United States Patent Office

2,855,659

Patented Oct. 14, 1958

2,855,659

SINTERED POWDERED METAL PISTON RING

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No Drawing. Application December 29, 1954
Serial No. 478,483

6 Claims. (Cl. 29—182.5)

This invention relates to sintered powdered metal piston rings containing aluminum oxide particles and particularly to a sintered, forged and/or pressed powdered ferrous base metal piston ring of this type characterized by high wear resistance.

Porous metal bearing parts have been commonly used in industry during recent years. Heretofore, however, porous metal parts have not been successfully used in piston rings because of their relatively low wear resistance. A principal object of the present invention, therefore, is to provide a novel sintered and forged or sintered and cold pressed powdered metal piston ring having good antifriction properties and a high degree of wear resistance due to the presence of aluminum oxide particles. A further object of this invention is to eliminate the necessity of expensive chromium plating of piston rings without sacrificing wear resistance by providing a powdered ferrous base piston ring containing hard aluminum oxide particles. Still a further object of the invention is to provide a simple and inexpensive process for forming a sintered, forged and/or pressed powdered metal piston ring having proper porosity.

The above and other objects are attained in accordance with my invention by a sintered and worked powdered metal piston ring having controlled porosity and high wear resistance due to the presence of dispersed particles of aluminum oxide.

Tests on piston rings formed in accordance with my invention indicate that the wear resistance of these rings compares favorably with that of chromium plated rings. Moreover, a sintered powdered metal piston ring of this type can be inexpensively manufactured to close dimensional tolerances because of the elimination of the expensive machining operations otherwise necessary. Since little or no machining is necessary, there is little scrap or waste.

Recently, sintered powdered ferrous base piston rings have been provided with increased wear resistance by the inclusion of either nickel-titanium or titanium-aluminum particles in the powdered metal mix. These developments are respectively disclosed in co-pending patent application S. N. 317,737, filed October 30, 1952, in the name of Alfred L. Boegehold, now abandoned, and co-pending patent application S. N. 444,402, filed July 19, 1954, in the names of Robert F. Thomson and Eric W. Weinman. However, the use of aluminum oxide particles in the mix, in accordance with the present invention, affords certain advantages over the use of nickel-titanium or titanium-aluminum particles. The hard, crystalline aluminum oxide particles are preferable from an economic standpoint since Alundum and corundum, for example, cost appreciably less than other typical nickel-titanium alloys or titanium-aluminum powders. Of course, aluminum oxide also does not contain any relatively critical materials, such as nickel or titanium.

On sintering, moreover, the high-melting aluminum oxide particles alloy with the powdered metal mix to

which they are added to a negligible extent as compared with nickel-containing compounds and tend to remain in substantially the same form in which they are introduced. Maximum wear resistance normally cannot be obtained if the particles alloy excessively with the base metal of the powdered mix.

Other objects and advantages of the present invention will more fully appear from the following detailed description of a preferred embodiment of my invention.

A piston ring is preferably formed in accordance with my invention from a mixture of powdered iron containing finely pulverized aluminum oxide. Even a relatively minute amount of the aluminum oxide powder improves the wear resistance of the piston ring to an appreciable extent, and the range of this constituent may vary from a small but effective amount to a quantity constituting approximately 20% by weight of the ring. However, in order to reduce costs and to provide the piston ring with the desired strength, particularly impact strength and shock resistance, the aluminum oxide content normally should be maintained between about 0.25% and 10%. When more than 10% powdered aluminum oxide is used in a sintered powdered ferrous base piston ring, the tensile strength and ductility of the ring are somewhat reduced. This reduction in physical properties becomes quite pronounced when the aluminum oxide content is raised above 20%. The brittleness of such a piston ring is evidenced by chipping or cracking of wear test specimens when they are being ground. Optimum properties are usually obtained when the ring contains approximately 1.5% to 6% of the crystalline aluminum oxide powder.

Finely divided graphite, preferably 80 mesh or finer, may be mixed with the metal powder and improves the quality of the piston ring if it is present in amounts not larger than about 4% by weight. An initial carbon content of about 0.3% to 4% is satisfactory, but to prevent loss of strength and hardness of the piston ring the graphite content should not exceed 4% in most instances. Alternatively, the desired amount of carbon may be added, or the initial carbon content adjusted, by subsequent heat treatment, such as carburizing, of the piston ring. It will be understood, of course, that a measurable amount of the carbon is usually lost during the sintering operation, and that it is the residual carbon which is important in determining the strength of the piston ring. Inasmuch as sintering may reduce the initial carbon content by approximately one-third, it is desirable to control the carbon additions and sintering operation so that the residual carbon content in the piston ring is between approximately 0.3% and 3% by weight. Thus, my preferred retained carbon content of about 0.6% to 1.5% normally requires the presence of between 1% and 2.3% carbon before sintering.

In view of the above considerations, I have found that a sintered powdered metal piston ring having optimum wear resistance properties in accordance with the present invention comprises approximately 1.5% to 6% by weight of crystalline Al_2O_3 powder, 0.6% to 1.5% by weight of carbon, and the balance substantially all iron.

If the ferrous metal piston ring is to be formed by means of a multiple pressing operation, as hereinafter described, a small but effective amount of zinc stearate not in excess of about 2.5% may also be beneficially included in the powdered iron mix. The zinc stearate eliminates any necessity for coating the dies with a lubricant during the briquetting operation. In general, I have found that best results are obtained with a mix having a zinc stearate content between approximately 0.3% and 2%. Other die lubricants, such as stearic acid in powder form, can also be used in place of the zinc stearate.

Among the aluminum oxides which may be used are

fused Al_2O_3, such as Alundum, and the impure Al_2O_3 containing minor amounts of iron oxide and known as "Turkish emery." Corundum (a form of natural Al_2O_3) and tabular corundum (calcined Al_2O_3) likewise can be successfully employed in accordance with the present invention. Specific examples of these forms of crystalline aluminum oxides include the commercially available compounds identified as Alundum 600X, Alundum 320B, corundum 300, tabular corundum —100+200 and Turkish emery 320. The numerals following the alumina classification in each instance indicate the approximate particle size of the alumina particles. The proper use of appropriate amounts of any of these forms of aluminum oxides in the manner hereinafter described results in the production of a sintered powdered metal part having substantially improved wear resistance. Approximately —100 to —600 mesh aluminum oxide powder may be used, but —250 to —350 mesh particles are preferred. Crystalline aluminum oxide particles which are too coarse are somewhat prone to cause scoring.

Among the ferrous base materials which may be successfully used are commercial iron powders, such as those made by grinding mill scale, deoxidizing, and pulverizing. A steel powder, which may be produced by atomizing very hard steel, grinding and reducing the carbon content of the powder, can also be employed. Moreover, both electrolytic iron and Swedish sponge iron powders are satisfactory base materials for wear-resistant powdered iron piston rings. The particle size of the iron powder is preferably between —50 and —300 mesh.

The wear-resistant sintered powdered metal piston ring may be produced by various processes. One highly satisfactory method involves briquetting the mixture of powdered iron, pulverized aluminum oxide, and graphite powder, if it is desired to add the latter, at an appropriate pressure in a ring-shaped die, thereby forming the briquette into the shape of a complete ring. A briquetting pressure of about 30,000 pounds per square inch has proved to be highly satisfactory, but pressures between approximately 20,000 and 120,000 pounds per square inch may be used. Before briquetting, it is important that the powdered metal constituents be thoroughly mixed in order to provide the resultant piston ring with uniform properties and structure.

The green briquette is then sintered under suitable conditions of time, temperature and atmosphere. Sintering temperatures between approximately 1900° F. and 2300° F. and sintering periods between one-half hour and one hour are highly satisfactory. These sintering times are not critical, however, and sintering periods as short as four minutes and as long as 90 minutes are satisfactory. Excellent results have been obtained by sintering the briquette at 2100° F. for one hour under a non-oxidizing furnace atmosphere, such as "Drycolene" gas or a gaseous mixture of "Neutralene" and a small amount of natural gas.

The dry Drycolene gas normally is composed of approximately 20% carbon monoxide, 3% hydrogen and 77% nitrogen. The Neutralene atmosphere mentioned above is a closely related gaseous mixture which usually consists of approximately 1.5% carbon monoxide, 1.5% hydrogen and 97% nitrogen. It has proved advantageous to mix about 100 parts of Neutralene with one part of natural gas. Other furnace atmospheres can be used, of course, but Drycolene and Neutralene are readily available and each provides a highly effective protective atmosphere. Gases with high hydrogen and very low carbon monoxide contents generally are less desirable because they have a greater tendency to decarburize the briquette and are more costly.

After sintering, the strength of the piston ring blank may be appreciably increased by cold pressing or forging it in a contour-shaped annular die into the desired piston ring blank shape. The forging operation is preferably one of hot forging, and it is usually expedient to forge the briquette before it has cooled after the sintering step. If desired, of course, the sintered briquette or piston ring blank may be permitted to cool and then be reheated to a temperature appropriate for forging. Forging temperatures approaching those used for sintering are generally suitable for use in the present invention. In order to obtain particular properties, however, it is permissible to cold forge or cold press the piston ring blank, but generally a hot forging operation is preferable. The forging or hot coining increases the tensile strength of the sintered blank, especially as the porosity approaches zero. Inasmuch as a dense structure permits scoring under severe engine operating conditions, it is desirable to carefully control the forging so as to provide the piston ring with proper porosity. More specifically, therefore, I have found it advisable to control forging so as to form a piston ring having between 2% and 13% porosity, thereby improving resistance to score. If the ring blank is to be cold pressed or sized rather than forged, a pressure of about 40,000 to 150,000 pounds per square inch is appropriate.

Another method of forming the wear-resistant piston ring which has been particularly satisfactory involves repeated pressing and sintering. In this multiple pressing and annealing treatment, the metal powder is first briquetted at about 30,000 to 90,000 pounds per square inch in an annular die. The briquette is next presintered at a temperature between approximately 1600° F. and 2100° F. for about 10 minutes to two hours. A presintering period of one hour at a temperature of 1600° F. to 1650° F. produces excellent results. The presintered piston ring blank is then sized or pressed at room temperature at a pressure of about 40,000 to 150,000 pounds per square inch in the same annular die and again sintered for about 15 minutes to two hours at a temperature between approximately 1900° F. and 2250° F. A one hour sintering period at 2050° F. to 2100° F. is usually preferred. Then the ring blank is again sized at room temperature at a pressure of about 40,000 to 150,000 pounds per square inch in a die which is shaped to the contour of the ring in its free and open position, the blank still being in the shape of a complete ring, however.

Following the forging or pressing operation, whichever is employed, the piston ring blank is preferably heated for about 30 to 60 minutes to a temperature between approximately 800° F. and 1100° F. with or without restraining the shape of the ring blank. This operation reduces stresses from cold pressing and tempers the martensite formed during rapid cooling of the forged blank. It also may be used to correct the shape of the ring blank if it has become distorted during hot working. Tempering for approximately 45 minutes at 900° F. has proved to be highly satisfactory. If hot forging has been used, it is desirable to rapidly die cool the blank before heat treatment.

When the heat treatment has been completed, a small segment of the piston ring blank is removed by a machining operation to produce the necessary gap in the ring in its free position. After machining, the piston ring may be advantageously surface treated with a phosphate type of anti-friction material, such as iron-manganese-phosphate. Other appropriate surface treatments could be used, of course.

It will be understood that a sintered powdered metal piston ring containing dispersed particles of aluminum oxide in accordance with this invention may be manufactured under the usual porous metal techniques as disclosed in a number of patents, such as Patents Nos. 1,738,163, 2,097,671, 2,075,444, etc. It is likewise obvious that other powdered iron alloys, as well as powdered steel and iron, can be used as the principal constituent in the piston ring. Also, instead of briquetting the metal powder as hereinbefore explained, it may be molded to shape as suggested in Koehring Patent No. 2,198,702 in

which event the forging operation, as before, is used to provide the sintered powdered metal piston ring with optimum porosity. All of these modifications are to be considered as within the scope of the present invention, which broadly comprehends the provision of a sintered powdered ferrous base metal piston ring containing dispersed particles of aluminum oxide.

Wear tests were conducted to compare sintered powdered piston ring materials formed in accordance with my invention with conventional cast iron piston ring materials. Each sample to be tested was machined to prepare a ⅛ inch by 1⅛ inch rubbing surface. The specimens were next successively locked in a fixture of the wear test machine and placed in contact with a rotating smooth-surfaced cast iron wheel having a face width of one inch. Increased wear resistance was measured by decreased weight loss in grams and in decreased volume loss in cubic inches. Score resistance, on the other hand, was indicated by the load required to cause scoring under prescribed test conditions. The severity of this test is indicated by the fact that an amount of equivalent wear to that undergone in approximately 10,000 miles of engine operation occurs in an 18½ hour test run period.

A wear test using this apparatus was conducted in which the specimen load was increased during the 18½ hour period from zero load and automatically adjusted to produce a constant frictional load of 64 pounds. At the end of this test period the cast iron specimens showed an average weight loss of approximately 0.016 gram, while sintered powdered metal specimens containing crystalline Al_2O_3 particles lost an average of only approximately 0.0045 gram. Similarly, while the conventional cast iron samples underwent a volume loss averaging about 140×10^{-6} cubic inches, the specimens formed in accordance with the present invention changed on the average only 22×10^{-6} cubic inches. The results of this test, showing the low weight and low volume loss of my new piston ring under severe wear tests, illustrate its high wear resistance.

Likewise, tests indicate that my new and improved wear-resistant piston ring material has considerably better anti-friction properties than cast iron. This property was measured by means of the specimen load required to produce a 64 pound frictional load. Thus, samples formed of sintered powdered iron containing the aforementioned dispersed particles of crystalline Al_2O_3 required an average of about 830 pounds specimen load to produce the 64 pound frictional load as compared with an average of only approximately 650 pounds specimen load when the cast iron samples were tested.

The importance of the aluminum oxide particles in my new sintered and worked piston ring material is apparent when the results of the above tests are compared with tests conducted on the same sintered and forged powdered iron material to which aluminum oxide had not been added. For example, the specimen load required to produce a 64 pound frictional load on the latter samples averaged only approximately 568 pounds, thus indicating that the coefficient of friction of such a material is substantially reduced by the presence of the crystalline Al_2O_3 particles. Likewise, under the aforementioned test conditions, the ordinary sintered and forged powdered iron piston ring material lost an average of 0.028 gram and underwent a reduction in volume averaging about 238×10^{-6} cubic inches.

When these piston ring materials were also subjected to a score test and compared, the specimens formed from the conventional powdered iron mix required a load averaging only 590 pounds to produce scoring, but an average load of approximately 697 pounds was required to cause any indication of scoring of my new sintered powdered metal piston ring material.

While the present invention has been described by means of certain specific examples, it is to be understood that other forms may be adopted and are contemplated

as being within the scope of the present invention as set forth in the following claims.

I claim:

1. A porous piston ring for an internal combustion engine, said piston ring being characterized by high wear resistance and being formed of a sintered and worked powdered metal mix comprising approximately 0.3% to 3% carbon, 1.5% to 6% of crystalline Al_2O_3, and the balance substantially all iron.

2. In an internal combustion engine, a highly wear-resistant piston ring formed of a sintered and worked powdered metal consisting essentially of approximately 0.3% to 3% by weight of carbon, 0.25% to 10% by weight of dispersed, hard particles of aluminum oxide, and the balance substantially all powdered iron.

3. The process of forming a powdered iron piston ring characterized by high wear resistance, said process comprising compressing a powdered metal mixture into an annular briquette, said mixture comprising approximately 0.3% to 4% graphite, 1.5% to 6% aluminum oxide which has been pulverized to form particles of −100 to −600 mesh size, and the balance substantially all iron; subsequently sintering said briquette; thereafter sizing the annular briquette at a pressure of about 40,000 to 150,000 pounds per square inch in a die which is shaped to the contour of the ring in its free and open position; and thereafter working said sintered briquette to provide it with optimum strength and porosity.

4. A process of forming a porous piston ring which comprises mixing pulverized Al_2O_3 with iron powder, briquetting the resultant mix at a pressure between 20,000 pounds per square inch and 120,000 pounds per square inch into an annular form, sintering the formed briquette under a nonoxidizing atmosphere for a period of time ranging from four minutes to 90 minutes at a temperature between approximately 1900° F. to 2300° F., subsequently forging said sintered briquette to a porosity between 2% and 13% in a die which is shaped to the contour of the finished ring in its free and open position, die cooling the formed piston ring blank, and thereafter tempering said blank for approximately 30 to 60 minutes at a temperature between 800° F. and 1100° F.

5. A process of forming a powdered metal piston ring characterized by high wear resistance, said process comprising forming a powdered iron mixture containing approximately 0.25% to 10% by weight of hard particles of finely pulverized Al_2O_3, briquetting said mixture at a pressure of about 30,000 to 90,000 pounds per square inch in an annular die, sintering said briquette at a temperature between approximately 1900° F. and 2250° F. for about 15 minutes to two hours, thereafter sizing the formed piston ring blank at room temperature at a pressure of about 40,000 to 150,000 pounds per square inch in a die which is shaped to the contour of the ring in its free and open position, and subsequently tempering said blank for approximately 30 to 60 minutes at a temperature between 800° F. and 1100° F.

6. A process for forming a powdered metal piston ring characterized by high wear resistance, said process comprising forming a mixture consisting of 1.5% to 6% by weight of finely divided crystalline aluminum oxide, 0.3% to 4% by weight of graphite and the balance substantially all powdered iron, briquetting said mixture at a pressure of about 30,000 to 90,000 pounds per square inch in an annular die, presintering said briquette at a temperature between approximately 1600° F. and 2100° F. for about 10 minutes to two hours, thereafter sizing the formed piston ring blank at room temperature at a pressure of about 40,000 to 150,000 pounds per square inch in an annular die, again sintering said blank for approximately 15 minutes to two hours at a temperature between approximately 1900° F. and 2250° F., thereafter again sizing said blank at room temperature at a pressure of about 40,000 to 150,000 pounds per square inch in a die which is shaped to the contour of the ring

in its free and open position, and subsequently tempering said blank for approximately 30 to 60 minutes at a temperature between 800° F. and 1100° F.

References Cited in the file of this patent

UNITED STATES PATENTS

2,072,070	Fisher	Feb. 23, 1937
2,213,523	Jones et al.	Sept. 23, 1940
2,224,595	Dawihl	Dec. 10, 1940
2,337,588	Calkins	Dec. 28, 1943
2,376,757	Chanosky	May 22, 1945
2,404,598	Sachse	July 23, 1946

FOREIGN PATENTS

750,430	Germany	Dec. 21, 1944
274,017	Switzerland	June 1, 1951
896,360	Germany	Nov. 12, 1953
896,363	Germany	Nov. 12, 1953

OTHER REFERENCES

"Alloy Cast Iron's Handbook" publ. by American Foundryman's Assn., 1944, pp. 252, 253.

Goetzel: "Treatise on Powder Metallurgy," New York Interscience, 1949, 1950, vol. I, pp. 403, 698; vol. II, p. 765. Also vol. I, pp. 680, 681, 698; vol. II pp. 348–352.