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D E C I S I O N
of 8 August 2005

Case Number: T 0275/03 - 3.2.2

Application Number: 97117584.9

Publication Number: 0861914

IPC:

Language of the proceedings: EN

Title of invention:

Method for producing silicon - chromium grain oriented
electrical steel

Applicant:

ARMCO Inc.

Opponent:

-

Headword:

-

Relevant legal provisions:

EPC Art. 84, 56

Keyword:

"Clarity, inventive step - (yes after amendment)"

Decisions cited:

-

Catchword:

-



Case Number: T 0275/03 - 3.2.2

D E C I S I O N
of the Technical Board of Appeal 3.2.2
of 8 August 2005

Appellant: Armco Inc.
(Applicant) Middletown,
Ohio 45044-3999 (US)

Representative: Beetz & Partner
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Decision under appeal: Decision of the Examining Division of the
European Patent Office posted 9 October 2002
refusing European application No. 97117584.9
pursuant to Article 97(1) EPC.

Composition of the Board:

Chairman: T. K. H. Kriner
Members: R. Ries
E. Dufrasne

Summary of Facts and Submissions

I. This appeal is against the decision of the examining division dated 9 October 2002 to refuse European patent application No. 97 117 584.9.

The grounds of refusal were that claim 1, the solitary independent claim, did not meet the clarity requirements of Article 84 EPC and did not involve an inventive step with respect to the prior art

D1: US-A-5 421 911

II. On 19 November 2002 the appellant (applicant) lodged an appeal against the decision and paid the prescribed fee on the same date. On 18 February 2003 a statement of grounds of appeal was filed.

III. Subsequent to a telephone consultation with the Board, the appellant filed on 17 June 2005 an amended set of application documents and requested that the decision under appeal be set aside and a patent be granted thereupon.

The wording of claim 1 of this request reads as follows:

"1. A method for producing a grain oriented electrical steel strip with superior magnetic properties from a hot processed strip, which uses at least two-stages of cold reduction and comprises the steps of:

- providing said hot processed strip,
 - consisting of 2.5 - 4.5 wt.% Si, 0.1 - 1.2 wt.% Cr, 0.01 - 0.025 wt.% C, Al < 0.005 wt.%,

S \leq 0.1 wt.%, Se \leq 0.14 wt.%, 0.01 - 1 wt.% Mn,
the balance being iron and incidental
impurities,

- having a volume resistivity of at least
45 $\mu\Omega$ -cm,
- an austenite volume fraction $\gamma_{1150^\circ\text{C}}$ prior to cold
reduction of at least 2.5 %, and
- an isomorphic layer on each surface of the
strip, said isomorphic layer having a thickness
of at least 10 % of the total thickness of the
hot processed strip prior to cold reduction to
an intermediate thickness,
- cold rolling said hot-processed strip in a first cold
reduction step to the intermediate thickness, wherein
the amount of reduction % is expressed by $\ln(a/b) > 0.8$,
wherein a is the thickness of said hot processed strip
and b the intermediate thickness after cold reduction,
- annealing said cold rolled strip,
- subsequently, cold rolling said annealed strip during
a second cold reduction step to a final thickness,
- decarburisation annealing said cold reduced strip to
minimize the C-content to an amount of less than
0.003 wt.% to prevent magnetic aging,
- coating at least one surface of said annealed strip
with an annealing separator coating, and
- final annealing said coated strip to effect secondary
grain growth, thereby providing a grain oriented
electrical steel strip having a permeability measured
at 796 A/m of at least 1780 H/m."

IV. The appellant argued as follows:

Contrary to the division's view expressed in the
impugned decision, a clear and precise definition of

the "isomorphic layer" was given in page 2, lines 23 to 27 of the application. Accordingly, the layer described a region of the strip surface depleted of carbon and exhibiting a single phase (isomorphic) ferrite microstructure. Various methods including X-ray diffractometry, scanning electron microscopy (SEM) or other appropriate methods could be used by the material scientist for determining reliably the thickness of the isomorphic layer. The meaning of the term "isomorphic layer" was, therefore, clear to the expert reader.

As to inventive step, document D1 related, contrary to the interpretation by the examining division, to a method for producing regular grain oriented electrical steel strip using a single cold reduction step rather than at least two cold reduction steps as claimed in the present application. More importantly, this document remained completely silent about the existence and thickness of the isomorphic layer referred to in the present application. In addition, document D1 dissuaded the practitioner from reducing the carbon content in the steel strip below 0.03 or even 0.025% and, therefore, this teaching led away from the claimed method using a hot processed strip which comprised i.a. 0.01 to 0.025% carbon to achieve the desired carefully balanced combination of physical and mechanical properties.

The claims and the subject matter to which they relate therefore satisfied the requirements of Article 84, 54 and 56 EPC.

Reasons for the Decision

1. The appeal is admissible.

2. *Article 123(2) EPC*

Amended claim 1 is based on originally filed claim 1 and the technical features given in following parts of the description as filed: The wording "which uses at least two stages of cold reduction" is disclosed in the application on page 1, lines 6 and 7, and the carbon range of 0.01 to 0.025 wt% finds support on page 7, line 37 to page 8, first line. The amount of reduction % expressed by $\ln(a/b) > 0.8$ is disclosed on page 12, lines 17 to 19 and the "carbon content of less than 0.003 wt% to prevent magnetic aging" has a basis on page 12, lines 22 to 24 in combination with page 4, line 16.

The dependent claims 2 to 9 correspond to original claims 2 to 4, and 6 to 10, respectively.

Consequently, the claims do not contravene Article 123(2) EPC.

3. *Clarity*

3.1 The examining division holds the view that the definition of the "isomorphic layer" given on page 2 lines 22 to 24 is unclear in its meaning and contradictory to the passage given on page 17, line 30 and page 18, first line. Moreover, it is considered unclear whether the thickness of the isomorphic layer has been measured or refers to a value calculated e.g.

by the formula (6) mentioned on page 10, line 14 of the application.

- 3.2 The Board cannot follow this position for the following reasons. As regards the definition given in the description on page 2, lines 22 to 24, the isomorphic layer describes a region on the strip surface which has been depleted of carbon and provides a single phase ferrite microstructure. It is further pointed out on page 9, lines 3 to 6 that specific amounts of Si, Cr and a suitable inhibitor along with the other residuals has to be adhered to in order to obtain an appropriate thickness of the (ferrite) isomorphic layer while providing a small but necessary amount of austenite in the starting strip prior to cold reduction. This interdependency is likewise expressed by equation (6) which is regarded as an indication helping to calculate the thickness (I) of the isomorphic layer (whereby I is in mm) to be expected when specific amounts $\gamma_{1150^{\circ}\text{C}}$ and Si are present. Bearing in mind this technical information, nothing contradictory can be found to the explanations given on page 17, line 30 to page 18, lines 3 of the application. Moreover, the Board has no reason to doubt the appellant's argument that the isomorphic layer can be identified without problems, e.g. by using metallographic etching or other appropriate methods, and that the thickness of the isomorphic layer can be determined reliably due to its specific nature (depleted of C, ferrite microstructure) by a skilled person who is in the present case a material scientist.

Hence, the requirements of Article 84 EPC are met.

4. *Novelty*

The novelty of the claimed process vis-à-vis the technical teaching given in document D1 has not been objected to by the examining division. In particular, a distinguishing feature was seen in the claimed reduction rate (%) in the first cold reduction step. Moreover, nothing is found anywhere in document D1 disclosing or pointing to the existence of the isomorphic layer. Hence, the subject matter of claim 1 is novel.

5. *Inventive step*

5.1 According to the jurisprudence of the boards of appeal, it is necessary, in order to assess inventive step, to establish the closest state of the art to determine in the light thereof the technical problem the invention addresses and successfully solves, and to examine the obviousness of the claimed solution in view of the prior art. This "problem-solution-approach" ensures assessing inventive step on an objective basis and avoids the risk of an ex-post-facto analysis.

The present application relates to a process for producing grain oriented electrical steel strip having

- uniform and consistent magnetic properties,
- a high level of volume resistivity (>45 $\mu\Omega$ -cm or more, preferably >50 $\mu\Omega$ -cm),
- a high degree of cube-on-edge orientation and
- a stable secondary grain growth (cf. the application, page 3, lines 14 to 21).

5.2 These objects are, at least in part, likewise addressed in document

D2: EP-A-0 743 370

which is held in the name of the applicant and cited in the European search report (cf. D2, page 3, lines 44 to 47). The method disclosed in document D2 comprises, *inter alia*, the steps of

- providing a hot rolled steel band consisting essentially of, in weight percent, 0.01 to 0.08% C, 2.25 to 7% Si, 0.015 to 0.05% Al, $\leq 0.01\%$ S, $>0.5 \text{ Mn}_{\text{eq}}$, 0.001-0.011% N, and optionally up to 3% Cr, up to 1% Cu, up to 2% Ni, up to 0.1% Sn, up to 0.5% P, up to 0.01% Se, and up to 0.1% Sb, the balance being iron and residual impurities to provide a volume resistivity of at least $50 \mu\Omega\text{-cm}$,
- providing $\gamma_{1150^\circ\text{C}}$ in the hot rolled band of at least 5%,
- optionally initial annealing said band,
- cold rolling said annealed band in 1, 2 or more stages to the final thickness,
- decarburisation annealing the band to a carbon content below 0.005%, typically below 0.003% (cf. D2, page 6, line 41)
- nitriding said band following primary recrystallisation and prior to secondary grain growth,
- coating the strip with an annealing separator and
- final annealing the strip at $\geq 1100^\circ\text{C}/\geq 5\text{h}$ (cf. in particular D2, claims 1 and 6).

From the technical point of view and having regard to its publication date (20 November 1996), document D2 represents in the Board's view the closest prior art. However, document D2 is silent about the existence of an isomorphic surface layer on both sides of the hot rolled sheet and fails to specify the preferred

reduction rate of the first cold rolling step.

Moreover, the method set out in D2 provides prior to secondary grain growth a nitriding treatment that is not required in the claimed process.

- 5.3 Starting from this prior art, the problem underlying the present application resides in providing a process by which the previously mentioned magnetic and electrical properties of the grain oriented electrical steel strip are reliably obtained but without, however, degrading its physical properties and processability. This means a steel exhibiting improved mechanical property characteristics that provide in particular superior toughness and lower brittleness, i.e. a greater resistance to strip breakage during processing (cf. the application page 4, line 34 to page 5, line 4).

The solution to this problem resides in selecting a carefully balanced steel composition comprising C, Si, Mn and Cr within narrowly confined ranges, the provision of a (ferritic) isomorphic layer of a specific thickness on each surface of the hot rolled band and applying a reduction rate of $\ln(a/b) > 0.8$ (corresponding to a minimum reduction rate of $> 50\%$) in the first cold rolling step. It is apparent from the examples and in particular from the results depicted in Figures 1 and 2 that the identified problem has been successfully solved by the claimed process.

- 5.4 In particular the mechanical properties of the electrical steel sheet have not at all been tested in document D2. As set out in the present application, however, a strong interdependency has been observed to exist between the various processing and compositional

parameters which benefit or adversely affect the sensitive balance of the above mentioned physical and mechanical properties. For instance, a lower core loss and a higher volume resistivity is achieved by increasing the percentage of Si which simultaneously requires a corresponding increase of the percentage of carbon. However, both carbon and silicon adversely affect the physical properties by promoting a higher brittleness and by increasing the difficulty in completely removing carbon during the decarburisation annealing step. Likewise, additions of chromium are found to interfere with the development of the cube-on-edge texture but could on the other hand impair the decarburisation of the steel strip. Having regard to the complex interactions of all parameters, the composition of the claimed steel sheet has been modified by restricting the range of carbon to 0.01 to 0.025% and that of aluminium to less than 0.005%. Although document D2 specifies a broad carbon range between 0.01 and 0.08%, it recommends the carbon content to fall within a range of 0.025 to 0.050% as to stabilize the austenite and to prevent secondary metal refining and cost increase (cf. D2, page 6, lines 12 to 16; claims 4, 7). As can be learned from the exemplifying compositions given in D2, Tables 1, 3, 5, 7 and comprising at least 0.10% Cr, a carbon content of about 0.04 has been selected.

Moreover, at least 0.015% (preferably 0.020%) acid soluble aluminium is indispensably present to allow sufficient levels of AlN to form (cf. D2, page 6, lines 22 to 24). In contrast thereto, the amount of acid soluble Al of the steel alloy used in the claimed process is restricted to less than 0.005% to provide

stable secondary growth (cf. page 8, lines 32 to 34). As regards at least the steel composition, document D2 is, therefore, leading away from the steel alloy designed in the claimed process.

In addition, the claimed process requires that an isomorphic layer having a thickness of at least 10% of the total thickness of the hot rolled steel is provided prior to cold rolling. This is important since thinning the isomorphic layer weakens the secondary grain growth, impairs the quality of the cube-on-edge orientation and increases the difficulty in obtaining a carbon content less than 0.003% in the final cold rolled sheet (cf. the application page 8, lines 4 to 8; Figure 2).

Document D2 does not even remotely mention an isomorphic layer and, consequently, it could not have been obvious to select a specific thickness of that layer as has been done in the claimed process.

- 5.5 In the view of the examining division, document D1 represents the closest prior art. Although the process given in D1 does not require a nitriding step, this document D1 appears to be concerned essentially with the provision of a process which enables to obtain the desired magnetic and electrical properties in regular grain oriented electrical steel having 0.005% Al by using a single cold reduction process (cf. column 4, lines 64 to column 5, line 5; column 17, lines 1 to 7). Hence, the teaching given in D1 clearly tries to avoid a two-stage cold rolling treatment. Nothing is said in the D1 about the mechanical properties such as brittleness and toughness of the electrical steel sheet. As in document D2, the steel used in document D1 typically exhibits an aim melt composition of 0.03 to

0.05% carbon (cf. D1, column 5, lines 34 to 42) and thus clearly dissuades from using carbon contents lower than 0.025% which are found in D1 to make the secondary recrystallisation unstable and impair the magnetic permeability (cf. D1, column 8, line 59 to column 9, line 3; claim 1). In consequence thereof, the carbon content in all examples is selected to be about 0.035% or higher. As in document D2, the presence of an isomorphic layer is not mentioned in document D1. Hence, also the teaching of document D1 could not lead in an obvious manner to the claimed process. In view of these considerations, an inventive step with respect to the technical teaching of document D1 cannot be disputed.

5.6 Given this situation, the subject matter of claim 1 also involves an inventive step (Article 56 EPC).

5.7 The dependent claims 2 to 9 relate to preferred embodiments of the process set out in claim 1 and are, therefore, also allowable.

Order

For these reasons it is decided that:

1. The decision under appeal is set aside.

2. The case is remitted to the first instance with the order to grant a patent on the basis of

claims 1 to 9 submitted with letter of 17 June 2005

description: pages 1 to 11, 14 to 18 as filed,

description pages 12, 13 submitted with letter of
17 June 2005

Figures 1 and 2 as filed.

The Registrar:

The Chairman:

V. Commare

T. H. K. Kriner