Jan. 3, 1967 R. L. COAN 3,295,198

PROCESS OF ADHERING STAINLESS STEEL TO ALUMINUM AND PRODUCTS PRODUCED THEREBY

Filed March 13, 1964

AS INSERT

AS BELT

FIG. 1

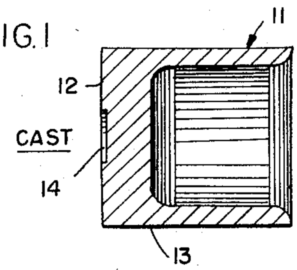


FIG. 6

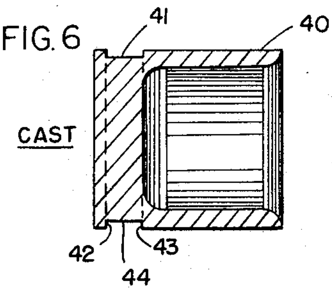


FIG. 2

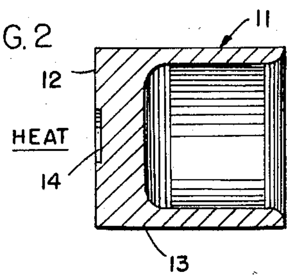


FIG. 7

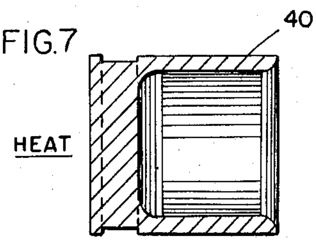


FIG. 3

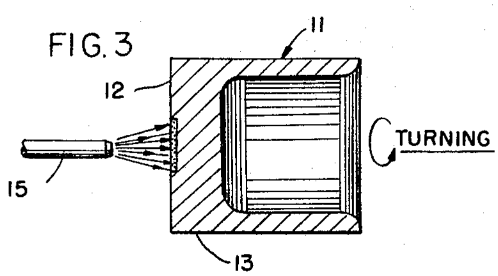


FIG. 8

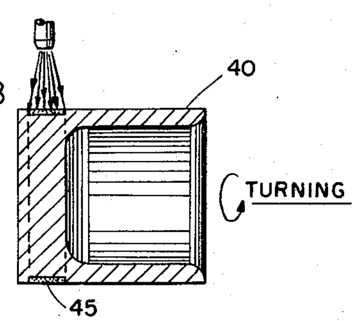


FIG. 4

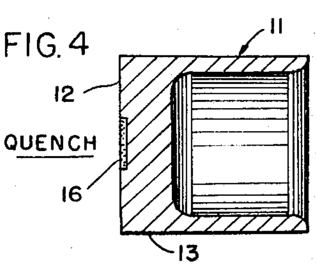


FIG. 9

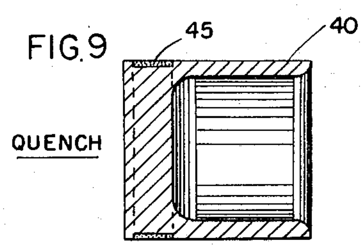
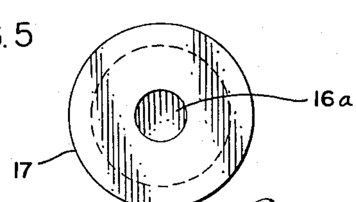


FIG. 5



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PROCESS OF ADHERING STAINLESS STEEL TO ALUMINUM AND PRODUCTS PRODUCED THEREBY

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7 Claims. (Cl. 29—527)

This invention relates to a process of adhering stainless steel to aluminum and to the products produced thereby. More specifically, the present invention is concerned with a process or method of providing a flame-sprayed deposit of stainless steel onto an aluminum body which is characterized by an improved adherence between the two metals. As indicated, the present invention is also concerned with the novel products produced by such a process.

Modern engines of both the internal combustion and diesel type are commonly equipped with pistons made of cast or extruded aluminum. The use of solid aluminum pistons in these engines while affording certain advantages has not proved to be completely satisfactory, particularly with regard to certain problems relating to heat dissipation and wear. For example, in diesel engines, it is highly desirable for their efficient operation that the head of the pistons be maintained at a relatively high temperature for improving the auto-ignition of the compressed air and fuel mixture. Aluminum, by itself however, is not particularly suitable for this purpose since it is characterized by a high thermal conductivity, being in the nature of 155 B.t.u./hour (square foot) (degree F./foot) at 932 degrees F. Accordingly pistons composed of pure aluminum tend to dissipate heat rather quickly, thereby adversely affecting the engine's operation. Further, since pure aluminum has a relatively low Brinell hardness, about 18, certain portions of the piston tend to wear rather quickly.

In order to overcome these problems, aluminum pistons have been provided with inserts of other material, generally stainless steel. These inserts have been secured mechanically by means of bolts, screws and the like, one technique being to bore a tapered hole through the head of the piston and to fit therein a machined stainless steel insert. This insert was secured to the piston by a nut threadedly engaged to the one end of the insert. Such inserts have not proved to be satisfactory since they are not able to withstand the continuing thermal and mechanical stresses built up within the piston during engine operation. Further, the difficulty of machining the insert and bore so that there would be perfect interfit between mating surfaces resulted in power loss and high production costs.

The mechanically secured insert however, has been the basic technique for overcoming the disadvantages of solid aluminum since previously known techniques were not capable of obtaining a sufficiently high adherence between stainless steel and aluminum for producing pistons of the required character.

The present invention was developed in response to the need for a durable piston having heat dissipation characteristics conducive to efficient diesel engine operation. In accordance with this invention, an aluminum piston body is provided with a flame-sprayed deposit of stainless steel which becomes an integral part of the aluminum surface.

It is therefore an object to the present invention to provide a process or method of producing a stainless steel coating onto an aluminum body which is characterized by an improved adherence between the two metals.

Another object of the present invention is to provide a method of integrally forming a stainless steel insert in an aluminum piston body which is characterized by an improved adherence between the two metals.

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It is a further object of the present invention to provide a method or process of depositing a flame-sprayed stainless steel into a preformed cavity in an aluminum body which is characterized by an improved adherence between the metals which remains intact despite high mechanical and thermal stresses.

A still further object of the present invention is to provide an aluminum piston having an integrally formed stainless steel coating which is characterized by an improved adherence between the two metals.

A yet further object of the present invention is to provide an aluminum piston having a stainless steel insert integrally formed in the head thereof which remains intact despite high thermal and mechanical stresses applied thereto.

A yet further object of the present invention is to provide an improved piston having an integrally formed stainless steel sleeve around the ring belt area thereof which possesses improved adherence characteristics.

Other further objects of the present invention will be indicated from the following detailed explanation of my invention, when considered in conjunction with the accompanying drawing, wherein:

FIGURE 1 is a longitudinal sectional view of a cast piston blank having a cavity formed therein in accordance with the present invention;

FIGURE 2 is a view similar to FIGURE 1, wherein the piston blank is being heated in accordance with the present invention;

FIGURE 3 is a view similar to FIGURE 1, wherein the cavity formed in the piston head is being flame-sprayed with molten stainless steel in accordance with the present invention;

FIGURE 4 is a view similar to FIGURE 1, wherein the sprayed piston is going through the quenching step of the present invention;

FIGURE 5 is an end view of the finished piston of the present invention;

FIGURE 6 is a longitudinal sectional view of a piston blank having a circumferential groove formed therein along the ring belt area;

FIGURE 7 is a view similar to FIGURE 6 illustrating the piston blank being heated;

FIGURE 8 is a view similar to FIGURE 6 illustrating the piston being flame-sprayed with stainless steel while being rotated;

FIGURE 9 is a view similar to that shown in FIGURE 6, illustrating the flame-sprayed piston blank and undergoing the quenching step of the present invention.

The present invention relates generally to the art of flame-spraying a stainless steel coating onto the surface of an aluminum body and, more particularly, to a method of improving the adherence of such a coating. In accordance with the present invention, an aluminum body to be coated is pre-heated to a temperature of between 300 and 400 degrees F. to remove surface moisture. The portions to be coated with stainless steel are then sandblasted or shaved to remove any aluminum oxide which may be formed thereon. If it is desired that the stainless steel and aluminum surface be continuous, the area to be sprayed is then machined to a pre-determined depth, i.e. the thickness of the intended coating. The aluminum body is then heated to between 600 and 900 degrees F. and the cavity formed therein is flame-sprayed with a metallizing or Schooping gun which is fed with a stainless wire or powder, as will hereinafter be more fully explained. After the flame-spraying phase of the operation has been completed, the aluminum body is quickly quenched and machined to the dimensions of the finished product. In the application of this process, the stainless steel integrally forms with the surface of the aluminum, enabling the finished product to be used under conditions of extreme mechanical and thermal stress without adversely affecting the adherence of the stainless steel to the aluminum.

The products produced by this process exhibit superior heat dissipation characteristics over those of an all aluminum piston. For example, stainless steel heat buttons integrally formed in the head of an aluminum piston have a thermal conductivity of about 12.4 B.t.u./hour (sq. ft) (degree F. per foot) at 932 degrees F., which is less than one-tenth that of pure aluminum. Thus, the stainless steel heat button enables the head of the piston to be maintained at a higher and more constant temperature thereby improving diesel engine operation.

Similarly, since the Brinell hardness of stainless steel is between 135 and 200, it follows that improved wear characteristics are obtained by applying a stainless steel coating to those portions of the piston which exhibit a tendency to wear, such as for example, the ring belt area.

Referring to the drawing, FIGURE 1 illustrates a cast aluminum piston blank **11**, having a head portion **12**, ring belt area **13** and skirt **14**. The cast piston blank has been heated to between 300 and 440° F. and a cylindrical well **14** has been cut in the head **12**. While the actual depth and cross-sectional area of the well can be varied in accordance with the requirements of the finished piston, a well having a 1½ inch diameter and ⅛ inch depth has been advantageously used in forming heat buttons for diesel engines.

After the preliminary treatment the piston blank **11** is then heated, as is illustrated in FIGURE 2. With piston blanks composed of cast aluminum it has been found that higher temperature heating, in the range of 800 to 900° F. results in a better bond between the subsequently deposited stainless steel and the aluminum. Any conventional heating devices, such as an oxy-acetylene torch or an induction furnace can be used for this purpose.

As soon as the cast aluminum piston blank **11** reaches the desired temperature, the flame-spraying process can be commenced. For the flame-spraying operation, the piston blank can be advantageously rotated on a lathe with a nozzle **15** of a metallizing gun positioned about three inches from the area to be sprayed. These guns generally come in two types, a wire fed variety and one which uses a metal dust or powder. The former type which employs ordinary commercial wire has been found to be desirable because of the availability of stainless steel in wire form. In a wire fed gun, the wire is directed from a reel through the nozzle into contact with a flame which melts the wire and, in combination with compressed air, blows the atomized metal against the surface being coated at a high velocity. The metal, as it impinges the surface at this high velocity solidifies and becomes an integral part of the surface. Typical gases which can be used for atomizing the metal are oxygen, acetylene, natural gas, butane and coal gas. An oxyacetylene model has been advantageously employed with the operating pressures of the oxygen and acetylene each being 30 pounds per square inch and with an air operating pressure of between 50 and 70 pounds per square inch.

In spraying the molten metal into the recess **14** it is important that the entire surface area thereof be covered by the first pass for effecting good adherence between the aluminum and stainless steel.

With regard to the various stainless steel wires which can be employed, it has been found that the strongest adherence between the aluminum and the deposited metal is obtained with stainless types 316 and 317, thus making wire of this type particularly suitable for use where high thermal and mechanical stresses are present. The exact reason for the superior adherence with these types of wire is not thoroughly understood, however, it is believed to be attributable to the molybdenum content in each of these stainless steels. For example, 316 stainless has a molybdenum content of from 1.75 to 2.75 percent and 317 stainless has a molybdenum content of from 3 to 4 percent.

After the spraying has been completed, the piston blank **14** with the integrally formed stainless steel deposit **16** should then be immediately quenched in a tap water or oil bath. It has been found that the quick quench immediately after spraying produces a better bond.

Upon completion of the quenching step, the piston blank can then be machined to the desired dimensions. Thus, the finished piston **17**, as is shown in FIGURE 5, has a smooth upper surface **18** which includes a stainless steel heat button **16*a*** integrally formed therein.

In the cast aluminum piston **40** illustrated in FIGURE 6, a groove **41** has been cut into the ring belt area. This groove has opposed side walls **42** and **43** which are separated by an inner rim portion **44**. While the depth of the side walls and width of the inner rim can be varied depending upon the requirements of the finished piston, it has been found that a depth of from 0.030 to 0.040 inch and an inner rim width of about 1½ inches is sufficient, when coated with a flame-sprayed deposit of stainless steel, to produce a ring belt covering exhibiting excellent wear properties.

The piston blank **40** can be prepared for flame-spraying in the same manner as was illustrated with regard to piston blank **11**. For example, the surface is heated be-between 300 and 400 degrees F. and the groove **41** is cut therein so that the flame-sprayed deposit will bond directly will bond directly to the aluminum. After this initial preparation, the piston blank **40** is heated to between 800 and 900 degrees F. When this temperature is reached the flame-spraying process can be commenced. In applying a coating to the ring belt area of a piston blank it has been found that the metallizing gun can be hand-held with the nozzle **15** thereof, positioned about three inches from the piston blank which is rotated on a lathe. After the deposit **45** is built up so that the surface thereof is approximately flush with the adjacent surface of the aluminum piston, the piston blank **40** can be quickly quenched and then machined to finish the outer surface as desired. The stainless steel sleeve can then be grooved to receive a piston ring.

With extruded aluminum piston blanks it has been found that a temperature range of from 600 to 800 degrees F. for the heating step illustrated in FIGURES 2 and 7, with the specific range of from 650 to 750 degrees F., produces a better bond. However, with both forged and cast pistons, 316 and 317 stainless steel has produced the best adherence between the flame spaced deposit and the aluminum.

Example 1

A cast aluminum piston blank was heated with an oxy-acetylene torch to 350 degrees F. The piston blank was then mounted on a lathe and a cylindrical bore of 1½ inches in diameter and ⅛ inch depth was cut in the center of the piston head. The piston blank was then heated with an oxy-acetylene torch to 900 degrees F. After the 900 degree F. temperature was reached a metallizing gun fed with No. 2 gauge, type 316 stainless steel wire was set 2½ inches from the base of the recess and used to deposit a stainless steel coating in the recess. The gun was operated on oxygen, acetylene and air with operating pressures of 30 pounds per square inch for the oxygen, 30 pounds per square inch for the acetylene and 60 pounds per square inch for the air. It took about five minutes to build up a stainless steel layer in the cavity which was flush with the head surface of the piston blank. As soon as the deposit was built up to the level of the adjoining piston head surfaces, the piston blank was removed from the lathe and quenched in tap water at a temperature of 45 degrees F.

Example 2

A cast aluminum piston blank was initially heated with an oxy-acetylene torch to 400 degrees F. and then was mounted on a lathe. A continuous groove was cut in the ring belt area with a depth of 0.04 inch and a width of 1½ inches. While still mounted on the lathe, the piston blank was heated to 800 degrees F. with an oxy-acetylene torch. When the 800 degree F. was reached the groove was flame-sprayed with a metallizing gun which was fed with No. 2 gauge, type 316 stainless wire. The gun was operated on oxygen, acetylene and air with operating pressures of 30 pounds per square inch for the oxygen and acetylene, and of 70 pounds per square inch for the air. The metallizing gun was hand-held for this operation. As soon as the groove was completely filled with stainless steel the piston blank was removed from a lathe and quickly quenched in a tap water bath which was at a temperature of 50 degrees F.

Example 3

A forged aluminum piston blank was initially heated to 350 degrees F. and then mounted on a lathe. A cylindrical recess was cut in the center of the piston head, the recess having a depth of .015 inch and a diameter of 2 inches. The piston blank was then heated to a temperature of 600 degrees F. As soon as this temperature was reached the recess was flame-sprayed with a metallizing gun which was fed with No. 2 gauge, type 316 stainless steel. The gun was operated on oxygen, acetylene and air with operating pressures of 30 pounds per square inch for the oxygen and acetylene, and of 50 pounds per square inch for the air. When the recess was completely filled with stainless steel, the piston blank was removed from the lathe and quickly quenched in tap water at a temperature of 45 degrees F.

Example 4

A forged aluminum piston blank was heated to 400 degrees F. and mounted on a lathe. A groove of .035 inch depth and 1½ inches wide was cut in the ring belt area. The piston blank was then heated to a temperature of 750 degrees F. and, as soon as this temperature was reached, the groove was sprayed with a metallizing gun which was fed with No. 2 gauge, type 316 stainless steel wire. The gun was operated on oxygen, acetylene and air with operating pressures for both the oxygen and acetylene of 30 pounds per square inch and of 60 pounds per square inch for the air. As soon as the groove was completely filled with stainless steel, the piston blank was quickly quenched in a tap water bath, which was at a temperature of 45 degrees F.

While in the foregoing specification this invention has been described in relation to specific embodiments thereof and many details have been set forth for the purpose of illustration, it will be apparent for those skilled in the art that the invention is susceptible to other embodiments, and that many of the details described herein can be varied considerably without departing from the basic principles of the invention.

I claim:

1. In a process for bonding stainless steel to aluminum, the steps of forming a depression in an aluminum body, heating said depression to a temperature of between 600 and 900 degrees F. spraying stainless steel in liquid form containing molybdenum in the amount of between 1.5 and 4.0 percent into said depression, and then quickly quenching the aluminum body with the stainless steel deposit in water.

2. The process of claim **1** in which the depression is heated to between 650 and 750 degrees F. prior to depositing the stainless steel coating therein.

3. In the process of claim **1**, initially preheating the aluminum body to a temperature of between 300 and 400 degrees F. to remove moisture, and other foreign material from the surface thereof.

4. In a process for bonding stainless steel to aluminum, the steps of heating the aluminum body to a temperature of between 300 and 400 degrees F. to remove moisture and other contaminants from the surface thereof, forming a depression in the aluminum body, heating said depression to a temperature of between 600 and 900 degrees F., flame-spraying the depression with stainless steel having a molybdenum content of between 1.5 and 4.0 percent, and quickly quenching the aluminum body and stainless steel deposit in water.

5. In a process for bonding stainless steel to a forged aluminum body, the steps of heating the forged aluminum body to a temperature of between 300 and 400 degrees F. for removing water and other surface contaminants therefrom, forming a depression in the forged aluminum body, heating said depression to a temperature of between 600 and 800 degrees F., flame-spraying said depression with stainless steel having a molybdenum content of between 1.5 and 4.0 percent, and quickly quenching the aluminum body and stainless deposit in a tap water bath.

6. The process of claim **5** wherein said depression is heated to a temperature of between 650 and 750 degrees F. just prior to the flame-spraying step.

7. In a process for bonding stainless steel to a cast aluminum body the steps of heating the aluminum body to a temperature of between 300 and 400 degrees F. to remove moisture and other surface contaminants therefrom, forming a depression in the aluminum body, heating said depression to a temperature of between 800 and 900 degrees F., flame-spraying said depression with stainless steel having a molybdenum content of between 1.75 and 4.0 percent, and quickly quenching said aluminum body and stainless steel deposit in water.

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