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(71) Applicant: **FEDERAL-MOGUL CORPORATION** [US/US]; 26555 Northwestern Highway, Southfield, MI 48033 (US).

(72) Inventor: **SAXTON, David, Michael**; 6106 Vineyard Avenue, Ann Arbor, MI 48108 (US).

(74) Agents: **ARTZ, John, A.** et al.; Dickinson Wright PLLC, 2600 W. Big Beaver Road, Suite 300, Troy, MI 48084-3312 (US).

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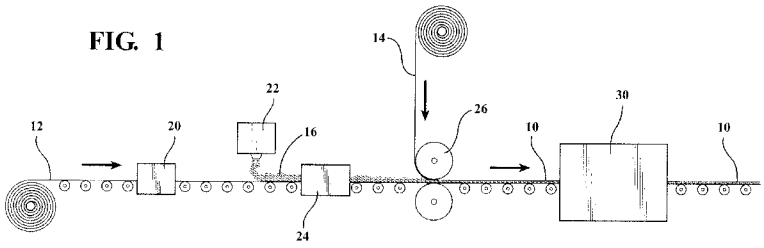
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(54) Title: BI-MATERIAL STRIP AND A METHOD OF BONDING STRIPS OF DIFFERENT MATERIALS TOGETHER

FIG. 1



(57) Abstract: A continuous hot bonding method for producing a bi-material strip with a strong bond therebetween is provided. The method comprises sanding a first strip formed of steel; and applying a layer of first particles, typically formed of copper, to the sanded first strip. The method next includes heating the first strip and the layer of the first particles, followed by pressing a second strip formed of an aluminum alloy onto the heated layer of the first particles. The aluminum alloy of the second strip includes tin particles, and the heat causes the second particles to liquefy and dissolve into the melted first particles. The first particles and the second particles bond together to form bond enhancing metal particles, which typically comprise bronze.

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BI-MATERIAL STRIP AND A METHOD OF BONDING STRIPS OF DIFFERENT MATERIALS TOGETHER

CROSS REFERENCE TO RELATED APPLICATION

[0001] This U.S. utility patent application claims the benefit of U.S. Provisional Patent Application Serial No. 61/712,016, filed October 10, 2012, which is incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0002] The present invention is related to a bi-material strip including a strip of steel bonded to a strip of an aluminum alloy, and a method of forming such a bi-material strip.

2. Related Art

[0003] Bi-material strips including both a strip of an aluminum alloy and a strip of steel are typically used in, among other things, bearings, bushings and washers for various automotive and non-automotive applications. One method to form such bi-material strips is by heating the steel strip to a predetermined temperature, feeding both strips through a high-pressure roller which presses them against one another and finally by quenching the resulting bi-material strip.

SUMMARY OF THE INVENTION

[0004] One aspect of the invention provides a method of forming a bi-material strip. The method includes providing a first strip formed of steel; and applying a layer of first particles to the first strip. The first particles are formed primarily of at least one of copper, nickel, and magnesium. The method next includes heating the layer of the first particles

applied to the first strip; and applying a second strip to the layer of the first particles. The second strip is formed of an aluminum alloy including second particles formed of tin.

[0005] Another aspect of the invention provides a bi-material strip. The bi-material strip includes a first strip formed of steel, and a second strip formed of an aluminum alloy bonded to the first strip. An intermediate layer including a plurality of bond enhancing metal particles bond the first strip to the second strip. The bond enhancing metal particles include first particles and second particles bonded together. The first particles are formed primarily of at least one of copper, nickel, magnesium, and alloys thereof; and the second particles are formed of tin.

[0006] The bond enhancing metal particles provide a strong bond between the first strip and the second strip. In addition, the bi-material strip can be formed very quickly, efficiently, and in high volumes at relatively low cost.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] Other advantages of the present invention will be readily appreciated, as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

[0008] Figure 1 illustrates a method of forming a bi-material strip according to one exemplary embodiment;

[0009] Figure 2 is a cross-sectional view of the bi-material strip formed according to the method of Figure 1; and

[0010] Figure 3 is a cross-sectional view of a first strip with melted first particles after a heating step in the method of Figure 1 and a second strip prior to bonding the second strip to the first strip.

DESCRIPTION OF THE ENABLING EMBODIMENTS

[0011] The invention provides a method of forming a bi-material strip **10** including a first strip **12** formed of steel and a second strip **14** formed of an aluminum alloy with a strong bond therebetween. The strong bond is provided by applying first particles **16** to the first strip **12** prior to hot bonding the strips **12**, **14** together. The method typically includes a continuous process allowing the bi-material **10** strip to be formed quickly, efficiently, and in high volumes at relatively low cost. The resulting bi-material strip **10** may be used in a wide range of different automotive and non-automotive parts including, but not limited, to bearings, bushings or washers.

[0012] Figure 1 illustrates the method of forming the bi-material strip **10** according to one exemplary embodiment, which can be referred to generally as a hot bonding process. Figure 2 illustrates the bi-material strip **10** according to one exemplary embodiment. The method includes providing the first strip **12** formed of steel, and providing the second strip **14** formed of the aluminum alloy. The steel can be any desirable type of steel, and the aluminum alloy can be any desirable type of aluminum alloy that includes second particles **18** formed of tin. In one preferred embodiment, the aluminum alloy is A-515, which is known to have a high tin content. The first strip **12** and the second strip **14** are typically fed continuously into the process, as shown in Figure 1.

[0013] The method begins by cleaning the first strip **12** by continuously feeding the first strip **12** through a cleaning assembly **20** to remove contaminants therefrom. In one preferred embodiment, the cleaning assembly **20** is a sander and the cleaning step includes sanding an upper surface of the first strip **12**.

[0014] The method next includes applying the first particles **16** to the sanded upper surface of the first strip **12**. The first particles **16** are formed primarily of at least one of copper, nickel, and magnesium. For example, the first particles **16** can be formed of pure

copper, nickel, or magnesium. Alternatively, the first particles **16** can be formed of alloys whose primary ingredient constituent is copper, nickel, or magnesium. In one preferred embodiment, the first particles **16** are formed of copper. The first particles **16** also preferably have a nominal size capable of providing localized stresses in the resulting bond between the strips **12**, **14** to improve the resulting bond between the strips **12**, **14**. In one embodiment, the nominal particle size of the first particles **16** is approximately 0.05 millimeters.

[0015] The first particles **16** are typically applied to the upper surface of the first strip **12** until the first particles **16** form a layer having a thickness capable of providing the strong bond between the strips **12**, **14**. In one embodiment, the thickness of the layer is approximately 0.1 millimeters. However, it should be appreciated that depending on the desired characteristics of the final bond, the size of the first particles **16** and thickness of the layer applied onto the first strip **12** can be varied. Preferably, the step of applying the first particles **16** to the first strip **12** includes spreading the unheated first particles **16** over the upper surface using a spreading device **22**. It should be appreciated that any desirable type of powder spreading device **22** could be employed.

[0016] Next, the method includes heating the first strip **12** with the layer of the first particles **16** to a predetermined temperature, wherein the predetermined temperature is high enough to at least partially melt the first particles **16** and the steel along the upper surface of the first strip **12**. The heating step typically includes continuously feeding the first strip **12** through a heater **24**, preferably an induction heater. However, it should be appreciated that any desirable type of heater **24** could be used. During the heating step, at least some of the first particles **16** melt and interact with the steel of the first strip **12**. Figure 3 is a cross-sectional view of the first strip **16** with the melted first particles **16** immediately after exiting the heater **24**. Figure 3 also shows the second strip **14** prior to the bonding step.

[0017] After the heating step, the method includes reducing the amount of oxides formed on the first particles **16** and on the upper surface of the first strip **12** during the prior steps. The reducing step includes continuously feeding and exposing the first strip **12** with the layer of the first particles **16** to a reducing atmosphere including hydrogen, such as an atmosphere consisting of pure hydrogen or a mixture of hydrogen and an inert gas such as nitrogen or argon.

[0018] While the first strip **12** and the first particles **16** are still hot or heated, the method includes pressing a lower surface of the second strip **14** onto the layer of the first particles **16** to form the bi-material strip **10**. The pressing step preferably includes continuously feeding the first strip **14** and the second strip **14** through a high pressure roller **26**, as shown in Figure 1, such that the layer of the first particles **16** is sandwiched between the first strip **12** and the second strip **14**. The roller **26** presses the strips **12**, **14** against one another to form the bond between the strips **12**, **14**.

[0019] During the pressing step, heat from the first strip **12** and the melted first particles **16** is transferred to the second strip **14**. Typically, the pressing step causes at least some of the second particles **18** along the lower surface of the second strip **14** to liquefy and dissolve into the melted first particles **16**. The second particles **18** bond to the first particles **16** and form bond enhancing metal particles **28**, which include both the first particles **16** and the second particles **18**, between the strips **12**, **14**. Thus, the pressing step should be conducted while the first strip **12** and the first particles **16** are still at a temperature high enough to cause the second particles **18** along the lower surface of the second strip **14** to melt. When the first particles **16** include copper, the copper of the first particles **16** and the tin of the second particles **18** dissolve into each other, so the resulting bond enhancing metal particles **28** comprise bronze, which provides a strong bond between the first strip **12** and the second strip **14**. Preferably, none of the second particles **18** formed of tin are present along

the bond line at the lower surface of the second strip **14**, as shown in Figure 2, which is greatly exaggerated. The lack of tin along the bond line also contributes to the strong bond between the first strip **12** and the second strip **14**. The bond enhancing particles **28** form an intermediate layer **32** bonding the first strip **12** to the second strip **14**. The entire intermediate layer **32** can consist of the bond enhancing particles **28**.

[0020] After bonding the first strip **12** to the second strip **14** to form the bi-material strip **10**, the method includes cooling or quenching the bi-material strip **10** to a predetermined temperature. The cooling step typically includes continuously feeding the bi-material strip **10** from the roller **26** and through a quenching apparatus **30**, for example a tank filled with a coolant, such as water, to quickly cool the bi-material strip **10** to the predetermined temperature. It should be appreciated that any desirable type of quenching apparatus **30** could be employed to carry out the quenching process including, for example, at least one sprayer. After the quenching process is complete, the bi-material strip **10** may be cut, bent, pressed or put through any desirable process to form any desirable type of part or work piece. For example, the bi-material strip **10** could be used as a sliding element, such as a bearing, bushing, or washer.

[0021] Another aspect of the invention provides the resulting bi-material strip **10** including the first strip **12** bonded to the second strip **14** by the intermediate layer **32** including the bond enhancing metal particles **28**, as shown in Figure 2. As stated above, the bond enhancing metal particles **28** include the first particles **16** bonded to the second particles **18**, wherein the first particles **16** are formed primarily of at least one of copper, nickel, and magnesium; and the second particles **18** are formed of tin. The bond enhancing metal particles **28** are disposed on or along the upper surface of the first strip **12**, and the upper surface preferably has irregularities formed by the sanding step. In one preferred

embodiment, the first particles **16** are formed of copper and the bond enhancing particles **28** comprise bronze.

[0022] However, the properties of the resulting bond between the strips **12**, **14** may depend at least partially on, among other things, the temperature that the first strip **12** and the layer of the first particles **16** are heated to by the heater **24**; the pressure exerted by the roller **26**; and the amount of time between the rolling and cooling steps. Accordingly, the temperature of the heater **24**; the force applied by the roller **26**; and the distance between the roller **26** and the quenching apparatus **30** may all be adjusted to adjust the properties of the resulting bond between the first and second strips **12**, **14**.

[0023] Obviously, many modifications and variations of the present invention are possible in light of the above teachings and may be practiced otherwise than as specifically described while within the scope of the appended claims.

CLAIMS

1. A method of forming a bi-material strip, comprising the steps of:

providing a first strip formed of steel;

applying a layer of first particles to the first strip, the first particles being formed primarily of at least one of copper, nickel, and magnesium;

heating the layer of the first particles applied to the first strip;

applying a second strip to the layer of the first particles, wherein the second strip is formed of an aluminum alloy including second particles formed of tin.

2. The method of claim 1, wherein the step of applying the second strip to the layer of the first particles includes pressing a lower surface of the second strip onto the layer of the first particles while the layer of the first particles is hot.

3. The method of claim 2, wherein the pressing step includes bonding the first particles to the second particles.

4. The method of claim 3, wherein the bonding step includes forming bond enhancing metal particles between the first strip and the second strip, the bond enhancing metal particles including the second particles bonded to the first particles.

5. The method of claim 2, wherein the pressing step includes liquefying at least some of the second particles along the lower surface of the second strip.

6. The method of claim 2, wherein the pressing step includes feeding the first strip and the second strip through a roller such that the layer of the first particles is sandwiched between the first strip and the second strip.

7. The method of claim 1 including sanding an upper surface of the first strip prior to applying the layer of the first particles.

8. The method of claim 1, wherein the first particles have a particle size of 0.05 millimeters and the layer of the first particles has a thickness of 0.1 millimeters.

9. The method of claim 1, wherein the first particles are formed of copper and the bond enhancing particles comprise bronze.

10. The method of claim 1, wherein the heating step includes interacting at least some of the first particles with the steel of the first strip.

11. The method of claim 1, wherein the heating step includes induction heating.

12. The method of claim 1 including exposing the layer of the first particles and the first strip to an atmosphere including hydrogen to reduce the amount of oxides formed on the first strip and on the first particles after the heating step and before applying the second strip to the layer of the first particles.

13. The method of claim 1 including using the bi-material strip in a bearing, bushing, or washer.

14. The method of claim 1 including feeding the bi-material strip through a quenching tank filled with a coolant after applying the second strip to the layer of the first particles.

15. A method of forming a bi-material strip, comprising the steps of:

providing a first strip formed of steel;

cleaning the first strip by feeding the first strip through a cleaning assembly to remove contaminants therefrom;

the cleaning step including sanding an upper surface of the first strip;

providing first particles having a nominal size of approximately 0.05 millimeters and formed primarily of at least one of copper, nickel, and magnesium;

applying the first particles to the upper surface of the first strip until the first particles form a layer having a thickness of approximately 0.1 millimeters;

the applying step including spreading the first particles over the upper surface of the first strip;

heating the first strip with the layer of the first particles to a predetermined temperature, wherein the predetermined temperature is high enough to at least partially melt the first particles and the steel along the upper surface of the first strip;

the heating step including feeding the first strip through an induction heater;

the heating step including interacting at least some of the first particles with the steel of the first strip;

reducing the amount of oxides formed on the first particles and on the upper surface of the first strip;

the reducing step including exposing the first strip with the layer of the first particles to an atmosphere including hydrogen;

providing a second strip formed of an aluminum alloy, the aluminum alloy including second particles formed of tin;

pressing a lower surface of the second strip onto the layer of the first particles on the first strip while the first strip and the first particles are still heated to form a bi-material strip;

the pressing step including feeding the first strip and the second strip through a roller such that the layer of the first particles is sandwiched between the first strip and the second strip;

the pressing step including liquefying at least some of the second particles along the lower surface of the second strip;

the pressing step including bonding the first particles to the second particles;

the bonding step including forming bond enhancing metal particles including the first particles and the second particles between the first strip and the second strip;

cooling the bi-material strip to a predetermined temperature; and

the cooling step including feeding the bi-material strip through a quenching tank filled with a coolant.

16. A bi-material strip, comprising:

a first strip formed of steel;

a second strip formed of an aluminum alloy and bonded to said first strip; and

an intermediate layer including a plurality of bond enhancing metal particles bonding said first strip to said second strip, said bond enhancing metal particles including first particles bonded to second particles, wherein said first particles are formed primarily of at least one of copper, nickel, and magnesium, and said second particles are formed of tin.

17. The bi-material strip of claim 16, wherein said aluminum alloy includes said second particles formed of tin.

18. The bi-material strip of claim 16, wherein said bond enhancing metal particles are disposed along an upper surface of said first strip, and said upper surface has irregularities formed by sanding.

19. The bi-material strip of claim 16, wherein said first particles are formed of copper and said first particles are bonded to said second particles such that said bond enhancing particles comprise bronze.

20. The bi-material strip of claim 16, wherein said bi-material strip is used in a bearing, bushing, or washer.

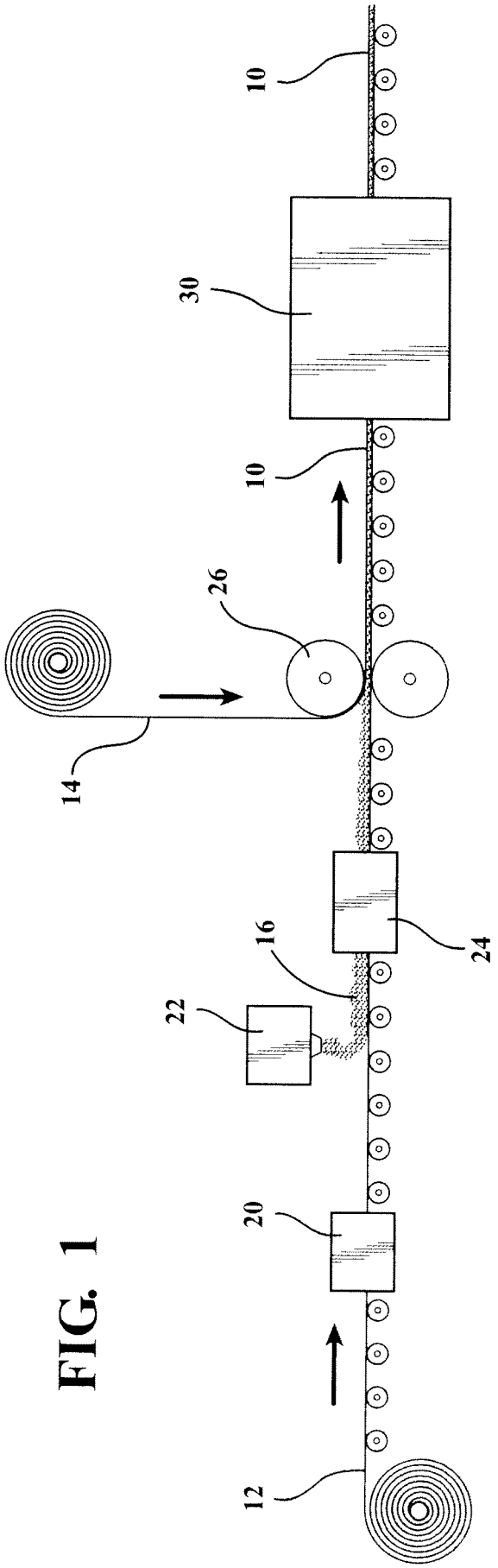


FIG. 1

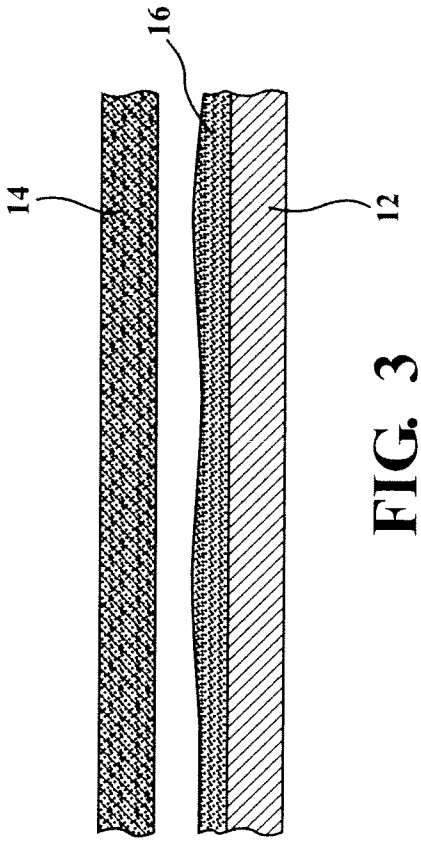


FIG. 3

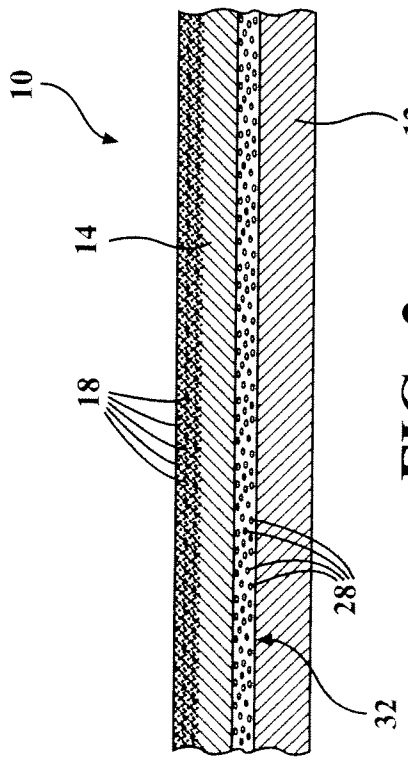


FIG. 2

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2013/064219

A. CLASSIFICATION OF SUBJECT MATTER
INV. B22F7/04 B23K20/227 B32B15/01 F16C33/12
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B32B B23K B22F F16C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2 735 170 A (BOHU ALUMINIUM & BRASS CORPORATION) 21 February 1956 (1956-02-21) column 1, lines 15-32 column 1, line 44 - column 2, line 52 figure 1 -----	1-20
X	US 2 490 549 A (SCHULTZ HAROLD W ET AL) 6 December 1949 (1949-12-06) column 1, lines 16-27 column 1, line 45 - column 3, line 36 figures 1-3 ----- -/--	1-20

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
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Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Stocker, Christian

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 3 078 563 A (GOULD JAMES C ET AL) 26 February 1963 (1963-02-26)	16-20
A	column 1, lines 10-13 column 1, lines 35-45 column 2, lines 21-69 column 3, line 56 - column 4, line 56 figures 1-3	1-15

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