(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 4 067 530 A1

(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
05.10.2022 Bulletin 2022/40

(21) Application number: **20893836.5**

(22) Date of filing: **28.09.2020**

(51) International Patent Classification (IPC):
C23C 2/12 *(2006.01)* ***C22C 38/18*** *(2006.01)*

(52) Cooperative Patent Classification (CPC):
B21D 22/02; C21D 1/18; C21D 1/74; C21D 9/00; C22C 38/02; C22C 38/04; C22C 38/06; C22C 38/18; C22C 38/24; C22C 38/26; C22C 38/28; C22C 38/32; C22C 38/38; C23C 2/12; C23C 2/40

(86) International application number:
PCT/CN2020/118368

(87) International publication number:
WO 2021/103805 (03.06.2021 Gazette 2021/22)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

(30) Priority: **29.11.2019 CN 201911202456**

(71) Applicant: **BAOSHAN IRON & STEEL CO., LTD.**
Shanghai 201900 (CN)

(72) Inventors:
- **TAN, Ning**
  Shanghai 201900 (CN)
- **LIU, Hao**
  Shanghai 201900 (CN)
- **HONG, Jiyao**
  Shanghai 201900 (CN)
- **JIN, Xinyan**
  Shanghai 201900 (CN)

(74) Representative: **Kuhnen & Wacker**
Patent- und Rechtsanwaltsbüro PartG mbB
Prinz-Ludwig-Straße 40A
85354 Freising (DE)

(54) THERMOFORMED COMPONENT HAVING EXCELLENT COATING ADHESION, AND MANUFACTURING METHOD THEREFOR

(57) A thermoformed component having excellent coating adhesion. The thermoformed component comprises a substrate layer and an aluminum coating coated on at least one surface of the substrate layer. The average roughness Ra of a surface of the thermoformed component is between 1.0 μm and 3.0 μm, the peak height and the peak-to-valley height Rt are between 8 μm and 30 μm, and the roughness peak count Rpc is greater than or equal to 50. A manufacturing method for the thermoformed component having excellent coating adhesion comprises the following steps: (1) immersing a substrate in an aluminum coating solution to obtain a plate having an aluminum coating on a surface thereof; (2) performing leveling; (3) performing blanking on the plate or cutting the plate to obtain a blank having a required component shape; (4) performing heat treatment; and (5) performing transfer processing and hot stamping, wherein the heated blank is quickly transferred to a mold for cooling and stamping to form a thermoformed component.

EP 4 067 530 A1

Description

TECHNICAL FIELD

[0001] The present disclosure relates to a material and a manufacturing method therefor, and particularly relates to a thermoformed material and a manufacturing method therefor.

BACKGROUND ART

[0002] In recent years, the application of thermoformed component in automobile industry has become very important. Especially, with respect to safety structural parts of automobile, it has irreplaceable advantages in some parts with high strength and complex shape. The materials used for thermoformed components are divided into those with coating and those without coating. The main purpose of the coating is to prevent the oxidation of the steel plate surface during the hot stamping process. The formed components can be directly coated and welded for use. At present, the materials without coating must be subject to surface shot peening after thermoforming to remove the oxide layer generated on the surface, otherwise it will affect the subsequent coating and welding of parts. The surface of materials hot-dipped with aluminum coating cannot be phosphated normally after thermoforming. The adhesion of paint film after electrophoresis depends entirely on the surface morphology of the coating. During the use of existing materials, there will be the problem that the coating adhesion can not meet the use.

[0003] For example, the Chinese patent document with the publication number of CN104651590A and the publication date of May 27, 2015, entitled "process for manufacturing stamped products, and stamped products prepared from the same" discloses a thermoforming material coated with aluminum or aluminum alloy and its manufacturing method. The method specifically controls the thickness and five-layer structure of the coating to ensure the welding performance of thermoformed component.

[0004] For another example, the Chinese patent document with the publication number of CN108588612A and the publication date of September 28, 2018, entitled "hot-stamping forming component, pre-coating steel-plating plate for hot-stamping forming, and hot-stamping forming process" discloses a hot-stamping formed component. In the technical solution disclosed in the patent document, the thickness of the coating is reduced and the protective effect of the coating is also reduced. Therefore, the fluctuation of the thermoforming process is easy to affect the surface performance of the component, thus affecting the subsequent service performance.

[0005] For another example, the Chinese patent document with the publication number of CN101583486 and the publication date of November 18, 2009, entitled "coated steel strip, methods of making the same, methods of using the same, stamping blanks prepared from the same, stamped products prepared from the same, and articles comprising such stamped products" discloses a hot stamped product of coated steel strip and a method. The technical solution disclosed in the patent document includes heating, transferring and cooling, but does not involve the hot stamping process, which will lead to the unstable quality of stamped products, such as shrinkage and cracking. The furnace atmosphere during the heating process is not controlled, which leads to the change of furnace atmosphere during the heating, especially the large change of oxygen content, which makes the appearance color of products easy to change. In the actual production, it is found that the appearance color of stamped products obtained from the same incoming materials under the same process is quite different.

SUMMARY OF INVENTION

[0006] An object of the present disclosure is to provide a thermoformed component having excellent coating adhesion. The thermoformed component has good paintability, good coating adhesion and good corrosion resistance, and is very suitable for automotive parts, such as front and rear doors, left and right anti-collision rods/beams, front and rear bumpers, A-pillar reinforcing plates, B-pillar reinforcing plates, floor middle channels, etc.

[0007] To achieve the above object, the present disclosure provides a thermoformed component having excellent coating adhesion, comprising a substrate layer and an aluminum coating coated on at least one surface of the substrate layer, wherein the average roughness Ra of a surface of the thermoformed component is between 1.0 μm and 3.0 μm, the peak-to-valley height Rt is between 8 μm and 30 μm, and the roughness peak count Rpc is greater than or equal to 50.

[0008] In the technical solution of the present disclosure, the aluminum coating comprises aluminum phase and aluminum silicon phase. In the heating process, the aluminum in the aluminum coating diffuses to the substrate layer, and the iron in the substrate layer diffuses to the aluminum coating to form Al_8Fe_2Si phase. The formation of new phase leads to a significant increase in surface roughness. With the further diffusion of iron and aluminum, Fe_2Al_5 phase is formed, and the surface roughness is basically maintained. Finally, FeAl alloy is completely formed in the aluminum coating, while the surface roughness decreases slightly.

[0009] The surface of thermoformed components after heat treatment mainly consists of Fe_2Al_5 and FeAl alloy. At the same time, because the silicon oxide, aluminum oxide and iron oxide produced by surface oxidation cannot react with phosphating solution, that is, normal phosphating coating cannot be formed, the coating adhesion of thermoformed components is completely guaranteed by the uneven structure of the surface, that is, the roughness of thermoformed components has an important impact on the coating adhesion.

[0010] The greater the surface roughness of the aluminum coating, the greater the roughness peak count Rpc value, the different diffusion paths of iron and aluminum, and the different speed of the formation of new phase, resulting in the greater the surface roughness of the formed components after heat treatment and the better the coating adhesion.

[0011] Further, in the thermoformed component having excellent coating adhesion of the present disclosure, the aluminum coating comprises a diffusion layer adjacent to the substrate layer and an alloy layer on the surface of the aluminum coating, wherein the ratio of the thickness of the diffusion layer to the total thickness of the aluminum coating is 0.08-0.5.

[0012] Further, in the thermoformed component having excellent coating adhesion of the present disclosure, the thickness of the diffusion layer is $\leq$ 16 μm; the total thickness of the aluminum coating is $\leq$ 60 μm.

[0013] Further, in the thermoformed component having excellent coating adhesion of the present disclosure, the thickness of the diffusion layer is 5~16 μm; the total thickness of the aluminum coating is 20~60 μm.

[0014] Further, in the thermoformed component having excellent coating adhesion of the present disclosure, the average roughness Ra of the surface of the thermoformed component is 1.5~2.5 μm.

[0015] Further, in the thermoformed component having excellent coating adhesion of the present disclosure, the peak-to-valley height Rt of the surface of the thermoformed component is 10~25 μm.

[0016] Further, in the thermoformed component having excellent coating adhesion of the present disclosure, the roughness peak count Rpc of the surface of the thermoformed component is 50~250, such as 80~180.

[0017] Further, the surface of the thermoformed component having excellent coating adhesion of the present disclosure comprises Fe_2Al_5 and FeAl alloy. Further, the surface of the thermoformed component having excellent coating adhesion of the present disclosure also comprises silicon oxide, aluminum oxide and iron oxide. Further, the surface of the thermoformed component having excellent coating adhesion of the present disclosure mainly consists of Fe_2Al_5 and FeAl alloy, and also comprises silicon oxide, aluminum oxide and iron oxide. Also, the content of Fe_2Al_5 in the surface of the thermoformed component having excellent coating adhesion of the present disclosure is higher than 40wt%.

[0018] Further, in the surface of the thermoformed component having excellent coating adhesion of the present disclosure, the mass percentage of chemical elements of the aluminum coating is: Si: 4~14%, Fe: 0~4%, Mg: 0~10%, Zn: 0~20%, and a balance of Al and other unavoidable impurities. Further, in the surface of the thermoformed component having excellent coating adhesion of the present disclosure, the mass percentage of chemical elements of the aluminum coating is: Si: 4~14%, Fe: 2~4%, Mg: 0~10%, Zn: 0~20%, and a balance of Al and other unavoidable impurities.

[0019] Further, in the thermoformed component having excellent coating adhesion of the present disclosure, the average weight of the aluminum coating is 20~120 g/m^2 per single surface.

[0020] Further, in the thermoformed component having excellent coating adhesion of the present disclosure, the average weight of the aluminum coating is 30~100 g/m^2 per single surface.

[0021] Further, in the thermoformed component having excellent coating adhesion of the present disclosure, the mass percentage of chemical elements of the substrate layer is:

C: 0.01~0.8%, Si: 0.05~1.0%, Mn: 0.1~5%, P≤0.3%, S≤0.1%, Al≤0.3%, Ti≤0.5%, B: 0.0005~0.1%, Cr: 0.01~3%, Nb≤0.5%, V≤0.5%, and a balance of Fe and other unavoidable impurities.

[0022] Further, in the thermoformed component having excellent coating adhesion of the present disclosure, the mass percentage of chemical elements of the substrate layer further meets at least one of the following:

C: 0.05~0.6%,
Si: 0.07~0.8%,
Mn: 0.3~4%,
P≤0.2%,
S≤0.08%,
Al≤0.2%,
Ti≤0.4%,
B: 0.0005-0.08%,
Cr: 0.01~2%,
Nb≤0.3%,
V≤0.3%.

[0023] Further, in the thermoformed component having excellent coating adhesion of the present disclosure, the mass percentage of chemical elements of the substrate layer further meets at least one of the following:

C: 0.15~0.5%,
Si: 0.1~0.5%,
Mn: 0.5~3%,
P≤0.1%,
S≤0.05%,
Al≤0.1%,
Ti≤0.2%,
Cr: 0.01~1%.

[0024] Further, in the substrate layer of the thermoformed component having excellent coating adhesion of the present disclosure, the content of Al is 0.03-0.09%, and the content of Ti is 0.01-0.2%, preferably 0.01-0.1%.

[0025] Further, in the substrate layer of the thermoformed component having excellent coating adhesion of the present disclosure, the content of Cr is 0.1-0.8%.

[0026] Further, in the substrate layer of the thermoformed component having excellent coating adhesion of the present disclosure, when Nb is comprised, the content of Nb is 0.001-0.1%, when V is comprised, the content of V is 0.001-0.01%.

[0027] Further, in the thermoformed component having excellent coating adhesion of the present disclosure, the mass percentage of chemical elements of the substrate layer is: C: 0.02~0.8%, Si: 0.05~0.5%, Mn: 0.1~3%, P≤0.1%, S≤0.05%, Al: 0.04-0.09%, Ti: 0.02-0.2%, B: 0.0005~0.09%, Cr: 0.15~0.8%, Nb: 0% or 0.001-0.1%, V: 0% or 0.002-0.008%, and a balance of Fe and other unavoidable impurities.

[0028] Further, in the thermoformed component having excellent coating adhesion of the present disclosure, the yield strength is 400~1400 MPa, the tensile strength is 500~2100 MPa, and the elongation is ≥4%.

[0029] Preferably, in the microstructure of the substrate of the thermoformed component having excellent coating adhesion of the present disclosure, the volume percentage of martensite is ≥70%, preferably ≥85%, more preferably ≥95%.

[0030] Accordingly, another object of the present disclosure is to provide a manufacturing method for the above thermoformed component having excellent coating adhesion, and through the manufacturing method, thermoformed component having excellent coating adhesion can be obtained.

[0031] To achieve the above object, the present disclosure provides a manufacturing method for the above thermoformed component having excellent coating adhesion, comprising the following steps:

(1) immersing a substrate in an aluminum coating solution to obtain a plate having an aluminum coating on a surface thereof;
(2) leveling: using a leveling roller having a roughness Ra of 0.5~3.0 μm to level the plate, and controlling the leveling elongation ≤2.0%, so that the surface thermal radiation coefficient of the plate is 0.1~0.8, the surface roughness Ra of the plate is 0.3~2.0 μm, and the peak roughness count RPC of the surface of the plate is 30~150;
(3) blanking: performing blanking on the plate or cutting the plate to obtain a blank having a required component shape;
(4) heat treatment: putting the blank into a heating furnace for heating and heat preservation, wherein the temperature of the heating furnace is 880-960 °C, the atmosphere in the heating furnace is air or nitrogen, and the residence time of the blank in the heating furnace is 2.5~10 min;
(5) transferring and hot stamping: quickly transferring the heated blank to a mold for cooling and stamping forming to form a thermoformed component.

[0032] In the manufacturing method of the present disclosure, in step (4), too low temperature of the heating furnace or too short residence time of the blank in the heating furnace will lead to insufficient diffusion of iron and aluminum, resulting in too low surface roughness and affecting the roughness of the final thermoformed component. If the temperature of the heating furnace is too high or the residence time of the blank in the heating furnace is too long, it will lead to excessive diffusion of iron and aluminum and complete formation of FeAl alloy, which will also reduce the roughness of the final thermoformed component. At the same time, the holes formed by element migration in the diffusion process will affect the surface conductivity, and cause shrinkage in the electrophoresis process, which will affect the paintability.

[0033] Further, in the manufacturing method of the present disclosure, in step (1), the mass percentage of chemical elements of the aluminum coating solution is: Si: 5~11%, Fe: 2~4%, Zn: 0~15%, Mg: 0~8%, and a balance of Al and other unavoidable impurities.

[0034] Further, in the manufacturing method of the present disclosure, in step (1), the mass percentage of chemical elements of the aluminum coating solution is: Si: 8~11%, Fe: 2~4%, Zn: 0~11%, Mg: 0~8%, and a balance of Al and other unavoidable impurities.

[0035] Further, in the manufacturing method of the present disclosure, in step (1), the mass percentage of chemical elements of the aluminum coating solution is: Si: 5~11%, Fe: 2~4%, and a balance of Al and other unavoidable impurities.

[0036] Further, in the manufacturing method of the present disclosure, in step (1), the mass percentage of chemical elements of the aluminum coating solution is: Si: 5~11%, Fe: 2~4%, optional Zn: 2~15%, optional Mg: 0.5-8%, and a balance of Al and other unavoidable impurities.

[0037] Further, in the manufacturing method of the present disclosure, in step (4), during the heating up process of blank heating, the heating rate does not exceed 10 °C/s in the range of heating up to 400~600 °C to pre-alloy zinc and aluminum in the coating and avoid damage or crack of the coating.

[0038] Further, in the manufacturing method of the present disclosure, in step (5), the blank is transferred to the mold within 20 seconds.

[0039] Further, in the manufacturing method of the present disclosure, in the hot stamping process of step (5), after the mold is closed, a pressure holding quenching is continued for 4~20 s, and the pressure holding pressure applied to the blank surface is ≥8 MPa. In some embodiments, the pressure holding pressure is 10~20 MPa.

[0040] Further, in the manufacturing method of the present disclosure, in step (5), the material of the mold meets the following requirement: the thermal diffusion coefficient at 700 °C is greater than 3.8 mm^2/s.

[0041] Further, in the manufacturing method of the present disclosure, in step (5), during stamping, the closing speed of the mold is 30~150 mm/s, so that the thermoformed component can ensure good forming performance and reduce stamping defects, such as cracking and necking.

[0042] Further, in the manufacturing method of the present disclosure, in step (5), the blank is cooled to 50~200 °C at a cooling rate of 30~150 °C/s to change the internal structure of the thermoformed component into the required structure, and ensure that the thermoformed component still maintains a good size and shape during the cooling process.

[0043] The present disclosure also includes a thermoformed component manufactured by the above method.

[0044] Compared with the prior art, the thermoformed component having excellent coating adhesion and its method have the following advantages and beneficial effects:

The thermoformed component having excellent coating adhesion of the present disclosure has good paintability, good coating adhesion and good corrosion resistance, and is very suitable for automotive parts, such as front and rear doors, left and right anti-collision rods/beams, front and rear bumpers, A-pillar reinforcing plates, B-pillar reinforcing plates, floor middle channels, etc.

[0045] In addition, the manufacturing method of the present disclosure also has the above advantages and beneficial effects.

DETAILED DESCRIPTION

[0046] The thermoformed component having excellent coating adhesion of the present disclosure and its manufacturing method will be further explained and illustrated with reference to specific examples. Nonetheless, the explanation and illustration are not intended to unduly limit the technical solution of the present disclosure.

Examples 1-10 and Comparative Example 1

[0047] The thermoformed components having excellent coating adhesion of Examples 1-10 and Comparative Example 1 are manufactured by the following step:

(1) Immersing a substrate in an aluminum coating solution to obtain a plate having an aluminum coating on a surface thereof.

(2) Leveling: using a leveling roller having a roughness Ra of 0.5~3.0 μm to level the plate, and controlling the leveling elongation ≤2.0%, so that the surface thermal radiation coefficient of the plate was 0.1~0.8, the surface roughness Ra of the plate was 0.3~2.0 μm, and the peak roughness count Rpc of the surface of the plate was 30~150.

(3) Blanking: performing blanking on the plate or cutting the plate to obtain a blank having a required component shape;

(4) Heat treatment: putting the blank into a heating furnace for heating and heat preservation, wherein the temperature of the heating furnace was 880-960 °C, the atmosphere in the heating furnace was air or nitrogen, the residence time of the blank in the heating furnace was 2.5~10 min, and during the heating up process of blank heating, the heating rate did not exceed 10 °C/s in the range of heating up to 400~600 °C.

(5) Transferring and hot stamping: quickly (such as within 20 seconds) transferring the heated blank to a mold for cooling and stamping forming to form a thermoformed component. Wherein, in the hot stamping process, after the mold was closed, a pressure holding quenching was continued for 4~20 s, the pressure holding pressure applied to the blank surface was ≥8 MPa, and the material of the mold met the following requirement: the thermal diffusion coefficient at 700 °C was greater than 3.8 mm^2/s, and during stamping, the closing speed of the mold was 30~150 mm/s, and the blank was cooled to 50~200 °C at a cooling rate of 30~150 °C/s.

[0048] Wherein, the manufacturing methods of every Examples and Comparative Example are as follows:

Example 1

[0049] A 1.2 mm steel plate with aluminum alloy coating was leveled by a leveling roller to obtain a plate before heat treatment and hot stamping having a surface roughness as shown in Table 2, and the plate was laser blanked into a blank with a certain size and shape. The mass percentage of chemical compositions of the aluminum coating solution was Si: 8.5%, Fe: 2.6%, Zn: 15%, Mg: 4%, and a balance of Al and other unavoidable impurities. The blank entered a heating furnace. The temperature of the heating furnace was 950 °C, the residence time was 3.5 minutes, the heating rate was 2 °C/s in the range of 400~600 °C, the transferring time was 4 seconds, the pressure holding time was 5 seconds, the pressure holding pressure was 10 MPa, the mold closing speed was 50 mm/s, the cooling speed was 50 °C/s, the finish temperature of cooling was 200 °C and the thermal diffusion coefficient of the mold at 700 °C was 4 mm^2/s.

Example 2

[0050] A 0.9mm steel plate with aluminum alloy coating was leveled by a leveling roller to obtain a plate before heat treatment and hot stamping having a surface roughness as shown in Table 2, and the plate was laser blanked into a blank with a certain size and shape. The mass percentage of chemical compositions of the aluminum coating solution was Si: 5%, Fe: 2.4%, Zn: 8%, Mg: 8%, and a balance of Al and other unavoidable impurities. The blank entered a heating furnace. The temperature of the heating furnace was 940°C, the residence time was 5 minutes, the heating rate was 5°C/s in the range of 400~600 °C, the transferring time was 6 seconds, the pressure holding time was 15 seconds, the pressure holding pressure was 20 MPa, the mold closing speed was 150 mm/s, the cooling speed was 150 °C/s, the finish temperature of cooling was 50°C and the thermal diffusion coefficient of the mold at 700 °C was 5 mm^2/s.

Example 3

[0051] A 1.0mm steel plate with aluminum alloy coating was leveled by a leveling roller to obtain a plate before heat treatment and hot stamping having a surface roughness as shown in Table 2, and the plate was laser blanked into a blank with a certain size and shape. The mass percentage of chemical compositions of the aluminum coating solution was Si: 9.0%, Fe: 2.7%, and a balance of Al and other unavoidable impurities. The blank entered a heating furnace. The heating rate of 400~600 °Cwas 5°C/s, the temperature of the heating furnace was 930°C, the residence time was 7 minutes, the heated blank was transferred to a mold within 8 seconds, and the thermal diffusion coefficient of the mold at 700 °C was 7 mm^2/s. The mold closing speed was 70 mm/s, the pressure holding time was 6 seconds, the pressure holding pressure was 12 MPa, the cooling speed was 100 °C/s, and the finish temperature of cooling was 100°C The proportion of martensite in the microstructure of the substrate of the thermoformed component is higher than 96%.

Example 4

[0052] A 2.8mm steel plate with aluminum alloy coating was leveled by a leveling roller to obtain a plate before heat treatment and hot stamping having a surface roughness as shown in Table 2, and the plate was laser blanked into a blank with a certain size and shape. The mass percentage of chemical compositions of the aluminum coating solution was Si: 8.8%, Fe: 2.7%, and a balance of Al and other unavoidable impurities. The blank entered a heating furnace. The temperature of the heating furnace was 920 °C, the residence time was 7 minutes, the heating rate of 400~600 °C was 10°C/s, the heated blank was transferred to a mold within 8 seconds, the mold closing speed was 70mm/s, the pressure holding time was 6 seconds, the pressure holding pressure was 15 MPa, the cooling speed was 60°C/s, the finish temperature of cooling was 60°C and the thermal diffusion coefficient of the mold at 700 °C was 6 mm^2/s. The proportion of martensite in the microstructure of the substrate of the thermoformed component is higher than 98%.

Example 5

[0053] A 1.1mm steel plate with aluminum alloy coating was leveled by a leveling roller to obtain a plate before heat treatment and hot stamping having a surface roughness as shown in Table 2, and the plate was laser blanked into a blank with a certain size and shape. The mass percentage of chemical compositions of the aluminum coating solution was Si: 10%, Fe: 3.5%, Zn: 2%, Mg: 1%, and a balance of Al and other unavoidable impurities. The blank entered a heating furnace. The temperature of the heating furnace was 935 °C, the residence time was 4.5 minutes, the heating rate was 4°C/s in the range of 400~600 °C, the heated blank was transferred to a mold within 7 seconds, the mold closing speed of upper and lower molds was 80mm/s, the pressure holding time was 5 seconds, the pressure holding pressure was 15 MPa, the thermal diffusion coefficient of the mold at 700 °C was 4 mm^2/s and the finish temperature of cooling was 100°C. The proportion of martensite in the microstructure of the substrate of the thermoformed component is higher than 95%.

Example 6

[0054] A 1.5mm steel plate with aluminum alloy coating was leveled by a leveling roller to obtain a plate before heat treatment and hot stamping having a surface roughness as shown in Table 2, and the plate was laser blanked into a blank with a certain size and shape. The mass percentage of chemical compositions of the aluminum coating solution was Si: 10%, Fe: 3.5%, Mg: 0.5%, and a balance of Al and other unavoidable impurities. The blank entered a heating furnace. The temperature of the heating furnace was 935 °C, the residence time was 5 minutes, the heating rate was 6°C/s in the range of 400~600 °C, the heated blank was transferred to a mold within 7 seconds, the mold closing speed of upper and lower molds was 80 mm/s, the pressure holding time was 5 seconds, the pressure holding pressure was 15 MPa, the thermal diffusion coefficient of the mold at 700 °C was 4 mm^2/s and the finish temperature of cooling was 120°C. The proportion of martensite in the microstructure of the substrate of the thermoformed component is higher than 95%.

Example 7

[0055] A 1.8mm steel plate with aluminum alloy coating was leveled by a leveling roller to obtain a plate before heat treatment and hot stamping having a surface roughness as shown in Table 2, and the plate was laser blanked into a blank with a certain size and shape. The mass percentage of chemical compositions of the aluminum coating solution was Si: 10%, Fe: 3.5%, and a balance of Al and other unavoidable impurities. The blank entered a heating furnace. The temperature of the heating furnace was 945°C, the residence time was 2.5 minutes, the heating rate was 7°C/s in the range of 400~600 °C, the heated blank was transferred to a mold within 7 seconds, the mold closing speed of upper and lower molds was 80 mm/s, the pressure holding time was 5 seconds, the pressure holding pressure was 15 MPa, the thermal diffusion coefficient of the mold at 700 °C was 6.8 mm^2/s and the finish temperature of cooling was 140°C. The proportion of martensite in the microstructure of the substrate of the thermoformed component is higher than 95%.

Example 8

[0056] A 2.0mm steel plate with aluminum alloy coating was leveled by a leveling roller to obtain a plate before heat treatment and hot stamping having a surface roughness as shown in Table 2, and the plate was laser blanked into a blank with a certain size and shape. The mass percentage of chemical compositions of the aluminum coating solution was Si: 10%, Fe: 3.5%, and a balance of Al and other unavoidable impurities. The blank entered a heating furnace. The temperature of the heating furnace was 940°C, the residence time was 3 minutes, the heating rate was 3°C/s in the range of 400~600 °C, the oxygen content of the atmosphere in the furnace was 22%, the heated blank was transferred to a mold within 7 seconds, the mold closing speed of upper and lower molds was 80 mm/s, the pressure holding time was 5 seconds, the pressure holding pressure was 15 MPa, the thermal diffusion coefficient of the mold at 700 °C was 7 mm^2/s and the finish temperature of cooling was 110°C. The proportion of martensite in the microstructure of the substrate of the thermoformed component is higher than 95%.

Example 9

[0057] A 2.4mm steel plate with aluminum alloy coating was leveled by a leveling roller to obtain a plate before heat treatment and hot stamping having a surface roughness as shown in Table 2, and the plate was laser blanked into a blank with a certain size and shape. The mass percentage of chemical compositions of the aluminum coating solution was Si: 10%, Fe: 3.5%, and a balance of Al and other unavoidable impurities. The blank entered a heating furnace. The temperature of the heating furnace was 935°C, the residence time was 5 minutes, the heating rate was 8°C/s in the range of 400~600 °C, the oxygen content of the atmosphere in the furnace was 22%, the heated blank was transferred to a mold within 7 seconds, the mold closing speed of upper and lower molds was 80 mm/s, the pressure holding time was 5 seconds, the pressure holding pressure was 15 MPa, the thermal diffusion coefficient of the mold at 700 °C was 4 mm^2/s and the finish temperature of cooling was 100°C. The proportion of martensite in the microstructure of the substrate of the thermoformed component is higher than 95%.

Example 10

[0058] A 2.8mm steel plate with aluminum alloy coating was leveled by a leveling roller to obtain a plate before heat treatment and hot stamping having a surface roughness as shown in Table 2, and the plate was laser blanked into a blank with a certain size and shape. The mass percentage of chemical compositions of the aluminum coating solution was Si: 10%, Fe: 3.5%, and a balance of Al and other unavoidable impurities. The blank entered a heating furnace. The temperature of the heating furnace was 950°C, the residence time was 2.5 minutes, the heating rate was 4°C/s in the range of 400~600 °C, the oxygen content of the atmosphere in the furnace was 20%, the heated blank was transferred to a mold within 15 seconds, the mold closing speed of upper and lower molds was 80 mm/s, the pressure holding time was 5 seconds, the pressure holding pressure was 15 MPa, the thermal diffusion coefficient of the mold at 700 °C was 5 mm^2/s and the finish temperature of cooling was 80°C. The proportion of martensite in the microstructure of the substrate of the thermoformed component is higher than 95%.

Comparative Example 1

[0059] A 1.5mm steel plate with aluminum alloy coating was leveled by a leveling roller to obtain a plate before heat treatment and hot stamping having a surface roughness as shown in Table 2, and the plate was laser blanked into a blank with a certain size and shape. The mass percentage of chemical compositions of the aluminum coating solution was Si: 10%, Fe: 3.5%, and a balance of Al and other unavoidable impurities. The blank entered a heating furnace. The temperature of the heating furnace was 935°C, the residence time was 5 minutes, the heating rate was 6°C/s in the range of 400~600 °C, the heated blank was transferred to a mold within 7 seconds, the mold closing speed of upper and lower molds was 80 mm/s, the pressure holding time was 5 seconds, the pressure holding pressure was 15 MPa, the thermal diffusion coefficient of the mold at 700 °C was 4 mm^2/s and the finish temperature of cooling was 120°C. The proportion of martensite in the microstructure of the substrate of the thermoformed component is higher than 95%.

[0060] Table 1 lists the mass percentage ratio of each chemical element of the substrate layers of the thermoformed components having excellent coating adhesion of Examples 1-10 and the substrate layer of Comparative Example 1.

Table 1. (wt%, and a balance of Fe and other unavoidable impurities)

Example	C	Si	Mn	P	S	Al	Ti	B	Cr	Nb	V
1	0.02	0.05	0.12	0.059	0.038	0.09	0.090	0.0005	0.15	-	-
2	0.06	0.23	1.19	0.015	0.001	0.04	0.030	0.040	0.27	-	-
3	0.49	0.50	2.51	0.024	0.04	0.08	0.027	0.0052	0.51	0.002	0.002
4	0.39	0.36	3.00	0.044	0.03	0.07	0.05	0.0062	0.71	0.003	0.005
5	0.78	0.48	0.50	0.081	0.02	0.05	0.48	0.0071	0.20	0.1	-
6	0.15	0.10	2.90	0.059	0.038	0.09	0.090	0.0031	0.15	-	-
7	0.25	0.23	1.19	0.015	0.001	0.04	0.030	0.0040	0.27	-	-
8	0.49	0.50	2.51	0.024	0.04	0.08	0.027	0.0052	0.51	0.005	0.008
9	0.39	0.36	3.00	0.044	0.03	0.07	0.05	0.0062	0.71	-	-
10	0.50	0.9	0.50	0.081	0.02	0.05	0.20	0.09	0.20	-	-
Comparative Example 1	0.25	0.23	1.19	0.015	0.001	0.04	0.030	0.0040	0.27	-	-

[0061] To verify the application effect of the present disclosure and prove the components having excellent coating adhesion of Examples 1-10 and the comparative thermoformed component of Comparative Example 1 were tested in the present disclosure. Table 2 lists the test results of every Examples and Comparative Example.

Table 2

Example		1	2	3	4	5	6	7	8	9	10	Comparat ive Example 1
Average weight of aluminum coating, g/m^2 per surface		23	30	50	60	100	70	80	85	80	75	75
Thickness, mm		1.2	0.9	1	2.8	1.1	1.5	1.8	2	2.4	2.8	1.5
Leveling elongation/%		0.5	0.8	1.5	0.3	0.6	0.7	1	1.2	1.8	2	0.7
Roughness of leveling roller/μm		0.5	1.2	3	1	1.5	1.5	1.8	1.2	1.9	2.8	***0.3***
Roughness of plate before heat treatment and hot stamping	Ra/μm	0.3	0.8	2	0.9	1.3	1	1.1	0.8	0.7	1.5	0.2
	Rpc	50	90	150	90	50	100	70	130	90	80	25
Roughness of finished product after heat treatment and hot stamping	Ra/μm	1.8	1.8	1.9	2	2.3	2	1.9	1.9	1.8	2.4	1.3
	Rt/μm	12	13	18	19	20	21	18	19	19	22	9
	Rpc	90	100	120	120	160	170	150	160	140	170	***40***
Thickness of 50% Al layer in alloy layer/μm		15	18	20	25	35	26	20	28	26	20	20
Thickness of diffusion layer/μm		5	6	7	8	16	10	8	8	8	8	8
Thickness of total aluminum coating/μm		22	25	30	33	60	40	35	40	38	30	30
Tensile strength of product after stamping/MPa		500	700	1820	2000	1900	1000	1550	1590	1600	1580	1500
Yield strength of product after stamping/MPa		400	500	1250	1350	1200	1050	1000	980	1100	1100	1100
Elongation/%		19	15	5	4	4.5	6	7	6	6	6	6
Paintability		The surface of the coating is uniform after pretreatment										Nonunifo rm
Coating adhesion after coating		Gra de 1	Gra de 1	Grade 2	Grade 2	Grade 1	Grade 1	Grade 2	Grade 1	Grade 2	Grade 1	Grade 5
Corrosion resistance, mm		1	1.5	3	3.5	2	2.3	3.5	3	3.8	3	5

*Test method for coating adhesion:
Referring to GB/T 9286-1998 cross cut test method, cutting grids on the surface with a knife, sticking an adhesive tape to the center of the formed grids, then pulling it off smoothly, observing the phenomenon of coating falling off, and judging the grade by calculating the state of grids according to the standard.

[0062] The paintability was evaluated with reference to GMW16170 standard.

[0063] The corrosion resistance was tested with reference to GMW14872.

[0064] As can be seen from Table 2, the yield strength of each example of the present disclosure is 400~1350 MPa, the tensile strength is 500~2000 MPa, and the elongation is 4~19%.

[0065] In addition, it can be seen from Table 2 that the surface roughness Ra of the finished product of the comparative thermoformed component of Comparative Example 1 after hot stamping is lower than 1.8 μm, Rt is less than 12 μm, Rpc is lower than 90, and the paintability of the thermoformed component of Comparative Example 1 is poor, the coating adhesion does not meet the requirements, and its performance is far inferior to that of the thermoformed components of every Examples of the present disclosure. In addition, it can be seen from table 2 that the higher the surface roughness of the material before heat treatment and hot stamping used by the thermoformed component, the higher the product roughness after heat treatment and hot stamping, and the better the coating adhesion.

[0066] To sum up, the thermoformed component having excellent coating adhesion of the present disclosure has good paintability, good coating adhesion and good corrosion resistance, and is very suitable for automotive parts, such as front and rear doors, left and right anti-collision rods/beams, front and rear bumpers, A-pillar reinforcing plates, B-pillar reinforcing plates, floor middle channels, etc.

[0067] In addition, the manufacturing method of the present disclosure also has the above advantages and beneficial effects.

[0068] It should be noted that the prior art part of the protection scope of the present disclosure is not limited to the embodiments given in the present disclosure, and all prior technologies that do not conflict with the solution of the present disclosure, including but not limited to prior patent documents, prior public publications, prior public use, etc., can be included in the protection scope of the present disclosure.

[0069] In addition, the combination mode of the technical features in the present disclosure is not limited to the combination mode recorded in the claims or the combination mode recorded in the specific embodiment of the present disclosure. All the technical features recorded in present disclosure can be combined or integrated in any way, unless there is a contradiction between them.

[0070] It should also be noted that the examples listed above are only specific examples of the present disclosure. Obviously, the present disclosure is not limited to the above examples, and the subsequent similar changes or deformations can be directly obtained or easily thought of by those skilled in the art from the contents disclosed in the present disclosure, which should belong to the protection scope of the present disclosure.

Claims

1. A thermoformed component having excellent coating adhesion, comprising a substrate layer and an aluminum coating coated on at least one surface of the substrate layer, wherein the average roughness Ra of a surface of the thermoformed component is 1.0~3.0 μm, the peak-to-valley height Rt is 8~30 μm, and the roughness peak count Rpc is ≥50.

2. The thermoformed component having excellent coating adhesion according to claim 1, wherein the aluminum coating comprises a diffusion layer adjacent to the substrate layer and an alloy layer on the surface of the aluminum coating, wherein the ratio of the thickness of the diffusion layer to the total thickness of the aluminum coating is 0.08-0.5.

3. The thermoformed component having excellent coating adhesion according to claim 1 or 2, wherein the thickness of the diffusion layer is ≤16 μm, and the total thickness of the aluminum coating is ≤60 μm.

4. The thermoformed component having excellent coating adhesion according to claim 1, wherein the mass percentage of chemical elements of the aluminum coating is: Si: 4~14%, Fe: 0~4%, Mg: 0~10%, Zn: 0~20%, and a balance of Al and other unavoidable impurities; preferably, the mass percentage of chemical elements of the aluminum coating is: Si: 4~14%, Fe: 2~4%, Mg: 0~10%, Zn: 0~20%, and a balance of Al and other unavoidable impurities.

5. The thermoformed component having excellent coating adhesion according to claim 1, wherein the average weight of the aluminum coating is 20~120 g/m^2 per single surface.

6. The thermoformed component having excellent coating adhesion according to claim 5, wherein the average weight of the aluminum coating is 30~100 g/m^2 per single surface.

7. The thermoformed component having excellent coating adhesion according to claim 1, wherein the mass percentage of chemical elements of the substrate layer is:

C: 0.01~0.8%, Si: 0.05~1.0%, Mn: 0.1~5%, P≤0.3%, S≤0.1%, Al≤0.3%, Ti≤0.5%, B: 0.0005~0.1%, Cr: 0.01~3%, Nb<0.5%>, V≤0.5%, and a balance of Fe and other unavoidable impurities.

8. The thermoformed component having excellent coating adhesion according to claim 7, wherein the mass percentage of chemical elements of the substrate layer further meets at least one of the following:

C: 0.05~0.6%,
Si: 0.07~0.8%,
Mn: 0.3~4%,
P≤0.2%,
S≤0.08%,
Al≤0.2%,
Ti≤0.4%,
B: 0.0005~0.08%,
Cr: 0.01~2%,
Nb≤0.3%,
V≤0.3%.

9. The thermoformed component having excellent coating adhesion according to claim 7 or 8, wherein the mass percentage of chemical elements of the substrate layer further meets at least one of the following:

C: 0.15~0.5%,
Si: 0.1~0.5%,
Mn: 0.5~3%,
P≤0.1%,
S≤0.05%,
Al≤0.1%,
Ti≤0.2%,
Cr: 0.01~1%.

10. The thermoformed component having excellent coating adhesion according to claim 1, wherein the yield strength of the thermoformed component having excellent coating adhesion is 400~1400 MPa, the tensile strength is 500~2100 MPa, and the elongation is ≥4%.

11. The thermoformed component having excellent coating adhesion according to claim 1, wherein the surface of the thermoformed component having excellent coating adhesion comprises Fe_2Al_5 and FeAl alloy; or the surface of the thermoformed component having excellent coating adhesion mainly consists of Fe_2Al_5 and FeAl alloy, and further comprises silicon oxide, aluminum oxide and iron oxide.

12. The thermoformed component having excellent coating adhesion according to claim 9, wherein the volume percentage of martensite in the microstructure of the substrate layer of the thermoformed component having excellent coating adhesion is ≥95%.

13. A manufacturing method for the thermoformed component having excellent coating adhesion of any one of claims 1-12, comprising the following steps:

(1) immersing a substrate in an aluminum coating solution to obtain a plate having an aluminum coating on a surface thereof;
(2) leveling: using a leveling roller having a roughness Ra of 0.5-3.0 μm to level the plate, and controlling the leveling elongation ≤2.0%, wherein the surface thermal radiation coefficient of the plate is 0.1~0.8, the surface roughness Ra of the plate is 0.3~2.0 μm, and the peak roughness count RPC of the surface of the plate is 30~150;
(3) blanking: performing blanking on the plate or cutting the plate to obtain a blank having a required component shape;
(4) heat treatment: putting the blank into a heating furnace for heating and heat preservation, wherein the temperature of the heating furnace is 880-960 °C, the atmosphere in the heating furnace is air or nitrogen, and the residence time of the blank in the heating furnace is 2.5~10 min;
(5) transferring and hot stamping: quickly transferring the heated blank to a mold for cooling and stamping forming to form the thermoformed component.

14. The manufacturing method according to claim 13, wherein in step (1), the mass percentage of chemical elements of the aluminum coating solution is: Si: 5~11%, Fe: 2~4%, Zn: 0~15%), Mg: 0~8%, and a balance of Al and other unavoidable impurities; preferably being: Si: 8~11%, Fe: 2~4%, Zn: 0~11%, Mg: 0~8%, and a balance of Al and other unavoidable impurities.

15. The manufacturing method according to claim 13, wherein in step (4), during the heating up process of blank heating, the heating rate does not exceed 10 °C/s in the range of heating up to 400~600 °C.

16. The manufacturing method according to claim 13, wherein in step (5), the blank is transferred to the mold within 20 seconds.

17. The manufacturing method according to claim 13, wherein in the hot stamping process of step (5), after the mold is closed, a pressure holding quenching is continued for 4~20 s, and the pressure holding pressure applied to the blank surface is ≥8 MPa.

18. The manufacturing method according to claim 13, wherein the material of the mold meets the following requirement: the thermal diffusion coefficient at 700 °C is greater than 3.8 mm^2/s.

19. The manufacturing method according to claim 13, wherein in step (5), the closing speed of the mold during stamping is 30~150 mm/s.

20. The manufacturing method according to claim 13, wherein in step (5), the blank is cooled to 50~200 °C at a cooling rate of 30-150 °C/s.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2020/118368

A. CLASSIFICATION OF SUBJECT MATTER

C23C 2/12(2006.01)i；C22C 38/18(2006.01)i

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)

C23C，C22C 38

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)

EPODOC, JPABS, CNABS, CNKI: 镀铝, 粗糙度, 铝液, 热冲压, aluminum plat+, roughness, aluminum melt, aluminum pad, hot form+, hot stamp+

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN 105829578 A (NIPPON STEEL & SUMITOMO METAL CORPORATION) 03 August 2016 (2016-08-03) claims 1 and 6, description paragraphs 0022, 0037, 0079-0080, 0089-0090 and 0113, embodiment 1	1-20
A	CN 106165112 A (KOBE STEEL, LTD.) 23 November 2016 (2016-11-23) entire document	1-20
A	KR 20130110532 A (HYUNDAI STEEL CO) 10 October 2013 (2013-10-10) entire document	1-20
A	CN 110117167 A (MAANSHAN IRON & STEEL CO., LTD.) 13 August 2019 (2019-08-13) entire document	1-20

☐ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

* Special categories of cited documents:
- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier application or patent but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed
- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
- "&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
08 December 2020	**16 December 2020**

Name and mailing address of the ISA/CN	Authorized officer
China National Intellectual Property Administration (ISA/CN) **No. 6, Xitucheng Road, Jimenqiao, Haidian District, Beijing 100088** **China**	
Facsimile No. **(86-10)62019451**	Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2020/118368

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
CN 105829578 A	03 August 2016	ES 2762572 T3	25 May 2020
		ZA 201603964 B	18 December 2019
		RU 2016128897 A	30 January 2018
		TW I589733 B	01 July 2017
		JP WO2015098653 A1	23 March 2017
		TW 201529894 A	01 August 2015
		MX 2016007462 A	19 August 2016
		JP 6376140 B2	22 August 2018
		EP 3070187 A1	21 September 2016
		KR 101849480 B1	16 April 2018
		RU 2655421 C2	28 May 2018
		WO 2015098653 A1	02 July 2015
		EP 3070187 A4	26 July 2017
		US 2019160519 A1	30 May 2019
		US 10232426 B2	19 March 2019
		CN 105829578 B	16 January 2018
		EP 3070187 B1	30 October 2019
		KR 20160095078 A	10 August 2016
		CA 2933039 C	25 June 2019
		CA 2933039 A1	02 July 2015
		PL 3070187 T3	31 March 2020
		US 2016318093 A1	03 November 2016
CN 106165112 A	23 November 2016	CN 106165112 B	10 May 2019
		JP 6510760 B2	08 May 2019
		JP 2015195315 A	05 November 2015
		KR 20180135122 A	19 December 2018
		WO 2015151773 A1	08 October 2015
		TW 201602411 A	16 January 2016
		TW I598464 B	11 September 2017
		KR 20160129870 A	09 November 2016
KR 20130110532 A	10 October 2013	None	
CN 110117167 A	13 August 2019	None	

Form PCT/ISA/210 (patent family annex) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- CN 104651590 A **[0003]**
- CN 108588612 A **[0004]**
- CN 101583486 **[0005]**