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PROTECTIVE SYSTEM

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This invention relates to coated aluminum pistons for internal combustion engines, particularly engines having aluminum alloy cylinder walls.

Aluminum alloy pistons have long been successfully used in internal combustion engines, including both light and heavy two-cycle and four-cycle gasoline engines, and also in diesel engines. Pistons operate at relatively high temperatures, and reciprocate at high speeds, so that aluminum alloys are particularly useful in this application, because of their high heat conductivity and low weight relative to their strength and volume. Another established use of aluminum alloys is in the heads of internal combustion engines, where the low weight of aluminum alloys is useful, and high heat conductivity is also important. While these applications of aluminum alloys have been helpful in reducing engine weight, and in increasing engine efficiency, the application of aluminum alloys to engine blocks has been retarded by difficulties which have been encountered in connection with the cylinder walls. Aluminum alloy pistons present difficult problems of scoring and scuffing when used in aluminum alloy cylinder walls. This problem has been overcome in many commercially accepted engines by inserting cast iron or like cylinder wall liners in an aluminum block. However, this solution of the problem is complicated and expensive and less efficient in operation, and for many years an extensive search has continued for a practical and economical means for producing an engine, particularly of the type used in conventional automobiles, having aluminum pistons operating successfully over a standard service life in a cast aluminum alloy block having cylinder walls of the same or of a similar alloy, unlined and uncoated.

This object has heretofore been achieved to a large extent, but the one test which has not heretofore been met is repeated cold-starting at —20 degrees Fahrenheit, which is a requirement in some areas of the United States and other countries. The insertion of special cylinder liners is undesirable, for reasons of cost as pointed out above, and it is not practicable to plate or spray the cylinder walls because of the technical problems of working inside such small spaces or because of the cost of the plating itself. Various coatings for the pistons have been tried, including chrome plating, without success because of the poor wear characteristics or adhesion difficulties. Furthermore, analysis of the problem has been complicated by the presence of the piston rings, which have to be made of special materials, such as cast iron or steel, frequently with a chrome plating.

Since the coatings tried for the pistons were not successful, there was no assurance whether the problem stemmed solely from the coatings tried on the pistons, or whether it might be seriously influenced by the operation of the rings. The present invention overcomes these difficulties by providing a coating on an aluminum alloy piston which has proved successful in repeated cold-starts and general operating tests when used in a cast aluminum alloy block having no liner or coating on the aluminum

alloy cylinder walls. The success of the coating has demonstrated, furthermore, that the conventional chrome-plate piston rings work successfully in this combination, without any special modification.

More particularly, we have discovered that a copper-tin-phosphorus alloy can be coated on aluminum alloy pistons to provide a hard, tough coating which has a low efficient of friction against aluminum alloy cylinder walls, and which can be applied in such manner as to give a sufficiently porous surface to retain lubricant for good long-wearing operation against aluminum alloy cylinder walls, even when tested under severe cold-starting conditions. A copper-tin-phosphorus alloy is readily coated on aluminum alloy pistons by flame spraying, after the piston surface to be coated has first been roughened, as by shot blasting or the like. The roughened surface has an extremely tenacious adherence to the copper-tin-phosphorus alloy, as evidenced, for example, by resistance to scraping with a knife point. On the other hand, if the piston surface is smooth when coated, the copper-tin-phosphorus coating is readily detached.

The portion of the piston which requires coating is the portion below the rings which is in sliding contact with the cylinder wall, generally referred to as the skirt of the piston. Some pistons have split skirts, and others have skirts extending solidily all of the way around the piston. Some pistons have special steel struts embedded in them, and others do not. It is conventional to cam-grind pistons to an oval shape, which expands to a generally circular shape to fit the circular cylinder walls after the engine has reached full operating temperature. The copper-tin-phosphorus coating of the invention is applicable to any of these piston designs, and, although particularly useful in connection with the close tolerance engines of the kind used in automobiles, is also useful for coating the skirts of aluminum alloy pistons of other internal combustion engines having aluminum alloy cylinder walls. Such cylinder walls are preferably of aluminum alloy in which the principal alloying element is silicon in high proportions (e.g., up to 25% or more), for good wearing properties, but the invention is also applicable in connection with cylinder walls of aluminum alloys generally.

The particular aluminum alloy of which the piston is made, including the skirt, is not critical for purposes of the invention. Piston alloys conventionally have silicon as the principal minor alloying element, in relatively high proportions, such as about 12% or more, but the amount or presence of silicon is not critical with respect to operation of the coating of the invention.

For the purposes of the invention, copper-tin-phosphorous is an alloy consisting of about 1% to about 11% tin, .03% to .35% phosphorous, and substantially the entire balance consisting of copper. The preferred range for tin is from about 3% to 8% and the preferred range for phosphorous is from about .1% to about .3%. Phosphorous is necessary as a hardener for the coating. Minor amounts of other metals may be present in the alloy for convenience of manufacture, but these other metals are not significant for purposes of the invention, in connection with coating aluminum alloy piston skirts for improved performance in aluminum alloy cylinders. For example, lead may be present in an amount of .05% maximum, iron in an amount of .1% maximum, and zinc in an amount of .2% maximum.

The low coefficient of friction of a copper-tin-phosphorous coating on aluminum alloy piston skirt operating in an aluminum alloy cylinder helps to prevent scoring and scuffing, but another important feature is the semi-porous nature of the coating when it is flame sprayed onto the skirt. The degree of porosity depends principally upon the flame spraying conditions, which can be varied to obtain the desired porosity, as will be understood by those familiar with conventional flame spraying techniques. The advantage of semi-porosity of the coating is the ability to retain lubricating oil after the motor has been run up to operating temperature and then stopped for several hours, when the hot oil has a tendency to drain away from the piston and cylinder walls. The retained oil helps to lubricate the piston and cylinder walls during the next start, before normal circulation of oil is effective. The desired semi-porosity of the copper-tin-phosphorous coating of the invention is not lost during operation of the engine, because the copper-tin-phosphorous is hard and tough enough to retain its shape and hold the pores open for oil retention. Consequently, when the motor is subjected to severe cold-start testing, the combination of lubricant retained on the coating, and the naturally low coefficient of friction of the coating, successfully prevent scoring and scuffing of the cylinder wall, and any corresponding injury to the piston skirt.

In order to demonstrate the invention, the engine of a Renault 4 CV automobile, 1956 model, was torn down, and several of the cast iron cylinder sleeves were replaced with aluminum alloy cylinder sleeves (about 15% to 20% silicon). The aluminum pistons were duplicated with aluminum pistons of the same aluminum alloy (about 12% silicon) and identical construction. The test pistons were provided with chrome-plated steel piston rings of the same size and shape as the original rings. All critical dimensions were duplicated as exactly as possible, in each of the replacement parts before they were installed.

One set of pistons was prepared in accordance with the invention, by turning them to approximately the desired final outer diameter (a little over two inches), and then grit blasting them (using No. 30 angular steel grit supplied by National Carborundum Company) to roughen the outer surface of the solid-type skirt of each of the pistons in this set. Each piston was then placed about 3 inches away from a standard flame sprayer which was supplied with air at 70 p.s.i. and a stream of burning oxygen and acetylene gas, which converted a feed wire of copper-tin-phosphorous alloy (about 5% tin, .25% phosphorous, and substantially the entire balance copper) into fine molten droplets. These droplets were sprayed against the roughened surface of the piston skirt until it had a substantially uniform coating about 0.02" thick all around the piston. This coating was then cam-ground down to the final standard dimensions of the piston, and the pistons thus prepared were installed in the aluminum alloy sleeves, and the rebuilt engine was installed in the automobile, which was driven 500 miles at 30 m.p.h. to break in the pistons before the tests began.

The broken-in rebuilt engine was supplied with the standard amount of oil (10–30 weight motor oil, Shell Oil Company's X–100 Multi-Vis). A special oil pan was installed, with means for pumping refrigerant through it, and refrigerant was pumped through the oil pan and engine block until the whole engine had reached a temperature below 0° F. This temperature was maintained for a minimum of three hours at the beginning of each test cycle, and then the engine was started and idled for one minute. It was then driven on the road for ten minutes at 25 m.p.h., and the throttle was then opened wide for about 15 minutes, which caused the automobile to run at about 65 to 70 m.p.h., and the oil temperature to reach about 180° F. The automobile was then stopped and allowed to stand idle at normal temperature for about 3½ to 16 hours, which completed the first cycle of the cold-start test. This test cycle was repeated numerous times, and then the engine was torn down for inspection of parts. The pistons having the copper-tin-phosphorous coating, and the surrounding aluminum alloy cylinder walls were found to be in excellent condition, with no evidence of scuffing, which refers to wide and deep destruction of the surface finish of the cylinder wall, and no significant scoring, which refers to narrow, shallow lines indented into the surface finish of the cylinder wall.

For purposes of comparison Babbitt metal was similarly sprayed on the skirts of like pistons, and these pistons were similarly installed and run in the engine. It was found that the piston skirts became scuffed, and the aluminum alloy cylinder lining became scored and scuffed, after three cycles of cold starts. A set of uncoated pistons caused excessive scuffing and scoring even before the first cold-start cycle was reached. Coatings of a silicone resin on some of the pistons, of a polytetrafluorethylene resin ("Teflon" of du Pont de Nemours) on other pistons, and a coating of molybdenum disulfide on still other pistons, applied by other methods than flame spraying, produced excessive scuffing and scoring after three cold-start cycles, in each case. Sets of aluminum alloy pistons plated with chrome were tried and frequently found to scuff excessively during the cold-start tests.

The oil retaining capacity of the sprayed copper-tin-phosphorous coating of the invention is illustrated by preparing one group of four test specimens of uncoated aluminum alloy having polished surfaces, and a second group of four specimens of the same alloy roughened and sprayed with the copper-tin-phosphorous of the invention (e.g., 94.75% copper, 5% tin and .25% phosphorous), which are polished to the same extent as the coated skirts used for the group one specimens. Both groups of specimens are immersed in oil (Shell "Rotella," SAE 20 weight) for half an hour at room temperature, and are then hung with the test surfaces in substantially vertical position and at a temperature of 160° F. for 4 hours. The first group of specimens (regardless of which aluminum alloy is used) shows an average oil retention capacity of 1.5 milligrams per square inch, as against an average of 7.1 milligrams per square inch for the specimens coated in accordance with the invention, based on figures obtained by weighing the test specimens dry before immersion in the oil, and weighing them after being immersed and hung as described.

While present preferred embodiments of the invention, and methods of practicing the same, have been illustrated and described, it will be understood that the invention is not limited thereto, but may be otherwise variously embodied and practiced within the scope of the following claims.

We claim:

1. A piston for an internal combustion engine, said piston having an aluminum alloy skirt, and a coating of copper-tin-phosphorous adhering to said skirt.

2. A piston for an internal combustion engine, said piston having an aluminum alloy skirt, and a coating of copper-tin-phosphorous adhering to said skirt, said coating being semi-porous, so that it is capable of absorbing a substantial quantity of oil.

3. A piston for an internal combustion engine, said piston having an aluminum alloy skirt, a coating of copper-tin-phosphorous adhering to said skirt, said coating being semi-porous, so that it is capable of absorbing a substantial quantity of oil, and said copper-tin-phosphorous coating adhering directly to the aluminum alloy of the skirt, with a roughened interface therebetween.

4. A piston for an internal combustion engine, said piston having an aluminum alloy skirt, said aluminum alloy of the skirt having silicon as its principal alloying element, and a coating of copper-tin-phosphorous adhering to said skirt.

5. A piston for an internal combustion engine, said piston having an aluminum alloy skirt, and a coating of copper-tin-phosphorous adhering to said skirt, said copper-tin-phosphorous coating consisting of from about 1% to about 11% tin, from about .03% to about .35% phosphorous, and substantially the entire balance of copper.

6. A piston for an internal combustion engine, said piston having an aluminum alloy skirt, and a coating of

copper-tin-phosphorous adhering to said skirt, said copper-tin-phosphorous coating consisting from about 3% to about 8% tin, from about .1% to about .3% phosphorous, and substantially the entire balance of copper.

7. An internal combustion engine comprising: an aluminum alloy cylinder wall, a piston slidable in direct contact with the aluminum alloy surface of said cylinder wall, said piston having an aluminum alloy skirt, and a coating of copper-tin-phosphorous adhering to said skirt.

8. An internal combustion engine comprising: an aluminum alloy cylinder wall, said aluminum alloy cylinder wall having silicon as its principal alloying element, a piston slidable in direct contact with the aluminum alloy surface of said cylinder wall, said piston having an aluminum alloy skirt, and a coating of copper-tin-phosphorous adhering to said skirt.

No references cited.