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(54) ROBUST CRASH DURABLE ADHESIVE BONDING OF BORON STEEL

(57) Method for selectively removing at least part of an Aluminium-Silicon (Al-Si) coating (11) from Al-Si-coated Boron steel (10), which comprises the steps of bonding an offer strip (12) to said Al-Si-coated Boron steel (10) using an adhesive (13), curing said adhesive (13), whereby said adhesive (13) adheres to said Al-Si coating (11), and subjecting said offer strip (12) to a peel and/or shear force (F_{peel} and/or F_{shear}) to mechanically remove at least part of said Al-Si coating (11) from said Al-Si-coated Boron steel (10). The method can also comprise the step of bonding a component (15) to at least one point/line/area (14) on Al-Si-coated Boron steel (10) from which at least part of the Al-Si coating (11) has been removed.

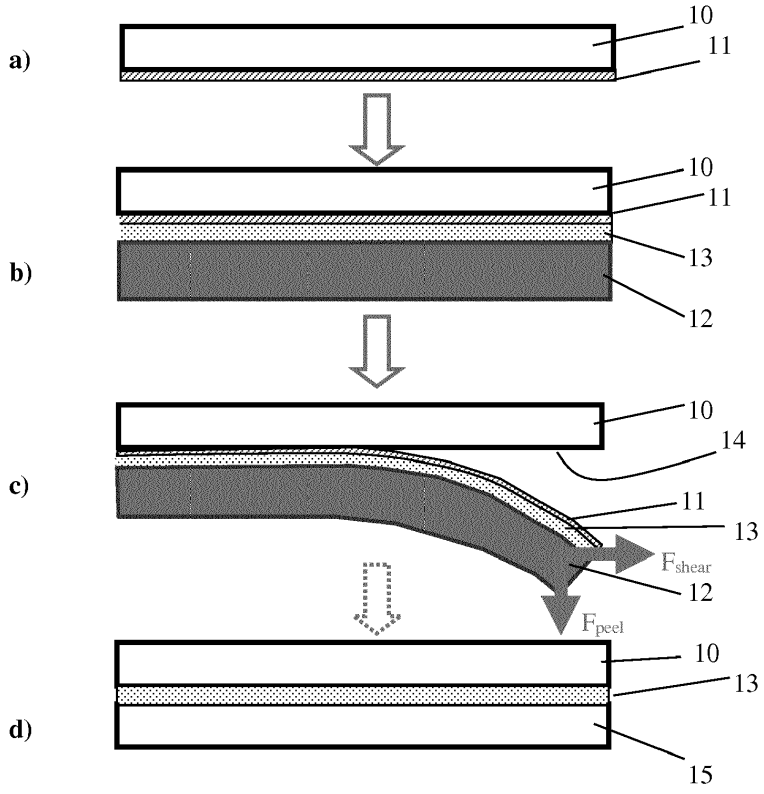

Fig. 1

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Description

TECHNICAL FIELD

[0001] The present invention concerns a method for selectively removing at least part of an Aluminium-Silicon (Al-Si) coating from Al-Si-coated Boron steel. The present invention also concerns a method for bonding Al-Si-coated Boron steel to another component.

BACKGROUND OF THE INVENTION

[0002] Hot press forming of Boron steel is being increasingly used in automotive industries due to Boron steel's high tensile strength and minimal spring back. The use of Boron steel can namely result in a weight reduction of vehicle body parts and improvements in vehicle safety and fuel efficiency. High-strength Boron steel sheets are often coated with an Al-Si layer in order to prevent oxidation, corrosion and scaling of components during hot press forming, and this can increase the components' reliability with a view to dimensional accuracy and stress distribution when they are in service.

[0003] However, the Al-Si coating adversely affects the strength of bonds that are formed when Al-Si-coated Boron steel is welded or adhered to another component. Unlike hot-dip galvanized steel surface coatings, the Al-Si metallic surface layer does not namely form a strong metallic bond to the underlying base metal. It is known that the Al-Si coating tends to delaminate in from the base metal along adhesive bond lines during bond line failure under static or dynamic loading (for example in crash and durability tests). The delamination may occur at the base metal, or close to the base metal.

[0004] Diploma work no. 52/2011 entitled "Adhesively Bonded Steel Structures" by Man-Shin Tan and Nozhan Sharifian, performed at Volvo Car Corporation under the supervision of Johnny K. Larsson, which was published in 2011 focused on the effect of adhesive in the crash performance of High and Ultra High Strength Steels including Usibor™ (Boron steel with an Al-Si coating). The Diploma thesis concluded that epoxy-based adhesive should not be used together with Usibor™ because the delamination of Usibor™'s Al-Si surface coating causes the epoxy-based adhesive to fail.

SUMMARY OF THE INVENTION

[0005] An object of the present invention is to provide an improved method for selectively removing at least part of an Al-Si coating from Al-Si-coated Boron steel.

[0006] The method comprises the steps of bonding an offer strip to the Al-Si-coated Boron steel using an adhesive, and curing the adhesive, whereby the adhesive adheres to the Al-Si coating, and subjecting the offer strip to a peel and/or shear force, for example by peeling and/or shearing off the offer steel strip from the Al-Si-coated Boron steel to which it has been bonded, to mechanically remove at least part of the Al-Si coating from the Al-Si-coated Boron steel. The Al-Si coating is removed as the offer strip is peeled and/or sheared off because the bond formed between the Al-Si coating and the adhesive is stronger than the bond formed between the Al-Si coating and the Boron steel.

[0007] All, or at least part of the Al-Si coating on at least one part of an Al-Si-coated Boron steel surface may therefore be removed in order to provide at least one uncoated point/line/area, i.e. at least one region of any desired shape or size from which all or some of the Al-Si coating has been removed, which may for example subsequently be used as a bond point/line/area to which another component may be bonded. A bond formed in the at least one uncoated point/line/area will be stronger than a bond formed on part of the Al-Si-coated Boron steel from which the Al-Si coating has not been removed due to the lack of an Al-Si coating in that at least one uncoated point/line/area, or due to the reduced amount of Al-Si in that at least one uncoated or less coated part. A reduced amount of Al-Si coating is intended to mean a reduced amount of Al-Si as regards the area over which the Al-Si coating is spread, and/or the thickness of the Al-Si coating.

[0008] For example, a crash durable adhesive may subsequently be applied to the at least one uncoated part and cured, whereby a robust, durable and crash durable adhesive bond may be provided. The risk of bond failure due to the delamination of an Al-Si coating from Al-SI-coated Boron steel is eliminated or reduced using a method according to the present invention. The resulting cohesive bond line failure mode allows for Computer-aided engineering (CAE) modelling of the bond line based on cohesive zone models.

[0009] The expression "offer strip" as used in this document is intended to mean any sacrificial component of any suitable size, shape, thickness and material, such as a relatively thin, long, narrow piece of material, which is arranged to be temporarily bonded to at least part of the surface of Al-Si-coated Boron steel and subsequently removed so that the adhesive and the Al-Si coating to which that adhesive has adhered is also removed with the offer strip.

[0010] It should be noted Boron steel components are manufactured with a knowledge of where they are to be bonded to at least one other component. A skilled person will therefore be able to provide a suitable offer strip for use with a particular component in order to remove at least part of an Al-Si from a particular part or parts of that component. One offer strip may be used to remove the Al-Si coating from one or a plurality of parts of a Boron steel component. Alternatively, a plurality of offer strips may be used to remove the Al-Si coating from a single part of a Boron steel component.

[0011] The expression "curing the adhesive" is intended to mean any physical and/or chemical process that is required to cause an adhesive to form a bond between the surfaces between which it is applied. For example,

some adhesives require a chemical reaction, such as but not limited to crosslinking, to convert them from a liquid (or thermoplastic polymer) to solid (or thermoset polymer). Once cured, these adhesives provide high strength, flexible to rigid bonds that resist temperature, humidity, and many chemicals. Some adhesives require either high temperature or substances or media (light, humidity, radiation) from the surroundings to initiate the curing mechanism and activate their hardener.

[0012] The expression "whereby the adhesive adheres to the Al-Si coating" is intended to mean that the adhesive forms a bond with the Al-Si coating so that once the offer strip is subjected to a peel and/or shear force, then at least part of the Al-Si coating to which the adhesive is bonded will come away from the base metal (the Boron steel) to which it is also bonded.

[0013] According to an embodiment of the invention the adhesive comprises a crash-durable structural adhesive or a high strength structural adhesive. The adhesive may be an epoxy-based adhesive.

[0014] According to an embodiment of the invention the offer strip comprises one of the following: steel, a high strength steel, an uncoated or hot-dip galvanized coated steel.

[0015] The present invention also concerns a method for bonding Al-Si-coated Boron steel to another component, which comprises the steps of the method for selectively removing at least part of an Al-Si coating from Al-Si-coated Boron steel according to any embodiment of the present invention. The method for bonding Al-Si-coated Boron steel to another component (which may also be a Al-Si-coated Boron steel component from which at least part of its Al-Si coating has been selectively removed using a method according to the present invention) namely comprises the steps of bonding an offer strip to the Al-Si-coated Boron steel using an adhesive, curing the adhesive, whereby the adhesive adheres to the Al-Si coating, and subjecting the offer strip to a peel and/or shear force to mechanically remove at least part of the Al-Si coating from the Al-Si-coated Boron steel and thereby provide at least one uncoated point/line/area on the Al-Si-coated Boron steel, and then bonding the component to the at least one uncoated point/line/area.

[0016] According to an embodiment of the invention the adhesive comprises a crash-durable structural adhesive or a high strength structural adhesive.

[0017] According to an embodiment of the invention the component is bonded to the at least one uncoated point/line/area by means of adhesion.

[0018] According to an embodiment of the invention the adhesive is also used to bond the component to the at least one uncoated point/line/area, i.e. either the same adhesive is used to provide the final permanent bond between the uncoated Boron steel and the component and the temporary bond between the offer strip and the Al-Si-coated Boron steel, or different adhesives are used for each of these bonds.

[0019] According to an embodiment of the invention the component is bonded to the at least one uncoated point/line/area by means of welding, such as by resistance spot welding, laser welding, arc welding, or any other bonding method.

[0020] According to an embodiment of the invention the offer strip comprises one of the following: steel, a high strength steel, an uncoated or hot-dip galvanized coated steel.

[0021] According to an embodiment of the invention the component at least one of the following: a vehicle component, such as a vehicle pillar, a tailor roller blank (TRB), a steel component, such as a component comprising coated or uncoated automotive grade steel or a component comprising coated or uncoated automotive grade Boron steel, an aluminium component, such as a component comprising automotive grade aluminium. The Al-Si-coated steel and/or the component that is attached thereto may comprise hardened Boron steel, which comprises martensitic material, having a tensile strength of 1300 MPa or more.

[0022] The present invention further concerns the use of a coating-removal and/or bonding method according to any of the embodiments of the invention to provide Al-Si-coated (preferably automotive-grade) Boron steel with at least one robust, durable and crash durable bond.

BRIEF DESCRIPTION OF THE DRAWING

[0023] The present invention will hereinafter be further explained by means of non-limiting examples with reference to the appended schematic figures in which;

Figure 1 shows the steps of a method according to an embodiment of the invention,

Figure 2 shows the region between Al-Si-coated Boron steel and an offer strip that has been bonded thereto,

Figure 3 is a flow diagram showing the steps of a method according to an embodiment of the invention, and

Figure 4 shows a vehicle comprising at components that have been bonded together using a method according to the invention.

[0024] It should be noted that the drawings may not have been drawn to scale and that the dimensions of certain features may have been exaggerated for the sake of clarity.

DETAILED DESCRIPTION OF EMBODIMENTS

[0025] Figure 1a) shows Boron steel 10, having a surface comprising an Aluminium-Silicon (Al-Si) coating 11. The Boron steel may constitute at least part of a Boron steel component of any size and shape. Any known man-

ufacturing method may be used to produce and coat such a Boron steel component. A component may for example be manufactured by hot forming which involves heating blanks of Boron steel to austenitization temperature in a furnace, for example to a temperature over 900°C, and then quenching and shaping it during controlled cooling processes in order to impart different strengths to different parts of the Boron steel component. The Al-Si coating 11 need not necessarily be uniformly applied to the entire surface of Boron steel 10 but can be applied to any part or parts of the surface of Boron steel 10 in any uniform or non-uniform pattern, and/or it may have a uniform or non-uniform thickness as desired.

[0026] The method according to the present invention comprises the step of bonding an offer strip 12 to the Al-Si coating 11 of the Boron steel 10 using an adhesive 13. The adhesive 13 may be a crash-durable structural adhesive or a high strength structural adhesive.

[0027] The adhesive 13 is namely applied to one or more parts of the Al-Si coating 11 and/or one or more parts of the offer strip 12 as desired. The offer strip 12 may comprise: steel, a high strength steel, an uncoated or hot-dip galvanized coated steel or any other material that is suitable for being bonded to the Al-Si coating 11 of Boron steel 10 and then being peeled and/or sheared off therefrom.

[0028] In the embodiment illustrated in Figure 1, adhesive 13 is applied to the Al-Si coating 11 and/or the surface of the offer strip 12 in such a way that the entire Al-Si coating of the Al-Si-coated Boron steel 10 will be bonded to the offer strip 12 when the offer strip 12 is joined to the Al-Si-coated Boron steel 10. The adhesive 13 is cured in order to form an adhesive bond with the Al-Si coating 11 as shown in figure 1b).

[0029] Once the adhesive 13 has been cured, the offer strip 12 is subjected to a peel and/or shear force F_{peel} and/or F_{shear}, to mechanically remove at least part of the Al-Si coating 11 from the Al-Si-coated Boron steel 10. In the illustrated embodiment, the entire Al-Si coating 11 is mechanically removed from the surface of the Al-Si-coated Boron steel 10.

[0030] Once the Al-Si coating 11 has been mechanically removed in part, or in its entirety as desired, the Boron steel 10 will have been provided with at least one uncoated point/line/area 14 as shown in figure 1c) to which one or more components 15 can be bonded as shown in figure 1d). It may for example be beneficial in some applications not to remove the entire Al-Si coating 11 so that it can provide some oxidation and/or corrosion protection.

[0031] The component 15 may be bonded to the at least one uncoated point/line/area 14 by means of adhesion, for example using the same adhesive 13, or a different adhesive as that used to temporarily bond the offer strip 12 to the Al-Si coating 11 of the Boron steel 10.

[0032] Alternatively, or additionally the component 15 may be bonded to the at least one uncoated point/line/area 1 by means of welding.

[0033] A metallurgical structure analysis may be used to determine that at least part of an Al-Si coating 11 has been removed from Al-Si- coated Boron steel at the uncoated bond point(s)/line(s)/area(s). The adhesive or welding bond thus formed will be much more robust, durable and crash durable than if at least part of the Al-Si coating 11 had not been removed prior to the formation of such a bond.

[0034] The component 15 may be a vehicle component, such as a vehicle pillar, a tailor roller blank (TRB), a steel component, such as a component comprising coated or uncoated automotive grade steel or a component comprising coated or uncoated automotive grade Boron steel, an aluminium component, such as a component comprising automotive grade aluminium.

[0035] Figure 2 shows the region between Boron steel 10 comprising an Al-Si coating 11 and an offer strip 12 that has been bonded thereto by means of an adhesive 13. A sorption interphase 16 comprising oil and low molecular weight polymer, oriented fillers etc. may form between the adhesive 13 and the Al-Si coating 11. The offer strip 12 may also comprise a surface layer 17, such as an oxide or Zn-layer.

[0036] Figure 3 is a flow diagram showing the steps of a method according to an embodiment of the invention. The method comprises the steps of selectively bonding an offer strip 12 to Al-Si-coated Boron steel 10 using an adhesive 13, curing the adhesive 13 and subjecting the offer strip 12 to a peel and/or shear force F_{peel} and/or F_{shear} to mechanically remove at least part of the Al-Si coating 11 from the Boron steel 10 and thereby provide at least one uncoated point, line or area 14 to which one or more components 15 may be bonded.

[0037] Figure 4 shows a vehicle 18 that comprises at least one component that has been subjected to a method according to the present invention during the manufacture of the vehicle 18.

[0038] For example, a vehicle pillar, such as an A-pillar 19 or a B-pilllar 20 may comprise Al-Si-coated Boron steel from which at least part of the Al-Si coating has been removed using a method according to the present invention and/or a which has been bonded to another component using a method according to the present invention.

[0039] For example, the A-pillar 19 of the vehicle, (i.e. the structural support on a side of a vehicle's windscreen located just ahead of and above the vehicle's front doors or roof rail, i.e. the structural component that extends between the roof and the side of the vehicle), may comprise at least two component parts that have been bonded together using a method according to the present invention. A first upper component part of the A-pillar 19 may comprise automotive grade steel having a tensile strength of 800 MPa or less. A second lower part of the A-pillar 19 may comprise hardened Boron steel comprising martensitic material having a tensile strength of 1300 MPa or more. The two component parts may be bonded together, for example by means of adhesion or welding, using a method according to the present invention in or-

der to improve the strength and the durability of the bond formed between them.

[0040] According to an embodiment of the invention the component may constitute a tailor rolled blank (TRB). A TRB or "tailored blank" is a metal sheet, which is typically composed of various steel grades and thicknesses. This allows different parts of a vehicle reinforcement manufactured from the TRB to be adapted to local loads, which would otherwise require additional strengthening components. Benefits of using TRBs therefore include reducing component weight and manufacturing costs. Typically, individual sheet metal plates are welded together by laser welding to produce a TRB.

[0041] A component comprising Boron steel is stiffer and more lightweight than a corresponding component comprising normal steel on account of the alloys that have been added during manufacture, thereby making a vehicle having at least one such component safer and more fuel-efficient than a vehicle that does not comprise Boron steel components.

[0042] Such a vehicle 18 having such Boron steel components 19, 20 that have been bonded using a method according to the present invention may show improved performance in safety tests and certifying procedures, for example in crash tests, such as side impact tests.

[0043] Further modifications of the invention within the scope of the claims would be apparent to a skilled person.

Claims

1. Method for selectively removing at least part of an Aluminium-Silicon (Al-Si) coating (11) from Al-Si-coated Boron steel (10), **characterized in that** it comprises the steps of bonding an offer strip (12) to said Al-Si-coated Boron steel (10) using an adhesive (13), curing said adhesive (13), whereby said adhesive (13) adheres to said Al-Si coating (11), and subjecting said offer strip (12) to a peel and/or shear force (F_{peel} and/or F_{shear}) to mechanically remove at least part of said Al-Si coating (11) from said Al-Si-coated Boron steel (10).

2. Method according to claim 1, **characterized in that** said adhesive (13) comprises a crash-durable structural adhesive or a high strength structural adhesive.

3. Method according to claim 1, **characterized in that** said offer strip (12) comprises one of the following: steel, a high strength steel, an uncoated or hot-dip galvanized coated steel.

4. Method for bonding Aluminium-Silicon (Al-Si)-coated Boron steel (10) to another component (15), **characterized in that** it comprises the steps of bonding an offer strip (12) to said Al-Si-coated Boron steel (10) using an adhesive (13), curing said adhesive (13), whereby said adhesive (13) adheres to said Al-Si coating (11), and subjecting said offer strip (12) to a peel and/or shear force (F_{peel} and/or F_{shear}) to mechanically remove at least part of said Al-Si coating (11) from said Al-Si-coated Boron steel (10) and thereby provide at least one uncoated point/line/area (14) on said Al-Si-coated Boron steel (10), and then bonding said component (15) to said at least one uncoated point/line/area (14).

5. Method according to claim 3, **characterized in that** said adhesive (13) comprises a crash-durable structural adhesive or a high strength structural adhesive.

6. Method according to claim 3 or 4, **characterized in that** said component (15) is bonded to said at least one uncoated point/line/area (14) by means of adhesion.

7. Method according to claim 5, **characterized in that** said adhesive (13) is also used to bond said component (15) to said at least one uncoated point/line/area (14).

8. Method according to claim 3 or 4, **characterized in that** said component (15) is bonded to said at least one uncoated point/line/area (14) by means of welding.

9. Method according to any of claims 3-8, **characterized in that** said offer strip (12) comprises one of the following: steel, a high strength steel, an uncoated or hot-dip galvanized coated steel.

10. Method according to any of claims 3-9, **characterized in that** said component (15) at least one of the following: a vehicle component, such as a vehicle pillar (19), a tailor roller blank (TRB), a steel component, such as a component comprising coated or uncoated automotive grade steel or a component comprising coated or uncoated automotive grade Boron steel, an aluminium component, such as a component comprising automotive grade aluminium.

11. Use of a method according to any of the preceding claims to provide Al-Si-coated Boron steel (10) with robust, durable and crash durable bonds.

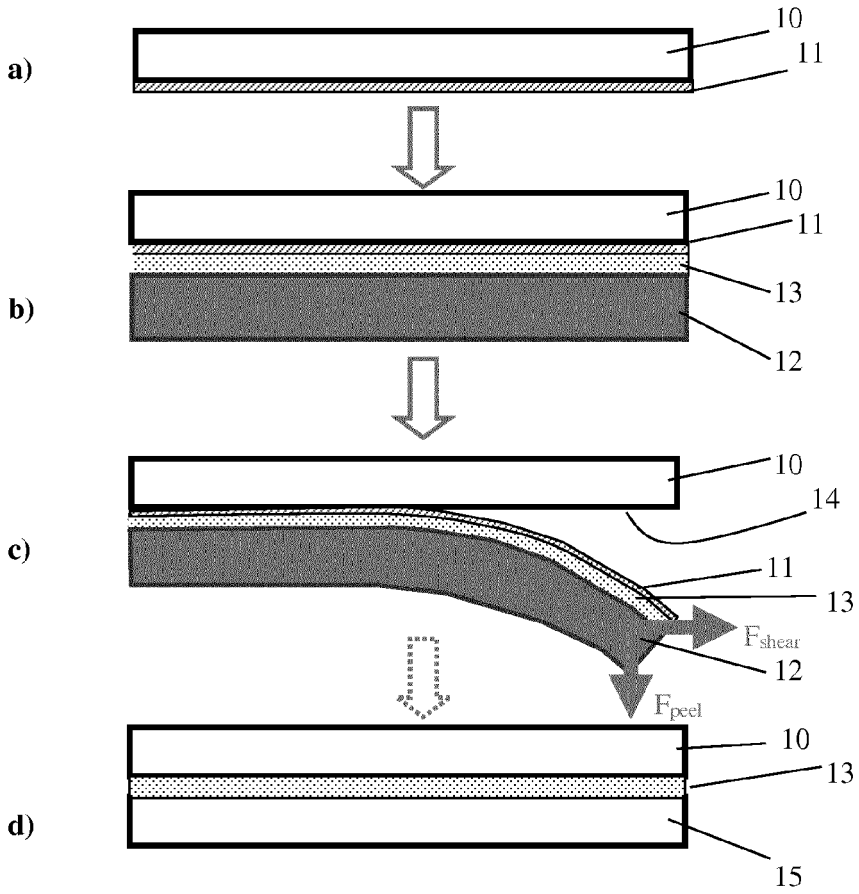
a)
10
11
b)
10
11
13
12
c)
10
14
11
13
F_{shear}
12
F_{peel}
d)
10
13
15

Fig. 1

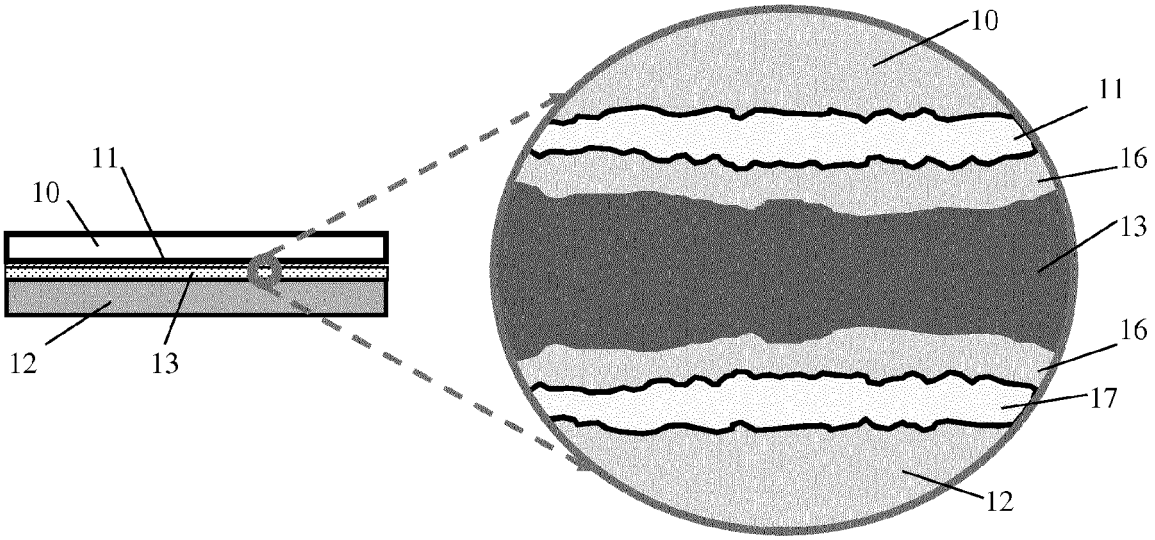
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Fig. 2

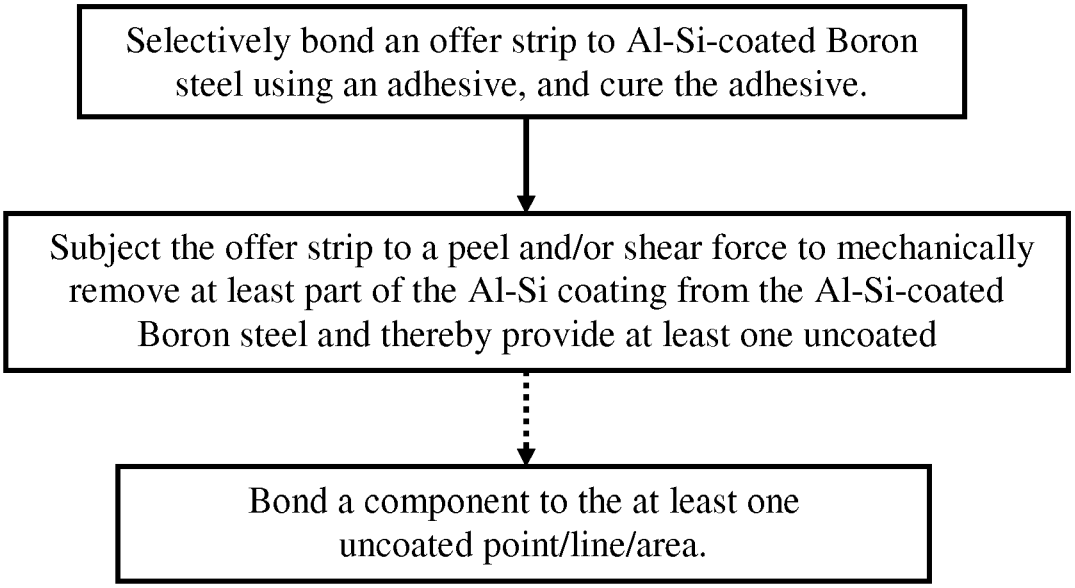
Selectively bond an offer strip to Al-Si-coated Boron steel using an adhesive, and cure the adhesive.
Subject the offer strip to a peel and/or shear force to mechanically remove at least part of the Al-Si coating from the Al-Si-coated Boron steel and thereby provide at least one uncoated
Bond a component to the at least one uncoated point/line/area.

Fig. 3

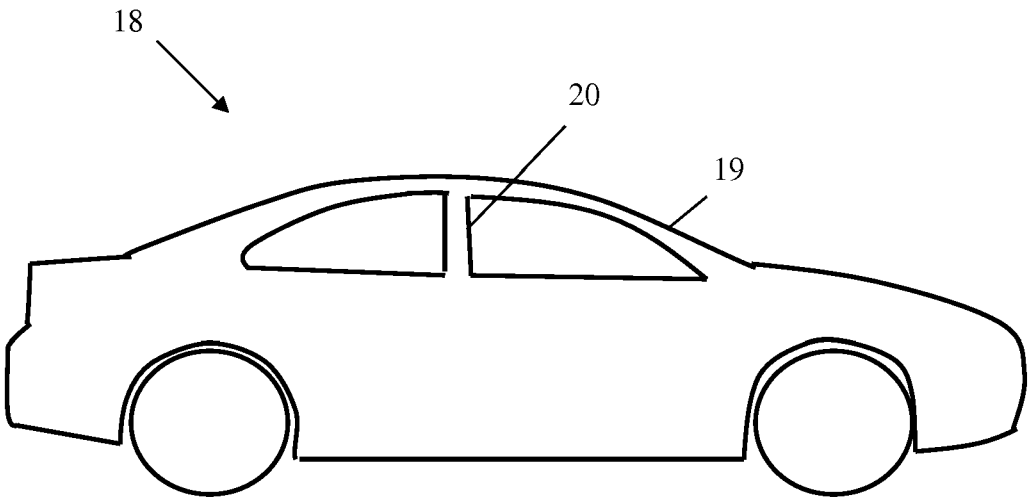
18
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Fig. 4

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EUROPEAN SEARCH REPORT

Application Number
EP 15 20 0622

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	Kreling ET AL: "ADHESIVE BONDING OF PRESS-HARDENED HIGH-STRENGTH STEELS FOR AUTOMOTIVE APPLICATIONS", , 4 September 2015 (2015-09-04), XP055250191, Retrieved from the Internet: URL:https://www.researchgate.net/profile/Stefan_Kreling/publication/266892782_ADHESIVE_BONDING_OF_PRESS-HARDENED_HIGH-STRENGTH_STEELS_FOR_AUTOMOTIVE_APPLICATIONS/links/55e974d308ae65b6389af4d0.pdf?inViewer=0&pdfJsDownload=0&origin=publication_detail [retrieved on 2016-02-15] * page 1 - page 3 * -----	1-11	INV. C23C2/12 C23C2/26
X	Man-Shin Tan ET AL: "Adhesively Bonded Steel Structures", , 1 May 2011 (2011-05-01), XP055250169, Retrieved from the Internet: URL:http://publications.lib.chalmers.se/records/fulltext/152928.pdf [retrieved on 2016-02-15] * paragraphs [02.2], [2.2.1], [2.5.3], [03.3], [3.3.2] * * paragraphs [04.3], [4.3.3], [04.5], [04.6], [0005], [0006]; table App. 6 * -----	1-11	TECHNICAL FIELDS SEARCHED (IPC) C23C C22C B23K C21D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	14 June 2016	Tsipouridis, P

CATEGORY OF CITED DOCUMENTS

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Non-patent literature cited in the description

- **MAN-SHIN TAN ; NOZHAN SHARIFIAN.** Adhesively Bonded Steel Structures. Volvo Car Corporation **[0004]**