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D E C I S I O N
of 14 November 2003

Case Number: T 1055/01 - 3.2.2

Application Number: 94907693.9

Publication Number: 0641867

IPC: C22C 38/16

Language of the proceedings: EN

Title of invention:
Thin cast piece of ordinary carbon steel containing large quantities of copper and tin, thin steel sheet, and method of production thereof

Applicant:
Nippon Steel Corporation

Opponent:
-

Headword:
-

Relevant legal provisions:
EPC Art. 56

Keyword:
"Inventive step (no)"

Decisions cited:
-

Catchword:
-

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Case Number: T 1055/01 - 3.2.2

D E C I S I O N
of the Technical Board of Appeal 3.2.2
of 14 November 2003

Appellant: NIPPON STEEL CORPORATION
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Decision under appeal: **Decision of the Examining Division of the European Patent Office posted 26 April 2001 refusing European application No. 94907693.9 pursuant to Article 97(1) EPC.**

Composition of the Board:

Chairman: W. D. Weiß
Members: R. Ries
E. J. Dufrasne

Summary of Facts and Submissions

I. This appeal is against the decision of the examining division posted on 26 April 2001 to refuse European patent application No. 94 907 693.9.

The ground of refusal was that the subject matter of claim 1 lacked novelty with respect to document

D3: L. T. Shiang and P. J. Wray: "The microstructure of strip-cast low-carbon steels and their response to thermal processing", Metallurgical Transactions A, volume 20A, July 1989

when read before the background of documents

D7: "Jernkontorets Forskning", 1984, page 5 and

D8: "Spurenelemente im Stahl - Möglichkeiten zur Beeinflussung im Schmelzbetrieb" by Kodym M. et al., in "Spurenelemente in Stählen", Verlag Stahleisen mbH, Düsseldorf, Germany, ISBN 3-514-00324, pages 19 to 22.

The examining division reasoned with reference to document D3 that the twin-roll cast 1.5 to 2.2 mm thick steel strip exhibited a thickness, composition and a primary dendrite arm spacing within the ranges claimed in the application. As regards the amounts of Cu and Sn, at least the lower limits claimed for these components were held not to depart from the usual contents admitted as impurities in conventional steels, as set out in documents D7 or D8. The subject matter of

claim 1 was, therefore, anticipated by the explicit and implicit disclosure of document D3.

II. On 26 June 2001 the appellant (applicant) lodged an appeal against the decision and paid the prescribed fee on the same date. On 5 September 2001 a statement of the grounds of appeal was filed.

III. On appeal the following document already considered during substantive examination was discussed:

D1: translation into English language of JP-A-162 943

IV. In response to the Board's communication, the appellant submitted further arguments in support of its position and enclosed five revised sets of claims (main request and auxiliary requests 1 to 4).

V. At the end of the oral proceedings which were held on 14 November 2003 the applicant requested that the decision under appeal be set aside and a patent be granted on the basis of the main request filed on 14 October 2003 or, alternatively, on one of the auxiliary requests 1 to 4 filed on the same date.

Claim 1 of the main request reads as follows:

"1. A thin cast strip of a common carbon steel, comprising 0.15 to 10% by weight of Cu and 0.03 to 0.5% by weight of Sn, and optionally 0.02 to 0.7% by weight of Ni, wherein the chemical ingredients of said thin cast strip other than Cu and Sn are those of at least one common carbon steel selected from the group consisting of steel product designation "SPHC"

specified in JIS G3131 (corresponding to ASTM A621-82), steel product designation "SS41" specified in JIS G3101 (corresponding to ASTM A569-72), steel product designation "SPHT3" specified in JIS G3132 (corresponding to SAE 1026), steel product designation "S48C" specified in JIS G4051 (corresponding to ASTM A446-85), a steel comprising 0.03 to 0.5% C, 0.01 to 0.3% Si, 0.1 to 2% Mn, 0.001 to 0.05% P, 0.001 to 0.05% S and the balance being iron and unavoidable impurities and a steel comprising 0.03 to 0.05% C, 0.005 to 0.015% Si, 0.1 to 0.2% Mn, 0.005 to 0.02% P, 0.002 to 0.01% S, and the balance being iron and unavoidable impurities, wherein the common carbon steel comprises optionally one or more selected from, in wt%, Ti: ≤0.08%, Nb: ≤0.04%, B: ≤0.0002%, Cr: ≤0.04%, Mo: ≤0.25%, V: ≤0.03% and Zr: ≤0.06% and having a thickness of 0.1 to 15 mm produced by a twin roll continuous casting process, wherein the primary arm spacing of the cast strip in a surface layer portion, said surface layer portion having a depth of 2 mm from the surface of the cast strip when the thickness of the cast strip is 4 mm to 15 mm and having a depth reaching to the center of the cast strip when the thickness of the cast strip is less than 4 mm, is in the range of 5 to 100 µm."

Claim 1 of the first auxiliary request reads as follows:

"1. A thin cast strip of a common carbon steel, comprising 0.15 to 10% by weight of Cu and 0.03 to 0.5% by weight of Sn, and optionally 0.02 to 0.7% by weight of Ni, wherein the chemical ingredients of said thin cast strip other than Cu and Sn are those of at least one common carbon steel selected from the group consisting of steel product designation "SPHC"

specified in JIS G3131, steel product designation "SS41" specified in JIS G3101, steel product designation "SPHT3" specified in JIS G3132, steel product designation "S48C" specified in JIS G4051, a steel comprising 0.03 to 0.5% C, 0.01 to 0.3% Si, 0.1 to 2% Mn, 0.001 to 0.05% P, 0.001 to 0.05% S and the balance being iron and unavoidable impurities and a steel comprising 0.03 to 0.05% C, 0.005 to 0.015% Si, 0.1 to 0.2% Mn, 0.005 to 0.02% P, 0.002 to 0.01% S, and the balance being iron and unavoidable impurities, and having a thickness of 0.1 to 15 mm produced by a twin roll continuous casting process, wherein the primary arm spacing of the cast strip in a surface layer portion, said surface layer portion having a depth of 2 mm from the surface of the cast strip when the thickness of the cast strip is 4 mm to 15 mm and having a depth reaching to the center of the cast strip when the thickness of the cast strip is less than 4 mm, is in the range of 5 to 100 μm, and wherein

the common carbon steel of steel product designation "SPHC" comprises, wt%, C: ≤0.15%, Mn: ≤0.6%, P: ≤0.050%, S: ≤0.050%, with the balance being iron and unavoidable impurities,

the common carbon steel of steel product designation "SS41" comprises, in wt%, C: not limited, Mn: not limited, P: ≤0.050%, S: ≤0.050%, with the balance being iron and unavoidable impurities,

the common carbon steel of steel product designation "SPHT3" comprises, in wt%, C: ≤0.25%, Si: 0.35%, Mn: 0.30-0.90%, P: ≤0.040%, S: ≤0.040%, with the balance being iron and unavoidable impurities, and

the common carbon steel of steel product designation "S48C" comprises, in wt%, C: 0.45-0.51%, Si: 0.15-0.35%, Mn: 0.6%-0.90%, P: ≤0.030%, S: ≤0.035%,

with the balance being iron and unavoidable impurities, and

wherein the common carbon steel comprises optionally one or more selected from, in wt%, Ti: ≤0.08%, Nb: ≤0.04%, B: ≤0.0002%, Cr: ≤0.04%, Mo: ≤0.25%, V: ≤0.03% and Zr: ≤0.06%."

Claim 1 of the second auxiliary request reads:

"1. A thin cast strip of a common carbon steel, comprising 0.15 to 10% by weight of Cu and 0.03 to 0.5% by weight of Sn, and optionally 0.02 to 0.7% by weight of Ni, wherein the chemical ingredients of said thin cast strip other than Cu and Sn are those of at least one common carbon steel selected from a steel comprising 0.03 to 0.5% C, 0.01 to 0.3% Si, 0.1 to 2% Mn, 0.001 to 0.05% P, 0.001 to 0.05% S and the balance being iron and unavoidable impurities and a steel comprising 0.03 to 0.05% C, 0.005 to 0.015% Si, 0.1 to 0.2% Mn, 0.005 to 0.02% P, 0.002 to 0.01% S, and the balance being iron and unavoidable impurities, wherein the common carbon steel comprises optionally one or more selected from, in wt%, Ti: ≤0.08%, Nb: ≤0.04%, B: ≤0.0002%, Cr: ≤0.04%, Mo: ≤0.25%, V: ≤0.03% and Zr: ≤0.06% and having a thickness of 0.1 to 15 mm produced by a twin roll continuous casting process, wherein the primary arm spacing of the cast strip in a surface layer portion, said surface layer portion having a depth of 2 mm from the surface of the cast strip when the thickness of the cast strip is 4 mm to 15 mm and having a depth reaching to the center of the cast strip when the thickness of the cast strip is less than 4 mm, having a depth of 2 mm from the surface of the cast strip is in the range of 5 to 100 µm."

Claim 1 of the third auxiliary request reads as follows:

"1. A thin cast strip of a common carbon steel, comprising 0.15 to 10% by weight of Cu and 0.03 to 0.5% by weight of Sn, and optionally 0.02 to 0.7% by weight of Ni, wherein the chemical ingredients of said thin cast strip other than Cu and Sn are those of at least one common carbon steel selected from the group consisting of steel product designation "SPHC" specified in JIS G3131, steel product designation "SS41" specified in JIS G3101, steel product designation "SPHT3" specified in JIS G3132, steel product designation "S48C" specified in JIS G4051, a steel comprising 0.03 to 0.5% C, 0.01 to 0.3% Si, 0.1 to 2% Mn, 0.001 to 0.05% P, 0.001 to 0.05% S and the balance being iron and unavoidable impurities and a steel comprising 0.03 to 0.05% C, 0.005 to 0.015% Si, 0.1 to 0.2% Mn, 0.005 to 0.02% P, 0.002 to 0.01% S, and the balance being iron and unavoidable impurities, and having a thickness of 3 to 15 mm produced by a twin roll continuous casting process, wherein the primary arm spacing of the cast strip in a surface layer portion, said surface layer portion having a depth of 2 mm from the surface of the cast strip when the thickness of the cast strip is 4 mm to 15 mm and having a depth reaching to the center of the cast strip when the thickness of the cast strip is less than 4 mm, is in the range of 5 to 100 μm, and wherein

the common carbon steel of steel product designation "SPHC" comprises, in wt%, C: ≤0.15%, Mn: ≤0.6%, P: ≤0.050%, S: ≤0.050%, with the balance being iron and unavoidable impurities,

the common carbon steel of steel product designation "SS41" comprises, in wt%, C: not limited, Mn: not limited, P: ≤0.050%, S: ≤0.050%, with the balance being iron and unavoidable impurities,

the common carbon steel of steel product designation "SPHT3" comprises, in wt%, C: ≤0.25%, Si: 0.35%, Mn: 0.30-0.90%, P: ≤0.040%, S: ≤0.040%, with the balance being iron and unavoidable impurities, and

the common carbon steel of steel product designation "S48C" comprises, in wt%, C: 0.45-0.51%, Si: 0.15-0.35%, Mn: 0.6%-0.90%, P: ≤0.030%, S: ≤0.035%, with the balance being iron and unavoidable impurities, and

wherein the common carbon steel comprises optionally one or more selected from, in wt%, Ti: ≤0.08%, Nb: ≤0.04%, B: ≤0.0002%, Cr: ≤0.04%, Mo: ≤0.25%, V: ≤0.03% and Zr: ≤0.06%."

Compared to the third auxiliary request, claim 1 of the fourth auxiliary request additionally comprises the following wording (in bold letters):

"1. A thin cast strip.... V: ≤0.03% and Zr: ≤0.06%, and **wherein the thin cast strip has a surface cracking depth of not more than 30 µm.**

VI. The appellant argued as follows:

The cast thin steel strip featuring in claim 1 of all requests is directly cast from a molten metal and corresponds in its properties to a hot rolled steel sheet although a hot rolling step has not been performed. It is therefore clearly distinguished from

the hot rolled thin steel sheet disclosed in document D1.

Moreover, the problem solved by the present invention is different from that specified in document D1 which aims at avoiding the formation of cracks during hot rolling caused by red shortness. By contrast, the object of the present invention is to avoid the formation of surface cracks of the thin steel sheet during the casting step so that a crack-free thin cast steel sheet is obtained which is not hot rolled.

The process disclosed in document D1 therefore suggests a solution to the problem of red shortness during hot rolling but it does not suggest how the problem of avoiding surface cracks during casting could be successfully solved. The highest cooling rate in document D1 is 60°C/s which is far below the cooling speed in the range of 100 to 10 000°C/s required in the claimed method. Such a cooling rate is for the first time proposed in the present invention. Hence the technical teaching given in document D1 cannot be simply applied to solve the problem underlying the present invention.

Document D3 is more remote since it is concerned with a twin roll cast steel strip not comprising any of Cu or Sn and consequently, the problems associated with the presence of these tramp elements are not addressed in the this document. Since the cooling rates in the twin roll casting process vary according to the selected cooling conditions, it is not correct to consider that the specific cooling rate disclosed in document for a 1.5 to 2.2 mm thick steel sheet can be generally

applied to any type of twin roll casting process. Given that the problem underlying the present invention is neither addressed by document D1 nor by document D3, a motivation for combining the technical teaching given in these two documents does not exist. Consequently the claimed subject matter involves an inventive step.

Reasons for the Decision

1. The appeal is admissible.

2. *The application*

The present application is concerned with the twin-roll casting of thin steel strip of a steel material comprising large amounts of copper and tin which originate from the use of Cu- and Sn-contaminated scrap as a raw material. High amounts of the tramp elements copper and tin, however, entail the drawback of red shortness (or hot shortness), a crack phenomenon which occurs when the cast strip is heated up and hot rolled. The application states on pages 1 and 2 that the problem of red shortness arises from Cu- and Sn-enriched zones in its microstructure. These zones are unevenly distributed at the grain boundaries of the steel and form a low melting liquid film when the cast steel strip is reheated to the required hot rolling temperature. According to page 2 of the introductory part of the application, one possibility to cope with this problem is the addition of rather high amounts of nickel which prevent the formation of a liquid film but present other problems including increased costs.

Hence, the problem underlying the present application resides in providing a thin twin roll cast steel strip which is not prone to surface cracking (resulting from the presence of Cu and Sn) and which does not require the addition of expensive Ni as an alloying element (cf. the application, page 3, lines 3 to 26).

This problem can be overcome if the microstructure installed in the cast strip comprises a fine dendrite structure having a primary dendrite spacing in the range from 5 to 100 µm. The claimed microstructure is obtained by rapidly solidifying the steel melt so that macro-segregation in the centre portion of the steel strip does not occur and the degree of (micro) segregation of Cu and Sn between the dendrites is remarkably lowered or even suppressed (cf. the application page 3, line 27 to page 4, line 29; page 5, lines 16 to 23; page 9, lines 8 to 14).

3. *The closest prior art*

3.1 Like the present application, document D1 relates to a method of producing thin steel sheet from steel melts containing high amounts of the tramp elements copper, tin and sulphur. The steel compositions given in document D1, Table 1, fall within the elemental ranges stipulated in claim 1 of the present application. The steel melts are continuously cast either by twin-belt, single-belt or twin-roll casting to produce a steel strip having a thickness of 50 mm or less which is then hot-rolled (cf. D1, page 6, third paragraph; page 7: Effects of the Invention). Like the present application, document D1 focuses the skilled reader's attention to the problem that the tramp elements Cu, Sn and S tend

to segregate during the solidification of the steel melt. A detailed explanation of the segregation behaviour of Cu, Sn and S, which complies with the corresponding description of this phenomenon given in the present application, is disclosed in document D1, page 3, lines 5 to 20. It is stated that the segregations lead to cracking and surface flaws in the form of fine splits which not only adversely affect the appearance of the surface of the sheet but may prevent hot rolling itself or at least a subsequent cold rolling. Before this technical background document D1, therefore, aims at providing a method for producing thin steel sheet which is not susceptible to develop cracks during hot working so that the hot working process is simplified to produce thin steel sheet directly from continuously cast slab in such a manner that the cast thickness is 50 mm or less (cf. D1, page 2, Detailed Description of the Invention).

3.2 The appellant has argued that the problem specified in the application is quite different from that of document D1. In its view, the known method tries to avoid cracking of the steel strip **during hot rolling** performed after casting, whereas the object of the present application is to avoid surface cracks **during the casting step** so that a thin cast strip without cracks and without further hot rolling is obtained.

3.3 Exhaustive scrutiny however shows that the appellant's reliance on document D1 is misplaced. Document D1 makes it undoubtedly clear that the nature of cracking is closely related to the segregation of the tramp elements Cu, Sn and S **during casting and solidifying the liquid steel** and to the formation of a liquid film

or precipitates by these elements at the austenite grain boundaries when (re-)heating the cast strip to the hot rolling temperature (cf. D1, page 4, lines 1 to 5). Like the present application, the method given in document D1 aims at effectively influencing the segregation behaviour of these elements already during the casting step so that, in consequence thereof, cracks and surface defects, in the cast steel strip or during the subsequent hot rolling step, can be prevented (cf. D1, page 4, lines 7 to 12). The problem underlying the process given in document D1 and that of the present application is, therefore, the same.

4. *Inventive step (main request)*

4.1 As set out in document D1, page 4, lines 22 to 28, the extent of cracking during hot rolling, which originates from differences in thickness, the rate of extraction and the other factors during the casting process, can be effectively influenced by controlling the solidification rate of the molten steel in the caster. Although the cooling rate during twin roll casting is essentially governed by the thickness of the slab, a minimum cooling rate CR depending on the total of Cu, Sn and S and expressed by the formula CR(°C/s) ≥ 15x[%Cu+%Sn+S] is nevertheless required (cf. D1, page 5, lines 13 to 16). Document D1 thus discloses the concept of providing in the twin-roll caster a solidification rate sufficiently high to reduce or minimize the segregation of Cu, Sn and S and to provide a microstructure in which cracking problems do not occur, irrespective of whatever process (hot rolling, cold rolling, annealing, etc) the steel strip undergoes after casting. Bearing in mind the technical knowledge

given in document D1, the skilled person is prompted to select without applying an inventive activity a "high" cooling rate of solidification in order to prevent or avoid the harmful segregations of Cu and Sn and, in consequence thereof, the disadvantages associated therewith. This technical concept has also been followed in the present application, where the cooling solidification rate of the molten steel constitutes the governing factor to suppress the deleterious segregation of Cu, Sn and S and to provide a specific primary dendrite arm spacing up to a certain depth from the surface of the steel strip (cf. the application page 8, lines 17 to 37).

4.2 It is true that document D1 remains silent about the **primary** dendrite arm spacing of 5 to 100 µm up to a depth of 2 mm from the surface of the strip and that the highest cooling is 60°C/s for a cast thickness of 4 mm (example F).

It can, however, be concluded from document D3 that these parameters are generally achieved when performing conventional twin-roll casting. In this document, conventional steel strip having a thickness in the range of 1.5 to 2.2 mm from steel comprising only residual amounts of Cu, Sn and S, has been produced at a local solidification rate between 590 to 850°C/s so that the primary arm spacing is in the range of 17 to 25 µm at the surface, being coarser near the centre of the strip (cf. D3, page 1191: III. Experimental Results; page 1192, Table I, page 1196: IV. Discussion; Table II). Even in case Cu and Sn are actually present in amounts above the impurity level, these data remain essentially unchanged since the steel composition is

not a determining factor. Despite the fact that document D3 fails to mention the problem underlying the present application and document D1, it nevertheless helps a skilled person to assess which values of the technical parameters are achieved in a conventionally twin roll cast steel sheet. In the light of the teaching given in document D3, the cooling rates and the primary dendrite arm spacing stipulated in present claims 1 to 6, therefore, meet merely the normal expectations of a person skilled in this field of technology.

In view of these considerations, the subject matter of claim 1 is obvious from the combined teaching given in documents D1 and D3.

4.3 The appellant has argued that, contrary to document D1, claim 1 is directed to a thin cast steel strip which in its properties corresponds to a hot rolled strip and does not require hot rolling.

It is, however, noted that the claimed thin cast steel strip merely represents an intermediate product which is intended to be cold rolled or annealed and temper rolled (cf. the application page 5, lines 26 to 37 and page 12, lines 17 to 30). A comparable intermediate product in the form of a thin cast steel sheet is produced also by the method disclosed in the document D1. Claim 1 of the present application does not even exclude to perform a hot rolling step, as required in the method known from document D1. In this respect no patentable difference exists between the cast strip according to claim 1 of the present application and the intermediate cast steel strip disclosed in document D1.

4.4 In consequence thereof, the subject matter of claim 1 of the main request does not involve an inventive step.

5. The same statement is true for claim 1 according to the first and second auxiliary requests which additionally include the composition of various standard steels and upper limits for the residuals.

6. Claim 1 of the third and fourth auxiliary requests stipulate a restriction of the thickness of the twin-roll cast steel sheet to 3 to 15 mm.

It is true that the scientific publication D3 is restricted to the investigation of the as-cast microstructure of a 1.5 to 2.2 mm twin-roll cast strip. This limitation in the thickness does, however, not prevent the skilled reader from taking into account also other thickness ranges for steel sheet obtained by twin roll casting. Document D1 for instance discloses cast thicknesses of 4 mm, 10 mm or even 50 mm up to which the segregation of the tramp elements and hot shortness resulting thereof can be effectively suppressed. Hence, also the restriction of the sheet thickness featuring in claim 1 of the third and fourth auxiliary does not represent inventive matter.

7. Given this situation, there is no need investigate in detail for instance whether or not the claims of all requests satisfy the requirements of Articles 123(2) and 84 EPC.

Order

For these reasons it is decided that:

The appeal is dismissed.

The Registrar:

V. Commare

The Chairman:

W. D. Weiß

R.R.