SOLDER FILLERS FOR ALUMINUM BODY PARTS AND METHODS OF APPLYING THE SAME

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ABSTRACT

One aspect of the present invention is a method of applying a solder filler to an aluminum body part. The method includes abrading the surface of an aluminum body part at a temperature of at least about 500 degrees Celsius with a solder filler at a temperature of at least about 500 degrees Celsius.
MELTING POINT ANALYSIS
66.5Sn/30.0Zn/3.5Cu

HYPOSOLID, CRYSTALLINE PHASE
695 F (368 C)

HYPSOLID, CRYSTALLINE PHASE
636 F (280 C)

SUITABLE RANGE FOR ABRASIVE SOLDERING
383 F (195 C)

Fig. 1
SOLDER FILLERS FOR ALUMINUM BODY PARTS
AND METHODS OF APPLYING THE SAME

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application is a continuation-in-part of U.S. patent application Ser. No. 10/663,300, entitled “Tin-And
Zinc-Based Solder Fillers For Aluminum Body Parts And
Methods Of Applying The Same” and filed on Apr. 9, 2002,
which is hereby incorporated by reference.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] One aspect of the present invention generally relates to solder fillers for aluminum body parts and methods
of applying the same, and more specifically, to tin-based
solder fillers for aluminum body parts and methods of
applying the same.

[0004] 2. Background Art

[0005] Soldering processes are widely recognized and
utilized within the automotive industry. According to one
definition, soldering is a process of joining metal body parts.
The process typically includes treating the metal body
surface with a filler material, otherwise referred to herein as
a body filler or body solder, to alloy with the parent metal,
i.e. the metal body. In automotive applications, tin-based and
zinc-based body solder is commonly utilized. The tin-
based body solder is often applied to metal body parts,
such that an exchange of atoms, i.e. alloying, occurs at the
interface between the applied body solder and the metal
body surface. Prior to soldering, one or more oxide layers
of the parent metal are typically removed, or can be displaced
via mechanical abrasion.

[0006] Aluminum alloys are finding an increased presence
as a material in the manufacture of automobiles. The 5000
series of aluminum alloys are being used more and more.
Many of these alloys are characterized by their substantial
Mg content, i.e. greater than about 0.5 weight percent metal
body parts. Soldering aluminum alloys typically entails
either (1) a chemical reaction between a flux and the parent
metal, to alter, dissolve, or remove the oxide layer, or (2) the
mechanical break up of oxide particles prior to the soldering
step. Two basic types of fluxes, inorganic fluxes and organic-
amine fluxes, are usually considered in connection with
aluminum body parts. Both have been successfully used in
connection with the soldering of certain aluminum body
parts. However, these fluxes do have certain disadvantages.
For example, inorganic fluxes used for the soldering or
soldering of aluminum alloys can be corrosive before, during
and after the soldering process. Moreover, the use of inor-
ganic fluxes typically includes the complete removal of
residues after the pre-treatment step to ensure that minimal
corrosion takes place at a later time. The removal step can
be time-consuming and expensive. Although organic-amine
fluxes are considered less corrosive both before and after
soldering, they typically offer a relatively limited active
temperature range during heat cycling. Moreover, although
removal of organic-amine fluxes is often not necessary, these
fluxes can alter the surface appearance of the aluminum after
the soldering step. Both types of fluxes, fluoride fumes
are usually generate during the heating cycle, and should be
evacuated from work areas.

[0007] In light of the foregoing, fluxes based on current
proposals for use with certain aluminum alloys can be
unsatisfactory, especially those aluminum alloys containing
greater than about 0.5% Mg. Moreover, a flux designed
specifically for the 5000 series of aluminum alloys has not
been proposed. Engineering an effective flux for this type of
alloy has been hindered by the relatively high levels of Mg,
a rapidly oxidizing element. The levels of Mg are also
relatively high in other light weight, high strength aluminum
alloys increasingly used for automotive construction.

[0008] With respect to deoxidizing via abrasion, body
solders that contain zinc, including tin-based solders, are
known to provide good mechanical abrasion of aluminum
while it is being heated, because of the sharp-edged, crys-
talline nature of basic Zn crystals. Even while in a molten
state, zinc-containing alloys relatively quickly abrade and
dissolve other metals with ease. However, the application
of zinc-containing alloys to aluminum body parts has been
largely commercially unsuccessful.

[0009] In certain soldering applications, a timing step is
used to provide more solderable coating than that of the
untreated metal surface. Tinning can be described as a hot
process for applying one or more solderable coatings to base
metals to form a true metallurgical bond between the two at
the interface. Tinning can make subsequent soldering steps
more successful. To date, tinning processes for aluminum
body parts have been largely unsatisfactory.

[0010] Body fillers are also needed in certain applications
for joining aluminum body seams. Current proposals for
joining aluminum alloy body panels have been largely
unsatisfactory. For example, wetting 5000 series aluminum
alloys followed by a relatively low temperature process has
not been successful in forming a relatively strong metallur-
gical bond. Using conventional high temperature processes
on 5000 series aluminum alloys, for example inert atmos-
phere, vacuum brazing, or welding (e.g. laser) have been
largely unsatisfactory.

[0011] By way of background, body fillers have been
widely used in the automotive industry to provide smooth
and continuous surfaces by covering and concealing surface
imperfections such as spot welded joints or body surface
flaws. Numerous compositions have been used as body
fillers for steel automotive body panels. For example, lead-
containing body fillers have been heavily utilized. Environ-
mental concerns have caused the automotive industry to
move away from lead-containing fillers and focus on develop-
ing lead-free compositions.

[0012] Polymeric materials have been used as fillers.
However, such materials bond mechanically to the body part
surface rather than metallurgically. The mechanical bonds
are much weaker than metallurgical bonds. In addition,
metallic components oftentimes must be added to the polymeric
materials in order to make the polymer conductive for
electro-deposition coating. Additionally, the polymeric
material softening temperature is typically very close to the
paint baking oven temperature. As a result, during the paint
drying stage, the polymeric material can melt, thus destroy-
ing the paint finish.

[0013] Body fillers have been proposed for aluminum
automotive body panels, as well. Some body solders fillers,
thermally-sprayed solder fillers, and MIG-welded fillers
used on steel panels have been unsuccessfully applied to aluminum body parts. Many thermal sprayed and MIG welded filler compositions for steel body parts have the potential to produce stress cracks and heat distortion when used with aluminum body panels. This detrimental result occurs because the processing temperature required for the steel solders is too high relative to the melting point temperatures of the aluminum alloys used in aluminum body panels.

Aluminum/silicon alloys have also been applied to aluminum pillar joints using MIG welding and thermal spraying techniques. However, these application processes have the potential to produce stress cracks and heat distortion when used with aluminum body panels since the processing temperature for the aluminum/silicon alloys is relatively close to the melting point temperatures of typical aluminum body panels.

In light of the foregoing, it would be desirable to provide a method of applying solder fillers to aluminum body parts that provide favorable thermal and mechanical properties. It would also be desirable to provide new solder fillers for aluminum body parts and application methods that provide favorable thermal and mechanical properties, including the inhibition of stress cracking and heat distortion of the aluminum body parts.

These and other advantages will become more apparent to those of ordinary skill in the art upon reference to the following description.

SUMMARY OF THE INVENTION

One aspect of the present invention is a method of applying solder fillers to aluminum body parts that provide favorable thermal and mechanical properties. Another aspect of the present invention is solder fillers for aluminum body parts and application methods that provide favorable thermal and mechanical properties, including the inhibition of stress cracking and heat distortion of the aluminum body parts.

According to a first embodiment of the present invention, a method of applying a solder filler to an aluminum body part is disclosed. The method includes abrading the surface of an aluminum body part at a temperature of at least 300 degrees Celsius with a solder filler at a temperature of about 300 degrees Celsius. The solder filler can be a tin-based solder filler. The tin-based solder filler can consist of, e.g., 50% Sn, 20% Zn, and 30% Cu. The method can further include the application of a fluxing agent and the removal of the abraded surface. The method can further include heating the surface to a temperature in the range of about 300 degrees Celsius to about 900 degrees Celsius prior to the abrading step. The method can further include heating the tin-based solder filler to a temperature in the range of about 300 degrees Celsius to about 900 degrees Celsius prior to the abrading step. In one embodiment, the tin-based solder filler can consist by weight of 66.5% Sn, 30% Zn, and 3.5% Cu. In certain embodiments, the tin-based solder filler has a melting point in the range of about 195 degrees Celsius and 368 degrees Celsius.

According to another embodiment of the present invention, a method of deoxidizing an aluminum body part is disclosed. The method includes abrading the surface of an aluminum body part at a temperature of about 300 degrees Celsius with a tin-based solder filler at a temperature of about 300 degrees Celsius. The tin-based solder filler can consist of, e.g., 66.5% Sn, 30% Zn, and 3.5% Cu. In certain embodiments, the abrading step is preceded by a fluxing step.

According to another embodiment of the present invention, a method of soldering an aluminum body part is disclosed. The method includes abrading at least a portion of the surface of an aluminum body part with a tin-based solder filler consisting of, by weight, 55% to 85% Sn, 12% to 40% Zn, and 3% to 5% Ni, Fe, Cu or Co, applying a second solder filler to a portion of the abraded surface portion, and heating the second solder filler to bond the solder filler to the aluminum body part. The second solder filler can be comprised of weight of about 95% Sn and about 5% Sb. In certain embodiments, the second solder filler has a melting point in the range of about 232 degrees Celsius and 240 degrees Celsius. The applying step can include fusing the abraded surface portion in the second body part.

In another embodiment, a solder filler for aluminum body parts consists by weight of 81% to 85% Sn, 3% to 5% Zn, and 12% to 14% Cu is disclosed.

In yet another embodiment, a solder filler for aluminum body parts consists by weight of 55% to 85% Sn, 12% to 40% Zn, and 3% to 5% Ni, Fe, Cu or Co is disclosed.

The above and other aspects and features of embodiments of the present invention are readily apparent from the following detailed description of the best mode for carrying out the invention when taken in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

The features of the present invention which are believed to be novel are set forth with particularity in the appended claims. The present invention, both as to its organization and manner of operation, together with further objects and advantages thereof, may best be understood with reference to the following description, taken in connection with the accompanying drawing which:

FIG. 1 is a melting point analysis of a tin-based alloy according to one embodiment of the present invention.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE PRESENT INVENTION

As required, detailed embodiments of the present invention are disclosed herein. However, it is to be understood that the disclosed embodiments are merely exemplary of the invention that may be embodied in various and alternative forms. Therefore, specific functional details described herein are not to be interpreted as limiting, but merely as a representative basis for the claims and/or as a representative basis for teaching one of ordinary skill in the art to variously employ the present invention.

In a first embodiment, before applying the solder filler to the aluminum body part, a fluxing agent is applied
to the aluminum body part. Heat is then applied to the fluxing agent to deoxidize the surface of the aluminum body part. The solder filler is then applied to the deoxidized surface of the aluminum body part. The solder filler is usually produced in wire or rod form for application to the body part. After a full heating cycle and soldering has occurred, the fluxing agent is rendered inert.

[0028] Preferably, a mixture of organic compounds and metallic salts is used as fluxing agents for the tin-based solder fillers. These fluxing agents usually exhibit paste-like consistencies suitable for brush, spray and syringe dispensing. Preferably, amine is used as a fluxing agent for the tin-based alloy systems. It is understood that other fluxing agents may be used with the tin-based alloy systems as long as the agents can be dispensed using a wide variety of techniques.

[0029] The preferable fluxing agents for the zinc-based alloy system is a combination of complex salts. These fluxing agents exhibit a paste-like or slurry-like consistency suitable for brush, spray and syringe dispensing. Preferably, complex organometallic salts are used as a fluxing agent for the zinc-based alloy systems. It is understood that other fluxing agents may be utilized with the zinc-based alloy systems as long as the agents can be dispensed using a wide variety of techniques.

[0030] In an alternative embodiment, the fluxing agent is mixed with one of the solder fillers of the present invention to form a filler/flux mixture. For tin-based solder fillers, a mixture of 10% of fluxing agent and 90% of tin-based solder filler is prepared for the solder filler application process. For zinc-based solder fillers, a mixture of 50% of fluxing agent and 50% of zinc-based solder filler is prepared for the solder filler application process. The fluxing agent can be mixed with powdered solder filler to form a paste. The paste can be applied to the aluminum body part through brushing, spraying, or syringe dispensing. Alternatively, the fluxing agent is injected into hollow solder filler wire. The wire or rod is applied directly to the aluminum body part or it can be shaped into a preformed disk, ring, or tape or a contour close to the filled surface for easy application. The filler/flux wire is particularly suitable for filling in ditches or other blisters or the surface of an aluminum body part. It is understood that other mixing techniques may be utilized that are consistent with the application of a filler material to an aluminum body part.

[0031] Once the solder filler or filler/flux mixture is applied to the aluminum body part, heat is applied to bond the solder filler to the body part. Heat may be applied to the aluminum body part through the use of convective, conductive or radiant heat. A fuel gas flame or a plasma torch may be utilized for heating. Flux residue is created by heating the filler/flux mixture. This residue is non-corrosive and can be easily washed away during the normal cleaning, sanding and grinding carried out prior to painting the aluminum body part.

[0032] The final result of the final body filler application process is a smooth, continuous surface on aluminum body panels. It is understood that the application process may have to be repeated to build up the height of the solder filler in cases of deep dents or ditches.

[0033] The present invention also includes several alloy compositions that are useful as solder fillers for aluminum body parts. Two types of tin-based solder filler alloys are disclosed. A first preferred tin-based alloy includes 12% to 22% copper, 3% to 5% zinc, and 73% to 85% tin. More preferably, the first preferred tin-based alloy consists of 20% copper, 3% zinc, and 77% tin. A second preferred tin-based solder filler alloy includes 3% to 5% copper, iron, cobalt or nickel, 12% to 40% zinc and 55% to 85% tin. More preferably, the second preferred tin-based alloy consists of 3.5% nickel, 30% zinc, and 66.5% tin. The tin-based alloy compositions contain other trace elements in order to provide a suitable viscosity for a solder filling material. Additionally, a zinc-based solder filler alloy is disclosed including a preferred composition of 78% to 98% zinc and 2% to 22% aluminum. More preferably, the zinc-based alloy consists of 80% zinc and 20% aluminum is utilized. In addition to use with aluminum body panels, the zinc-based alloys are also suitable as solder fillers for steel body parts.

[0034] The alloy compositions of this invention exhibit many desirable properties. These properties are linked principally to the physical properties of the alloys. The tin-based solder filler alloys preferably have melting point temperatures ranging from 250 degrees Celsius to 350 degrees Celsius and the zinc-based alloys preferably have melting point temperatures ranging from 400 degrees Celsius to 500 degrees Celsius. The melting point temperatures of the disclosed alloy compositions are preferably at least 100 degrees Celsius lower than that of typical body panel aluminum alloys. The melting point temperatures for automobile body panel made of aluminum alloys typically range from 620 degrees Celsius to 660 degrees Celsius. Consequently, the application of the disclosed compositions inhibits stress cracking and heat distortion of the aluminum body parts. However, the melting points of the disclosed alloy compositions are high enough that the alloys remain solid in paint processing ovens. Additionally, the metallic nature of the disclosed alloys provide a solder exhibiting favorable thermal and electrical conductivity and satisfactory mechanical properties for electronic coating processes. Moreover, the zinc-based alloys will not galvanize with aluminum body parts.

[0035] According to another embodiment of the present invention, a method of applying a tin-based solder filler to an aluminum body part is presented. This method is especially useful for pre-treating an aluminum body part prior to soldering, e.g. filling and joining. In certain embodiments, the pre-treatment step includes abrading or swaging the surface of the aluminum body part with a solder filler. In certain applications, the aluminum body panel can be a 500 series aluminum alloy, or other aluminum alloy having at least about 0.5 percent Mg content by weight. Advantageously, by use of this abrading step, the soldering process does not have to include a fluxing step. The abrading step can generate a metallurgically stable interface for the application of soldering materials.

[0036] In certain embodiments, the aluminum body part is heated to an elevated temperature range and is maintained in that temperature range during the abrading step. The temperature range can be within the range of about 300 degrees Celsius and 900 degrees Celsius. One or more sources of heat can be used to elevate and maintain the elevated temperature range. Using multiple sources of heat can deliver satisfactory volume and distribution of the solder filler. In certain embodiments, the elevated temperature
range is within the range of about 300 degrees Celsius and about 450 degrees Celsius, which is considered to be a relatively low temperature range. This relatively low temperature range is often used to join aluminum body parts since it offers certain advantages, for example, reduction of stress cracking and warping. This range also offers relatively greater control of the heating process, and a relatively wide processing window, in which relatively safe forms of heat can be utilized, for example, induction, infrared, hot air and/or combinations thereof.

[0037] In certain embodiments, the solder filler is also heated to an elevated temperature range and is maintained in that temperature range during the abrading step. The temperature range can be within the range of about 300 degrees Celsius and 900 degrees Celsius. In other embodiments, the elevated temperature range is with the larger range of about 300 degrees Celsius and about 450 degrees Celsius.

[0038] In certain applications, the solder filler can be a tin-based solder filler, and more specifically, can include, by weight percent, 55% to 85% Sn, 12% to 40% Zn, and 3% to 5% Ni, Fe, Cu or Co, although other alloys may be used in accordance with embodiments of the present invention. In one embodiment, the tin-based solder filler consists, by weight, of 66.5% Sn, 30% Zn, and 3.5% Cu. In certain embodiments, a tin-based solder filler having a melting point in the range of about 195 degrees Celsius to about 368 degrees Celsius is suitable. FIG. 1 is a melting point analysis graph of the above-identified tin-based solder filler. One of the reasons for using an alloy containing a certain amount of Zn is Zn metal’s highly crystalline structure, which provides an effective abrading material.

[0039] Optionally, the abrading step can be followed by moving an instrument along the surface of the aluminum body part to remove residue formed during the abrading step. This residue can contain oxidized materials. In certain embodiments, the moving step can be accomplished by scraping the surface of the aluminum body panel with a sharp instrument. The moving step can occur after the abrading step is started, but before it concludes.

[0040] According to one example, the aluminum body panel is a 5000 series aluminum body panel having greater than about 0.5% Mg content by weight, which is heated to a temperature of about 350 degrees Celsius. A tin-based solder material can also be heated to about 350 degrees Celsius prior to the abrading step. According to this example, the tin-based solder material can include, by weight percent, 55% to 85% Sn, 12% to 40% Zn, and 3% to 5% Ni, Fe, Cu or Co. The heated tin-based solder material is then applied to the heated body panel, in a scrubbing motion. By using an operating temperature of about 350 degrees Celsius, it has been found that the oxide layer of the aluminum body panel is noticeably easier to scrape off than when the body panel is at room temperature.

[0041] Examples of uses for the fluxless abrading step include, but are not limited to, filling ditches or imperfections in aluminum body panels to generate a smooth, class-A metallic finish. Moreover, strips on untreated aluminum body panels can be pre-tinned. The pre-tinned strips are later folded to become hems prior to forming a finished part. In other embodiments, after the fluxless abrading step, other panels can be joined to the abraded aluminum body panel. For example, other panels and parts can be joined using sufficiently overlapping seams where the mating surfaces of both parts have been previously abraded. In such circumstances, a second solder filler is selected for the joining step. Considerations for selecting the second solder filler can include, but are not limited to, strength and operating temperature range. In certain embodiments, a solder filler including by weight of about 95% Sn and about 5% Sb is utilized. Advantageously, the second body filler material can wet to the abraded, i.e. tinned, surface, for more easily than that of the un-tinned surface. Selection of the second solder material may result in modifying certain characteristics of the finished joints. Such characteristics may include ductility, strength, hardness, etc. Micro structure examination tensile tests and other methods may be employed to aid in matching alloys and solder fillers with complimentary heating methods to produce the best quality joints.

[0042] While the best mode for carrying out the invention has been described in detail, those familiar with the art to which this invention relates will recognize various alternative designs and embodiments for practicing the invention as defined by the following claims.

What is claimed is:
1. A method of applying a solder filler to an aluminum body part, the method comprising:

- abrading the surface of an aluminum body part at a temperature of at least about 300 degrees Celsius with a solder filler at a temperature of at least about 300 degrees Celsius.

2. The method of claim 1 wherein the solder filler is a tin-based solder filler.

3. The method of claim 2 wherein the tin-based solder filler consists of, by weight, 55% to 85% Sn, 12% to 40% Zn, and 3% to 5% Ni, Fe, Cu or Co.

4. The method of claim 1 further comprising moving an instrument along the surface of the aluminum body part to remove a portion of the abraded surface.

5. The method of claim 1 further comprising heating the surface to a temperature in the range of about 300 degrees Celsius to about 900 degrees Celsius prior to the abrading step.

6. The method of claim 2 further comprising heating the tin-based solder filler to a temperature in the range of about 300 Celsius to about 900 Celsius prior to the abrading step.

7. The method of claim 3 wherein the tin-based solder filler consists of weight of 66.5% Sn, 30% Zn, and 3.5% Cu.

8. The method of claim 2 wherein the tin-based solder filler has a melting point in the range of about 195 degrees Celsius and 368 degrees Celsius.

9. The method of claim 1 wherein the aluminum body part is comprised of a 5000 series aluminum alloy.

10. The method of claim 1 wherein the aluminum body part is comprised of an aluminum alloy having greater than about 0.5% Mg.

11. A method of deoxidizing an aluminum body part, the method comprising:

- abrading the surface of an aluminum body part at a temperature of about 300 degrees Celsius with a tin-based solder filler at a temperature of at least about 300 degrees Celsius.

12. The method of claim 11 wherein the tin-based solder filler consists of weight of 66.5% Sn, 30% Zn, and 3.5% Cu.
13. The method of claim 11 wherein the abrading step is not preceded by a fluxing step.

14. A method of soldering an aluminum body part, the method comprising:
   abrading at least a portion of the surface of an aluminum body part with a tin-based solder filler consisting of, by weight, 55% to 85% Sn, 12% to 40% Zn, and 3% to 5% Ni, Fe, Cu or Co;
   applying a second solder filler to a portion of the abraded surface portion; and
   heating the second solder filler to bond the solder filler to the aluminum body part.

15. The method of claim 14 wherein the second solder filler is comprised by weight of about 95% Sn and about 5% Sb.

16. The method of claim 14 wherein the second solder filler has a melting point in the range of about 232 degrees Celsius and about 240 degrees Celsius.

17. The method of claim 14 wherein the applying step includes filling the abraded surface portion.

18. The method of claim 14 wherein the applying step includes joining the abraded surface portion to a second body part.

19. A solder filler for aluminum body parts consisting by weight of 81% to 85% Sn, 3% to 5% Zn, and 12% to 14% Cu.

20. A solder filler for aluminum body parts consisted by weight of 55% to 85% Sn, 12% to 40% Zn, and 3% to 5% Ni, Fe, Cu or Co.