

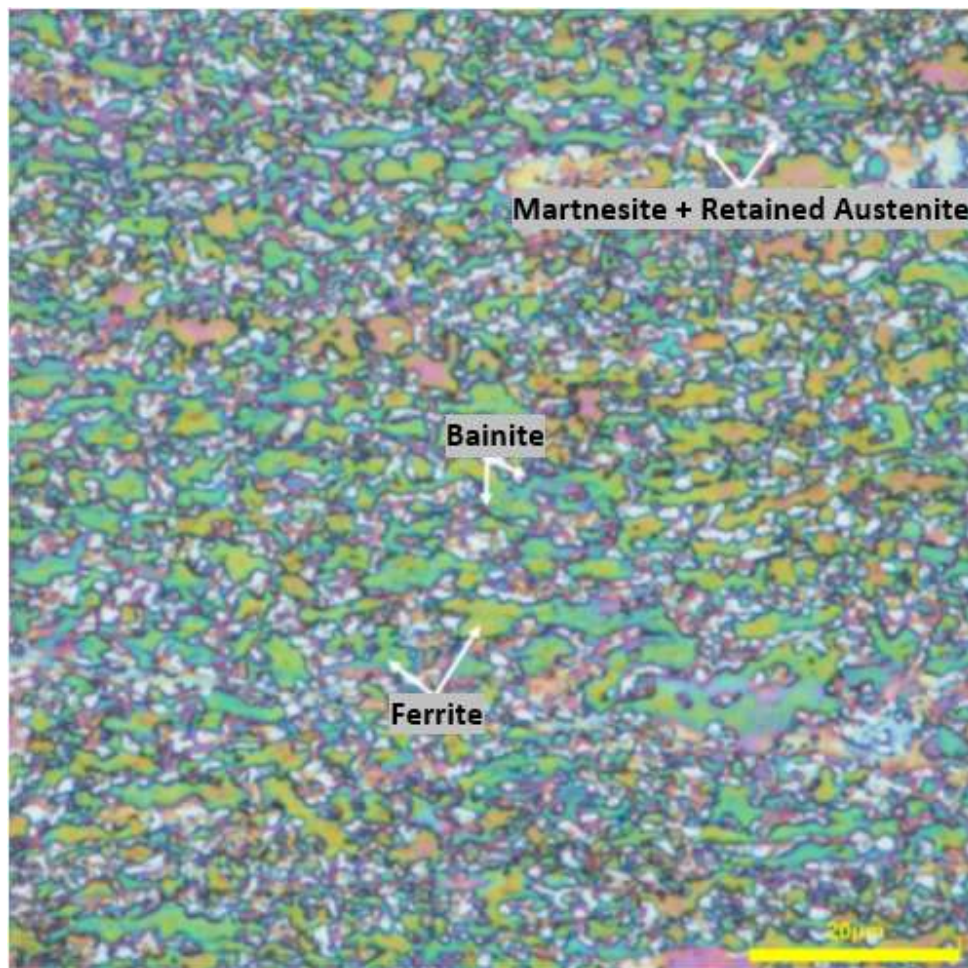


Figure 1

FORM 2

THE PATENT ACT 1970
(39 OF 1970)

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The Patent Rules, 2003

COMPLETE SPECIFICATION
(See Section 10 and Rule 13)

1 TITLE OF THE INVENTION :

**COLD-ROLLED HOT-DIP GALVANNEALED DP780 STEEL SHEET WITH
EXCELLENT WELDING PERFORMANCE AND SUPERIOR ADHESIVENESS OF
COATED LAYER AND MANUFACTURING METHOD THEREOF.**

2 APPLICANT (S)

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3 PREAMBLE TO THE DESCRIPTION

COMPLETE

The following specification particularly describes the invention and the manner in which it is to be performed.

FIELD OF THE INVENTION

The present invention belongs to the technical field of cold-rolled advanced high-strength steel and particularly relates to a cold rolled hot-dip galvanized dual-phase DP780 grade advanced high strength steel(AHSS)with excellent welding performance and superior adhesiveness of coated layer suitable for the automobile application and a method of manufacturing thereof involving a step of dual annealing.

BACKGROUND OF THE INVENTION

A balance of safety, performance, fuel efficiency, and affordability are the key parameters, which motivate the automakers in designing the lightweight vehicle. In this context, high-strength steel is attracting automobile engineers to use them in major parts of the car body. However, forming and welding are the key challenges in the use of these steels. For this purpose, Advanced High Strength Steels (AHSS) especially dual-phase steel provide the solutions due to their unique features such as high strength, low yield ratio, high toughness, good formability, dent resistance, and good fatigue properties, paintability and weldability. The dual-phase steel microstructure consists of a combination of ferrite and martensite phases with a small amount of bainite/pearlite and retained austenite.

The additional requirement of corrosion protection has, in many cases, led to the further need for galvanized high strength steel. Among the AHSS, a particularly strong interest has been shown in a hot-dip galvanized 780 MPa minimum tensile strength dual-phase product (DP 780).

A proper or careful design of chemistry and process parameters is required in producing the hot-dip galvanized dual-phase steel. In the steel content, Carbon enables the formation of martensite at practical cooling rates by increasing the hardenability of the steel. Manganese, chromium, molybdenum, titanium, niobium, vanadium, and boron added individually or in combination, also help increase hardenability. Carbon also strengthens the martensite as a ferrite solute

strengtheners, as silicon. These additions are carefully balanced, not only to produce unique mechanical properties but also to maintain the generally good resistance spot welding capability. In addition to this, a high amount of alloying elements (such as manganese, silicon, and aluminum) are required to achieve the desired properties. These elements are highly prone to the formation of oxides during the annealing process which ultimately causes poor surface quality.

Chinese patent application 102758136 discloses the manufacturing of a hot-dip galvanized steel sheet with tensile strength higher than 780MPa. The hot-dip galvanized steel sheet comprises, by weight, 0.060–0.085% of C; 0.20–1.0% of Si; 1.30–1.9% of Mn; no more than 0.3% of Cr+Mo; 0.002–0.05% of Nb; 0.002–0.05% of Ti; 0.02–0.05% of total Al; 0.006–0.02% of P; no more than 0.01% of S; and balance of Fe and inevitable impurities. Microstructure of a substrate is ferrite + martensite. The Si content with high Mn content deteriorates the hotdip galvanizability and coating adhesion.

Indian patent application 202021010453 discloses a cold-rolled hot-galvanized dual-phase steel with improved corrosion resistance and a production method thereof, wherein the steel comprises the following main chemical components: C:0.07–0.12 %; Mn:1.5–1.9%; Si:0.1–0.35%; Al:0.1–0.3%; S:0.005 % or less; N:0.005 % or less Ti: 0.005–0.05%; Mo:0.02–0.1% and Cr:0.21–0.4%; and the balance being Fe and other unavoidable impurities; wherein [Al]/[Si] ratio is in a range of 0.4 to 2 and the production process mainly adopts cold rolling, hot dip galvannealing, and the product of the patent application does not relate to the improvement of welding performance and adhesiveness of the coated layer.

As Mn, Si and Al are the oxidizable elements. They form their respective metal oxides during annealing. These metal oxides deteriorate the weldability and coating adhesion and cause an uncoated spot which is commonly known as a bare spot. And again, aluminum deteriorates weldability.

The present invention resolves the above problems of the prior arts and provides a manufacturing process of cold-rolled hot-dip galvanized advanced high strength steel sheet with an excellent welding performance and surface quality which give superior adhesiveness to the coated layer. The present invention, with the selective chemical composition, adopted a process of dual annealing where the cold-rolled coils are processed through a continuous annealing line before hot-dip galvannealing. The purpose of the former annealing process is the formation of oxidation layers at high annealing temperature, which can be removed by electrolytic cleaning and pickling process at the entry of CGL before hot-dip galvannealing process to tackle the bare spot issue. This results in defect free coated surface and microstructure consisting of a soft ferrite matrix containing islands of martensite as the secondary phase (martensite increases the tensile strength) with a small amount of bainite/pearlite and retained austenite. Therefore, the overall design of DP steels is governed by the proper steel design (chemical composition) and annealing heat cycle to achieve the surface defect free steel with a tensile strength of 780 MPa.

OBJECTS OF THE INVENTION

The basic object of the present invention is directed to provide cold-rolled hot dip galvanized advanced high strength steel sheets having excellent welding performance and surface quality which give superior adhesiveness to the coated layer and method of manufacturing the same.

A still further object of the present invention is directed to provide cold-rolled hot dip galvanized advanced high strength steel sheets involving selective composition and processing to achieve the desired microstructure, welding performance, and adhesiveness of property to the coated layer.

A still further object of the present invention is directed to provide cold-rolled hot dip galvanized advanced high strength steel sheets having tensile strength of 780 MPa or more.

A still further object of the present invention is directed to provide cold-rolled hot dip galvanized advanced high strength steel sheets by involving a process of dual annealing where the cold-rolled coils are processed through a continuous annealing line before hot-dip galvanizing to achieve the surface defect free steel with a tensile strength of 780 MPa.

Other objects and advantages will become apparent from the following description of the present invention.

SUMMARY OF THE INVENTION

The basic aspect of the present invention is directed to a cold-rolled hot-dip galvanized DP780 steel sheet comprises the base steel with following chemical composition in terms of weight %: C: 0.07–0.12 %; Mn: 1.6–2.1 %; Si: 0.12–0.30 %; Al: 0.03–0.2 %; S: 0.001–0.005 %; N: 0.002–0.006 %; Ti: 0.005–0.05 %; Nb: 0.005–0.05 %; V: 0.005–0.05 %; Mo: 0.02–0.1 %; Cr: 0.3–0.55 %; B: 0.0018–0.0030%; the balance being Fe and other unavoidable impurities and satisfies the following relation: weight % [Mn] / ([Si] + [Al]): 3.2–14, preferably 4–5 and carbon equivalent 0.3% or less and which is free of bare spots favouring arresting deterioration in weldability and coating adhesion on surface.

In one aspect of the present invention, said cold-rolled hot-dip galvanized DP780 steel sheet is obtained of the casted steel slab having the above-mentioned composition subjected to hot rolling, pickling cum cold rolling, continuous annealing and hot dip galvanizing process.

In another aspect of the present invention directed to said cold-rolled hot-dip galvanized DP780 steel sheet, wherein the base steel comprising wt % of Ti, Nb or V in combination less than 0.09 wt%.

In another aspect of the present invention directed to said cold-rolled hot-dip galvanized DP780 steel sheet, wherein the microstructure of the base steel sheet comprises the following components in percentage by volume: 55–65 of ferrite, 25–32% of martensite, 0–4% retained austenite and bainite/pearlite of 8–17%.

In another aspect of the present invention, the thickness of the cold-rolled hot-dip galvanized DP780 steel sheet is 1.4 mm.

In another aspect of the present invention, the cold-rolled hot-dip galvanized DP780 steel sheet having yield strength in the range of 450–550 MPa, tensile strength in the range of 780–900 MPa, yield ratio in the range of 0.5–0.70, strain hardening coefficient ≥ 0.15 , hole expansion ratio (HER) in the range of 35–60 % and bake hardening index (BHI) in the range of 30–60 MPa.

In another aspect of the present invention, the cold-rolled hot-dip galvanized DP780 steel sheet spot-welded joint has cross tensile strength (CTS) 7.5–18 kN/spot when performed with plug diameter/nugget diameter (Pd/Nd) ≥ 0.70 and current range from 7.2 to 8.8 kA.

In another aspect of the present invention, the cold-rolled hot-dip galvanized DP780 steel sheet passes the mastic adhesive test to evaluate the adhesiveness.

In another aspect of the present invention, the cold-rolled hot-dip galvanized DP780 steel sheet having a uniform coating weight of 90 gsm for top and bottom with defect-free surface.

Said cold-rolled hot-dip galvanized DP780 steel sheet also passes antipowdering test.

A still further aspect of the present invention is directed to a method of manufacturing cold-rolled hot-dip galvanized DP780 steel sheet as described

above. The steps are Continuous Casting Process to manufacture slab of desired chemistry, hot rolling, acid pickling, cold rolling, continuous annealing and continuous hot dip galvannealing process to obtain the final sheet with desired properties.

Continuous Casting Process: To achieve the designed chemistry, the carbon-rich molten pig iron is converted into steel using the Basic Oxygen Furnace (BOF) in primary steel making stage. For temperature homogenization, chemistry achievement as mentioned in the scope of invention the aim grade for C, Mn, S, P, Si, Al and other alloying elements the heat is processed through Ladle Heating Furnace (LHF) in Secondary making process. To homogenize the liquid steel composition and bath temperature and to remove inclusions from the liquid steel RH degassing process is then adopted. Subsequently, the molten steel is casted into slab in the continuous casting process. The casted heat of chemical composition in terms of weight %:

C: 0.07–0.12 %;

Mn: 1.6–2.1 %;

Si: 0.12–0.30 %;

Al: 0.03–0.2 %;

S: 0.001–0.005 %;

N: 0.002–0.006 %;

Ti: 0.005–0.05 %;

Nb: 0.005–0.05 %;

V: 0.005–0.05 %;

Mo: 0.02–0.1 %;

Cr: 0.3–0.55 %;

B: 0.0018–0.0030%;

the balance being Fe and other unavoidable impurities and satisfies the following relation: weight % [Mn] / ([Si] + [Al]): 3.2–14, preferably 4–5 and carbon equivalent 0.3% or less.

Step 2: Hot Rolling: Reheating the slab to temperature in the range from 1180—1300 °C, the reheated slab being subjected to roughing rolling in roughing mill with roughing mill delivery temperature of 1050—1080 °C to form a rough rolled substrate, the rough rolled substrate being subjected to finish rolling with finish mill exit temperature ranging from A_{c3} °C to $A_{c3}+100$ °C to form a hot-rolled substrate, coiling the hot-rolled substrate at coiling temperature in the range of 550—650 °C to form a hot-rolled coil.

Step 3: Acid Pickling: Pickling the hot-rolled coil in a continuous line with concentrated acid-HCl to remove the surface scale to form a hot-rolled pickled coil.

Step 4: Cold Rolling: Cold rolling the hot-rolled pickled coil to form a cold-rolled coil, wherein it processed with a cold reduction of 35–60 %.

Step 5: Continuous Annealing: Subjecting the cold-rolled coil to continuous annealing, soaking the cold-rolled coil at a temperature range between 770°C to 830°C with a residence time of 50 sec to 100 sec, slow cooling further said steel at a temperature range of 630°C to 680°C with a cooling rate of 1–4 °C/sec, rapid cooling of said steel at a temperature in the range of 450 °C to 510 °C with a cooling rate of 15 °C/sec, over aging of said steel at a temperature range between 360 °C to 410 °C more with a residence time of 180–350 sec. No skin pass or oiling is applied in after this stage.

Step 6: Continuous Hot Dip Galvannealing: Annealing the cold rolled closed annealed steel sheet at soaking section within the inter critical temperature range of $A_{c1}+10$ °C to $A_{c3}-10$ °C with residence time ranging from 65–160 sec; Rapid cooling the steel from SS temperature up to a temperature range of 440–470 °C; dipping the sheet in the zinc bath where the temperature of the said steel in the range starting from 440–460 °C; galvannealing at temperature range of 530–570

°C to form Zn-Fe alloy coating on the substrate; Subjecting the coated steel to skin pass elongation of 0.2% to 0.8%.

BRIEF DESCRIPTION OF THE ACCOMPANYING DRAWING

Figure 1: shows the microstructure of the cold rolled hot-dip galvanized advanced high strength steel sheets according to present invention.

DETAILED DESCRIPTION OF THE INVENTION WITH REFERENCE TO ACCOMPANYING DRAWING AND EXAMPLES

The present invention pertains to cold rolled hot-dip galvanized advanced high strength steel sheets with excellent welding performance and superior surface quality and method of manufacturing the same. The hot-dip galvanized sheets have a tensile strength of ≥ 780 MPa with an excellent balance of strength and elongation. It is having selective chemical composition and processing through a dual annealing route of continuous annealing and hot-dip galvanizing process with optimum process parameters, to obtain desired properties, excellent formability, weldability, adhesive property, and surface quality. Also, the advancement favors the generation of cold-rolled hot-dip galvanized advanced high strength steel sheet having excellent corrosion resistance with uniform coating weight with desired Fe% 8–12% for good weldability, formability, and antipowdering property. The present invention emphasized achieving a defect-free excellent surface quality steel with uniform coating weight.

Following abbreviations, terminologies and expressions are used to describe the present invention are stated below in alphabetical order:

Ac1 - critical temperature at which pearlite transforms to austenite during heating

Ac3 – the final critical temperature at which free ferrite is completely transformed into austenite during heating

BHI- Bake hardening Index (MPa)

CAL- Continuous Annealing Line
 Ceq % - Carbon Equivalent
 CGL – Continuous Galvanizing Line
 CS - Center Speed
 CT- Coiling Temperature
 El – Elongation (%)
 FET- Finishing Mill Entry Temperature
 FT-Finishing Temperature
 HER–Hole Expansion Ratio
 MPa-Mega Pascal
 n- Strain hardening coefficient
 RCS -Rapid cooling section
 SS-Soaking section
 SRT -Slab Reheating Temperature
 SPM - Skin Pass Elongation (%)
 Sec- Second
 UTS - Ultimate Tensile Strength (MPa)
 Wt- Weight
 YS - Yield Strength (MPa)

The present invention discloses a cold-rolled hot-dip galvanized DP780 steel with excellent welding performance and superior adhesiveness to the coated layer comprises the base steel sheet with following chemical composition in terms of weight %: C: 0.07–0.12 %; Mn: 1.6– 2.1 %; Si: 0.12–0.30 %; Al: 0.03–0.2 %; S: 0.001–0.005 %; N: 0.002–0.006 %; Ti: 0.005–0.05 %; Nb: 0.005–0.05 %; V: 0.005–0.05 %; Mo: 0.02–0.1 %; Cr: 0.3–0.55 %; B: 0.0018–0.0030%; the balance being Fe and other unavoidable impurities and satisfies the following relation: weight % [Mn] / ([Si] + [Al]): 3.2-14, preferably 4–5 and carbon equivalent 0.3% or less. The base steel further comprises following elements in weight% selected from the group of elements comprising Ti, Nb or V less than 0.09 wt%.

As described above, since steel sheets having a tensile strength of 780 MPa or more have begun to be used as materials for automobiles and automobile parts, the present invention is a high-strength steel sheet for spot welding having a tensile strength of 780 MPa or more (hereinafter referred to as “the steel sheet of the present invention”). The upper limit of the tensile strength is not particularly limited, but currently, the limit is about 900 MPa.

Hereinafter, the steel composition is described hereunder with an explanation of metallurgical factors governing the ranges of the constituents in a composition according to a preferred embodiment wherein all the elements are in weight % are demonstrated.

Carbon (C: 0.07–0.12 %) - Carbon effectively increases the strength and hardenability by facilitating the formation of martensite at a practical cooling rate. Carbon as an austenite former stabilizes the austenite and lowers the martensite formation temperature. To achieve the dual-phase phenomenon a minimum of 0.07%C is required. An increase in C content promotes more martensite formation. But the carbon content used should be limited to 0.12% as more than that deteriorates the weldability and ductility of the steel.

Manganese (Mn: 1.6–2.1%) - Manganese which is an austenite stabilizer increases the hardenability of steel. It dissolves in the ferrite matrix which leads to the deformation of the crystal lattice and the generation of an elastic strain field. This strain field hinders the movement of dislocation and enhances the strength of ferrite by solid solution strengthening. Mn suppresses the austenite to ferrite transformation temperature which leads to fine ferrite grains. Mn lowers the MS temperature. To utilize the desired amount of strengthening effect a $\text{Mn} \geq 1.6\%$ is required. However, an increase in Mn content can lead to poor coating due to the formation of Manganese oxide during annealing. Hence the upper limit of Mn is restricted to 2.1%.

Silicon (Si: 0.12—0.30%) - Silicon is a ferrite stabilizer and refines grain size too, by increasing the nucleation rate of ferrite from austenite. It also imparts considerable solid solution strengthening to ferrite. It suppresses the formation of cementite and enriches the carbon content in austenite and makes it more stable. To achieve the strengthening effect a minimum of 0.12% Si is required. However, $\text{Si} \geq 0.30\%$ shows poor galvanizing property because of the commonly known mechanism called “Sandeline effect”.

Aluminum (Al: 0.03—0.2%)- Aluminium, is primarily used as a deoxidizer during the steel-making process. It suppresses the cementite precipitation. Like Si, Al also suppresses the cementite precipitation and in this way, it can be used as a replacement for Si. However, Al does not strengthen the ferrite matrix, hence more Mn needs to be added to achieve the desired strength level. Al also acts as a deoxidizer during the steel-making process to kill dissolved oxygen. It also improves corrosion resistance by preferential oxidation before zinc coating and for which Al is preferred to be greater than 0.1 % by weight. Al also adds on to fix harmful dissolved N to form AlN. Increasing Al level above 0.2 wt% causes longitudinal cracks while casting. Accordingly, the upper limit is set to 0.2% as high Aluminum content can lead to poor weldability.

Sulphur (S: 0.001—0.005%) –Sulphur is a residual element, generally preferable in the least amount because of its adverse effect on the quality of steel. Not only does it deteriorate the formability and ductility but the toughness as well. With the manganese, it forms manganese sulfides precipitate which is useful in preventing hot cracking of a steel slab. But a large amount of these precipitates can lead to poor fatigue and formability properties. So, the upper limit of sulphur is limited to 0.005%.

Nitrogen(N: 0.002–0.006%)- Nitrogen is an element present in steel as an impurity. It must be minimized as least as possible as it deteriorates the aging resistance of steel. So, to avoid room temperature aging the N content must be restricted to 0.006% or more preferably $\leq 0.005\%$.

Ti, Nb and V (collectively <0.09 wt %): Ti, Nb and V are effective for precipitation strengthening and microstructure refinement of the steel. They suppress the formation of pearlite during cooling from an annealing temperature. They have a strong effect on retarding austenite recrystallization. They also contribute to accelerating the transformation of austenite to ferrite. These alloying elements can be added to steel alone or in combination to obtain maximum benefit. However, when the content of these alloying elements exceeds a certain limit, a large number of formed precipitates deteriorates the castability and rollability of steel during the manufacturing process. So, to avoid the formability and shape fixability the Ti, Nb and V limit must be collectively limited to 0.09 wt % or less.

Molybdenum or/and Chromium (Mo: 0.02–0.1andCr: 0.3–0.55wt %): Mo and Cr, both are effective in enhancing the hardenability of steel. Also, they are beneficial in retarding pearlite or bainite formation. Mo is effective in delaying the fracture resistance of steel. Mo, helps in grain refinement of the matrix, thus helpful in the internal oxidation of Al during the heating process. Mo and Cr also reduce the annealing time to achieve a dual-phase structure. Mo and Cr can replace Si, thus coating property and coating adhesion can be improved. Cr is effective in ferrite strengthening and in suppressing softening of a heat-affected zone (HAZ) upon welding. However, Higher Mo content reduces the workability. Therefore the upper limit should be 0.1wt% or less. The addition of chromium should satisfy restricted up to 0.55wt% for better weldability. Both Mo and Cr in combination or individually can be added in enhancing the hardenability of steel.

Boron (B: 0.0018–0.0030 wt%): Even a small amount of boron is very much effective in enhancing the hardenability of steel thus helpful in the formation of martensite. It helps suppress the formation of ferrite from austenite grain boundaries. To obtain this benefit, boron content should be ≥ 0.0018 wt%. However, when it exceeds a limit of 0.003% they segregate at the grain boundaries, very less amount of ferrite formation and a high amount of martensite forms, which leads to poor formability.

The method of manufacturing the cold-rolled hot-dip galvanized DP780 steel is described as following.

Further, the present invention provides a method of manufacturing cold-rolled hot-dip galvanized DP780 steel with excellent welding performance and superior adhesiveness to the coated layer comprising the following steps. The method of manufacturing is casting process, hot rolling, acid pickling, cold rolling, continuous annealing, continuous hot galvanizing and galvannealing.

Step 1: Continuous Casting Process: To achieve the designed chemistry, the carbon-rich molten pig iron is converted into steel using the Basic Oxygen Furnace (BOF) in primary steel making stage. For temperature homogenization, chemistry achievement as mentioned in the scope of invention the aim grade for C, Mn, S, P, Si, Al and other alloying elements the heat is processed through Ladle Heating Furnace (LHF) in Secondary making process. To homogenize the liquid steel composition and bath temperature and to remove inclusions from the liquid steel RH degassing process is then adopted. Subsequently, the molten steel is casted into slab in the continuous casting process. The casted heat of chemical composition in terms of weight %:

C: 0.07–0.12 %;

Mn: 1.6–2.1 %;

Si: 0.12–0.30 %;

Al: 0.03–0.2 %;

S: 0.001–0.005 %;

N: 0.002–0.006 %;

Ti: 0.005–0.05 %;

Nb: 0.005–0.05 %;

V: 0.005–0.05 %;

Mo: 0.02–0.1 %;

Cr: 0.3–0.55 %;

B: 0.0018–0.0030%;

the balance being Fe and other unavoidable impurities and satisfies the following relation: weight % [Mn] / ([Si] + [Al]): 3.2–14, preferably 4–55 and carbon equivalent 0.3% or less.

Step 3: Hot rolling: reheating the slab to temperature in the range from 1180–1300 °C, the reheated slab is subjected to roughing rolling in roughing mill with roughing mill delivery temperature of 1050–1080 °C to form a rough rolled substrate, the rough rolled substrate being subjected to finish rolling with finish mill exit temperature ranging from A_{c3} °C to $A_{c3}+100$ °C to form a hot-rolled substrate, coiling the hot-rolled substrate at coiling temperature in the range of 550°C–650 °C to form a hot-rolled coil.

Steps 4: Acid pickling: pickling the hot-rolled coil in a continuous line with concentrated acid-HCl to remove the surface scale to form a hot-rolled pickled coil;

Step 5: Cold rolling: cold rolling the hot-rolled pickled coil or the hot-rolled coil to form a cold-rolled coil, wherein acid pickling and cold-rolling the hot rolled steel sheet with cold reduction of 35–60 %.

Step 6: Continuous annealing: Before continuous annealing, preferably the cold-rolled coils are processed and cleaned through the electrolytic cleaning process to remove the rolling emulsion present on the surface and then afterward annealed through different sections of the furnace. At the furnace entry, the coil is heated in the preheating and heating section with a heating rate of around 0.5–5 °C/sec to reach the soaking zone temperature. At the soaking section, the temperature was maintained in the range of 790°C to 840°C to generate high-temperature manganese oxide so that this can be removed in the entry of the CGL line during electrolytic cleaning and pickling. After soaking for around 110 to 230 seconds based on the thickness of the coils, the coil is passed through slow cooling at a cooling rate of 0.3–1.5 °C/sec with a temperature range from 670 °C to 730°C. Following the slow cooling section, the strip sheet was rapidly cooled at a cooling rate of 30 °C/sec or more up to a rapid cooling section temperature of 400-500°C to avoid any martensite formation. Afterward, the strip was processed in the over-aging section with a temperature range from 300°C–400 °C with a residence of 350 sec or more. No skin pass is applied in the CAL.

Step 6: Continuous Hot Dip Galvannealing: After annealing at CAL, the strips are processed through a Continuous Galvanizing line where at entry electrolytic cleaning removes the oxide layer and cleans the surface to make it suitable for the galvannealing process. The cleaned coil passes through the preheating and heating section where it is heated at the rate of 0.5–5 °C/sec up to the soaking section temperature. The soaking section temperature was maintained in the range from 765°C to 815°C to achieve retained austenite in the final microstructure. Annealing time is kept in the range of 65 to 160 seconds to allow sufficient time for annealing and homogenization of austenite microstructure. Succeeding the soaking section, annealed strip sheet passes through the rapid cooling section at a cooling rate of 20°C/Sec or more and cooled up to a rapid cooling section temperature of 440 °C or more. This is to keep martensite area fraction in microstructure around 8–35%. After RCS, the annealed strip passes through a zinc pot where rapidly cooled steel strip is coated with zinc at a zinc pot temperature of

440–470°C. The Galvanized steel sheet is passed through a galvannealing furnace at a temperature of 520°C or more temperature for create iron-zinc (Fe-Zn) diffusion on the surface resulting in three hard, dark-grey Fe-Zn alloy layers above the steel substrate. Galvannealed steel sheet is then provided with skin-pass elongation in the range from 0.20 to 1 % to arrest yield point elongation.

The properties of the cold-rolled hot-galvanized dual-phase steel are described as follows:

1. The base steel sheet used for cold-rolled hot-dip galvannealed DP 780 steel comprises the following components in percentage by volume: 55–65 of ferrite, 25–32 % of martensite, 0–4% retained austenite and bainite/pearlite of 8–17%. Accompanying **Figure 1** shows the microstructure of the cold rolled hot-dip galvannealed advanced high strength steel sheets according to present invention which is the Optical Microstructure of Steel no. 4s at 1000X magnification.
2. The thickness of the cold-rolled hot-dip galvannealed DP780 steel is 1.4 mm.
3. The cold-rolled hot-dip galvannealed DP 780 steel has yield strength in the range of 450–550 MPa, tensile strength in the range of 780–900 MPa, yield ratio in the range of 0.5-0.70, strain hardening coefficient ≥ 0.15 , hole expansion ratio (HER) ≥ 35 % and bake hardening index (BHI) in the range of 30-60 MPa.
4. The cold-rolled hot-dip galvannealed DP780 steel spot-welded joint has a cross tensile strength (CTS) 7.5–18 kN/spot when performed with plug diameter/nugget diameter (Pd/Nd) ≥ 0.70 and current range from 7.2 to 8.8 kA. The cold-rolled hot-dip galvannealed DP 780 steel can form a welded joint having a high cross tensile strength and a small variation in strength between joints and a good fracture form.
5. The cold-rolled hot-dip galvannealed DP780 steel passes the mastic adhesive test to evaluate the adhesiveness.

6. The cold-rolled hot-dip galvanized DP780 steel has a uniform coating weight with defect-free surface.

The above properties make cold-rolled hot-dip galvanized DP780 steel of the present invention suitable for automobile applications.

Hereinafter, the present invention will be described specifically by way of examples.

Examples

With 4 different set of example four heats (named as Steel no: 1, 2, 3, 4) of different chemistry as mentioned in Table 1, were casted in continuous casting with slab thickness of 220 mm. The slabs of these heat were fully scarfed and then processed in hot rolling followed by pickling and cold rolling process with a process parameters as shown in Table 2. As shown in Table 3, Steel no. 1, 2 and 3 were followed the conventional CGL for annealing of the CRFH coils. However, for Steel no. 4, again two sets of annealing processes were followed, one sets of coils processed through only CGL routing while another set was processed though CAL+CGL routing.

A details of chemical compositions, process parameters and testing results of the present advancement and comparative steel grades are illustrated in following table 1 to table 7 as details below:

Table 1: Elemental Compositions in weight % of the inventive steel sheets along with comparative examples.

Table 2: Hot rolling and cold rolling of the inventive steel sheets with comparative steel sheets having chemical compositions as per Table 1.

Table 3: CAL and CGL Parameters of inventive with comparative steel sheets having chemical compositions as per Table 1 and being processed as per Table 2.

Table 4: Mechanical properties (like YS, UTS, El%, n-value, BHI) and HER% of inventive and comparative steels having chemical composition as per Table 1 and being processed as per Table 2, 3 and 4.

Table 5: Coating properties and micro structural phase fractions of inventive and comparative steels having chemical composition as per table 1 and being processed as per Table 2, 3 and 4.

Table 6: Spot welding properties of the inventive steel sheets for sample no. 4s having chemical composition as per table 1 and being processed as per Table 2, 3 and 4.

Table 7: Adhesive property test for sample no. 4s having chemical composition as per table 1 and being processed as per Table 2, 3 and 4.

Table 1:

	Chemical Composition (in Wt %)											
Sam ple No.	C	Mn	Si	Ti	Cr	Nb	Mo	Al	B	Mn/(Si +Al)	Ceq	Rem arks
1a	0.09	1.85	0.16	0.04	<u>0.60</u>	0.01	<u>0.001</u>	0.03	<u>0.0005</u>	<u>9.74</u>	0.23	C
1b	0.09	1.85	0.11	0.04	<u>0.60</u>	0.01	<u>0.001</u>	0.03	<u>0.0005</u>	<u>13.60</u>	0.23	C
2a	<u>0.12</u>	1.57	0.27	0.02	<u>0.57</u>	0.04	<u>0.001</u>	0.05	<u>0.0004</u>	4.91	0.26	C
2b	<u>0.12</u>	1.57	0.27	0.02	<u>0.57</u>	0.04	<u>0.001</u>	0.05	<u>0.0004</u>	4.91	0.26	C
2c	<u>0.12</u>	1.57	0.27	0.02	<u>0.57</u>	0.04	<u>0.001</u>	0.05	<u>0.0004</u>	4.91	0.26	C
2d	<u>0.12</u>	1.57	0.27	0.02	<u>0.57</u>	0.04	<u>0.001</u>	0.05	<u>0.0004</u>	4.91	0.26	C
2e	<u>0.12</u>	1.57	0.27	0.02	<u>0.57</u>	0.04	<u>0.001</u>	0.05	<u>0.0004</u>	4.91	0.26	C
3a	0.11	1.57	<u>0.31</u>	0.02	<u>0.56</u>	0.04	<u>0.001</u>	0.05	<u>0.0005</u>	4.33	0.25	C
3b	0.11	1.57	<u>0.31</u>	0.02	<u>0.56</u>	0.04	<u>0.001</u>	0.05	<u>0.0005</u>	4.33	0.25	C
4a	0.09	1.71	0.23	0.02	0.36	0.05	0.052	0.13	0.0027	4.78	0.23	I
4b	0.09	1.71	0.23	0.02	0.36	0.05	0.052	0.13	0.0027	4.78	0.23	I
4c	0.09	1.71	0.23	0.02	0.36	0.05	0.052	0.13	0.0027	4.78	0.23	I
4d	0.09	1.71	0.23	0.02	0.36	0.05	0.052	0.13	0.0027	4.78	0.23	I
4e	0.09	1.71	0.23	0.02	0.36	0.05	0.052	0.13	0.0027	4.78	0.23	I
4f	0.09	1.71	0.23	0.02	0.36	0.05	0.052	0.13	0.0027	4.78	0.23	I
4g	0.09	1.71	0.23	0.02	0.36	0.05	0.052	0.13	0.0027	4.78	0.23	I
4h	0.09	1.71	0.23	0.02	0.36	0.05	0.052	0.13	0.0027	4.78	0.23	I
4i	0.09	1.71	0.23	0.02	0.36	0.05	0.052	0.13	0.0027	4.78	0.23	I
4j	0.09	1.71	0.23	0.02	0.36	0.05	0.052	0.13	0.0027	4.78	0.23	I
4k	0.09	1.71	0.23	0.02	0.36	0.05	0.052	0.13	0.0027	4.78	0.23	I

4l	0.09	1.71	0.23	0.02	0.36	0.05	0.052	0.13	0.0027	4.78	0.23	I
4m	0.09	1.71	0.23	0.02	0.36	0.05	0.052	0.13	0.0027	4.78	0.23	I
4n	0.09	1.71	0.23	0.02	0.36	0.05	0.052	0.13	0.0027	4.78	0.23	I
4o	0.09	1.71	0.23	0.02	0.36	0.05	0.052	0.13	0.0027	4.78	0.23	I
4p	0.09	1.71	0.23	0.02	0.36	0.05	0.052	0.13	0.0027	4.78	0.23	I
4q	0.09	1.71	0.23	0.02	0.36	0.05	0.052	0.13	0.0027	4.78	0.23	I
4r	0.09	1.71	0.23	0.02	0.36	0.05	0.052	0.13	0.0027	4.78	0.23	I
4s	0.09	1.71	0.23	0.02	0.36	0.05	0.052	0.13	0.0027	4.78	0.23	I
4t	0.09	1.71	0.23	0.02	0.36	0.05	0.052	0.13	0.0027	4.78	0.23	I

**I - Present inventive example, C- Comparative Examples*

**Underline boxes indicates “outside the appropriate range”*

** $CE = C + (Si/30) + (Mn/20) + 1.5 * (P + 2S)$*

Note:

1. Steel marked as 1a and 1b have same chemical composition as steel number 1;
2. Steel marked as 2a, 2b, 2c, 2d and 2e have same chemical composition as steel number 2;
3. Steel marked as 3a, 3b have same chemical composition as steel number 3;
4. Steel marked as 4a, 4b, 4c and up to 4t have same chemical composition as steel number 4;

With different processing parameters to validate the claimed process. The uniqueness in chemistry and process parameters in each sample with their properties are explained in details in examples.

Table 2:

	Hot Rolling Parameters		Cold Rolling Parameters
Sample no.	FT (°C)	CT (°C)	CCM Red%
1a	901	550	39
1b	898	562	39
2a	900	569	60
2b	900	569	60
2c	903	566	46
2d	908	555	39
2e	908	555	39
3a	910	560	39

3b	910	560	39
4a	895	560	46
4b	895	560	46
4c	920	540	46
4d	920	540	46
4e	910	555	46
4f	910	555	46
4g	900	540	50
4h	920	560	50
4i	915	570	50
4j	910	580	46
4k	905	580	46
4l	910	585	46
4m	910	580	46
4n	900	570	39
4o	900	570	39
4p	900	585	39
4q	910	570	39
4r	900	580	39
4s	915	595	39
4t	910	570	39

Table 3:

	CAL Process Parameters						CGL Process Parameters						
Sam ple No.	SS Tem p (°C)	SCS (°C)	RCS (°C)	OAS (°C)	Resi den ce Tim e (Sec .)	Coo ling Rate (°C/ s)	SS Tem p.(°C)	RC S Tem p. (°C)	Resi den ce Tim e (Sec .)	Co oli ng Rat e	GV F Tem p	CG L_S PM El%	Re ma rks
1a	NP	NP	NP	NP	NP	NP	808	491	53	18	510	0.5	C
1b	NP	NP	NP	NP	NP	NP	778	519	51	18	511	0.5	C
2a	NP	NP	NP	NP	NP	NP	815	501	32	30	509	0.59	C
2b	NP	NP	NP	NP	NP	NP	807	479	32	31	510	0.4	C
2c	NP	NP	NP	NP	NP	NP	819	517	39	23	504	0.59	C
2d	NP	NP	NP	NP	NP	NP	804	499	63	15	505	0.67	C
2e	NP	NP	NP	NP	NP	NP	798	489	63	15	501	0.48	C
3a	NP	NP	NP	NP	NP	NP	820	480	40	26	498	0.4	C
3b	NP	NP	NP	NP	NP	NP	830	480	44	24	501	0.4	C

4a	NP	NP	NP	NP	NP	NP	761	478	45	19	507	0.12	C
4b	NP	NP	NP	NP	NP	NP	781	484	45	20	506	0.45	C
4c	NP	NP	NP	NP	NP	NP	792	463	53	19	509	0.28	C
4d	NP	NP	NP	NP	NP	NP	794	482	53	18	506	0.55	C
4e	NP	NP	NP	NP	NP	NP	792	460	64	16	504	0.46	C
4f	NP	NP	NP	NP	NP	NP	792	496	64	14	505	0.46	C
4g	781	666	500	387	88	20	782	477	33	28	499	0.3	I
4h	783	649	410	392	88	29	783	480	33	27	500	0.3	I
4i	782	657	479	392	88	22	781	480	33	27	508	0.3	I
4j	777	654	479	406	88	22	780	476	42	22	504	0.3	I
4k	777	660	476	404	88	23	776	479	42	21	511	0.3	I
4l	828	714	319	230	134	32	775	477	42	21	508	0.35	I
4m	826	694	331	232	134	29	774	480	42	21	499	0.35	I
4n	816	708	321	239	175	24	809	482	64	16	504	0.35	I
4o	811	706	318	235	170	25	792	479	64	15	505	0.35	I
4p	814	705	320	236	170	24	789	480	64	15	508	0.35	I
4q	814	706	320	247	175	24	809	478	62	16	506	0.35	I
4r	812	712	307	241	175	25	814	478	64	16	501	0.35	I
4s	808	700	290	245	163	27	802	480	64	15	509	0.35	I
4t	775	667	480	384	114	18	778	519	58	14	506	0.4	I

**Note: In the above table no: 3, NP: Not performed*

Table 4:

	Mechanical Properties							
Sample No.	YS (Mpa)	UTS (Mpa)	EL (80Gl %)	Yield Ratio	n-value	BHI	HER%	Remarks
1a	531	823	17	0.65	<u>0.11</u>	<u>19</u>	29	C
1b	496	795	19	0.62	<u>0.12</u>	<u>15</u>	31	C
2a	<u>438</u>	780	18.8	0.56	<u>0.12</u>	51	36	C
2b	<u>445</u>	791	18	0.56	<u>0.12</u>	49	39	C
2c	<u>444</u>	793	18.6	0.56	<u>0.12</u>	47	37	C
2d	512	841	<u>13.2</u>	0.61	<u>0.12</u>	41	41	C
2e	512	841	<u>13.2</u>	0.61	<u>0.11</u>	41	38	C
3a	<u>449</u>	<u>778</u>	<u>17.8</u>	0.58	<u>0.11</u>	37	<u>29</u>	C
3b	426	764	16.3	0.56	<u>0.11</u>	37	30	C
4a	589	901	<u>11.8</u>	0.65	<u>0.11</u>	63	35	C

4b	614	907	<u>8.1</u>	0.68	<u>0.11</u>	65	31	C
4c	567	882	<u>15.6</u>	0.64	<u>0.11</u>	75	34	C
4d	568	879	<u>15.8</u>	0.65	<u>0.11</u>	74	32	C
4e	579	891	<u>14</u>	0.65	<u>0.11</u>	63	33	C
4f	555	888	<u>14.4</u>	0.63	<u>0.12</u>	62	36	C
4g	528	848	18	0.62	0.15	45	37	I
4h	520	828	21	0.63	0.17	48	36	I
4i	525	831	19	0.66	0.17	45	38	I
4j	592	887	14	0.67	0.17	49	35	I
4k	469	797	19	0.59	0.17	45	36	I
4l	468	782	19	0.60	0.19	48	40	I
4m	459	785	22	0.60	0.19	49	41	I
4n	532	824	20	0.65	0.18	41	39	I
4o	501	799	21	0.63	0.19	40	45	I
4p	540	856	19	0.63	0.17	42	41	I
4q	479	838	19	0.57	0.17	45	40	I
4r	488	801	20	0.61	0.17	42	42	I
4s	551	859	18	0.64	0.17	41	39	I
4t	557	857	20	0.65	0.17	51	39	I

Note:

Tensile Test as per: ASTM A370-2012

BHI Test as per: ASTM A 653/A 653M – 09

HER% as per: ISO 16630-2009

Table 5

	Coating Properties					Microstructural Phase fraction (From Combined report of optical microscopy and XRD)		
Samp le No.	Coati ng wt (Targ et: 90- 120 g/m ²)	Fe%(To p)	Fe%(Botto m)	Powderi ng Level_t op Remark s	Powdering Level_Bott om Remarks	Ferri te %	Martens ite %	Retained Austanite+Bai nite %+Pearlite
1a	<u>75</u>	10	10.1	G	G	67	24	9
1b	<u>75</u>	10.1	9.9	G	G	65	25	10
2a	91	10.9	10.6	NG	NG	67	25	8
2b	95	10.8	10.6	NG	NG	65	28	7

2c	93	11.4	10.5	G	G	62	32	6
2d	91	10.1	9.9	NG	NG	65	30	5
2e	92	10.2	10	NG	NG	60	32	8
3a	<u>74</u>	11.7	11.9	NG	NG	60	29	11
3b	<u>80</u>	11.5	11.9	NG	NG	63	30	7
4a	<u>76</u>	10.9	10.9	G	G	62	28	10
4b	<u>82</u>	10.8	10.6	NG	G	73	23	4
4c	<u>83</u>	10.4	9.5	G	NG	64	30	6
4d	<u>87</u>	10.3	10	NG	NG	62	27	11
4e	<u>89</u>	11	11	NG	G	69	24	7
4f	<u>71</u>	10.3	11	NG	NG	66	26	8
4g	95	10.3	10.6	G	G	64	27	9
4h	92	10.3	10.6	G	G	67	26	7
4i	93	10.3	10.7	G	G	64	25	11
4j	94	10.2	10.6	G	G	64	26	10
4k	91	10.4	10.3	G	G	61	27	12
4l	96	10.3	10.9	G	G	66	25	9
4m	97	10.9	11	G	G	62	26	12
4n	95	10	9.8	G	G	65	28	7
4o	94	10	10.1	G	G	60	27	13
4p	93	11.7	11.2	G	G	63	26	11
4q	94	10	10	G	G	60	25	15
4r	94	10.5	10.1	G	G	57	26	17
4s	95	10.2	10.7	G	G	58	28	14
4t	92	10.3	10.5	G	G	55	30	15

**Note: Abbreviation for G=Good & NG= Not good, as used in table: 5*

Coating weight measured or tested as per ASTM A90/A90M

Table: 6

Sample no	Current (kA)	Nd	Test :1			Test :2			Remarks
			Strength (kN)	Pd (mm)	Pd/Nd ≥ 0.75	Strength (kN)	Pd (mm)	Pd/Nd ≥ 0.75	
4s-1	7.20	5.32	8.57	4.29	0.81	7.79	0.00	0.00	Pass
4s-2	7.40	5.48	9.06	4.35	0.79	8.49	4.54	0.83	Pass

4s-3	7.60	5.90	8.90	4.73	0.80	8.91	4.71	0.80	Pass
4s-4	7.80	6.12	9.00	4.89	0.80	8.99	5.06	0.83	Pass
4s-5	8.00	6.21	8.26	5.03	0.81	8.93	4.92	0.79	Pass
4s-6	8.20	6.76	12.42	6.43	0.95	18.77	5.20	0.77	Pass
4s-7	8.40	6.65	11.95	5.32	0.80	14.25	5.30	0.80	Pass
4s-8	8.60	6.90	16.38	5.71	0.83	14.38	6.31	0.91	Pass
4s-9	8.80	7.18	16.55	2.40	0.33	17.75	5.70	0.79	Pass

Note: Welding test as per: AWS D8.9M:2012

For validating weldability of the invented steel, samples from the best steel sheet i.e 4s has been chosen. The samples of the sheer was spot-welded whose joint has a cross tensile strength (CTS) 7.5-18 kN/spot when performed with plug diameter/nugget diameter (Pd/Nd) ≥ 0.70 and current range from 7.2 to 8.8 kA.

Table: 7

Product : Mastic Adhesive no:1				
Test		Specification	TEST#1	
Initial Adhesion Characteristic (170 Deg C x 20 Mins)	Shearing Strength Mpa (Kgf/cm2)	Min 2 Kgf/cm2	2.96	
Low Baking Resistance (160 Deg.C x 20 Mins +(140deg.C x 20 Mins)		Not to Exceed 30 % of Initial Drop Rate	23.30	
Moisture Resistance Test (50 Deg.C x 95% RH x 120 Hrs)	Shearing Strength Mpa (Kgf/cm2)	Min 2 Kgf/cm2	2.76	
Oil Surface Fixation Test		Applied Sealer adheres cleanly to test piece & no Cobwebbing	Passes	

Product : Mastic Adhesive no:2 and 3				
Test		Specification	TEST#2	TEST#3
Initial Adhesion Characteristic (170 Deg C x 20 Mins)	Shearing Strength Mpa (Kgf/cm2)	Min 8 Kgf/cm2	9.07	9.19
Low Baking Resistance (160 Deg.C x 20 Mins + (140deg.C x 20 Mins)		Not to Exceed 30 % of Initial Drop Rate	23.87	23.34

Moisture Resistance Test (50 Deg.C x 95% RH x 120 Hrs)	Shearing Strength Mpa (Kgf/cm2)	Min 8 Kgf/cm2	9.33	9.07
Oil Surface Fixation Test		Applied Sealer adheres cleanly to test piece & no Cobwebbing	Passes	Passes

For validating adhesiveness, three kinds of Mastic Adhesive are used. With these adhesives tests like Initial Adhesion Characteristic, Low Baking Resistance, Moisture Resistance Test and Oil Surface Fixation Test and Oil Surface Fixation Test with different test conditions which are mentioned in table: 7.

As illustrated in table 1 to table 7, the weight percent range of constituents and the selective process parameters according to the invention are validated through following examples 1 & 4:

Example-1:

For example steel no. 1a and 1b have the same chemistry with wt% of Cr (high in amount), without Mo and B addition which are out of scope of the invention, and processed in CGL only shows poor BHI and poor surface quality.

Example-2:

For example Sample no. 2a,2b,2c,2d and 2e have same chemistry with wt% of C (high), Cr (without Mo and B addition) with different Si & Ti content , which are out of scope of the invention, and processed in CGL only shows low YS , low n value and poor surface quality.

Example-3:

For example Sample no. 3a and 3b have same chemistry with wt% of Si (high), Cr (high), without Mo and B addition which are out of scope of the invention, and processed in CGL only shows low YS, low UTS, low n-value, low HER% and poor surface quality.

Example-4:

Sample no: 4a-4t have the same chemistry which are in the scope of the invention. However they vary with different sets of process parameters.

For example 4a-4f, processed only in CGL after cold rolling with variation in SS temperature shows poor surface quality. While sample no. 4g-4t processed in CAL with CGL after cold rolling shows good surface quality in terms of coating powdering level and uniform coating weight and good mechanical property as well. Further, the weldability and adhesive properties of the invented steel is excellent as discussed in table no. 6 and 7.

It can be appreciated from Table 1 to Table 7 that steel sheets remarked as “T” are satisfying all the scopes of the present invention and exhibits excellent strain hardening property, HER% and coating properties. These steels exhibit improved n value >0.15 , HER % ≥ 35 , UTS ≥ 780 MPa and Yield strength more than 450 MPa. Whereas, Steel remarked that ‘C’ from Table 1 to Table 7 doesn’t comply with atleast one of the scope of the present invention and does not conform with minimum one or more of the end product attributes as mentioned in the scope of the present invention.

We Claim:

1. A cold-rolled hot-dip galvanized DP780 steel sheet comprises the base steel with following chemical composition in terms of weight %:

C: 0.07—0.12 %;

Mn: 1.6—2.1 %;

Si: 0.12—0.30 %;

Al: 0.03—0.2 %;

S: 0.001—0.005 %;

N: 0.002—0.006 %;

Ti: 0.005—0.05 %;

Nb: 0.005—0.05 %;

V: 0.005—0.05 %;

Mo: 0.02—0.1 %;

Cr: 0.3—0.55 %;

B: 0.0018-0.0030%;

the balance being Fe and other unavoidable impurities and satisfies the following relation: weight % $[Mn] / ([Si] + [Al])$: 3.2—14, preferably 4—5 and carbon equivalent 0.3% or less and which is free of bare spots favouring arresting deterioration in weldability and coating adhesion on surface .

2. The cold-rolled hot-dip galvanized DP780 steel sheet as claimed in claim 1, obtained of said composition based casted steel slab subjected to hot rolling, pickling cum cold rolling, continuous annealing and hot dip galvannealing process.

3. The cold-rolled hot-dip galvanized DP780 steel sheet as claimed in claim 1, wherein the base steel comprises the weight % of Ti, Nb or V in combination is less than 0.09 wt%.
4. The cold-rolled hot-dip galvanized DP780 steel sheet as claimed in claim 1, wherein the microstructure of the base steel sheet comprises the following components in percentage by volume: 55-65 of ferrite, 25-32 % of martensite, 0 - 4% retained austenite and bainite/pearlite of 8-17%.
5. The cold-rolled hot-dip galvanized DP780 steel sheet as claimed in claim 1, wherein the thickness of the cold-rolled hot-dip galvanized DP780 steel is 1.4 mm.
6. The cold-rolled hot-dip galvanized DP780 steel sheet as claimed in claim 1, which is cold-rolled hot-dip galvanized DP780 steel having yield strength in the range of 450-550 MPa, tensile strength in the range of 780-900 MPa, yield ratio in the range of 0.5-0.70, strain hardening coefficient ≥ 0.15 , hole expansion ratio (HER) in the range of 35-60 % and bake hardening index (BHI) in the range of 30-60 MPa.
7. The cold-rolled hot-dip galvanized DP780 steel sheet as claimed in claim 1, which generates cold-rolled hot-dip galvanized DP780 steel spot-welded joint having a cross tensile strength (CTS) 7.5-18 kN/spot when performed with plug diameter/nugget diameter (Pd/Nd) ≥ 0.70 and current range from 7.2 to 8.8 kA.
8. The cold-rolled hot-dip galvanized DP780 steel sheet as claimed in claim 1, which passes the mastic adhesive test to evaluate the adhesiveness.
9. The cold-rolled hot-dip galvanized DP780 steel sheet as claimed in claim 1, comprising a uniform coating weight of 90 gsm for top and bottom defect-free surface.

10. The cold-rolled hot-dip galvanized DP780 steel sheet as claimed in claim 1, which passes antipowdering test.
11. A method of manufacturing cold-rolled hot-dip galvanized DP780 steel sheet as claimed in claim 1, including casting process, slab continuous casting, hot rolling, acid pickling, cold rolling, continuous annealing, continuous hot galvanizing and galvannealing and is characterized in that:

Step 1: Continuous Casting Process: To achieve the designed chemistry as mentioned in claim 1, the carbon-rich molten pig iron is converted into steel using the Basic Oxygen Furnace (BOF) in primary steel making stage. For temperature homogenization, chemistry achievement as mentioned in the scope of invention the aim grade for C, Mn, S, P, Si, Al and other alloying elements the heat is processed through Ladle Heating Furnace (LHF) in Secondary making process. To homogenize the liquid steel composition and bath temperature and to remove inclusions from the liquid steel RH degassing process is then adopted. Subsequently, the molten steel is casted into slab in the continuous casting process.

Step 2: Hot Rolling: Reheating the slab to temperature in the range from 1180—1300 °C, the reheated slab being subjected to roughing rolling in roughing mill with roughing mill delivery temperature of 1050—1080 °C to form a rough rolled substrate, the rough rolled substrate being subjected to finish rolling with finish mill exit temperature ranging from A_{c3} °C to $A_{c3}+100$ °C to form a hot-rolled substrate, coiling the hot-rolled substrate at coiling temperature in the range of 550—650 °C to form a hot-rolled coil.

Step 3: Acid Pickling: Pickling the hot-rolled coil in a continuous line with concentrated acid-HCl to remove the surface scale to form a hot-rolled pickled coil.

Step 4: Cold Rolling: Cold rolling the hot-rolled pickled coil to form a cold-rolled coil, wherein it processed with a cold reduction of 35–60 %.

Step 5: Continuous Annealing: Subjecting the cold-rolled coil to continuous annealing, soaking the cold-rolled coil at a temperature range between 770°C to 830°C with a residence time of 50 sec to 100 sec, slow cooling further said steel at a temperature range of 630°C to 680°C with a cooling rate of 1–4 °C/sec, rapid cooling of said steel at a temperature in the range of 450 °C to 510 °C with a cooling rate of 15 °C/sec, over aging of said steel at a temperature range between 360 °C to 410 °C more with a residence time of 180–350 sec. No skin pass or oiling is applied in after this stage.

Step 6: Continuous Hot Dip Galvannealing: Annealing the cold rolled closed annealed steel sheet at soaking section within the inter critical temperature range of $Ac1+10\text{ }^{\circ}\text{C}$ to $Ac3-10\text{ }^{\circ}\text{C}$ with residence time ranging from 65–160 sec; Rapid cooling the steel from SS temperature up to a temperature range of 440–470 °C; dipping the sheet in the zinc bath where the temperature of the said steel in the range starting from 440–460 °C; galvannealing at temperature range of 530–570 °C to form Zn-Fe alloy coating on the substrate; Subjecting the coated steel to skin pass elongation of 0.2% to 0.8%.

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ABSTRACT

TITLE: COLD-ROLLED HOT-DIP GALVANNEALED DP780 STEEL SHEET WITH EXCELLENT WELDING PERFORMANCE AND SUPERIOR ADHESIVENESS OF COATED LAYER AND MANUFACTURING METHOD THEREOF.

The present invention discloses a cold-rolled hot-dip galvanized DP780 steel with excellent welding performance and superior adhesiveness to the coated layer comprises the base steel sheet with following chemical composition in terms of weight %: C: 0.07-0.12%; Mn:1.6- 2.1 %; Si:0.12–0.30 %; Al:0.03-0.2 %; S:0.001-0.005 %; N:0.002-0.006 %; Ti:0.005-0.05 %; Nb:0.005-0.05 %; V:0.005-0.05 %; Mo:0.02-0.1 %; Cr:0.3-0.55 %; B:0.0018-0.0030%; the balance being Fe and other unavoidable impurities and satisfies the following relation: weight % $[Mn] / ([Si] + [Al])$: 3.2-14, preferably 4-5 and carbon equivalent 0.3% or less. The casted steel slabs having the above composition are subjected to hot rolling, pickling cum cold rolling, continuous annealing and hot-dip galvannealing process. The cold-rolled hot-dip galvanized DP780 steel spot-welded joint has a cross tensile strength(CTS)7.5-18 kN/spot when performed with plug diameter/nugget diameter (Pd/Nd) ≥ 0.70 and current range from 7.2 to 8.8kA, and the sheets passes the mastic adhesive test to evaluate the adhesiveness.

(Figure 1)