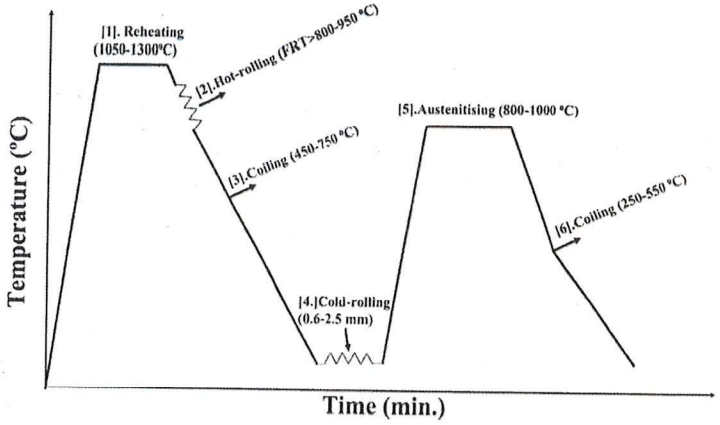


Figure 1

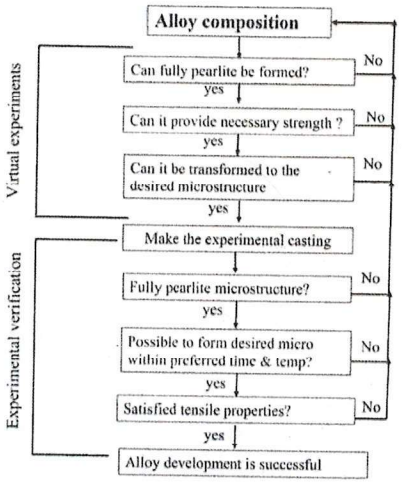


Figure 2

Dated 24th day of April, 2023

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INDIAN INSTITUTE OF TECHNOLOGY KHARAGPUR
(Applicants)

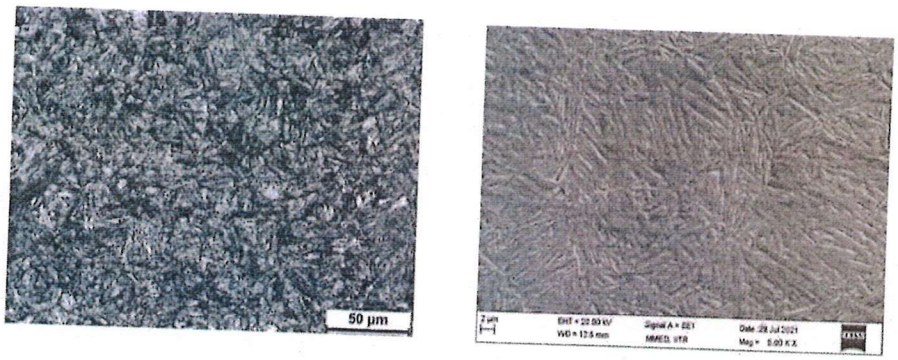


Figure 3

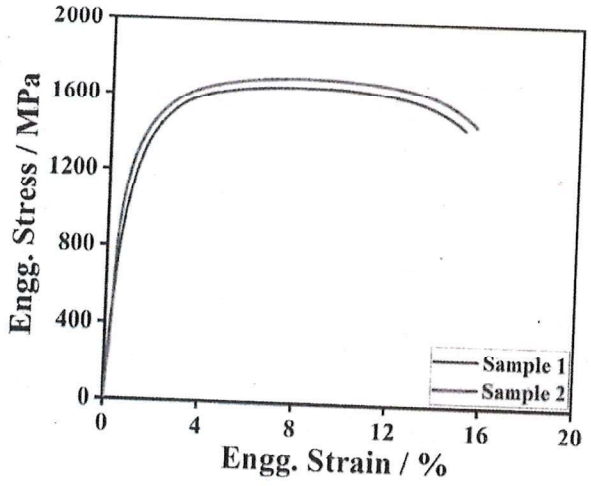


Figure 4

Dated .24th. day of _ April _, 2023

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

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INDIAN INSTITUTE OF TECHNOLOGY KHARAGPUR

(Applicants)

FORM 2

THE PATENTS ACT, 1970

(39 of 1970)

&

The Patent Rules, 2003

COMPLETE SPECIFICATION

(See sections 10 & rule 13)

1. TITLE OF THE INVENTION

A COLD ROLLED BAINITIC STEEL WITH HIGH STRENGTH AND HIGH ELONGATION

2. APPLICANT (S)

S. No.	NAME	NATIONALITY	ADDRESS
1	**INDIAN INSTITUTE OF TECHNOLOGY ROORKEE**	IN	Roorkee- 247667, Uttarakhand, India.
2	**INDIAN INSTITUTE OF TECHNOLOGY KHARAGPUR**	IN	Kharagpur, West Bengal- 721302, India.

3. PREAMBLE TO THE DESCRIPTION

COMPLETE SPECIFICATION

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

FIELD OF INVENTION:

[001] The present invention relates to designing the composition of cold-rolled steel sheets and a method of manufacturing the same. The present invention, in particular, relates to high-strength cold-rolled steel sheet having high elongation, mainly for the automobile structural components or the like, and a method of manufacturing the same.

DESCRIPTION OF THE RELATED ART:

[002] In order to suppress emissions of carbon dioxide gas from a vehicle, it is desirable to reduce the weight of a vehicle body by employing a high-strength steel sheet. In addition, to ensure the safety of an occupant, a high-strength steel sheet has been widely used instead of a soft steel sheet in the vehicle body.

[003] Thus, the main challenge for a metallurgist is to design novel steel to achieve a good balance of strength and elongation. It is imperative that the newly developed alloy with such high strength and elongation combination should be in the cold-rolled form as most of the automotive crash resistance components are made from such steels only.

[004] Henceforth, in order to further reduce the weight of the vehicle body, it is necessary to increase the strength level of the high-strength steel sheet to be equal to or higher than that of the related art. However, in general, when strength of the steel sheet is increased, formability deteriorates. In order to use the steel sheet as a vehicle member, it is necessary to perform various forming processes, and thus, it is also necessary to improve formability in addition to the strength for forming the high-strength steel sheet as a vehicle member.

[005] In addition, in a weight reduction of a component for a mechanical structure that configures a vehicle or the like, thickness reduction of the component by achieving a high strength of steel to be used and volume reduction of the component itself by forming a piercing hole are efficient. However, in forming the piercing

hole, it is preferable to employ punching on an industrial scale, but excessive stress and strain are concentrated on an end surface of a punching portion. Therefore, in particular, in the high-strength steel sheet, in the case of performing the punching, there is a problem in that voids are generated on a boundary of a low-temperature transformation phase or residual austenite, and punching fatigue properties deteriorate.

[006] For example, in the case of using the high-strength steel sheet in a frame component, elongation and hole expansibility as above described formability are required in the steel sheet. Therefore, in the related art, in the high-strength steel sheet, several means for improving elongation and hole expansibility are suggested.

[007] Reference may be made to the following:

[008] IN Publication No. 201917041661 relates to a cold-rolled steel sheet with a tensile strength of at least 980 MPa has a prescribed chemical composition. The microstructure in the area% is ferrite: 1-29% retained austenite: 5-20% martensite: less than 10% pearlite: less than 5% and balance: bainite and/or tempered martensite. The total length of interfaces where ferrite is in contact with martensite or with retained austenite having an equivalent circular radius of at least 1 μm is 100 μm or less per 1000 μm2.

[009] Lower assured minimum strength (980 MPa), presence of pearlite (upto 5%), presence of ferrite (1-29%) make this steel different from present invention. Their processing is also different. Low coiling temperature after hot rolling (540-600 °C), lower amount of reduction in CR (52-60%), isothermal holding at IBT (5-108 s) at a temperature range of (390-410 °C), absence of continuous cooling are the differentiating parameters during processing.

[010] IN Publication No. 202017014938 relates to a cold rolled and heat treated steel sheet having a composition comprising of the following elements, expressed in percentage by weight 0.10 % = Carbon = 0.5 %, 1 % = Manganese = 3.4 %, 0.5 % = Silicon = 2.5 %, 0.03 % = Aluminum = 1.5%, Sulfur = 0.003 %, 0.002 % =

Phosphorus = 0.02 %, Nitrogen = 0.01% and can contain one or more of the following optional elements 0.05 % = Chromium = 1 %, 0.001 % = Molybdenum = 0.5 %, 0.001 % = Niobium = 0.1 %, 0.001 % = Titanium = 0.1 %, 0.01 % = Copper = 2 %, 0.01 % = Nickel = 3 %, 0.0001 % = Calcium = 0.005 %, Vanadium = 0.1 %, Boron = 0.003 %, Cerium= 0.1 %, Magnesium= 0.010 %, Zirconium= 0.010 % the remainder composition being composed of iron and the unavoidable impurities caused by processing, and a microstructure of the said rolled steel sheet comprises by area fraction, 10 to 30% Residual Austenite, 5 to 50% Annealed Bainite, 10 to 40 % of Bainite, 1% to 20% Quenched Martensite, and less than 30 % Tempered Martensite where the combined presence of Bainite and Residual Austenite shall be 30% or more.

[011] Presence of annealed bainite (5-50%), presence of tempered martensite (upto 30%), make this a different steel from present invention.

[012] Their processing route is also different. Low coiling temperature after hot rolling (450-550 °C), lower amount of reduction in CR (48-51%), isothermal holding at IBT (200-350s) at a temperature range of (400-410 °C), absence of continuous cooling are the differentiating parameters during processing.

[013] IN Publication No. 202017028366 relates to a high-strength cold-rolled steel sheet, having a tensile strength of 1320 MPa or more.

[014] Here the microstructural constituents are different. Here, the presence of tempered martensite (15-60%), total volume of ferrite+ bainite content (10-50%) is mentioned which is absent in present invention. The microstructure in IN202017028366 also mentions the presence of ferrite/bainite ~10-50% which is lower than our application. Cr is also absent in this patent and is a differentiator.

[015] Their processing route is also different. Isothermal holding at IBT (10 sec or more) at a temperature range of (250-350 °C), absence of continuous cooling are the differentiating parameters during processing. Moreover, they have used 2nd and

3rd annealing as well after the IBT treatment and none of these were adopted in present study.

[016] IN Publication No. 202017029395 relates to a high-strength cold rolled steel sheet, having a tensile strength of 980 MPa or more, essentially consisting of: a composition containing, in mass%, C: more than 0.15% and 0.45% or less, Si: 0.5% or more and 2.5 % or less, Mn: 1.5% or more and 3.0% or less, P: 0% to 0.05%, S: 0% to 0.01%, Al: 0.01 % or more and 0.1 % or less, and N: 0% to 0.01 %, with a balance consisting of Fe and inevitable impurities; and a microstructure in which: a total area ratio of ferrite and bainitic ferrite is 20 % or more and 80 % or less; an area ratio of retained austenite is more than 10 % and 40 % or less; an area ratio of tempered martensite is more than 0 % and 50 % or less; a ratio of retained austenite with an aspect ratio of 0.5 or less to the retained austenite is 75 % or more in area ratio; further as described in claims and description.

[017] Here the microstructural constituents are different. Here, the presence of tempered martensite is mentioned which is absent in present invention.

[018] Their processing route is also different. Isothermal holding at IBT (10 sec or more) at a temperature range of (250-550 °C), absence of continuous cooling are the differentiating parameters during processing. Moreover, they have used 2nd and 3rd annealing as well after the IBT treatment and none of these were adopted in present invention.

[019] IN Publication No. 202017019819 relates to a high-strength cold-rolled steel sheet having a prescribed chemical composition, wherein: the metallic structure of the steel sheet includes, by area ratio, 10-50% of ferrite and a granular bainite in total, 10- 50% of one or both of upper bainite and lower bainite in total, more than 0% but not more than 30% of a tempered martensite, at least 5% of residual austenite, and 0-10% of one or more of pearlite, cementite, and martensite in total; the area ratio of ferrite is not more than 25% with respect to the total area ratio of ferrite and the granular bainite; and the steel sheet has a tensile strength of at least 980 MPa. (EN)

[020] Presence of tempered martensite, only about 25% of ferrite/bainite make it different from present invention.

[021] Their processing route is also different. Isothermal holding at IBT (3 sec or more), comparatively higher coiling temperature (500-650 °C) after CR, absence of continuous cooling are the differentiating parameters during processing.

[022] IN Publication No. 202017016161 relates to a cold rolled heat treated steel sheet having a composition comprising of the following elements, expressed in percentage by weight 0.1 % = Carbon = 0.5 %, 1 % = Manganese = 3.4 %, 0.5 % = Silicon = 2.5 %, 0.03 % = Aluminum = 1.5 %, 0% = Sulfur = 0.003 %, 0.002 % = Phosphorus = 0.02 %, 0% = Nitrogen = 0.01 % and can contain one or more of the following optional elements 0.05 % = Chromium = 1 %, 0.001 % = Molybdenum = 0.5 %, 0.001 % = Niobium = 0.1 %, 0.001 % = Titanium = 0.1 %, 0.01 % = Copper = 2 %, 0.01 % = Nickel = 3 %, 0.0001 % = Calcium = 0.005 %, 0% = Vanadium = 0.1 %, 0% = Boron = 0.003 %, 0% = Cerium= 0.1 %, 0% = Magnesium= 0.010 %, 0% = Zirconium= 0.010 %, the remainder composition being composed of iron and unavoidable impurities caused by processing, the microstructure of said steel sheet comprising in area fraction, 10 to 30% Residual Austenite, 50 to 85% Bainite, 1 to 20% Quenched Martensite, and less than 30% Tempered Martensite.

[023] Presence of tempered martensite, which is absent in present invention.

[024] Their processing route is also different. Low coiling temperature after hot rolling (450-550 °C), isothermal holding at IBT (15-100 sec) at a temperature range of (below 500 °C), absence of continuous cooling are the differentiating parameters during processing. Moreover, they have used 2nd annealing as well after the IBT treatment and none of these were adopted in present invention.

[025] IN Publication No. 202017017355 relates to a cold rolled and heat treated steel sheet, the steel comprising, in weight percentage, 0.18% = carbon = 0.24%, 1.5% = manganese = 2.5%, 1.2% = silicon =2%, 0.01% = aluminum =0.06%,

0.2%= chromium = 0.5%, phosphorus = 0.02%, sulfur = 0.03%, and optionally one or more of the following elements niobium = 0.06%, titanium = 0.08%, vanadium =0.1%, calcium = 0.005% and the balance including iron and unavoidable impurities, the steel sheet having a microstructure comprising 0% to 15% of tempered martensite, 10% to 15% of residual austenite and optionally up to 30% of ferrite in area fractions, the balance being made of bainite, bainite content being at least 55% and having an internal oxide layer of 3 microns or less on both surfaces of said steel sheet. It also deals with a manufacturing method and with use of such grade for making vehicle parts.

[026] The description mentions about the presence of upto 30% ferrite and upto 15% tempered martensite both of which are not applicable for present case. Moreover, the chemical compositions are also different: *e.g.*C and Cr content are far less (0.18-0.24 wt%, 0.2% Cr).

[027] Their processing route is also different. Low coiling temperature after hot rolling (below 570 °C), isothermal holding at IBT (200-1000 sec) at a temperature range of (350-450 °C), absence of continuous cooling are the differentiating parameters during processing. Hot band annealing at a temperature between 350°C and 750°C before CR was also not adopted in present invention.

[028] IN Publication No. 202127001813 relates to a high-strength steel plate having excellent delayed fracture resistance and tensile strength of at least 980 MPa; and a method for producing the same.

[029] Presence of martensite is very high and bainite content is very low compared to present steel. Moreover, ferrite is present which is not the case for present system. They have too low amount of austenite compared to ours. Full chemical composition is not disclosed. Guaranteed minimum strength is only 980 MPa.

[030] IN Publication No. 202127001812 relates to a high-strength steel plate having excellent delayed fracture resistance and a tensile strength of at least 980 MPa; and a method for producing same.

[031] Presence of martensite is very high and bainite content is very low compared to present steel. Moreover, ferrite is present which is not the case for us. They have too low amount of austenite compared to ours. Full chemical composition is not disclosed. Guaranteed minimum strength is only 980 MPa.

[032] IN Publication No. 202117010987 relates to a cold rolled and heat treated steel sheet having a composition comprising of the following elements 0.13 % = Carbon = 0.18 %,1.1 % = Manganese = 1.8%, 0.5 % = Silicon = 0.9 %, 0.6 % = Aluminum = 1%, 0.002 % = Phosphorus = 0.02 %, 0 % = Sulfur = 0.003 %,0 % = Nitrogen = 0.007% and can contain one or more of the following optional elements 0.05% = Chromium = 1 %, 0.001% = Molybdenum = 0. 5%, 0.001% = Niobium = 0.1%, 0.001% = Titanium = 0.1%, 0.01% = Copper = 2%, 0.01% = Nickel = 3%, 0.0001% = Calcium = 0.005%, 0 % = Vanadium = 0.1%, 0 % = Boron = 0.003%, 0 % = Cerium = 0.1%, 0 % = Magnesium ? 0.010%, 0 % = Zirconium ? 0.010%, the remainder composition being composed of iron and unavoidable impurities caused by processing, the microstructure of said steel sheet comprising in area fraction, 60 to 75% Ferrite, 20 to 30% Bainite, 10 to 15% Residual Austenite, and 0% to 5% Martensite, wherein the cumulated amounts of Residual Austenite and Ferrite is between 70% and 80%.

[033] The above patent described the presence about 60-75% ferrite along with 20-30% bainite. This microstructure is different from present invention.

[034] Their processing route is also different. Low coiling temperature after hot rolling (below 625 °C), isothermal holding at IBT (5-500 sec) at a temperature range of (250-470 °C), absence of continuous cooling are the differentiating parameters during processing. Annealing of hot rolled steel sheet at temperature between 400 °C and 750 °C before CR and cold rolled steel sheet by a two-step heating were not adopted in present invention.

[035] IN Publication No. 202117018670 relates to a high-strength steel sheet excellent in strength-ductility balance and stability of mechanical properties, and a method for manufacturing the same.

[036] The microstructural description is open-ended, no quantified number is given for any harder phase. No mechanical property is mentioned.

[037] Their processing route is also different. Lower amount of maximum reduction in CR (52-60%), lower annealing temperature after CR (720-750°C), direct quenching upto room temperature (10 C/s cooling rate), absence of continuous cooling are the differentiating parameters during processing.

[038] IN Publication No. 202117050387 relates to a cold rolled and coated steel sheet having a composition comprising of the following elements, expressed in percentage by weight:0.140%=Carbon=0.2%, 1.5%=Manganese=2.15%, 0.5%=Silicon=0.8%, 0.4%=Aluminum=0.8%, 0%=Phosphorus=0.09%, 0% =Sulfur=0.09%, 0%=Nitrogen=0.09%, 0.01% = Niobium = 0.1%, 0.01% = Titanium = 0.1%, and can contain one or more of the following optional elements 0%=Chromium=0.1%, 0%=Nickel=3%, 0%=Calcium=0.005%, 0%=Copper=2%, 0%=Molybdenum=0.5%, 0%=Vanadium=0.1%, 0%=Boron=0.003%, 0%=Cerium=0.1%, 0%=Magnesium?0.010%, 0%=Zirconium?0.010% the remainder composition being composed of iron and unavoidable impurities caused by processing, the microstructure of said steel sheet comprising in area fraction, 40 to 60% Inter-critical Ferrite, 25 to 45% Transformed Ferrite, 8% to 20% and 5% to 20% Fresh Martensite, 0 to 10% Bainite, wherein the cumulated amount of Inter-critical and Transformed Ferrite is between 75% and 85%. Presence of bainite is very less and intercritical ferrite is present. No austenite is mentioned. These makes this steel different than present invention.

[039] Their processing route is also different. Low coiling temperature after hot rolling (below 600 °C), hot band annealing at 400-750 C before cold rolling, step heating to annealing temperature after CR, isothermal holding at IBT (5-500 sec) at a temperature range of (350-410 °C), absence of continuous cooling are the differentiating parameters during processing.

[040] IN Publication No. 202017014941 relates to a cold rolled and heat treated steel sheet having a composition comprising of the following elements, expressed

in percentage by weight:0.10 % = Carbon = 0.5 %,1 % = Manganese = 3.4%, 0.5 % = Silicon = 2.5 %, 0.03 % = Aluminum = 1.5 %, 0 % = Sulfur = 0.003 % 0.002 % = Phosphorus = 0.02 %, 0 % = Nitrogen = 0.01%and can contain one or more of the following optional elements 0.05% = Chromium = 1 %, 0.001% = Molybdenum = 0. 5%, 0.001% = Niobium = 0.1%, 0.001% = Titanium = 0.1%, 0.01% = Copper = 2%, 0.01% = Nickel = 3%, 0.0001% = Calcium = 0.005%, 0 % = Vanadium = 0.1%, 0 % = Boron = 0.003%, 0 % = Cerium = 0.1%, 0 % = Magnesium ? 0.010%, 0 % = Zirconium ? 0.010% the remainder composition being composed of iron and unavoidable impurities caused by processing, the microstructure of said steel sheet comprising in area fraction, 10 to 30% Residual Austenite, 10 to 40% Bainite, 5% to 50% Annealed Martensite, 1% to 20% Quenched Martensite and less than 30% Tempered Martensite, wherein the cumulated amounts of Bainite and Residual Austenite is more than or equal to 25%.

[041] Presence of tempered martensite, annealed martensite and very low amount of bainite make this steel different than present invention.

[042] IN Publication No. 201937039631 relates to a high strength cold-rolled steel sheet which has a tensile strength of 980 MPa or more exhibits excellent ductility and stretch flange characteristics and has a low defect ratio in a hole enlargement test. Guaranteed tensile property is too low compared to present invention.

[043] Their processing route is also different. Lower amount of minimum reduction in CR (above 30 %), isothermal holding at IBT (10 sec or more) at a temperature range of (300-500°C), absence of continuous cooling are the differentiating parameters during processing. Moreover, they have used 2nd annealing as well after the IBT treatment and none of these were adopted in present invention.

[044] IN Publication No. 201617028485 relates to a high strength cold-rolled steel sheet which has a high yield ratio and which exhibits excellent elongation and hole expansion properties. This steel sheet includes 0.15-0.25 mass% of C 1.8-3.0 mass% of Mn and 0.0003-0.0050 mass% of B.

[045] Presence of tempered martensite is mentioned but that is absent in present invention. Addition of alloying elements is also different from our work (C is too low, no Si is disclosed, B is present).

[046] Their processing route is totally different. Hot rolling is performed in three steps. absence of continuous cooling are the differentiating parameters during processing.

[047] IN Publication No. 201737009410 relates to a high strength cold rolled steel sheet which solves problems of the prior art and has a good balance among a plurality of characteristics (yield ratio strength elongation bore expanding properties and delayed fracture resistance), and a method for producing this high strength cold-rolled steel sheet.

[048] Presence of ferrite and tempered martensite make it different than present invention. No tensile property is mentioned.

[049] IN Publication No. 201717022731 relates to a high-strength cold-rolled steel sheet having a tensile strength of 980 MPa or more, a yield ratio of 66% or less, an elongation of 19% or more and a hole expansion ratio of 30% or more, the high-strength cold-rolled steel sheet having a chemical composition containing, by mass%, C: 0.15% to 0.25%, Si: 1.0% to 2.0%, Mn: 1.8% to 2.5%, P: 0.10% or less, S: 0-.010-% or less, Al: 0.10% or less, N: 0.010% or less, and optionally one or more selected from V: 0.10% or less, Nb: 0.10% or less, Ti: 0.10% or less, and optionally B: 0.010% or less, and optionally one or more selected from Cr: 0.50% or less, Mo: 0.50% or less, Cu: 0.50% or less, Ni: 0.50% or less, Ca: 0.0050% or less, REM: 0.0050% or less, the balance being Fe and inevitable impurities including Sb: 0.01% or less, Sn: 0.10% or less, Zn: 0.01% or less, and Co: 0.10% or less, and a multi-phase microstructure including ferrite having an average crystal grain diameter of 5 μm or less in an amount of 30% to 55% in terms of volume fraction, retained austenite having an average crystal grain diameter of 2 μm or less in an amount of 5% to 15% in terms of volume fraction, and tempered martensite having an average crystal grain diameter of 2 μm or less in an amount of 30% to

60% in terms of volume fraction, the remainder being pearlite in an amount of 5% or less in terms of volume fraction, and tempered bainite in an amount of 30% or less in terms of volume fraction, wherein the average crystal grain diameters are circle-equivalent diameters of the phases, wherein the number of grains of the retained austenite existing in an area of 1000 μm2 is 10 or more. Presence of tempered martensite, tempered bainite, ferrite and pearlite make this a different steel than ours. bainite & tempered martensite is very high, and the strength is less in comparison to the present invention.

[050] Their processing route is also different. Low coiling temperature after hot rolling (below 650 °C), lower amount of minimum reduction in CR (above 30 %), isothermal holding at IBT (120 sec or more) at a temperature range of (320-500°C), absence of continuous cooling are the differentiating parameters during processing. Moreover, they have used 2nd, 3rd and 4th annealing as well after the IBT treatment and none of these were adopted in the present invention.

[051] IN Publication No. 201917023775 relates to a cold-rolled steel sheet, the steel comprising, in weight percentage, 0.19% ≤ carbon ≤ 0.24%, 1.9% ≤ manganese ≤ 2.2%, 1.4% ≤ silicon ≤ 1.6%, 0.01% ≤ aluminum ≤0.06%, 0.2%≤ chromium ≤ 0.5%, phosphorus ≤ 0.02%, sulfur ≤ 0.003%, and optionally one or more of the following elements 0.0010% ≤ niobium ≤ 0.06%, 0.001% ≤ titanium ≤ 0.08%, 0.001%≤ vanadium ≤0.1%, 0.001% ≤ calcium ≤ 0.005% and the balance including iron and unavoidable impurities, the steel sheet having a microstructure comprising 5% to 15% of tempered martensite, 10% to 15% of residual austenite and optionally up to 5% of ferrite in area fractions, the balance being made of bainite, bainite content being at least 70%. It also deals with a manufacturing method and with the use of such grades for making vehicle parts.

[052] Presence of tempered martensite is different from our work. Moreover, C content is far less than present invention. No assured mechanical property is mentioned.

[053] Their processing route is also different. Low coiling temperature after hot rolling (below 600 °C), isothermal holding at IBT (250 sec or more) at a temperature range of (350-450°C), absence of continuous cooling are the differentiating parameters during processing. Hot rolled steel sheet was exposed to an annealing at a temperature between 400 and 750°C which was not adopted in present invention.

[054] IN Publication No. 11840/DELNP/2015 relates to a cold-rolled and hot-dip coated steel sheet presenting a tensile strength above 1000 - 50xAIMPa, a uniform elongation above 15% and a low density.

[055] Presence of kappa precipitates, high amount of ferrite make it different than present invention.

[056] IN Publication No. 8669/DELNP/2013 relates to a high-strength hot-rolled steel sheet having excellent local deformability comprising: in mass%, C: not less than 0.07% nor more than 0.20%; Si: not less than 0.001% nor more than 2.5%; Mn: not less than 0.01% nor more than 4.0%; P: not less than 0.001% nor more than 0.15%; S: not less than 0.0005% nor more than 0.03%; Al: not less than 0.001% nor more than 2.0%; N: not less than 0.0005% nor more than 0.01%; 0: not less than 0.0005% nor more than 0.01%; and a balance being composed of iron and inevitable impurities.

[057] Low C content and absence of Cr makes it different from present invention. No mention about austenite and minimum 95% bainite makes its microstructure different from present invention.

[058] Their processing route is also different. Hot rolling is in two steps. Low coiling temperature after hot rolling (350-650 °C), lower amount of reduction in CR (above 40 %). They did not disclose anything related to the thermal treatment after cold rolling, like, annealing temperature, cooling rate, continuous cooling or isothermal holding etc.

[059] IN Publication No. 202037033022 relates to a high-strength cold-rolled steel sheet and method of production thereof. The high-strength cold-rolled steel sheet is characterized by having: a composition of: C: 0.060% to 0.250%, Si: 0.50% to 1.80%, Mn. 1.00% to 2.80%, P: 0.100% or less, S: 0.0100% or less, Al: 0.010% to 0.100%, and N: 0.0100% or less, optionally at least one element selected from the group consisting of Mo: 0.01% to 0.50%, B: 0.0001% to 0.0050%, and Cr: 0.01% to 0.50%, optionally at least one element selected from the group consisting of: Ti: 0.001% to 0.100%, Nb: 0.001% to 0.050%, and V: 0.001% to 0.100%, optionally at least one element selected from the group consisting of Cu: 0.01% to 1.00%, Ni: 0.01% to 0.50%, As: 0.001% to 0.500%, Sb: 0.001% to 0.100%, Sn: 0.001% to 0.100%, Ta: 0.001% to 0.100%, Ca: 0.0001% to 0.0100%, Mg: 0.0001% to 0.0200%, Zn: 0.001% to 0.020%, Co: 0.001% to 0.020%, Zr: 0.001% to 0.020%, and REM: 0.0001% to 0.0200%, on a mass percent basis, a remainder being Fe and incidental impurities and a steel microstructure containing 1 to 8% by area of martensite wherein a standard deviation of a grain size of martensite at five portions being 0.7 pm or less.

[060] Low C content, optional addition of Cr (max 0.5%) make its composition different than present invention. Incomplete microstructural description (1-8% martensite is mentioned only).

[061] Their processing route is also different. Lower amount of minimum reduction in CR (above 30 %), isothermal holding at IBT (5 to 1000 sec) at a temperature range of (350-500°C), absence of continuous cooling are the differentiating parameters during processing. Moreover, they have used 2nd annealing as well after the IBT treatment and this was not adopted in present invention.

[062] IN Publication No. 202017019184 relates to a cold rolled and heat treated steel sheet having a composition comprising of elements, expressed in percentage by weight 0.11% = Carbon = 0.15%, 1.1%= Manganese =1.8%, 0.5%= Silicon =0.9%, 0.002%= Phosphorus = 0.02%, 0%= Sulfur =0.003%, 0%= Aluminum =0.05%, 0%= Nitrogen =0.007%, and can contain one or more of optional elements

0.05%= Chromium =1%, 0.001%= Molybdenum =0.5%, 0.001%= Niobium =0.1%, 0.001%= Titanium = 0.1%, 0.01% = Copper = 2%, 0.01% = Nickel = 3%, 0.0001% = Calcium = 0.005%, 0%= Vanadium =0.1%, 0%= Boron =0.003%, 0% = Cerium = 0.1%, 0 % = Magnesium ? 0.010%, 0%= Zirconium ?.010% the remainder being composed of iron and unavoidable impurities, the microstructure of said steel sheet comprising, 50 to 80% Ferrite, 10 to 30% Bainite, 1 to10% Residual Austenite, and 1% to 5% Martensite, wherein the cumulated amounts of Bainite and Residual Austenite is more than or equal to 25%.

[063] Low C content, considering Cr as optional element, low amount of bainite, low amount of austenite make this steel different from present invention. Also, this patent does not disclose anything about tensile strength.

[064] Their processing route is also different. Fast cooling after HR (30 °C/s), low coiling temperature after hot rolling (below 350-550 °C), low temperature of annealing after CR (400-750 °C), isothermal holding at IBT (5-500 sec.) at a temperature range of (250-470°C), absence of continuous cooling are the differentiating parameters during processing. Optional hot band annealing, two steps of heating to reach the soaking temperature were not adopted in present invention.

[065] Publication No. US2022112586 relates to a cold-rolled steel sheet having a composition consisting of (in wt. %): C 0.15-0.25; Si 0.5-1.6; Mn 2.2-2.8; Cr≤0.8; Mo≤0.2; Al 0.03-1.0; Nb≤0.04; V≤0.04; Ti 0.02-0.04; B 0.001-0.005; balance Fe apart from impurities, wherein the impurity contents of Cu and Ni are limited to ≤0.15, the cold-rolled steel has a multiphase microstructure comprising a matrix of bainitic ferrite and ≤10 vol. % polygonal ferrite and the tensile strength (Rm) is 980-1500 MPa.

[066] Low C content, presence of polygonal ferrite make its composition and microstructure different than ours. Their minimum guaranteed minimum tensile strength (1100 MPa), yield strength (780 MPa) and total elongation (7%) are much lower than present invention.

[067] Their processing route is also different. Low coiling temperature after hot rolling (below 550 °C), lower amount of minimum reduction in CR (above 30 %), isothermal holding at IBT (180 sec or more) at a temperature above (405°C), absence of continuous cooling are the differentiating parameters during processing. Hot band annealing used for scale removal was not adopted in present invention.

[068] Publication No. MX2017010754 relates to cold-rolled steel sheet has a predetermined chemical composition, and has a metallographic structure containing, by area fraction, 40.0% to below 60.0% of polygonal ferrite, 30.0% or more of bainitic ferrite, 10.0-25.0% of retained austenite, and 15.0% or less of martensite. In the retained austenite, the proportion of retained austenite having an aspect ratio of 2.0 or less, a major axis length of 1.0 μm or less, and a minor axis length of 1.0 μm or less is 80.0% or more.

[069] Presence of polygonal ferrite (40-60%) makes its microstructure different than present invention.

[070] Their processing route is also different. Low coiling temperature after hot rolling (330-615°C), cooling at three different cooling rate after HR upto coiling temperature, lower amount of reduction in CR (above 30 %), isothermal holding (30 sec or more) at IBT (250-600°C), absence of continuous cooling are the differentiating parameters during processing. Hot band annealing used for scale removal was not adopted in present invention.

[071] Publication No. WO2016158160 relates to a high-strength cold-rolled steel sheet having a tensile strength of 980 MPa or more, having good workability as evaluated by ductility and stretch-flangeability, and having excellent collision characteristics; and a method for producing steel sheet.

[072] Low minimum guaranteed tensile strength (980 MPa), presence of ferrite (10-65%) and the presence of tempered martensite make this steel different from present invention.

[073] Their processing route is also different. Low coiling temperature after hot rolling (600°C or less), lower amount of reduction in CR (above 30 %), absence of continuous cooling are the differentiating parameters during processing. Cold-rolled sheet subjected to electrogalvanizing, hot-dip galvanizing, or alloyed hot-dip galvanizing according to a conventional method were not adopted in present invention.

[074] It is a completely different product itself. This is coated steel whereas present invention is uncoated.

[075] Publication No. RU2768717 relates to metallurgy, namely to cold-rolled annealed steel sheet used for the fabrication of vehicle structural elements.

[076] Presence of martensite is very high but strength is low from present invention. Coiling temperature, soaking time is less and annealing temperature is on higher side comparison of present invention.

[077] Their processing route is also different. Low coiling temperature after hot rolling (400-590°C), lower amount of minimum reduction in CR (above 30 %), isothermal holding at IBT (270 sec or more) at a temperature above (385-450°C), higher range of minimum temperature after CR+annealing, absence of continuous cooling are the differentiating parameters during processing.

[078] Publication No. US2020392598 relates to a high-strength cold-rolled steel sheet that has a tensile strength of 1320 MPa or more, excellent ductility and stretch flangeability, and a low failure rate in a hole expanding test, and a method for manufacturing the same.

[079] Presence of tempered martensite makes it different microstructurally from present invention.

[080] Their processing route is also different. Very fast cooling rate after HR (20 °C/s), lower amount of reduction in CR (above 30 %), higher annealing temperature after CR (> 950 °C), isothermal holding at IBT (10 sec or more) at a temperature

above (250-350°C), absence of continuous cooling are the differentiating parameters during processing. Moreover, they have used 2nd and 3rd annealing as well after the IBT treatment and none of these were adopted in present invention.

[081] Publication No. US2020392610 relates to a high-strength cold-rolled steel sheet that has a tensile strength of 980 MPa or more, excellent ductility, and a low failure rate in a hole expanding test, and a method for manufacturing the same.

[082] Low minimum tensile strength (980 MPa), presence of tempered martensite make it different than present steel.

[083] Their processing route is also different. Fast cooling rate after HR (20 °C/s), lower amount of reduction in CR (above 30 %), cooling at a lower temperature range after CR+ annealing (250-350 °C), multiple annealing after CR (2nd and 3rd time), absence of continuous cooling are the differentiating parameters during processing.

[084] Publication No. US2020095651 relates to a high-strength cold-rolled steel sheet has a specific chemical composition and has a steel microstructure meeting conditions: total content of bainitic ferrite (BF) and tempered martensite (TM) is 65% (in area percent, hereinafter the same for steel microstructure) or more; a fresh martensite (M) content is 3% to 18%; a retained austenite content is 5% or more; and a polygonal ferrite (F) content is 5% or less.

[085] Presence of tempered martensite & and ferrite differentiates this from present steel.

[086] Their processing route is also different. Low coiling temperature after hot rolling (600°C), lower amount of reduction in CR (46-62 %), isothermal holding at IBT (10-70 sec) at a temperature above (200-420°C), absence of continuous cooling are the differentiating parameters during processing. Immersing the cold-rolled steel sheet in a zinc bath these was not adopted in present invention.

[087] This is completedly different product where the said steel is a coated one and present is uncoated.

[088] Publication No. US2020040421 relates to a high strength cold rolled steel sheet has a composition which contains, in terms of mass %, more than 0.15% and not more than 0.45% of C, 0.50-2.50% of Si, 1.50-3.00% of Mn, not more than 0.050% of P, not more than 0.0100% of S, 0.010-0.100% of Al and not more than 0.0100% of N, with the remainder including Fe and unavoidable impurities, has a total content of ferrite and bainitic ferrite of 20-80%, has a retained austenite content of more than 10% and not more than 40%, has a martensite content of more than 0% and not more than 50%, and is such that the proportion of retained austenite that has an aspect ratio of not more than 0.5 is not less than 75%, and the proportion of retained austenite having an aspect ratio of not more than 0.5 that is present at Bain group boundaries is not less than 50%.

[089] Low concentration of Al, possibility of the presence of ferrite, possibility of the presence of martensite upto 50% make this different than present steel.

[090] Their processing route is also different. Very fast cooling after HR (20-100 C/s), lower amount of minimum reduction in CR (30 % or more), isothermal holding at IBT (10 sec or more) at a temperature above (250-350°C), lower range of IBT (250-350 C), absence of continuous cooling are the differentiating parameters during processing. Moreover, they have used 2nd annealing as well after the IBT treatment and none of these were adopted in present invention.

[091] Publication No. JP2018178248 relates to a high strength cold-rolled steel sheet which has a tensile strength of 1,320 MPa or more, has excellent ductility, and also has low ductility anisotropy.

[092] Higher Mn concentration (2.5-4.0%), higher amount of martensite (15-50%), presence of ferrite make this different than present invention.

[093] Their processing route is also different. lower amount of reduction in CR (30% or more), absence of continuous cooling are the differentiating parameters during processing. They have used 2nd annealing as well after the IBT treatment, pickling step subjected to hot-rolled sheet none of these were adopted in present invention.

[094] Publication No. WO2018088421 relates to a high-strength cold-rolled thin steel sheet which has a tensile strength of 980 MPa or more, while exhibiting high ductility and high stretch flangeability; and a method for producing this high-strength cold-rolled thin steel sheet.

[095] Guaranteed tensile strength is low (980 MPa), presence of polygonal ferrite (10-70%) make it different than present invention.

[096] Their processing route is also different. Very fast cooling after HR (40-100°C/s), Low coiling temperature after hot rolling (450-650°C), lower amount of reduction in CR (30% or more), absence of continuous cooling are the differentiating parameters during processing. Moreover, they have used 2nd and 3rd annealing as well after the IBT treatment and none of these were adopted in present invention

[097] Publication No. MX2016012490 relates to a cold-rolled flat steel product and to a method for the production thereof. The flat steel product has a proof stress Rp0.2 of = 320 MPa, an elongation at break A80 of = 20% and a microstructure comprising (in % by unit area) 62-82% ferrite, 10-30% martensite, 1.5-8% residual austenite and in total = 10% other microstructural constituents.

[098] Very low C content (0.06-0.1 wt%), high amount of ferrite (62-82%), lower strength (YS: 330 MPa and UTS: 700 MPa), make this patent different than present invention.

[099] Their processing route is also different. Low coiling temperature after hot rolling (500-650°C), IBT temperature above (lower than 550 °C), absence of

continuous cooling are the differentiating parameters during processing, pickling treatment on hot-rolled plate for removal of oxide layer none of these was adopted in present invention.

[100] Publication No. JP2016113649 relates to a high strength cold-rolled steel sheet excellent in processability and capable of securing tensile strength (TS) of 980 MPa or more, strength-elongation balance (TS×EL) of 25000 MPa % or more and elongation flange property (λ) of 20% or more.

[101] Low guaranteed strength (980 MPa), absence of Cr, presence of polygonal ferrite (>35%) and tempered martensite make this steel different than present invention.

[102] Their processing route is also different. lower amount of reduction in CR (less than 40%), absence of continuous cooling are the differentiating parameters during processing. Cold-rolled sheet heated in intercritical region (not in fully austenite) and after IBT treatment reheating the plate immersed in a galvanizing bath were not adopted in present invention.

[103] Publication No. JP2015052132 relates to a high strength cold-rolled steel sheet having high level of: yield strength; tensile strength; a yield ratio; total elongation; a hole expansion ratio; and product of tensile strength and total elongation, and having a high yield ratio and excellent formability, and to provide a production method of the high strength cold-rolled steel sheet.

[104] Absence of Cr, presence of polygonal ferrite (60-90%) and tempered martensite (5-30%) make this steel different than present invention.

[105] No mentioning of slab heating temperature, maximum soaking time is mentioned as 1000 s (~15 min), Two stage cooling after the soaking at annealing temperature these was not adopted in present invention.

[106] Publication No. US2015027600 relates to a Si-containing high-strength cold-rolled steel sheet has a chemical composition comprising C: 0.0~20.3 mass %, Si:

0.8~2.0 mass %, Mn: 1.0~5.0 mass % and the remainder being Fe and inevitable impurities with a ratio of Si content to Mn content (Si/Mn) exceeding 0.4, and has a tensile strength TS of not less than 780 MPa, wherein a metallic structure of the steel sheet surface contains polygonal ferrite and/or bainitic ferrite having a Si concentration of not more than 3.0 mass % and a grain size of not more than 10 μm and does not have a Si-containing oxide layer on the steel sheet surface.

[107] Absence of Cr, low guaranteed strength (780 MPa), make this steel different than present invention.

[108] Their processing route is also different. Low coiling temperature after hot rolling (400-570°C), pickling of hot rolled material to remove scales formed on the steel sheet surface were not adopted in present invention.

[109] Publication No. KR20130027793 relates to an ultrahigh strength cold-rolled steel sheet and a hot-dip plated steel sheet with 1180MPa grade in tensile strength with excellent ductility and a manufacturing method for the same are provided to ensure excellent ductility and to improve strength by controlling alloying elements and an annealing process.

[110] Low amount of C (0.1-0.2 wt%), absence of Cr, presence of polygonal ferrite (10-20%), guaranteeing of a lower amount of strength (1180 MPa) make this steel different than present invention.

[111] Their processing route is also different. Low coiling temperature after hot rolling (500-600°C), faster cooling rate after HR (3-50 °C/s), absence of continuous cooling after CR+annealing are the differentiating parameters during processing. Pickling of HR steel and hot dip plating after IBT of CR strip were not adopted in present invention.

[112] Publication No. JP2012237044 relates to a high-strength cold-rolled steel sheet having a tensile strength of 1,180 MPa or more and being excellent in elongation and stretch flanging property.

[113] Low amount of C (0.1-0.2 wt%), high amount of martensite (15-40%), guaranteeing of a lower amount of strength (1180 MPa) make this steel different than present invention.

[114] Their processing route is also different. Fast cooling rate after HR (10-80 °C/s), low coiling temperature after hot rolling (450-600°C), lower amount of reduction in CR (20-50 %), isothermal holding at IBT (100-1000 sec.) at a temperature above (300-500°C), absence of continuous cooling are the differentiating parameters during processing. Two cold-rolling and two annealing are performed which were not adopted in present invention.

[115] Publication No. KR101329893 relates to an extremely thin cold-milled plate with high strength and moldability to obtain predetermined strength and moldability without second rolling by promoting bainitic transformation at continuous annealing without increasing initial strength by using alloys like Mn, B, etc.

[116] Low amount of C (0.15-0.25 wt%), absence of Cr, presence of ferrite (0-30%), absence of retained austenite make this steel different than present invention.

[117] Lower coiling temperature after HR (600 °C), higher cooling rate after HR (10-80 °C/s), lower annealing temperature after CR (<750 °C), holding at IBT absence of continuous cooling are the differentiating parameters during processing.

[118] Publication No. JP2011202207 relates to a high-strength cold-rolled steel sheet having elongation, stretch-flange formability and weldability.

[119] Low amount of C (0.15-0.25 wt%), absence of Cr, presence of tempered martensite/bainite (20-60%), no mentioning of maximum limit of austenite, presence of carbides make this steel different than present invention.

[120] Their processing route is also different. Higher cooling rate after HR (30°C/s), low coiling temperature after hot rolling (450°C or lower), isothermal holding at IBT (100-600 sec.) at a temperature above (300-500°C), absence of continuous cooling are the differentiating parameters during processing. After the cold-rolling

two-stage heat treatment was performed which was not adopted in present invention.

[121] Publication No. JP2011052271 relates to a high-strength cold-rolled steel sheet having excellent workability satisfying a yield ratio of 0.50 to 0.80 and a tensile strength of ≥1,180 MPa.

[122] Low amount of C (0.10-0.15 wt%), absence of Cr, presence of ferrite (35-65%), lower amount of bainite (15-45%) and lower extent of guaranteed minimum strength (>1180 MPa) make this steel different than present invention.

[123] Their processing route is also different. Low coiling temperature after hot rolling (450-650°C), lower amount of reduction in CR (20-50 %), absence of continuous cooling are the differentiating parameters during processing.

[124] Publication No. JP2010077511 relates to a high strength cold-rolled steel sheet which has excellent workability, and to provide a method for producing the same. The high-strength cold-rolled steel sheet has a componential composition comprising, by mass, 0.01 to <0.04% C and one or two kinds selected from Ti and Nb by 0.001 to 0.1% in total. The steel sheet has a structure where the average crystal grain size of a ferritic phase is >5.0 to 15.0 μm, the average crystal grain size of a martensitic phase is 2.0 to 10.0 and the average crystal grain size of a bainitic phase is 2.0 to 10.0 μm, and, by volume fraction, the ratio of the ferritic phase is 70 to 90%, and the total of the martensitic phase and the bainitic phase is 10 to 30%.

[125] Low amount of C (0.01-0.04 wt%), absence of Cr and Si and Mn, presence of high volume of ferrite (70-90%) and martensite (10-30%), absence of retained austenite make this steel different than present invention.

[126] Their processing route is also different. Very fast cooling after HR (5-200 °C/s), low coiling temperature after hot rolling (400-600°C), isothermal holding at IBT (10-300 sec) at a temperature above (450-650°C), higher coiling temperature

after CR+Annealing, absence of continuous cooling are the differentiating parameters during processing. It also include plating and galvannealing treatments which were not adopted in present invention.

[127] Publication No. US2010092332 relates to a high-strength cold-rolled steel sheet that has well-balanced tensile strength and elongation as well as well-balanced tensile strength and stretch-flangeability, and a plated steel sheet manufactured by plating the steel sheet.

[128] Low amount of C (0.10-0.28 wt%), absence of Cr, presence of high volume of polygonal ferrite (0-30%) make this steel different than present invention.

[129] Their processing route is also different. Higher cooling rate after HR (3-50°C/s), low coiling temperature after hot rolling (500-600°C), isothermal holding at IBT (10-70 sec.) at a temperature above (400-500°C), absence of continuous cooling are the differentiating parameters during processing.

[130] Publication No. JP2009256773 relates to a high-strength cold-rolled steel sheet and high-strength hot-dip galvannealed steel sheet having both of superior ductility and superior hole-expandability.

[131] Low amount of C (0.1-0.3 wt%), absence of Cr, lower amount of retained austenite (0-20%), no proper disclosure of other different microstructural constituents in percentage-wise manner, make this steel different than present invention.

[132] Their processing route is also different. Very high cooling rate after HR (30-120°C/s), lower amount of reduction in CR (30 % or more), isothermal holding at IBT (1-5 sec.) at a temperature above (400-500°C), higher coiling temperature after CR+Annealing, absence of continuous cooling are the differentiating parameters during processing.

[133] Publication No. JP2008214764 relates to a high tensile strength cold rolled steel sheet which has a superfine grain structure, and has excellent mechanical properties, particularly, in a strength-elongation balance and toughness.

[134] High amount of ferrite (minimum 65%), low amount of microstructural constituents other than ferrite and bainite (<3%), make this steel different than present invention.

[135] Their processing route is also different. Low coiling temperature after hot rolling (500-650°C), lower amount of reduction in CR (40% or more), isothermal holding at IBT (30-400 sec) at a temperature above (350-500°C), absence of continuous cooling are the differentiating parameters during processing.

[136] Publication No. US2005161134 relates to a high strength and low yield ratio cold-rolled steel sheet having high elongation property and high flange drawing property, or a plated steel sheet made by plating the same.

[137] Lower amount of C (0.1-0.25 wt%), absence of Cr, presence of polygonal ferrite (0-20%), lower guaranteed minimum tensile strength (980 MPa) make this steel different than present invention.

[138] Their processing route is also different. High cooling rate after HR (15-25°C/s), low coiling temperature after hot rolling (500-600°C), isothermal holding at IBT (180-600 sec.) at a temperature (320-450°C), absence of continuous cooling are the differentiating parameters during processing.

[139] Publication No. JP2005330584 relates to a high-strength cold-rolled steel sheet that has well-balanced tensile strength and elongation and well-balanced tensile strength and stretch-flangeability, and a plated steel sheet manufactured by plating the steel sheet.

[140] Low C content (0.1-0.28 wt%), absence of Cr, presence of polygonal ferrite (0-30%) make this steel different than present invention.

[141] Their processing route is also different. Higher cooling rate after HR (3-50°C/s), low coiling temperature after hot rolling (600°C), isothermal holding at IBT (60-600 sec.) at a temperature above (320-450°C), absence of continuous cooling are the differentiating parameters during processing.

[142] Publication No. JP2006283131 relates to a high strength cold-rolled steel sheet excellent in coating film adhesion, workability and hydrogen embrittlement resistance and having the tensile strength of ≥780 MPa.

[143] Low level of guaranteed minimum strength (780 MPa), presence of polygonal ferrite, make this steel different than present invention.

[144] Their processing route is also different. Higher cooling rate after HR (30°C/s), low coiling temperature after hot rolling (400-500°C), isothermal holding at IBT (60-600 sec.) at a temperature above (350-500°C), absence of continuous cooling are the differentiating parameters during processing.

[145] Publication No. JP2005002404 relates to a high-strength cold-rolled steel sheet which attains the tensile strength of ≥980 MPa and which has excellent strength-ductility balance and can be excellently worked by stretch flanging as well, and to provide its production method.

[146] Low C content (0.05-0.2 wt%), absence of Cr, high ferrite content (30-60%), low bainite content (20-40%), low austenite content (2-8%)High amount of ferrite (minimum 65%), low amount of microstructural constituents other than ferrite and bainite (<3%), make this steel different than present invention.

[147] Their processing route is also different. Higher cooling rate after HR (30°C/s), low coiling temperature after hot rolling (450-650°C), lower amount of reduction in CR (30-60%), isothermal holding at IBT (15 sec. or more) at a temperature above (350-550°C), absence of continuous cooling are the differentiating parameters during processing.

[148] Publication No. JPH1060593 relates to a high-strength cold-rolled steel sheet having a conjugated structure consisting of ferritic phase and pearlitic or bainitic phase uniformly dispersed in the ferritic phase and resultantly having an excellent balance between strength and elongation flanging formability.

[149] Ferrite as matrix phase with pearlite/bainite dispersed in it, low C content (0.03-0.17 wt%), low Si (<1 wt%), low Mn (0.3-2.0 wt%), absence of Cr, make this steel different than present invention.

[150] Their processing route is also different. Low coiling temperature after hot rolling (650°C or less), overaging temperature above (250-500°C), absence of continuous cooling are the differentiating parameters during processing. Pickling method after hot-rolling these was not adopted in our study.

[151] The carbon content of designed steel may vary in the range of 0.2 to 0.55 wt.%; the silicon content from 0.2 to 1.8 wt.%; and the manganese content varies from 0.7 to 3.8 wt.%. Also, the aluminium may vary from 0.02 to 1.8 wt.%, chromium from 0.1 to 2.0 wt.%; titanium and nitrogen may vary from 0.01-0.4 wt.% and 0.002-0.004 maximum, respectively.

[152] As described above, in order to further reduce the weight of the vehicle body, it is necessary to increase a use strength level of the high-strength steel sheet to be equal to or higher than that of the related art. In addition, for example, for using the high-strength steel sheet in a frame component of the vehicle body, it is necessary to achieve high tensile strength which is extremely difficult to satisfy.

[153] In order to overcome above listed prior art, the present invention aims to provide to high-strength cold-rolled steel sheet having high elongation, mainly for automobile components or the like, and a method of manufacturing the same. The present invention has the higher value of strength and elongation in comparison to the strength and elongation mentioned in the prior art. It also deals with a different manufacturing method in which reheating of the steel was carried out in a temperature range of 1050-1300 °C for minimum of 12-48 hrs. The finish rolling

temperature (FRT) is required to be above Ac_3 and preferably within 800-950°C with a thickness of 3-8 mm, After the FRT, the cooling will be done at 1-50°C per second and the strip will be coiled at 350-700 °C. The cold-rolled sheet was heated within 700-1000 °C for 1-15 min, coiled at 250-550°C. The cooling of the coil would be natural cooling leading to produce the desired microstructure containing 10-40% C-enriched austenite, 40-85% ultrafine nano-structured carbide-free bainite, and 1-30% martensite.

OBJECTS OF THE INVENTION:

[154] The principal object of the present invention is to provide a cold-rolled high strength carbide-free bainitic steel composition and its method of manufacturing.

[155] Another object of the present invention is to provide to a cold-rolled bainitic steel composition to deliver high strength and high elongation.

SUMMARY OF THE INVENTION:

[156] The present invention relates to a cold-rolled bainitic steel composition to deliver high strength (minimum UTS of 1400 MPa) and high elongation (minimum 13%) for the application in automotive industries. The steel will first be made in a steel converter having the composition in wt.%: C:- 0.20-0.50, Mn:- 1.0-2.0, Si:- 1.1-2.1, Cr:- 0.5-3.0, S: 0.008 max, p: 0.025 max, Al: 0.01-1.0, N: 0.005 max, Fe-balance along with some unavoidable impurities. It will be reheating of the steel was carried out in a temperature range of 1050-1300 °C for minimum of 12-48 hrs., hot rolling the slab into a strip at the required finish rolling temperature (FRT) 800-950 °C up to 2-6 mm thickness, coiling the strip in downcoiler at a coiling temperature of 350-700 °C. The strip will be cold-rolled at room temperature up to the desired thickness (0.6-5 mm). Subsequently, the cold-rolled sheet will be austenitized at 700-1000°C for 1 to 10 min and be coiled at 250-550°C to generate the optimum microstructure of 10–40% retained austenite, 40-85% ultra-fine bainitic ferrite, and 1-30% martensite for delivering the required properties.

BREIF DESCRIPTION OF THE INVENTION

[157] It is to be noted, however, that the appended drawings illustrate only typical embodiments of this invention and are therefore not to be considered for limiting of its scope, for the invention may admit to other equally effective embodiments.

[158] Figure 1 shows schematic heat treatment cycle of the newly developed alloy steel.

[159] Figure 2 shows schematic work plan of the newly developed alloy steel.

[160] Figure 3 shows microstructure of newly developed cold-rolled bainitic steel (a) Optical and (b) SEM.

[161] Figure 4 shows engineering stress v/s engineering strain diagram of two representative samples cold-rolled and continuously cooled at room temperature.

DETAILED DESCRIPTION OF THE INVENTION:

[162] The present invention provides a cold-rolled bainitic steel composition to deliver high strength (minimum UTS of 1400 MPa) and high elongation (minimum 13%) for the application in automotive industries. The steel will first be made in a steel converter having the composition in wt.%: C:- 0.20-0.50, Mn:- 1.0-2.0, Si:- 1.1-2.1, Cr:- 0.5-3.0, S: 0.008 max, p: 0.025 max, Al: 0.01-1.0, N: 0.005 max, Fe-balance along with some unavoidable impurities. It will be reheating of the steel was carried out in a temperature range of 1050-1300 °C for minimum of 12-48 hrs., hot rolling the slab into a strip at the required finish rolling temperature (FRT) 800-950 °C up to 2-6 mm thickness, coiling the strip in downcoiler at a coiling temperature of 350-700 °C. The strip will be cold-rolled at room temperature up to the desired thickness (0.6-5 mm). Subsequently, the cold-rolled sheet will be austenitized at 700-1000°C for 1 to 10 min and be coiled at 250-550°C to generate the optimum microstructure of 10–40% retained austenite, 40-85% ultra-fine bainitic ferrite, and 1-30% martensite for delivering the required properties.

[163] A 30 kg heat was made in a vacuum induction furnace following the chemistry given in Table 1. Subsequently, the cast steel was forged to 40 mm thickness and homogenized at 1050-1250°C for 24-48 hours after which the steel was cooled along with the furnace. All further experiments were carried out with homogenized steel only. The steel was hot rolled down to 3-8 mm thickness in 5-7 passes keeping the finish rolling temperature (FRT) within 800-950°C and coiled in downcoiler at a temperature range of 350-700°C. This hot-rolled coil was further cold-rolled down to 0.6-2.5 mm thickness in 5-8 passes without any intermediate heating. The cold-rolled sheet was further heated within 700-1000°C for 1-15 min, and coiled at 250-550°C to produce the desired microstructure shown schematically in Fig. 1. Fig. 2 shows the flow of logic in the current invention through schematic representation. The first part shows the progression in step-by-step manner towards finalization of composition in a theoretical manner whereas the second part describes the outcome of the actual experimental works. The microstructural constituents can easily be revealed by standard metallographic analysis and procedures like optical, SEM microscopy, and XRD analysis. Samples for metallographic examination were cut from various surfaces of the cold-rolled strips. The samples were polished according to the usual method and etched with 2% nital to reveal the presence of different phases as represented in Fig. 3, where Fig. 3a is the optical microscopy image and Fig. 3b is the Scanning electron microscopy (SEM) image. There were no signs of any diffusional transformations products such as ferrite, and/ cementite, and the resulting bainite is carbide-free bainite. Microstructures consists of 10-40% C-enriched austenite, 40-85% ultrafine nano-structured carbide-free bainite and 1-30% martensite. The newly developed steel is capable of delivering an excellent combination of tensile properties. Standard testing was conducted for hardness & tensile properties. Tensile samples were prepared in accordance with the ASTM E8 method (25 mm gauge length and 1 mm thickness) and tested in an Instron testing machine (model no. 5982). Fig. 4 reveals the engineering stress-strain diagram of newly developed cold-rolled carbide free bainitic steel. From this figure, it is evident that the newly developed steel is capable of delivering an outstanding combination of ultimate tensile strength (>1400 MPa)

and with elongation more than 14%. Summary of tensile tests results are shown in Table 2. The thickness of the carbide-free bainitic ferrites lies typically 75-110 nm.

Table 1:

	C	Si	Mn	Cr	Al	N	Ti	V	Nb
Min	0.20	0.2	0.7	0.1	0.02	0.002	0.01	0.01	0.01
Max	0.55	1.8	3.8	2.0	1.8	0.004	0.4	0.4	0.05

Table 2:

Hardness/VHN	YS / MPa	UTS / MPa	Uniform Elongation / %	Total Elongation / %
380-550	900-1050	1200-1500	10-14	15-20

[164] Numerous modifications and adaptations of the system of the present invention will be apparent to those skilled in the art, and thus it is intended by the appended claims to cover all such modifications and adaptations which fall within the true spirit and scope of this invention.

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WE CLAIM:

1. A cold-rolled bainitic steel composition with high strength and high elongation comprises carbon content in 0.2 to 0.55 wt.%; the silicon content from 0.2 to 1.8 wt.%; and the manganese content from 0.7 to 3.8 wt.% characterized in that the aluminium from 0.02 to 1.8 wt.%, chromium from 0.1 to 2.0 wt.%; titanium and nitrogen from 0.01-0.4 wt.% and 0.002-0.004 maximum, respectively.

2. The cold-rolled bainitic steel composition, as claimed in claim 1, wherein the method of preparing composition includes following steps:
   - prepare steel in a converter having the composition in wt.%: C:- 0.20-0.50, Mn:- 1.0-2.0, Si:- 1.1-2.1, Cr:- 0.5-3.0, S: 0.008 max, p: 0.025 max, Al: 0.01-1.0, N: 0.005 max, and Fe-balance along with some unavoidable impurities.
   - reheating of the steel was carried out in a temperature range of 1050-1300 °C for minimum of 12-48 hrs.,
   - hot rolling the slab into a strip at the required finish rolling temperature (FRT) 800-950 °C up to 2-6 mm thickness, coiling the strip in downcoiler at a coiling temperature of 350-700°C.
   - hot-rolled coil was further cold rolled down to 0.6-2.5 mm thickness in 5-8 passes without any intermediate heating.
   - Subsequently, the cold-rolled sheet will be austenitized at 700-1000°C for 1 to 15 min and be coiled at 250-550°C to generate the optimum microstructure of 10–40% retained austenite, 40-85% ultra-fine bainitic ferrite, and 1-30% martensite for delivering the required properties.

3. The cold-rolled bainitic steel composition, as claimed in claim 1, wherein the finish rolling temperature (FRT) is above Ac_3 and within 800-950°C with a thickness of 3-8 mm.

4. The cold-rolled bainitic steel composition, as claimed in claim 1, wherein the after the FRT, the cooling is done at 1-50°C per second and the strip is coiled at 350-700°C.

5. The cold-rolled bainitic steel composition, as claimed in claim 1, wherein the cold-rolled carbide-free bainitic steel produces a hardness of >450 VHN.

6. The cold-rolled bainitic steel composition, as claimed in claim 1, wherein the Ultimate Tensile Strength value of cold-rolled bainitic steel is a minimum of 1400 MPa whereas the YS (Yield Stress) is minimum 1000 MPa and elongation (> 14%) respectively.

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ABSTRACT

A COLD ROLLED BAINITIC STEEL WITH HIGH STRENGTH AND HIGH ELONGATION

The present invention relates to a cold-rolled bainitic steel composition to deliver high strength and high elongation for the application in automotive industries. The steel will first be made in a steel converter having the composition in wt.%: C:- 0.20-0.50, Mn:- 1.0-2.0, Si:- 1.1-2.1, Cr:- 0.5-3.0, S: 0.008 max, p: 0.025 max, Al: 0.01-1.0, N: 0.005 max, Fe-balance along with some unavoidable impurities.

Figure 1

Dated .24th. day of April 2023

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