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(54) **Strip of hot rolled micro-alloyed steel for obtaining finished pieces by cold pressing and shearing**

Streifen des warm gewalzten Mikro-legierten Stahls für das Erhalten der fertigen Stücke durch die betätigende und scherende Kälte

Bande d'acier micro-allié laminé à chaud pour obtenir les morceaux finis par le froid serrant et cisailant

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(56) References cited:
WO-A-03/087414 WO-A-2004/026497
GB-A- 1 275 096 US-B1- 6 488 790

- **DATABASE INSPEC [Online] THE INSTITUTION OF ELECTRICAL ENGINEERS, STEVENAGE, GB; Inspec No. Pub. Journal of Materials Processing Technology 20 July 2004 (2004-07-20), LEVY B S, VAN TYNE J, STRINGFIELD J M: "Characterizing steel tube for hydroforming applications" XP002323999 Database accession no. 8172068 & LEVY BS, VAN TYNE J, STRINGFIELDS: "Characterizing steel tube for hydroforming applications" JOURNAL OF MATERIALS PROCESSING TECHNOLOGY, vol. 150, no. 3, 10 July 2004 (2004-07-10), pages 280-289, SWITZERLAND ISSN: 0924-0136**
- **DATABASE INSPEC [Online] THE INSTITUTION OF ELECTRICAL ENGINEERS, STEVENAGE, GB; 19 April 2002 (2002-04-19), HUMBERT M ET AL: "Modelling of the variant selection mechanism in the phase transformation of HSLA steel produced by compact strip production" XP002324000 Database accession no. 7303672 & HUMBERT M, GARDIOLA B, ESLING C, FLEMMING G, HENSGER KE: "Modelling of the variant selection mechanism in the phase transformation of HSLA steel produced by compact strip production" ACTA MATERIALIA, vol. 50, no. 7, 19 April 2002 (2002-04-19), pages 1741-1747, UK ISSN: 1359-6454**
- **PATENT ABSTRACTS OF JAPAN vol. 2003, no. 12, 5 December 2003 (2003-12-05) & JP 2003 253381 A (MITSUBISHI HEAVY IND LTD), 10 September 2003 (2003-09-10)**

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Description

[0001] The present invention relates to a low carbon micro-alloyed steel strip that shows such features that it can replace, in producing finished pieces being stamped or cut, the cold rolled strips till now used to obtain structures of reduced weight and good mechanical strength.

[0002] From JP2003253381, WO03/087414, US 6.488.790, US 6 264 760 B are for example known methods for producing hot rolled micro-alloyed strips.

[0003] Said micro-alloyed or HSLA "High Strength Low Alloy" steels owe their name to the fact of including an addition of small quantities of niobium, vanadium, titanium and boron which hardly exceed the total quantity of 0.2%. These elements, instead of entering as alloying agents in the iron crystal lattice, carry out their action being combined with carbon and nitrogen in the matrix, thus forming finely dispersed carbides, nitrides and carbonitrides. These compounds contribute to the grain refining and cause the matrix hardening with their precipitation in the ferritic grains.

[0004] It is also known that these steels are particularly used in those applications where it is required to reduce the weight of a structure to be obtained without negatively affecting its mechanical strength. Their peculiar characteristic is that of showing a value of yield strength which nearers the tensile one, with a ratio between the two values that is higher than 70%. Consequently it is possible to obtain these results by reducing the stress resisting cross-section, while on the contrary, due to the proximity of the yield and tensile strengths, the material is provided with high elasticity features, being subject to a strong elastic recovery causing the finished piece to assume, upon pressing, undesired configurations. Therefore the use is restricted to those cases which do not require too strict tolerances of the finished pieces.

[0005] Object of the present invention is that of providing a strip of hot rolled, micro-alloyed low carbon steel with thickness ≥ 0.7 mm which, particularly upon pickling and skinpassing, shows substantially the same metallurgical and geometrical features, as well as relating to planarity and deformability, of a cold rolled strip for producing stamped or sheared finished pieces, such as to be used as a valid substitute thereof.

[0006] The strip according to the present invention is preferably, although not exclusively, manufactured with in-line plants of the thin-slab type, as disclosed e.g. in WO2004/026497 in the name of the present applicant, which is schematically represented in Fig. 1 and is characterized, as set forth in claim 1, by a grain fineness better than grade 10 of ASTM E 112 standard in a percentage $> 90\%$ of the whole structure, with a ratio between yield strength and breaking strength $\geq 70\%$.

[0007] Objects, advantages and features of the micro-alloys steel strip according to the present invention will appear more clearly from the following description with reference to the annexed drawings wherein:

Figure 1 schematically shows a thin slab casting and in-line rolling plant, particularly suitable to the production of micro-alloyed steel strips according to the invention;

Figure 2 shows a diagram of the graphs, plotted by points, of the frequency with which the presence of certain dimensions of the ferritic grain is statistically detected in a number of strip coils at the beginning, at the middle and the end, respectively, of each strip coil according to the invention;

Figure 3 shows a diagram representing the trend of strain limit of a steel according to the invention with warranted minimum yield strength of 355 N/mm².

[0008] As stated above, the strip of micro-alloyed steel according to the present invention is preferably, although not exclusively, produced in thin-slab plants as schematically represented in Fig. 1, where references is made in particular to the plant being the object of the international publication WO2004/026497. The following operating steps can be observed, downstream of the casting step: a) liquid core reduction; b) roughing step directly adjoining the continuous casting; c) heating in an induction furnace; e) finishing rolling; f) compact controlled cooling; g) coiling on a reel. Such a plant is able to keep the temperature of the pre-strip (d) above 900°C in the steps preceding the final rolling. The pre-strip rolling above preceding 900°C allows to keep solute in the γ iron (austenitic phase) most of the micro-alloying agents by completely exploiting their function of limiting the growth of the austenitic grain and enhancing the hardening by precipitation in ferritic phase during the cooling step after the final rolling.

[0009] It should be noted that these aspects are commonly disregarded in the traditional processes where the slab coming from continuous casting is cooled and subsequently heated for the final rolling. Therefore the action of the micro-alloying agents results strongly reduced because, while cooling, these precipitate roughly and without control, thus reducing the desired effect of a fine and diffused precipitation. This condition cannot be restored even through a subsequent heating of the slabs, unless high solubilization temperatures (beyond 1200°C) are reached, which however lead to other negative consequences such as the grain growing and the surface decarburization of the strip with consequent worsening of their qualities. Consequently the production of HSLA, especially of thickness < 2 mm, with the traditional system can only be performed through more complex and cumbersome processing cycles because, after the hot rolling, the strips have to be cold rolled and treated in an annealing line provided with a controlled cooling.

[0010] The micro-alloyed steel strip according to the present invention shows a ratio between yield and tensile strength load equal or higher than 70%, as well as a good capability of being formed and cut under cold conditions. These features are due to the favourable microstructural status rendering this product able to allow a valid alter-

native to the cold rolled micro-alloyed steel strips of equal thickness, with the additional advantage of being obtained with less addition of micro-alloying and alloying elements such as niobium, vanadium, titanium, manganese and chromium, as shown in Table 1.

[0011] Experimental tests have shown that the strips of the present invention are characterized by a fine grain structure better than grade 10 of the ASTM E 112 standard at a percentage higher than 90% in the whole structure, as it results from the graph of figure 2, clearly showing that the most grains, above all in the head region of the strip, has dimensions corresponding or lower (thereby a better fineness) than grade 10 of ASTM E 112 standard. These features of grain fineness and uniformity make this type of hot rolled strip particularly resistant to the fatigue tests. As it can be seen in figure 3, representing the experimental tests carried out in strips according to the invention, the fatigue resistance is higher than that of products obtained with conventional processes and comparable with that of cold rolled strips of the same grade. It will be noted that this occurs both in the range of the "fatigue strength", namely for the limit values of load at which the breaking of the piece is experienced upon subjecting the same to a number N of cycle lower than 10^7 , and in the range of the "fatigue limit", namely the limit strength determined by experimental tests, under which a piece does not break even if it is subjected to a number of strain cycles higher than the number conventionally adopted for the steel, i.e. $N=10^7$. In particular, the fatigue limit detected for the S355MC steel at $N=10^7$ cycles (corresponding to 357 N/mm²) was found better, with a margin of 5-10%, in correspondence with non-breaking probability of 50%. Furthermore, the ratio between the fatigue limit due to plain flexure (σ_{FP}) and the yield strength $\sigma_{FP}/R_{p0.2}$ is near to 1 and equal to 0.96, thereby constantly higher than that relating to the reference hot rolled material, comprised between 0.88 and 0.90, practically corresponding to the value of the same ratio as detected for cold rolled strips of the same grade.

[0012] The particular fine microstructure of these strips cause the same to be suitable for being finally cut and forming holes therein by punching, as well as the cold forming of complex shapes, in particular folds at 180° with bending radius equal to the thickness, for high strength steels having minimum warranted yield strength comprised between 275 and 700 N/mm². The cold forming of pieces having a complex shape is made easier also by the constant profile of the strip and its parallelism with deviation of less than 0.05 mm.

[0013] The various steel grades have a chemical analysis comprised within the limits listed in the following Table 1:

Element	Content (%)
C	0.04-0.08
Mn	0.15-2.0

(continued)

Element	Content (%)
Si	0.06-0.60
P	0.010 max
S	0.010 max
Cr	0.35 max
Ni	0.20 max
Mo	0.25 max
Cu	0.20 max
Nb	0.012-0.070
V	0.02-0.03
Ti	≤0.11
Al	0.025-0.050
N	0.0115 max

[0014] As it can be deduced from the table above, the total sum of micro-alloying elements (V, Ti and Nb) does not exceed 0.2%.

Claims

1. A hot rolled, micro-alloyed low carbon steel strip, with a thickness ≥ 0.7 mm and a fine grain microstructure, the pre-strip of which, upstream of the finishing rolling, is kept at a temperature $\geq 900^\circ\text{C}$, with a yield strength between 275 and 700 N/mm², **characterized by** having the following chemical composition: C 0.04-0.08%, Mn 0.15-2.0%, Si 0.06-0.60%, P $\leq 0.010\%$, S $\leq 0.010\%$, Cr $\leq 0.35\%$, Ni $\leq 0.20\%$, Mo $\leq 0.25\%$, Cu $\leq 0.20\%$, Nb 0.012-0.070%, V 0.02-0.03%, Ti $\leq 0.11\%$, Al $\leq 0.025-0.050\%$, N $\leq 0.0115\%$, the balance being Fe and unavoidable impurities, with at least the 90% of its grains having a fineness better than grade 10 of ASTM E 112 standard, the ratio between fatigue limit and yield strength $\sigma_{FP}/R_{p0.2}$ being $\geq 90\%$, with the ratio between yield strength and tensile strength being $\geq 70\%$.
2. A hot rolled, micro-alloyed steel strip according to claim 1, **characterized in that** the thickness tolerances are ≤ 0.05 mm.
3. A steel strip according to claim 1, **characterized by** the fact of comprising no additions of boron as micro-alloying element.
4. A steel strip according to claim 3, **characterized in that** the total sum of the micro-alloying elements, such as V, Ti and Nb, does not exceed 0.2%.

Patentansprüche

1. Warmgewalzter mikrolegierter kohlenstoffarmer Stahlstreifen, mit einer Dicke $\geq 0,7$ mm und einer feinkörnigen Mikrostruktur, wobei dessen Vorausstreifen, stromaufwärts der abschließenden Walzung, auf einer Temperatur von $\geq 900^\circ$ C gehalten wird, mit einer Dehngrenze zwischen 275 und 700 N/mm², **gekennzeichnet durch** folgende chemische Zusammensetzung:
C 0,04-0,08%, Mn 0,15-2,0%, Si 0,06-0,60%, P \leq 0,010%, S \leq 0,010%, Cr \leq 0,35%, Ni \leq 0,20%, Mo \leq 0,25%, Cu \leq 0,20%, Nb 0,012-0,070%, V 0,02-0,03%, Ti \leq 0,11%, Al \leq 0,025-0,050%, N \leq 0,0115% mit einem Rest aus Fe sowie unvermeidbaren Verunreinigungen, wobei mindestens 90% seiner Körner eine Feinheit besser als Stufe 10 der Norm ASTM E 112 haben, und das Verhältnis zwischen Ermüdungsgrenzwert und Dehngrenze $\sigma_{FF}/R_{p0,2} \geq 90\%$ ist, mit dem Verhältnis zwischen Dehngrenze und Zugfestigkeit $\geq 70\%$.

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2. Stahlstreifen gemäß Patentanspruch 1, **dadurch gekennzeichnet, dass** die Dicken-Toleranzen $\leq 0,05$ mm betragen.

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3. Stahlstreifen gemäß Patentanspruch 1, durch die Tatsache gekennzeichnet, dass keine Zusätze von Bor als mikrolegierendes Element enthalten sind.

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4. Stahlstreifen gemäß Patentanspruch 3, **dadurch gekennzeichnet, dass** die Gesamtsumme der mikrolegierenden Elemente, wie z. B. V, Ti und Nb 0,2% nicht überschreiten.

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Revendications

1. Feuillard d'acier micro-allié à faible teneur en carbone, laminé à chaud, avec une épaisseur $\geq 0,7$ mm et une microstructure à grains fins, la prébande de celui-ci, en amont du laminage de finition, étant maintenu à une température $\geq 900^\circ$ C, avec une limite d'élasticité conventionnelle comprise entre 275 et 700 N/mm², **caractérisé en ce qu'il** présente la composition chimique suivante : C 0,04 à 0,08 %, Mn 0,15 à 2,0 %, Si 0,06 à 0,60 %, P \leq 0,010 %, S \leq 0,010 %, Cr \leq 0,35 %, Ni \leq 0,20 %, Mo \leq 0,25 %, Cu \leq 0,20 %, Nb 0,012 à 0,070 %, V 0,02 à 0,03 %, Ti \leq 0,11 %, Al \leq 0,025 à 0,050 %, N \leq 0,0115 %, le complément étant du Fe et les inévitables impuretés, au moins 90 % de ses grains présentant un titre supérieur à la classe 10 de la norme ASTM E 112, le rapport entre la limite de fatigue et la limite d'élasticité conventionnelle $\sigma_{FF}/R_{p0,2}$ étant $\geq 90\%$, le rapport entre la limite d'élasticité conventionnelle et la résistance à la traction étant $\geq 70\%$.

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Fig.1

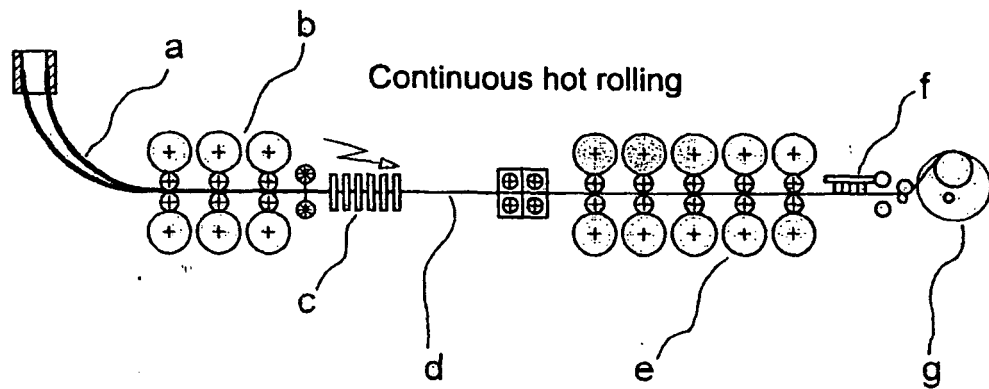


Fig.2

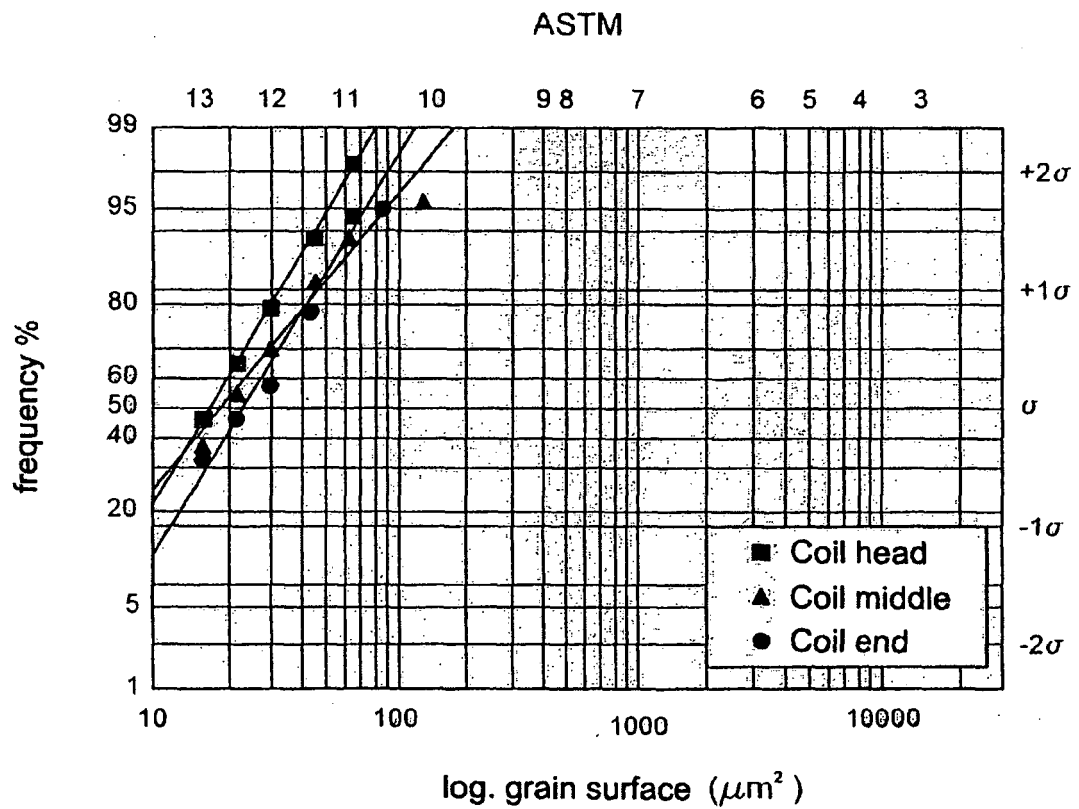
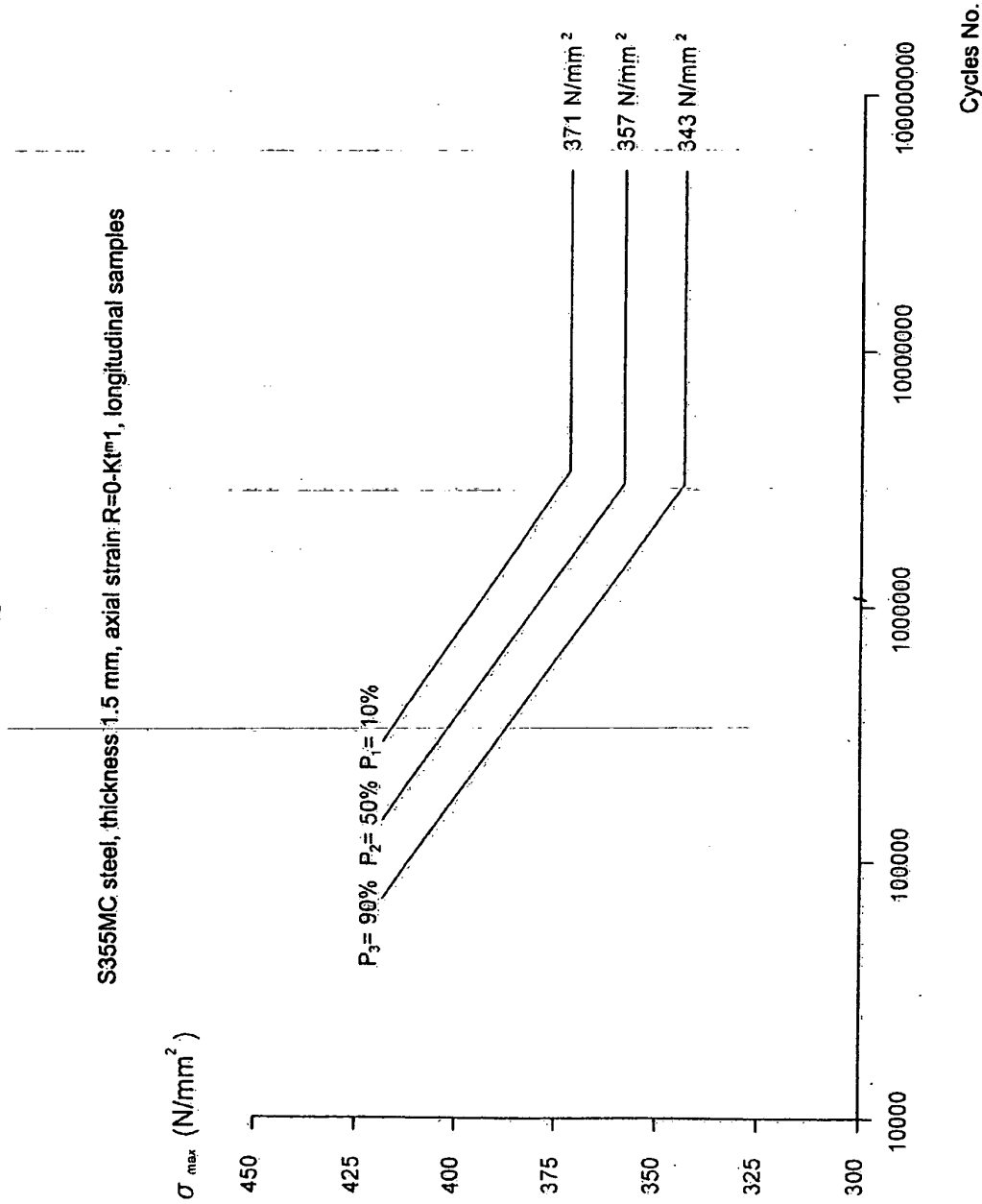


Fig.3



REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2003253381 B [0002]
- WO 03087414 A [0002]
- US 6488790 B [0002]
- US 6264760 B [0002]
- WO 2004026497 A [0006] [0008]