can range from 37½ to 95% of the composition. The preferred amount is about 50–60%. The chromium carbide imparts hard wear-resistance to the composition, but since it may have a tendency to also cause abrasive scoring, the preferred range is lower than the maximum range. However, under lubricated conditions, tendency toward the abrasive scoring is minimized and, therefore, higher amounts of chromium carbide can be used.

Preferably, a nickel-chromium alloy is used with the chromium carbide to act as a bonding material. The nickel-chromium alloy may contain minor amounts of carbon, manganese, iron, and silicon. A typical analysis of impurities is, for example, 0.25% carbon, 2.50% manganese, 1.00% iron, and 1.50% silicon. The chromium content of the alloy can range from 18.0–22.5% and the remainder is nickel. The nickel-chromium alloy can be used in amounts of up to 23.75% of the total composition. As can be seen in the figure, the composition can be used without the Ni-Cr alloy. However, it is preferable to use about 10–20% to insure good binding of the composition.

The components are physically mixed together and then fed into the plasma-arc gun. As mentioned previously, this technique is well known, and commercial equipment is available to practice plasma-arc flame spraying techniques. An example of apparatus which can be used to apply the composition of the invention is a Metco Type 2MB Plasma-Flame Gun distributed by Metco., Inc., Westbury, N.Y. The coating is sprayed on using a plasma-arc flame. The coating, for example, is applied to a thickness of about 0.015–0.020" and is polished down to a finished thickness of 0.010".

The base surface of the wear member, which is preferably iron or steel, must be free of all foreign material such as oxides, dirt particles, or greasy matter. The surface of the base material may be cleaned by using grit blasting, etching or other suitable techniques.

To further illustrate the invention, a composition was prepared in accordance with the invention by physically mixing 70 parts of a 75% chromium carbide and 25% nickel-chromium alloy (corresponding to the nickel-chromium alloy discussed above) powder mixture with 30 parts of molybdenum powder. The composition had an average particle size of 40–50 microns. The composition was sprayed onto the outer edge of a 5⅛" diameter piston ring having a height of ⅛" using a Metco plasma-arc gun. The torch was held in a stationary position horizontal to the edge of the ring which was fixed on a rotating mandrel set for 80 r.p.m. The ring was sprayed until a coating thickness of 0.015" was attained. The edge of the ring was then machined smooth leaving a coating thickness of 0.010". The ring was placed in a diesel engine operating at 200 BMEP (brake mean effective pressure) using conventional lubricants. The operating ring temperature was about 700° F. for a running period of 100 hours. The coating surface was then examined and found to have no scuffing, as scuffing would have been expected, and exhibited very little wear.

Although the invention has been described for use as a coating for piston rings in diesel engines operating at high BMEP, it is not intended to be limited to such applications but can be used in many other applications requiring high temperature-stable coatings having low friction, high wear-resistance and good antiscuffing and antiwelding properties.

We claim:

1. A piston ring for internal combustion engines, said ring having a wearing surface that is produced by flame spraying onto a ring body made of iron or steel a physical admixture of particles having a size of about 5–100 microns;

(a) said admixture consisting essentially of particles of
  (i) molybdenum,
  (ii) chromium carbide, and
  (iii) a nickel-chromium alloy containing about 18.0–22.5% by weight of chromium with the balance of said alloy being nickel;
(b) said admixture having a composition defined by the shaded portion of the figure;
(c) said admixture producing on the interface of the ring body and coating particles a mechanical and atomic bond thereby providing a wear-resistant coating suitable for operation in said internal combustion engines at temperatures above 700° F. under both lubricated and nonlubricated conditions.

2. The piston ring of claim **1** wherein said coating is applied to a thickness of about 0.015–0.020".

3. The piston ring of claim **1** wherein the composition of said admixture is 30% of molybdenum, 52½% of chromium carbide, and 17½% of nickel-chromium alloy.

4. The piston ring of claim **1** wherein said coating is initially applied to said ring at a thickness of about 0.015–0.020" which is subsequently polished to a final thickness of about 0.010".

5. A flame sprayable composition for the wearing surface of piston rings used in conventional internal combustion engines comprising:
(a) a physical admixture of particles having a size of about 5–100 microns;
(b) said particles consisting essentially of particles of
  (i) molybdenum,
  (ii) chromium carbide, and
  (iii) a nickel-chromium alloy containing 18.0–22.5% by weight of chromium with the balance of said alloy being nickel;
(c) said composition having a composition defined by the shaded portion of the figure; said composition, when flame sprayed onto said wearing surface of said piston rings, being wear-resistant at temperatures above 700° F. under both lubricated and nonlubricated conditions.

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WILLIAM D. MARTIN, Primary Examiner

U.S. Cl. X.R.

29—195, 196.6; 106—1; 117—22