Patented Mar. 13, 1951

2,544,670

UNITED STATES PATENT OFFICE

2,544,670

METHOD OF FORMING COMPOSITE ALUMINUM-STEEL PARTS BY CASTING ALUMINUM ONTO STEEL AND BONDING THERETO

Howard L. Grange and Dean K. Hanink, Detroit, Mich., assignors to General Motors Corporation, Detroit, Mich., a corporation of Delaware

No Drawing. Application August 12, 1947, Serial No. 768,270

10 Claims. (Cl. 22—204)

1

This invention relates to forming composite articles by casting and bonding aluminum or an aluminum base alloy onto steel or other ferrous metal.

The primary object of our invention is to provide a simple and practical procedure for strongly bonding aluminum or aluminum base alloys to steel or other ferrous metal parts. The simple procedure results in forming a strong bond between steel and aluminum that has a relatively low degree of brittleness at the junction between the two metals.

In carrying out the invention the steel or other ferrous metal part is immersed in a molten or fused salt bath capable of absorbing iron oxide and aluminum oxide. A salt bath of the following composition has proven highly satisfactory.

47% Potassium Chloride (KCl)
35% Sodium Chloride (NaCl)
12% Cryolite (Na_3AlF_6)
6% Aluminum Fluoride (AlF_3).

This salt bath has a melting point of about 1180° F. Addition of a small amount of lithium chloride to the above composition lowers the melting point thereof. For example, about 20% lithium chloride lowers the melting point to about 1075° F.

The exact composition of the salt bath is not critical and the proportions of potassium chloride, sodium chloride, cryolite and aluminum fluoride may be varied from the above. For example, the potassium chloride may range from about 37 to 57%, the sodium chloride from about 25 to 45%, the cryolite from about 8 to 20% and the aluminum fluoride from about 0.5 to 12%. The bath composition usually preferred is one that will become molten when heated to 1200° F. or somewhat lower. While in the foregoing examples the double salt Na_3AlF_6 (cryolite) is given, it should be understood that an equivalent amount of this component may be supplied in the form of the single salts, sodium fluoride and aluminum fluoride. We have found that it is essential to provide an excess of AlF_3 over that of the cryolite ratio in order to obtain the desired results.

The temperature of the molten or fused salt bath should be maintained above 1250° F. to obtain effective fluxing action. To avoid excessive volatilization and chemical instability of the molten salt it should not be maintained higher than 1600° F. Salt bath temperatures within the range of 1300° to 1450° F. are preferred. The fused salt bath must be activated by aluminum

2

in or in contact with the fused salt in order to provide effective fluxing action. This may be done by employing an aluminum or aluminum alloy coated container for the fused salt, or aluminum or aluminum alloy can be added to the salt. The aluminum or aluminum alloy may be added by immersing a bar or sheet of the metal in the fused salt bath. The bar or sheet of aluminum or aluminum alloy soon melts and goes to the bottom of the bath.

The steel or other ferrous metal part may be preheated, if desired, prior to immersion in the salt bath and this permits use of smaller quantities of salt and smaller sized salt bath heating means. Where preheating is employed it is preferred that the ferrous metal be preheated under conditions such that the surface is not oxidized. For this purpose heating in a non-oxidizing or reducing atmosphere furnace such as one employing hydrogen, Drycolene, etc., may be used. The term "Drycolene" is the trade-name for a furnace atmosphere gas produced in a charcoal generator utilizing a hydrocarbon gas and air as a gas source. The air and hydrocarbon gas are passed through hot charcoal at 1800° F. and transformed by chemical reaction with the charcoal into an atmosphere consisting of approximately 20% carbon monoxide, less than 2% hydrogen, less than .5% carbon dioxide, and the balance nitrogen. The preheating temperature preferably is on the order of 1200° F. to 1600° F. Where the ferrous metal is preheated to the temperature of the salt bath in a reducing atmosphere and is free of oxides of iron and other foreign matter, the time of immersion may be as little as one or two seconds if no complicated recesses are present. If complicated recesses are present a longer time may be required to ensure that the salt thoroughly cover or coat the ferrous metal part at those portions thereof to which the aluminum or aluminum base alloy is to be bonded. Where the ferrous metal has oxides of iron or other foreign matter on the surface thereof longer times of immersion will be required in order to obtain clean surfaces. Where the preheating step is not used a longer time of immersion is required. The time should be at least sufficient to heat the ferrous metal part to a temperature of at least about 1250° F. The exact time required will, of course, depend on the mass of the part and the size and thermal efficiency of the furnace and salt containing vessel. Holding the ferrous metal in the fused salt for an extended period of time is not harmful. The fused salt bath serves to clean the steel or

other ferrous metal from undesirable oxides and to flux the metal preparatory to dipping or immersing in a zinc alloy bath. No special preparation of the surface of the ferrous metal part prior to immersion in the fused salt bath is required since the molten salt bath flux dissolves iron oxides. The ferrous metal part, of course, must be dry to avoid a steam explosion when immersed in the molten salt. A small amount of oil will burn off with no deleterious effect. Where the ferrous metal part has an excessive amount of oil thereon or is badly rusted, known oil removing and rust removing procedures may be employed.

After treatment in the fused salt bath the ferrous metal part is then removed and immersed in a zinc alloy bath. A zinc alloy bath composed of about 9% aluminum and the balance zinc has proven highly satisfactory in practice. However, other zinc base alloy baths containing from about .5% to 12% aluminum also have been used successfully. A small or minute amount of aluminum must be present to protect the zinc from excessive oxidization. Aluminum, if present in the zinc-aluminum alloy in excess of about 12%, results in formation of an excessive quantity of a complex compound of iron, zinc and aluminum that adheres to the steel or other ferrous metal part in a thick viscous deposit that interferes with accurately locating the part within the mold cavity. The temperature of the zinc alloy bath is within the approximate range of 1300° F. to 1500° F. Temperatures of 1325° F. to 1375° F. are preferred. The time of holding the steel or other ferrous metal part in the zinc alloy bath can be as little as two seconds since a zinc alloy coating forms readily on the ferrous metal part. An extended period such as ten minutes is permissible and may be desirable in some cases to permit displacement of molten salt from parts of complicated recessed design.

The zinc alloy coated ferrous metal part is then removed from the zinc alloy bath and inserted in located position in a mold, the mold closed, and aluminum or aluminum base alloy poured into the mold while the zinc alloy coating is still molten or mushy. The mold gates preferably are so designed as to direct the incoming molten aluminum or aluminum-base alloy up and around the zinc-coated ferrous metal part. The coated ferrous metal part should be at or near the temperature of the aluminum or aluminum base alloy to avoid chill and blow effects and to promote removal of excess zinc alloy and final alloying of the aluminum or aluminum base alloy with the coated ferrous metal. After cooling, the ferrous metal and the cast aluminum or aluminum base alloy are strongly bonded into an integral assembly.

By aluminum base alloys is meant those aluminum alloys which contain about 80% or more of aluminum.

In one application of the invention the process has been employed in forming gear blanks consisting of a steel hub to which is bonded an aluminum alloy web and flange portion. In this instance the steel hub was formed of G. M. 1112 steel and Alcoa #142 aluminum casting alloy was used. The aluminum alloy of these gear blanks may be precipitation treated at 350° F. for 10 hours with a resulting hardness of 94 to 100 Brinell Hardness number with 500 kg. load.

Various changes and modifications of the embodiments of our invention described herein may be made by those skilled in the art without departing from the principles and spirit of our invention.

We claim:

1. The method of forming a composite metal product which comprises immersing ferrous metal in a fused salt bath composed about as follows: 37% to 57% KCl, 25% to 45% NaCl, 8% to 20% Na_3AlF_6, 0.5% to 12% AlF_3, said fused salt bath having aluminum in contact therewith, said fused salt bath being at a temperature of about 1250° F. to about 1600° F., said ferrous metal having a temperature while in said molten salt bath of at least about 1250° F., removing the heated ferrous metal from the molten salt bath and while it is still heated immersing the same in a molten zinc alloy coating bath composed predominately of zinc and containing about .5% to 12% aluminum, said zinc alloy coating bath being maintained at a temperature of about 1300° F. to 1500° F., holding the ferrous metal in said zinc alloy bath for at least about two seconds to form a coating thereon, removing the coated ferrous metal part from said molten zinc alloy coating bath, and, before the coating has completely solidified, applying a molten metal consisting of at least about 80% aluminum to said coated ferrous metal.

2. A method as in claim 1 in which the ferrous metal is preheated under non-oxidizing conditions prior to immersion in the fused salt bath.

3. A method as in claim 1 in which the ferrous metal is immersed in the fused salt bath while the ferrous metal is at room temperature and is heated in said fused salt bath to a temperature of at least 1250° F.

4. A method as in claim 1 in which the zinc alloy is composed of about 9% aluminum and the balance substantially all zinc.

5. A method as in claim 1 in which a small proportion not greater than 20% of lithium chloride is added to the fused salt bath.

6. A method as in claim 1 in which the fused salt bath is operated at a temperature within the range of 1300°–1400° F.

7. A method as in claim 1 in which the zinc alloy coating bath is maintained at a temperature within the range of 1325° to 1375° F.

8. The method of forming composite metal articles which comprises immersing steel in a fused salt bath composed approximately as follows:

47% potassium chloride
35% sodium chloride
12% cryolite
6% aluminum fluoride

said fused salt bath having aluminum in contact therewith, said fused salt bath being maintained at a temperature within the range of 1300° to 1450° F., holding the steel in said molten salt bath until the steel reaches a temperature of at least 1250° F., removing the heated steel from the molten salt bath and while the steel is still heated immersing the same in a zinc alloy coating bath composed of 9% aluminum and the balance substantially all zinc, said zinc alloy coating bath being maintained at a temperature within the range 1325° F. to 1375° F., holding the steel in said zinc alloy coating bath for a time of at least two seconds to form a coating on the steel, removing the coated steel from said molten zinc alloy coating bath and before the coating has completely solidified inserting the coated steel in a mold and casting molten metal consisting of

at least about 80% aluminum into contact with the coated steel.

9. A method as in claim 1 in which the fused salt is contained in an aluminum coated steel container.

10. A method as in claim 1 in which the fused salt has molten aluminum in contact therewith.

HOWARD L. GRANGE.
DEAN K. HANINK.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
597,111	Gooch	Jan. 11, 1898
1,454,214	Dean	May 8, 1923
1,550,280	Post	Aug. 18, 1925
1,807,689	Deputy	June 2, 1931
2,066,454	Bonath et al.	Jan. 5, 1937
2,101,553	Mattsson	Dec. 7, 1937
2,112,578	Rohrig	Mar. 29, 1938
2,123,181	Deputy	July 12, 1938
2,148,664	Wille et al.	Feb. 28, 1939
2,265,243	McCullough et al.	Dec. 9, 1941

FOREIGN PATENTS

Number	Country	Date
257,262	Great Britain	Nov. 17, 1927