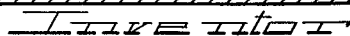


A. T. COLWELL

ALUMINUM-SILICON ALLOY EXTRUDED PISTONS

2 Sheets-Sheet 1



Archie T. Colwell

Mr. Sherman, Messrs. Groves & ~~Hayden~~

June 11, 1957

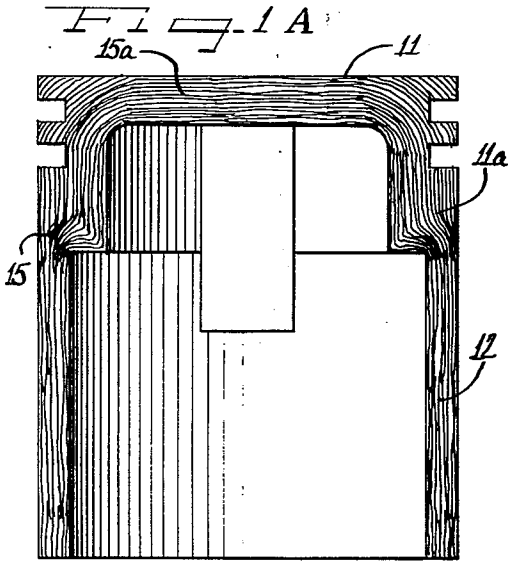
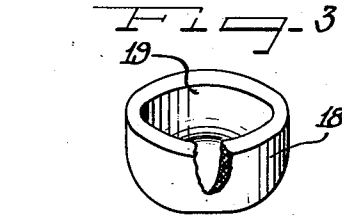
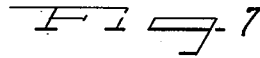
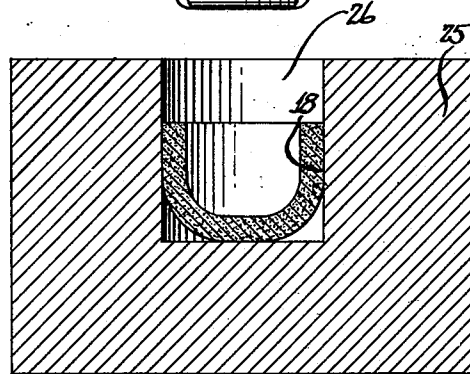
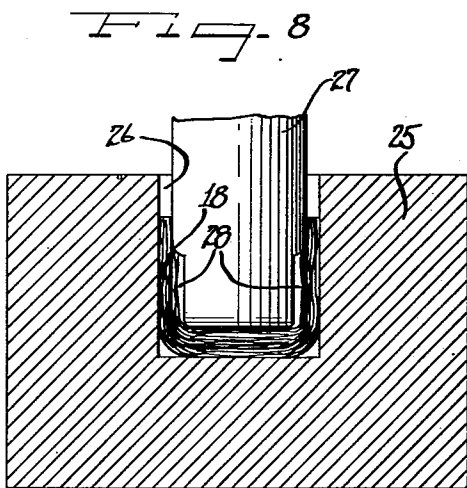
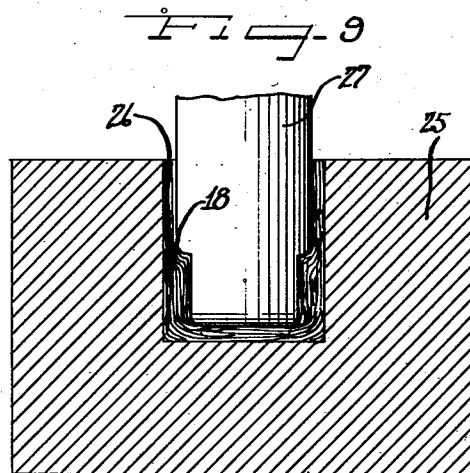
A. T. COLWELL

2,795,467

ALUMINUM-SILICON ALLOY EXTRUDED PISTONS

Filed July 3, 1953

2 Sheets-Sheet 2



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2,795,467

ALUMINUM-SILICON ALLOY EXTRUDED PISTONS

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10 Claims. (Cl. 309—10)

This invention relates to extruded aluminum pistons. More particularly it relates to pistons extruded from aluminum alloys containing comparatively high percentages of silicon.

One of the major problems involved in using aluminum alloy pistons in internal combustion engines is the difference of the coefficient of expansion of aluminum as compared to the cylinder wall, which is usually composed of cast iron or similar materials; aluminum having a coefficient of expansion approximately twice that of cast iron. Accordingly, as the temperature of an internal combustion engine increases the rate of expansion of an aluminum piston is roughly twice that of the cast iron cylinder walls. If this difference in the rate of expansion were not controlled, the pistons would soon bind. Various methods have been proposed for controlling the rate of expansion of aluminum pistons when used in cylinders of materials such as cast iron. Such methods as incorporating steel or cast iron bands into the piston and similar techniques to restrict the expansion of the piston have been successfully employed. However, it is to be noted that in all of these methods complicated steps must be taken, and extraneous expansion-retarders are necessarily incorporated into the aluminum piston.

It has been found recently that aluminum alloys containing appreciable percentages of silicon, namely in the range of from about 15 to 25% silicon by weight of the alloy, have a coefficient of expansion nearly equal to that of cast iron or steel. Accordingly, it has been proposed that pistons for internal combustion engines be produced from high silicon-containing aluminum alloys, thereby eliminating the necessity of incorporating expansion restrainers or similar means into the aluminum alloy pistons to minimize the difference in the rate of expansion between the piston and the cylinder wall. Hitherto, however, all attempts at producing a cast aluminum alloy piston containing sufficiently high percentages of silicon to offset this difference in coefficients of expansion have met with little success. Such pistons produced by casting high silicon-containing aluminum alloys have extreme wear resistance and coefficients of expansion nearly equal to cast iron, but are also extremely brittle. For example, it has been found that cast pistons of aluminum alloys containing silicon in excess of 18%, and having a diameter in excess of 1 to 1½", cannot withstand the pressure of the detonating fuel within the cylinder head. These brittle cast pistons invariably crack or fracture during operation in an internal combustion engine. Accordingly, the use of high silicon-containing aluminum alloys as pistons for internal combustion engines has been discontinued except in producing extremely small pistons; that is, in the range of from 1 to 1½" in diameter or less, which is indeed too small for successful operation in the internal combustion engines utilized in automobiles and the like.

I have found that if high silicon content aluminum pistons are made by an extrusion process, aluminum alloys containing silicon in the range from about 16 to 24% can

2

be used to produce pistons of any desired size. These pistons will have increased ductility; will not break or fracture under operating conditions; and have a coefficient of expansion substantially the same as cast iron. It has heretofore not been possible to extrude brittle high silicon aluminum alloys, but the technique of the present invention includes a new and improved extruding process, wherein the aluminum alloy to be extruded is formed into a specific shape or form before extruding. The extruding of the silicon-containing aluminum alloy greatly enhances the ductility, tensile strength, and elongation of the aluminum alloy in such a manner that pistons so produced display extremely high wear resistant qualities and the same desirable coefficient of expansion, but without the deleterious brittle nature of aluminum alloy pistons previously produced by casting.

In accordance with the foregoing, it is an object of this invention to produce a ductile piston of an aluminum alloy containing in excess of 16% silicon and having enhanced wear capacity especially in the land areas of the ring grooves and skirt.

Another object of this invention is to provide an extruded silicon-containing aluminum alloy piston the coefficient of expansion of which is nearly equal to that of cast iron.

Still another object is to provide a novel extruding technique for producing pistons from aluminum alloys containing silicon in excess of 16%.

A still further object is the provision of a piston extruded from an aluminum alloy containing in excess of 16% silicon, and displaying all the desirable properties of a cast piston of said alloy, but not displaying the undesirable brittleness of the cast alloy.

Other objects and advantages of the present invention will be apparent to one skilled in the art from the following description and the annexed sheets of drawings.

In the drawings:

Figure 1 is a longitudinal sectional view of an extruded trunk type aluminum piston of the present invention, displaced from an aluminum alloy blank containing from 16 to 25% silicon;

Figure 1A is a longitudinal sectional view of the extruded piston of Figure 1 taken along line 1A—1A;

Figure 2 is a dome-shaped slug of an aluminum alloy containing 16 to 24% silicon from which is extruded an aluminum piston of the present invention;

Figure 3 is similar to Figure 2, showing a spherical, cup-shaped aluminum alloy starting blank for extruding the piston of the present invention, part of the spherical blank being broken away to show its hollow interior;

Figures 4, 5 and 6, are cross sectional views of an extruding die assembly showing the steps and procedure of forming an extruded aluminum piston from a dome-shaped aluminum alloy blank containing 16 to 24% silicon; and

Figures 7, 8 and 9 are similar to Figures 4, 5 and 6, showing the procedure for extruding an aluminum alloy piston from a hollow, spherical, cup-shaped aluminum alloy blank containing 16 to 24% silicon, in an extruding die assembly.

As shown on the drawings:

In Figure 1 is illustrated a piston 10 extruded from an aluminum alloy containing at least 16% silicon. The piston 10 has a head portion 11, a ring flange portion 11a, a skirt portion 12, and opposed wrist pin boss portions 13.

Annular grooves 14 are formed on the external periphery of the head portion 11 for receiving piston rings. The extruded piston 10 does not have the crystalline structure causing the extreme brittleness in cast aluminum alloys containing 16% or more silicon. The metal structure has been modified by extrusion to impart ductility

throughout the piston, especially in the skirt portion 12. This is shown graphically in Figure 1 by the slip plane patterns 15 and 15a, wherein the crystalline structure of a brittle, cast starting material has been modified and elongated into the continuous slip plane patterns 15 and 15a extending from the head 11 through the skirt portion 12 and opposed wrist pin boss portions 13. These slip plane patterns are parallel to the surfaces of the piston body. In Figure 1a, the slip-plane modified crystalline structure extends from the head 11 through the ring-flange 11a and the skirt portion 12. These slip planes are parallel to the surfaces of the piston body, thereby greatly increasing the ductility of the extruded piston 10.

By this modification of the cast crystalline structure of the alloy into the continuous parallel slip plane pattern the physical properties, especially the ductility, strength, and elongation of this extruded piston, are greatly increased over its cast counterparts. For example, a piston produced by the extrusion of high silicon-containing aluminum alloys, not only displays the desirable properties of high wear resistance, and a coefficient of expansion nearly equal to that of cast iron, but is not brittle like a cast piston of the same alloy. The strength of the extruded pistons of this invention is increased about 25% over the cast strength of the alloy. The elongation of these extruded pistons is increased from about 1/2 to 3% over the cast alloy process. Further, extruding also increases the ultimate tensile strength from about 30,000 lbs. per square inch in the cast state, to about 33,000 lbs. per square inch when extruded.

Figure 2 shows the desired shape of a blank or slug employed as the starting material in the present invention for forming an extruded piston from an aluminum alloy containing 16% or more silicon. Because of the extremely brittle nature of cast aluminum alloys containing high concentrations of silicon, it is necessary to alter the usual techniques employed in extruding pistons or the like, as will be hereinafter explained. Accordingly, I have found that a piston may be extruded from such alloys if the starting blank or slug is substantially dome-shaped or rounded. In one embodiment of the present invention as shown in Figure 2, I prefer to employ a dome-shaped slug 16 of a high silicon-containing alloy wherein said slug has a dome-shaped end 17.

In another embodiment of the present invention, as shown in Figure 3, a spherical, cup-like blank 18 of a high silicon-containing aluminum alloy having a hollow interior 19 may be used in place of the solid, dome-shaped slug 16 as shown in Figure 2.

The range of composition of the aluminum alloy which may be employed in the present invention, may vary within limits. I have found that an aluminum alloy containing from about 16% to 24% silicon may be extruded to produce a piston suitable for use in an internal combustion engine; such pistons displaying high wear resistance properties; a coefficient of expansion nearly equal to that of cast iron; and improved ductility properties. Examples of the alloys which may be used are shown in Table 1.

Table 1

Substance:	Percentage employed
Silicon -----	16 to 24
Copper -----	1 to 2
Magnesium -----	0.5 to 1
Nickel -----	0.5 to 1
Iron -----	0.5 to 1
Zinc -----	0.1 to 0.5
Manganese -----	0.4 to 1
Cobalt -----	Trace
Chromium -----	Trace
Aluminum -----	The remainder

As illustrated in Figure 4, a cast starting slug 16 of the high silicon aluminum alloy is placed in an extruding die assembly having a die body 20 with a cylindrical die cavity 21 contained therein, and a punch member 22 hav-

ing a die face 23 for forming the wrist pin boss portions and the ring flange contours of the internal portion of the hollow piston. The slug 16 is introduced into the die cavity 21 of the die body 20 preparatory to forming an aluminum piston therefrom by extrusion. Because of the extremely brittle nature of a cast aluminum alloy containing silicon in concentrations of 16% or more, it is necessary to alter the shape of the cast starting blank in extruding a piston from such alloys. If a conventional, cylindrical blank were used a piston could not be properly extruded from such an alloy employing the usual extruding techniques. A cylindrical blank would substantially fill the entire die cavity. Accordingly, the punch member would be working directly against an immobile and solid mass of extremely brittle metal from the beginning of the extrusion process to the finish. However, when a dome-shaped, or spherical, cup-shaped blank is employed as in Figure 4, a void 20a exists between the domed head 17 of the blank 16 and the die body 20. Accordingly, when the punch member 22 begins its pressure stroke against the blank, there is a sufficient space 20a into which the deforming metal may be displaced. Thus, once the punch member can deform the blank to an amount sufficient to alter the brittle crystalline structure of the cast blank, it is then possible to extrude the entire blank into the desired piston.

Prior to introducing the dome-shaped blank 16 into the die cavity 21 of the die body 20, the blank is heated to a suitable extruding temperature. I have found that temperatures of from about 600° F. to about 1000° F. are operable, with temperatures of from about 850° F. to 950° F. being preferred.

After introducing the properly heated dome-shaped, high silicon-containing aluminum alloy blank 16 into the die cavity 21 the punch member 22 is then lowered into the die cavity 21 with a sufficient amount of pressure to facilitate extrusion of the heated blank. I have found that such suitable pressures range from about 60,000 pounds per square inch to about 80,000 pounds per square inch with 60,000 pounds per square inch being preferred. As the upper punch member 22 continues downwardly through the metal under pressure the dome-shaped blank 16 is forced upwardly and around the outer periphery of the punch member 22, filling the annular space 20a described between the cylindrical wall of the die body member 20 and the periphery of the punch member 22. As shown in Figure 5, as the punch member 22 proceeds downwardly under pressure the brittle, cast crystalline structure of the metal is extruded up and into the annular space and is substantially altered. As shown graphically in Figure 5, the crystal pattern of the metal being extruded is elongated forming parallel slip-planes extending continuously from the head portion through the skirt member 12.

In Figure 6 the extruding cycle has been completed, the punch 22 having reached the lowest point of its stroke. Thus, the die cavity 21 has been completely filled with the extruded metal of the blank 16 forming a piston. The crystalline structure of the piston thus formed has been changed to yield parallel slip planes 24 extending continuously through the skirt portions of the piston and into and through the head portion, thereby yielding a piston of increased elongation and ductility.

Figures 7, 8 and 9 are similar to Figures 4, 5 and 6 except that they illustrate the formation of an extruded piston from an aluminum alloy containing high concentrations of silicon, wherein the starting blank is a spherical, cup-shaped blank as shown by 18 in Figure 3. The extruding die assembly of Figure 7 comprises a die body 25, a cylindrical cavity 26 contained therein, and a punch member 27 with a die face 28 for forming the internal contour and elements of a hollow piston.

The spherical, cup-shaped aluminum blank is first heated to a suitable extruding temperature prior to in-

roducing the blank into the die cavity 26 of the die body 25. Temperatures of from about 600° F. to 1000° F. may be used, with a temperature range of from about 850° F. to 950° F. being preferred.

After the heated spherical cup-like blank is introduced into the die cavity 26 of the die body 25, the punch member 27 is lowered into the die cavity 26 and the piston formed under suitable extruding pressures. When employing a spherical, cup-shaped blank as the starting slug, molding pressures of from about 60,000 pounds per square inch to about 90,000 pounds per square inch may be employed, with 80,000 pounds per square inch being preferred.

Figure 9 shows the manner in which the crystalline structure of the spherical, cup-shaped starting blank has been modified into the slip-plane pattern, as previously described, yielding a piston displaying all the desirable properties of a cast piston produced from a high silicon-containing alloy, and also displaying increased ductility, elongation, and strength, which are found to be lacking in the cast counterpart.

By means of the present invention it is now possible to produce an extruded piston from an aluminum alloy containing from about 16% to 24% silicon. The piston so produced displays all the desired properties of its cast counterpart; namely, high wear resistance, and a coefficient of expansion substantially equal to cast iron. The extruded piston further has, however, approximately a 25% increase in strength due to the extrusion process; its elongation capacity is increased from ½ to 3%, and the ultimate tensile strength increased to about 33,000 pounds per square inch. The piston ring contacted land areas of the ring grooves 14 cut in the side flange of the piston head, and the land areas of the skirt which contact the cylinder wall, are capable of resisting wear to a much greater degree than as-cast surfaces of a similar piston because the slip planes produce parallel grain bands of enhanced wear capacity.

This increased strength, elongation and improved ductility now makes it possible to employ such extruded pistons in internal combustion engines, without the piston fracturing from the heat and force of detonation of the fuel in said engine, as was prevalent in similar pistons produced by casting techniques. The present extruded pistons can easily withstand detonation conditions encountered in internal combustion engines.

It is to be appreciated that modifications and variations may be made in the present invention without altering the scope of the novel concepts thereof.

I claim as my invention:

1. A ductile high silicon-containing aluminum piston containing at least 16% silicon which comprises a piston head portion having a depending ring flange, a pair of diametrically opposed depending pin bosses and a skirt portion, said ring flange being thicker than the skirt portion and thinner than the pin bosses, said piston having a crystalline structure with unbroken metal slip planes extending from the head into the ring flange, the pin bosses and skirt, and being parallel with the inner and outer peripheral faces thereof, said piston having a tensile strength not less than about 32,000 p. s. i., an elongation capacity from about ½ to 3% above the as-cast condition of the aluminum, and a mechanical strength capacity of about 25% above the as-cast strength of the aluminum.

2. A ductile silicon-aluminum alloy piston containing at least about 16% silicon, said piston having a head and a skirt portion with metal slip planes extending through the head and skirt in an unbroken condition and being substantially parallel to the opposed faces of the head and skirt, said piston having an ultimate tensile strength of at least about 32,000 p. s. i. and ductility greatly exceeding that of the as-cast alloy.

3. An aluminum trunk type piston composed of an alloy having the following composition: silicon 16 to

24%; copper 1 to 2%; magnesium 0.5 to 1%; nickel 0.5 to 1%; iron 0.5 to 1%; zinc 0.1 to 0.5%; manganese 0.4 to 1%; cobalt a trace; chromium a trace, and the remainder aluminum, said piston having a head portion and a depending skirt portion with unbroken metal slip planes extending throughout the skirt and head and being substantially parallel with the inner and outer faces thereof, said piston being more ductile, having greater strength and greater wear capacity than a piston of the same alloy without said slip plane construction.

4. A ductile trunk-type high silicon content aluminum alloy piston containing at least 16% silicon which comprises a head portion, a ring flange portion, opposed wristpin boss portions, and a skirt portion, all of said portions being integrally connected and each displaced from a blank, said head portion having a crystalline structure with unbroken slip planes continued from the head portion and extending parallel to the inner and outer faces of the ring flange, said boss portions having a crystalline structure with unbroken slip planes extended from the head portion and being parallel with the inner and outer faces of the boss portion, said skirt portion having a crystalline structure with unbroken slip planes extended from the ring flange and substantially parallel with the inner and outer faces of the skirt portion, said ring flange portion terminating intermediate the ends of the wristpin bosses and being substantially thicker than the skirt portion and thinner than the wristpin bosses, said wristpin bosses extending from the head portion and being substantially thicker than the ring flange and skirt portions with the opposed inner faces thereof in substantially parallel relation, and said ring flange and skirt having substantially parallel inner and outer faces, whereby unbroken slip planes of the metal extend from the head through sections of widely varying thickness to the extremity of the uniformly thin piston skirt portion and whereby said slip planes enhance the ductility, strength and wear resistance of said alloy.

5. As an article of manufacture, an extruded aluminum alloy piston, said alloy containing at least 16% silicon.

6. As an article of manufacture, an extruded aluminum alloy piston, said alloy containing from about 16% to 24% silicon.

7. As an article of manufacture, an extruded aluminum alloy piston containing from about 16 to 24% silicon, and displaying a coefficient of expansion nearly equal to cast iron.

8. A method for producing a piston from an aluminum alloy containing in excess of 16% silicon, characterized by the steps of, heating a dome-shaped blank of said alloy to a temperature of from about 600° F. to 1000° F., and extruding said piston from said dome-shaped blank under pressure.

9. A method for producing an extruded piston from an aluminum alloy containing from about 16% to 24% silicon, characterized by the steps of heating a domed, cup-shaped blank of said alloy, and extruding said piston from said blank under pressure.

10. A method for producing an extruded piston which comprises providing a rounded blank of an aluminum alloy containing at least 16% silicon, inserting said blank into a die, said blank being spaced at its rounded portion from the base of said die, and pressing a loosely fitting forming punch into said blank with sufficient pressure to extrude said blank into conformity with the base of said die and about the walls of said punch.

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