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Datasheet for the decision of 22 October 2008

Case Number: T 1035/07 - 3.2.03

Application Number: 01971506.9

Publication Number: 1326725

IPC: B22D 11/06

Language of the proceedings: EN

Title of invention:
Production of thin steel strip

Patentee:
NUCOR CORPORATION

Opponent:
-

Headword:
-

Relevant legal provisions:
EPC Art. 56

Relevant legal provisions (EPC 1973):
-

Keyword:
"Inventive step (yes)"

Decisions cited:
-

Catchword:
-

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Beschwerdekammern
Boards of Appeal
Chambres de recours

Case Number: T 1035/07 - 3.2.03

D E C I S I O N
of the Technical Board of Appeal 3.2.03
of 22 October 2008

Appellant: NUCOR CORPORATION
2100 Rexford Road
Charlotte, NC 28211 (US)

Representative: Lerwill, John
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Decision under appeal: **Decision of the Examining Division of the European Patent Office posted 16 January 2007 refusing European application No. 01971506.9 pursuant to Article 97(1) EPC.**

Composition of the Board:

Chairman: U. Krause
Members: G. Ashley
K. Garnett

Summary of Facts and Submissions

I. European patent application EP-A-01 971 506, which concerns the casting of steel strip, was refused by the Examining Division for lack of inventive step (Article 56 EPC).

II. The decision was posted on 16 January 2007. The Appellant (applicant) filed notice of appeal on 15 March 2007, having paid the appeal fee on 12 March 2007; a statement containing the grounds of appeal was filed on 22 May 2007.

III. In accordance with Article 15(1) of the Rules of Procedure of the Boards of Appeal, the Board issued a summons to attend oral proceedings together with a preliminary opinion, setting out its views on inventive step. The oral proceedings were duly held on 21 and 22 October 2008.

IV. Claims

Claim 1 of the main request, as submitted with the grounds of appeal, reads as follows:

"1. A method of producing steel strip comprising:

supporting a casting pool of molten low carbon steel on a pair of chilled casting rolls forming a nip between them and continuously casting solidified strip of no more than 5 mm in thickness and including austenite grains by rotating the rolls in mutually opposite directions such that the solidified strip moves downwardly from the nip, the low carbon steel being a silicon/manganese killed steel having the following composition by weight:

Carbon	0.02 - 0.08%
Manganese	0.30 - 0.80%
Silicon	0.10 - 0.40%
Sulphur	0.002 - 0.05%
Aluminium	less than 0.01%;

passing the strip through a rolling mill in which the strip is hot rolled in the temperature range of 900°C to 1100°C to produce a reduction in the strip thickness of at least 15%; and

subjecting the strip having austenite grains to accelerated cooling at a cooling rate in the range of 100°C/sec to 300°C/sec through the austenite to ferrite transformation range within the temperature range between 850°C and 400°C to transform the austenite into a mixture of polygonal ferrite and low temperature transformation products to produce a finished strip having a yield strength greater than 450 MPa."

Dependent claim 2 defines a preferred range of yield strength.

V. Prior Art

The following documents cited in the contested decision are of relevance:

D1: D. Senk et al, "Umformen und Kühlen von direktgegossenem Stahlband", Stahl und Eisen, Verlag Stahleisen GmbH, Düsseldorf, vol. 120, No. 6, pages 65 to 69, 16 June 2000

D9: WO-A-00/42228

D10: W. Blejde, R. Mahapatra & H. Fukase, "Application of Fundamental Research at Project "M", The Belton Memorial Symposium, Sydney, Australia 10-11 January 2000.

D11: W. Blejde, R. Mahapatra & H. Fukase, "Development of Low Carbon Thin Strip Production Capability at Project "M"" ISS 83rd Steelmaking Conference, Pittsburgh, March 2000.

VI. Submissions of the Appellant

The submissions of the appellant are summarised as follows.

D9 describes the continuous casting of a silicon/manganese killed steel in a twin roll caster. However, D9 provides no indication how high yield strength can be obtained without the steps of cold rolling and annealing. The hot rolled strip is cooled by water jets, which are only capable of producing a maximum cooling rate of 90°C/sec, compared to 100 to 300°C/sec required by the method of claim 1. These higher cooling rates were not common in strip casting before the priority date of the present application, and although a cooling rate of 300°K/sec is mentioned in D1, this relates to the cooling zone directly below the casting rolls before the strip enters the hot rolling mill.

D11 provides no disclosure of the effects of hot rolling other than refinement of austenite grains, and in particular there is no guidance as to how a high yield strength can be achieved whilst carrying out hot rolling.

D10 speculates as to what the effects of cooling rate might be on cast strip having a course austenitic grain size; the effects of hot reduction on the microstructure are not discussed. It might be expected that strength could be increased slightly, but yield strengths over 450 MPa would not be envisaged.

Given a desire to increase yield strength of hot rolled steel strip, the skilled person would turn to alternative measures such as modifying the steel chemistry. Neither D10 nor D11 address the conflict between hot rolling and achieving high yield strengths. The claimed method means that high yield strength can be obtained without forfeiting the benefits of hot rolling.

VII. Requests

The Appellant requests that the decision under appeal be set aside and a patent be granted on the basis of the claims of the main request filed with the grounds of appeal.

Reasons for the Decision

1. The appeal is admissible.

2. Article 123(2) EPC

Claim 1 of the main request is based upon claims 1, 3, 11 and 13 of the application as originally filed (WO-A-02/26424), and hence the requirements of Article 123(2) have been met.

3. Inventive Step (Article 56 EPC)

3.1 The present application (page 2, lines 15 to 28) recognises that the rate of cooling through the austenite transformation zone has a significant effect on the microstructure of the final strip. Accelerated cooling promotes the formation of low temperature transformation products which enable high yield strengths to be achieved, even if a significant amount of hot rolling has taken place.

3.2 Documents D9 and D1

3.2.1 Document D9 discloses a method of casting steel strip of less than 5 mm thickness (page 3, lines 22 to 25), the steel being a low carbon silicon/manganese killed steel having the composition defined in claim 1 (page 4, lines 31 to 37). According to D9, the cast strip can be hot rolled to a thickness reduction of not more than 40% (page 5, lines 18 to 21 and hot rolling mill 16). Following hot rolling, the steel strip is cooled at 10 to 20°C/sec and coiled at 600 to 700°C (page 8, lines 23 to 26). The strip is then uncoiled, cold rolled and annealed in order to produce the final properties in the steel.

3.2.2 The method of claim 1 thus differs from that of D9 in that, after hot rolling, the strip is subjected to accelerated cooling at a rate 100 to 300°C/sec through the austenite to ferrite transformation range with the consequence that a microstructure of low transformation products are obtained that provide a yield strength of greater than 450 MPa.

3.2.3 D9 mentions the use of fast cooling conditions (page 8, lines 29 to 31), and the Examining Division considered that the skilled person would understand this to mean cooling at 100 to 300°C/sec, especially as in the opinion of the Examining Division such rates were well known in strip casting, an example of which is given in D1 (Figure 4 and page 68 left-hand column). However, D1 is an academic paper presented to a meeting "Stahl 99" in 1999 in Düsseldorf, and as such is not considered to be part of the general knowledge of the average skilled person. D1 discloses that a cooling rate of 300°C/sec is possible directly after the strip exits the casting rolls, but no mention is made as to whether such a cooling rate could or should be employed after a hot rolling step, as is defined in claim 1.

3.2.4 In D9 the steel strip is cooled after hot rolling by water jets 18 (see Figure 1 and page 6, lines 21 to 23). According to the description of the present application, such a technique is only capable of a maximum cooling rate of 90°C/sec (page 2, lines 17 to 19 of the description), and hence the reference to "fast cooling" in D9 means cooling at this rate; the Board has no reason to doubt this statement. In order to achieve the higher cooling rates necessary for the present invention, a different cooling technique using cooling headers, is employed (see the description, page 11, lines 11 to 35). These higher cooling rates lead to low temperature transformation phases, such as bainite and/or martensite, and the correspondingly higher yield strengths.

Since it is necessary to adapt specially the cooling method of D9 to produce higher cooling rates, and such a modification is not obvious either from the teaching of D9 alone, or when take in combination with D1, the claimed method has an inventive step with respect to these documents.

3.3 Document D11

3.3.1 D11 is an article discussing strip casting low carbon silicon-killed steel in conjunction with hot rolling, and teaches (page 32, last paragraph of the section "Product Properties") that a "wide range of strip properties can be obtained with a single chemistry by controlling the microstructure of as-cast material, rolling temperature, amount of hot reduction and rate of product cooling". According to both the present application (page 11 line 36 to page 12, line 4) and D11 (page 32, left-hand column, second paragraph), the microstructure of the steel in D11 is a mixture of polygonal ferrite and low temperature transformation products. D11 is thus an appropriate starting point for the assessment of inventive step.

An example is given in D11 (see Table III) in which a 1.4 mm strip is cast, and then hot rolled at 1050°C with a reduction of 29% to give a product 1 mm in thickness. However, the resulting yield strength of the strip is 320 MPa, compared with the minimum value of 450 MPa given in claim 1.

3.3.2 Starting from D11, and in particular this example, the objective problem to be solved is how to increase the yield strength of the steel strip.

3.3.3 According to the present application, the solution is to increase the cooling rate; this provides the steel with a microstructure containing low temperature transformation products such that the steel has a yield strength above 450 MPa.

It is therefore necessary to assess whether, starting from D11, it would be obvious to increase the cooling rate to achieve this objective.

3.3.4 Document D10 (page 47) provides a discussion of the effects of cooling rate on the evolution of microstructure in steels formed by strip casting. D10 discloses that the coarse austenitic grain size associated with strip casting allows a range of microstructures to be produced from a single chemistry steel.

Figure 20 of D10 shows the range of microstructures available when strip casting low carbon steel and their associated tensile strengths. In particular Figure 20 shows that microstructures such as bainite and martensite, which are necessary for high strengths, can be produced by cooling on the run-out-table. Figure 19 indicates that the cooling rate in strip casting has a greater influence on yield strength than in a conventional hot strip mill process, and this is because of the presence of coarse austenite (paragraph bridging second and third columns on page 47).

3.3.5 The Examining Division thus argued that the skilled person wishing to produce a steel with a high yield strength, above 450 MPa, would aim for a microstructure based on low temperature transformation products, such as bainite and martensite. According to D10 these can be formed by providing run-out-table cooling, with the required cooling rate being determined by routine experimentation. However, this conclusion could only be derived at with knowledge of the invention.

3.3.6 The discussion of the cited example in D11 (see page 32, left-hand column, second paragraph and Figure 9(c)) discloses that the higher reduction of 29% creates a pronounced refinement of the as-cast microstructure. The effect of hot reduction is therefore to reduce the size of the austenite grains. According to D10 (page 47, right-hand column, second paragraph), finer austenite grains are relatively insensitive to changes in strip cooling rate, such that, for example, ultra fast cooling rates (in excess of 500°C/sec) are necessary with hot strip mill products in order to produce high strength steels.

Faced with the problem of increasing the yield strength, the skilled person thus knows that extremely high cooling rates are required in a conventional hot strip mill where the austenite grain size is fine, but such extreme rates are not required in strip casting because of the coarse austenite grain size. Claim 1 of the present application requires a rolling reduction of at least 15%, which would be accompanied by a corresponding reduction in grain size. In the absence of coarse austenitic grains, the skilled person would not expect that a cooling rate of 100 to 300°C/sec would lead to a yield strength greater than 450 MPa. With the aim of high yield strength in mind, the skilled person would turn to the more obvious solutions of changing the steel composition or reducing the amount of hot working.

3.3.7 The method of claim 1 can achieve the combination of high hot reduction and high yield strength because of the high cooling rate employed (100 to 300°C/sec). As set out above, this is higher than is normally used in strip casting and requires particular equipment; nevertheless it provides sufficient cooling to compensate for the effect a reduced austenite grain size resulting from the hot reduction has on formation of low temperature transformation phases. The consequence is that the advantages of hot rolling are available whilst achieving high yield strength. Since this combination is not rendered obvious by the available prior art documents, the claimed method has an inventive step.

Order

For these reasons it is decided that:

1. The decision under appeal is set aside.

2. The case is remitted to the Examining Division with the order to grant a patent on the basis of:
   (a) The main request filed with the grounds of appeal on 24 May 2007, consisting of claims 1 and 2;
   (b) The description pages 1, 6 to 12, as originally filed, pages 3, 4 and 5, as filed with the grounds of appeal on 24 May 2007, and pages 2,2a and 13, as filed during the oral proceedings.
   (c) Figure sheets 1 to 7, as originally filed.

The Registrar: The Chairman:

A. Counillon U. Krause