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(54) **Hot rolled dual-phase steel strip having features of a cold rolled strip**

Warmgewalztes Band aus Dualphasenstahl mit den Eigenschaften eines kaltgewalzten Bandes

Tôle d'acier dual phase laminée à chaud présentant les caractéristiques d'une tôle laminée à froid

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(56) References cited:
WO-A-89/11363
JP-A- 9 296 252
US-A- 5 832 985
US-B- 6 488 790
US-B1- 6 280 542

- **PATENT ABSTRACTS OF JAPAN vol. 016, no. 584 (C-1013), 24 December 1992 (1992-12-24) & JP 04 235219 A (NIPPON STEEL CORP), 24 August 1992 (1992-08-24)**
- **PATENT ABSTRACTS OF JAPAN vol. 1997, no. 07, 31 July 1997 (1997-07-31) & JP 09 067641 A (KAWASAKI STEEL CORP), 11 March 1997 (1997-03-11)**
- **PATENT ABSTRACTS OF JAPAN vol. 2000, no. 05, 14 September 2000 (2000-09-14) & JP 2000 063956 A (NKK CORP), 29 February 2000 (2000-02-29)**
- **"Properties and Selection: Irons, steels and high perfomance alloys" ASM METALS HANDBOOK, 1990, pages 424-429, XP002326811 OHIO, USA**

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Description

[0001] The present invention is directed to a hot rolled dual phase steel strip, having features similar to those of a corresponding cold rolled dual phase steel strip.
[0002] Low carbon steel strips of the dual phase type (ferrite-martensite) are known, being cold rolled, which have special geometrical, and metallurgical features, as well as relating to planarity and deformability, so as to render the same particularly adapted to the production of pressed or cut pieces requiring very strict tolerances, particularly when designed for the car manufacturing industry with a thickness of more than 1.0 mm.
[0003] It is also known that the dual phase steel strip obtained by hot rolling, such as according to the method disclosed in patents EP 0019193, EP 0072867, US 4790889 and US 4561910, do not show features of quality, particularly relating to their cold workability, that can be considered comparable with those of dual phase steel strips obtained by cold rolling.
[0004] A basic feature for this product, especially when it is intended to form structural portions in the car industry field, is in fact the tendency to be cold shaped, as well as a good mechanical resistance being fit to absorb shocks as a consequence of the crash tests recently developed in the car industry. It has been found that these steels must show a microstructure mainly formed of ferrite and, as a slightest portion, of martensite or bainite, i.e. a structure of high hardness that can be obtained by suddenly cooling the steel from an intercritic temperature comprised between 700 and 800°C. This way the residual austenite enriched with carbon is converted into martensite, giving rise to grains formed of very hard and brittle needle-shaped structures which, when inserted in a much softer ferritic matrix allow cold shaping of pieces, even of complex shape, being present in a very low percentage, never higher than 20% (martensite).
[0005] It is also known that this type of steel requires significant additions of chromium and phosphorous, especially the first mentioned element in order to increase the steel capacity of being hardened and to enhance the production of carbides, whereas the second mentioned element is added to make ferrite harder and cause the yield point to raise. Both elements have also the effect of increasing the tensile strength.
[0006] As already stated above, these products are generally derivating from cold rolled and continuously annealed strips, while just during the cooling step after annealing the desired dual phase structure is obtained to achieve the above-mentioned features. On the other hand this type of processing, with cold rolling and subsequent annealing, involves rather important burdens as far as the required costs and time are concerned, whereby it is a steadily more and more felt need in this field that of obtaining a hot rolled strip in dual phase steel which is provided with the same mechanical features of the traditional cold rolled steel.
[0007] An object of the present invention is therefore that of providing a steel strip of the above-mentioned type which, unlike the other cold rolled dual phase steels being known so far, has the same features and may replace without problems a cold rolled dual phase steel strip, in particular for cold pressed or cut pieces.
[0008] Another object of the present invention is that of providing a steel strip that, even without important additions of chromium and phosphorous, is provided with the same qualities as mentioned, which are peculiar of the steels wherein considerable amounts of these two elements are present.
[0009] The strip according to the present invention is preferably, although not exclusively, produced by means of in-line plants of the thin-slab type, as disclosed in EP 0415987 in the name of the present applicant and schematically illustrated in figure 1 and is characterized, as set forth in claim 1, by a carbon content comprised between 0.06 and 0.15%, manganese between 1.0 and 2.0% and other elements within % ranges as follows: C 0.06-0.15%, Mn 1.0-2.0%, Si $\leq$ 0.80%, P $\leq$ 0.010%, S $\leq$ 0.005%, Cr < 0.30%, Ni $\leq$ 0.30%, Mo $\leq$ 0.03%, Al 0.030 $\div$ 0.050%, with the balance being Fe and unavoidable impurities. This strip has a chemical composition poorer than that of the strip of this type according to the prior art and shows a constant geometrical profile along the whole length, with low tolerances relating to the thickness, comparable with those typical of a cold rolled strip.
[0010] Further objects, advantages and features of the dual phase steel strip according to the present invention will be clearer from the following description with reference to the annexed drawings in which:

Figure 1 schematically shows a casting and in-line rolling plant of the thin-slab type, particularly suitable for manufacturing steel strips according to the invention;
Figure 2 shows a graph representing mechanical features, particularly relating to the cold pressing, of a dual phase steel strip according to the invention when compared with a cold rolled strip of the same thickness; and
Figure 3 shows a diagram of the variations, graphically obtained by points, of the frequency with which the presence of certain dimensions of the ferritic grain is statistically detected in a number of coils.

[0011] As stated in the foregoing, the dual phase steel strip according to the present invention is preferably, although not exclusively, manufactured in thin-slab plants as schematically shown in figure 1, where reference is particularly made to the plant being the object of patent EP 0415987. The following processing steps can be distinguish therein, downstream of the continuous casting step: a) liquid core reduction; b) roughing step directly adjoining to the continuous casting; c) heating in an induction furnace; d) keeping temperature in a furnace provided with internal mandrel; e) finishing rolling;

f) compact controlled cooling; and g) coiling on a reel. It has been found in fact that the particular working conditions, typical of this plant, give the final product a particularly thin and homogeneous structure with positive consequences on the chemical-physical characteristics of the final product itself.

[0012] The features that, as set forth in claim 1, should be shown by the product, i.e. the hot rolled low carbon steel strip with a dual phase structure (formed of ferrite and martensite), are basically: a thickness of 1 to 8 mm with tolerances comprised between ± 0.06 mm and ± 0,15 mm, a parallelism< 0.05 mm and a structure with grain fineness better than grade 10 of the ASTM E 112 standard.

[0013] In the following table there are indicated, for various thicknesses from 1.5 to 8 mm, the corresponding standard tolerances, respectively for the usual hot coils, the cold rolled strips (distinguished between standard and strict tolerances) and the tolerances pertaining to a dual phase strip according to the invention. In the last column there are also indicated the crown or convexity values, i.e. corresponding to the differences between the values of thickness measured centrally and on the side edges of the strip.

Thickness	**Standard Tolerances**			**Tolerance of the strip of the invention**	
	EN 10051	**EN 10031 Cold Strips**		Hot Tolerances	Max Crown
	Hot Coils	Standard	Strict		
≥ 1.50	+/- 0.17	+/-0.11	+/-0.08	+/-0.06	0.03
1.51 - 2.00	+/-0.17	+/-0.13	+/-0.09	+/-0.07	0.04
2.01 - 2.50	+/- 0.18	+/-0.15	+/-0.11	+/-0.10	0.04
2.51-3.00	+/-0.20	+/-0.17	+/-0.12	+/-0.11	0.05
3.01-4.00	+/- 0.22			+/-0.12	0.06
4.01-5.00	+/-0.24			+/-0.12	0.06
5.01 - 6.00	+/-0.26			+/-0.12	0.07
6.01 - 8.00	+/- 0.29			+/-0.15	0.07

[0014] It is easy to see that the tolerances, as detected for the hot rolled steel strip according to the present invention not only correspond on average to less than one half of the tolerances relating to the traditional hot rolled strips, but are even lower than the strict tolerances of the cold strips having the same thickness.

[0015] Furthermore with reference to figure 3, it can be observed from a microcrystalline analysis of the structure of a steel strip according to the invention that more than 80% of the grains, detected on average at various positions on the strip and statistically for a number of strips, has lower dimensions than those corresponding to grade 10 of the ASTM E112 standard, and consequently a better fineness than that grade.

[0016] These features, together with a breaking strain > 20%, make this type of hot rolled strip particularly suitable for fine shearing and hole formation by punching, as well as cold stamping of complex shapes. In particular it has been practically proved that with strips according to the invention it has been possible to form bends at right angles and 180° with a radius ≤ 3 times the strip thickness for thicknesses ≤ 3.0 mm and ≤ 5 times the thickness for strips having thickness ≥ 3.1 mm without giving rise to defects in the region of maximum stress, this confirming the good plasticity of the material. It is clear that these results have been made possible thanks to the fine grain microstructure with homogeneous development of the grain in every direction, or of the polygonal type, with complete separation of the iron carbides from the ferritic grains. Such a structure eliminates any resilient recovery of the material upon shaping, thus allowing to meet in this way very strict tolerances.

[0017] Experimental tests of forming capability have been carried out by comparison with cold rolled strips of the same thickness. From these tests it appears, as resulting from figure 2, that FLD lines of the Forming Limit Diagram relating to two different steel strips can be overlapped, thus confirming that the strip according to the invention can suitably replace a cold rolled one. The tests of forming capability which have brought to the graphs of figure 2 have been carried out on a strip having thickness of 1.0 mm, at room temperature with a mould having diameter of 100 mm and a stamping speed of 1 mm/s.

[0018] Homogeneity and fineness of the microcrystalline structure therefore appear to be the reasons of the particular deformability shown by this type of strip.

[0019] It should be noted that in the case of the present invention the percentage at which the chromium and phosphorous elements are present can be limited to the values stated, without any necessity of high amounts of these elements being added, although the same good qualities are maintained, thanks to the fact that the temperature of slab, pre-strip and rolled strip never goes below the critical values beyond which the chromium carbides precipitate and phosphorous is separated from the solid solution.

Claims

1. A hot rolled, low carbon dual phase steel strip, with a structure composed of ferrite and martensite, having a thickness of 1 to 8 mm, particularly suitable for producing cold pressed and cut pieces requiring mechanical features of forming capability and a very small resilient recovery, consisting of peritectic steel with chemical analysis, **characterized by** having the following composition: C 0.06-0.15%, Mn 1.0-2.0%, Si ≤ 0.80%, P ≤ 0.010%, S ≤ 0.005%, Cr < 0.30%, Ni ≤ 0.30%, Mo ≤ 0.03%, Al 0.030 ÷ 0.050%, with the balance being Fe and unavoidable impurities, and having a constant geometrical profile on the whole length and thickness tolerances between ± 0.06 and 0.15 mm for thickness values of up to 8.00 mm with a crown between the strip centre and side edge of less than 0.07 mm, being provided with a homogeneous microcrystalline structure with fineness better than grade 10 of ASTM E 112 standard at a percentage higher than 80% of the whole structure.

2. A dual phase steel strip according to claim 1, **characterized by** having a coefficient of breaking strain >20%.

Patentansprüche

1. Ein warmgewalztes, kohlenstoffarmes Dualphasenstahlband mit einem aus Ferrit und Martensit zusammengesetzten Gefüge, mit einer Stärke von 1 bis 8 mm, insbesondere geeignet zum Herstellen kaltgepreßter und geschnittener Teile, welche mechanische Eigenschaften einer Formbarkeit und eines sehr kleinen elastischen Rückstellvermögens erfordern, bestehend aus peritektischem Stahl mit chemischer Analyse, **gekennzeichnet durch** die folgende Zusammensetzung: C 0,06-0,15%, Mn 1,0-2,0%, Si ≤ 0,80%, P ≤ 0,010%, S ≤ 0,005%, Cr < 0,30%, Ni ≤ 0,30%, Mo ≤ 0,03%, A1 0,030 ÷ 0,050%, wobei der Rest Fe und unvermeidbare Verunreinigungen sind, und **durch** ein konstantes geometrisches Profil auf der gesamten Länge und Stärkeabweichungen zwischen ± 0,06 und 0,15 mm für Werte der Stärke von bis zu 8,00 mm mit einer Balligkeit zwischen der Bandmitte und Seitenkante von weniger als 0,07 mm, versehen mit einem homogenen mikrokristallinen Gefüge mit einer Feinheit besser als Grade 10 des ASTM E 112 Standards bei einem Prozentsatz von mehr als 80% des gesamten Gefüges.

2. Ein Dualphasenstahlband nach Anspruch 1, **dadurch gekennzeichnet, daß** es einen Bruchspannungskoeffizienten > 20% aufweist.

Revendications

1. Bande d'acier double phase à faible teneur en carbone, laminée à chaud, avec une structure composée de ferrite et de martensite, ayant une épaisseur de 1 à 8 mm, spécialement adaptée pour la fabrication de pièces découpées et pressées à froid nécessitant des caractéristiques mécaniques d'aptitude au formage et de très faible récupération résiliente, composée d'acier péritectique avec analyse chimique, **caractérisée en ce qu'**elle possède la composition suivante: C 0,06 à 0,15 %, Mn 1,0 à 2,0%, Si ≤0,80 %, P ≤0,010 %, S ≤0,005 %, Cr < 0,30 %, Ni ≤0,30 %, Mo ≤0,03 %, Al 0,030 ÷ 0,050 % ; le solde étant constitué par du Fe et des impuretés inévitables, et ayant un profil géométrique constant sur la totalité de sa longueur, et des tolérances en termes d'épaisseur comprises entre ± 0,06 et 0,95 mm pour des valeurs d'épaisseur pouvant attendre 8,00 mm avec une couronne entre le centre de la bande et le bord latéral de moins de 0,07 mm, comprenant une structure microcristalline homogène avec une finesse de grains supérieure au grade 10 de la norme ASTM E 112 à un pourcentage de plus de 80 % de la structure globale.

2. Bande d'acier double phase selon la revendication 1, **caractérisée en ce qu'**elle possède un coefficient de résistante à la cassure > 20 %.

Fig. 1

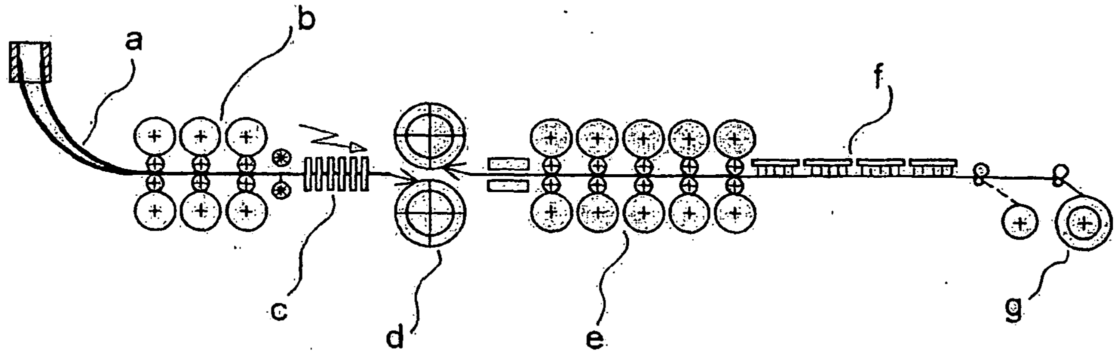

a
b
c
d
e
f
g

Fig.2

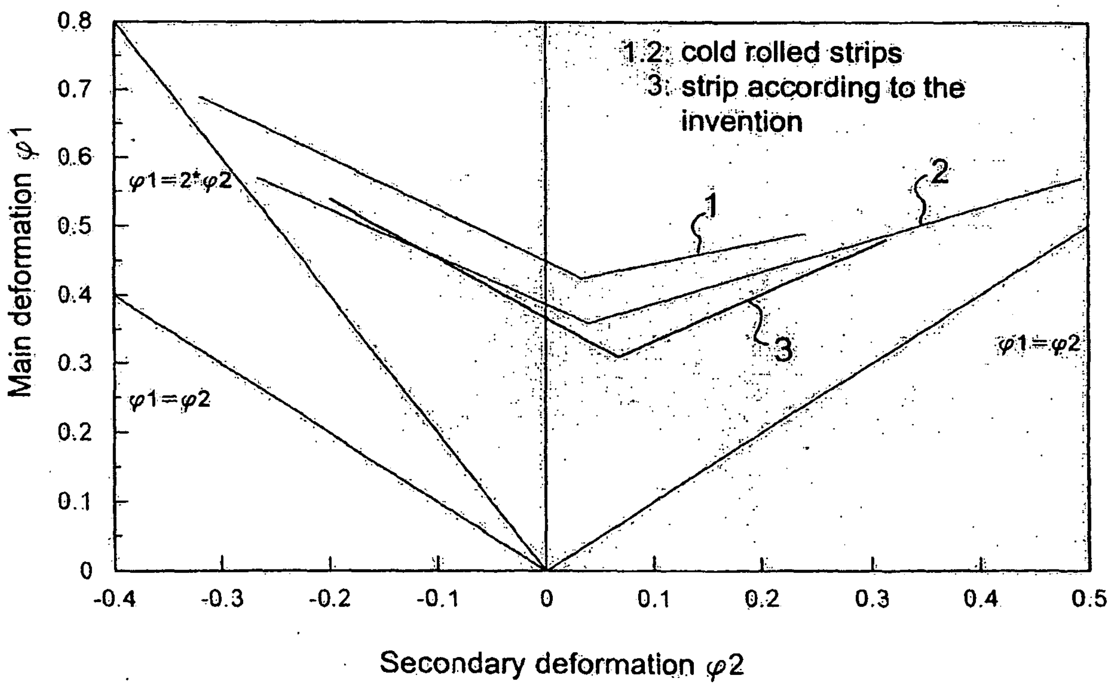
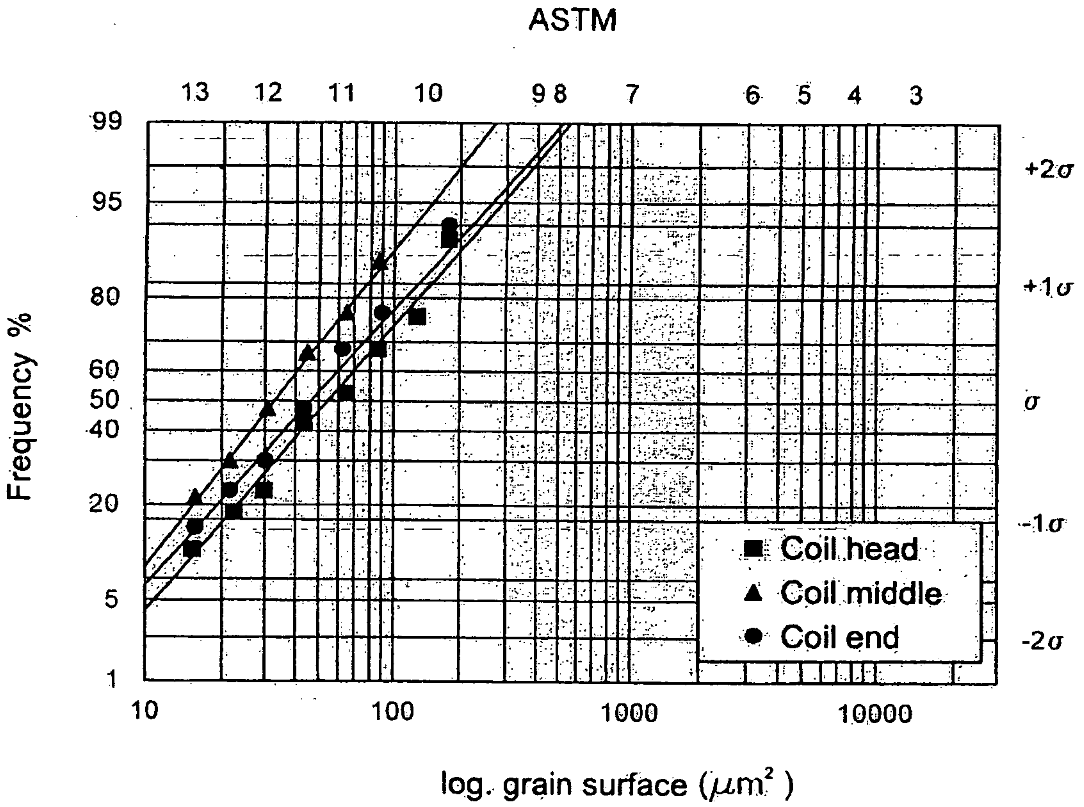

1.2: cold rolled strips
3: strip according to the invention
φ1=2*φ2
φ1=φ2
φ1=φ2
1
2
3
Main deformation φ1
Secondary deformation φ2
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5

Fig.3



ASTM
13
12
11
10
9 8
7
6
5
4
3
99
95
80
60
50
40
20
5
1
Frequency %
+2σ
+1σ
σ
-1σ
-2σ
Coil head
Coil middle
Coil end
10
100
1000
10000
log. grain surface (μm²)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- EP 0019193 A **[0003]**
- EP 0072867 A **[0003]**
- US 4790889 A **[0003]**
- US 4561910 A **[0003]**
- EP 0415987 A **[0009] [0011]**