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DECISION
of 11 November 2004

Case Number: T 0666/02 - 3.2.2

Application Number: 94910605.8

Publication Number: 0648853

IPC: C22C 38/24

Language of the proceedings: EN

Title of invention:

Non-heat-treated steel for hot forging, process for producing non-heat-treated hot forging, and non-heat-treating hot forging

Patentee:

NIPPON STEEL CORPORATION

Opponent:

Edelstahl Witten Krefeld GmbH

Headword:

-

Relevant legal provisions:

EPC Art. 56

Keyword:

"Inventive step (no)"

Decisions cited:

-

Catchword:

-



Case Number: T 0666/02 - 3.2.2

D E C I S I O N
of the Technical Board of Appeal 3.2.2
of 11 November 2004

Appellant:
(Opponent)

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Respondent:
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Decision under appeal:

Interlocutory decision of the Opposition
Division of the European Patent Office posted
10 April 2002 concerning maintenance of
European patent No. 0648853 in amended form.

Composition of the Board:

Chairman: T. K. H. Kriner
Members: R. Ries
A. Pignatelli

Summary of Facts and Submissions

- I. The grant of European patent No. 0 648 853 on the basis of European patent application 94910605.8 was mentioned on 19 May 1999.
- II. The granted patent was opposed by the present appellant on the grounds that its subject matter lacked novelty and did not involve an inventive step with respect to the state of the art (Articles 100(a), 54 and 56 EPC).

Of the pre-published documents relied upon in the appeal proceedings, only the following have played any significant role on appeal:

D1: JP-A-63 057742 and translation into English language

D5: JP-A-62 202054 and translation into English language

- III. With its decision posted on 10 April 2002 the Opposition Division held that the patent could be maintained in amended form on the basis of the fourth set of claims filed at the oral proceedings.

The independent claims 1 and 2 read as follows:

"1. A microalloyed hot forging comprising, in terms of weight%,
from 0.15 to 0.40% of C,
from 0.9 to 3.00% of Si,
from 1.20 to 3.00% of Mn,
from 0.10 to 0.50% of Cr,

from 0.03 to 0.10% of S,
from 0.05 to 0.50% of V,
from 0.0080 to 0.0200 of N,
optionally at least one of the following elements:
from 0.005 to 0.050% of Al and from 0.002 to 0.050% of
Ti,
from 0.05 to 1.00% of Mo and from 0.01 to 0.05% of Nb,
and balance Fe and unavoidable impurities,

having a carbon equivalent (Ceq.) represented by the
formula

$$\text{Ceq. (\%)} = \text{C} + 0.10(\% \text{Si}) + 0.18(\% \text{Mn}) + 0.21(\% \text{Cr}) + 0.155(\% \text{Mo})^{1/2} + 0.328(\% \text{V} + \% \text{Nb}) \text{ of at least } 0.82, \text{ and}$$

exhibiting a bainite transformation starting point
represented by the formula

$$\text{Bs(K)} = 1152 - 618(\% \text{C}) - 25(\% \text{Si}) - 76(\% \text{Mn}) - 55(\% \text{Cr}) - 69(\% \text{Mo}) - 127(\% \text{V} + \% \text{Nb}) \text{ of up to } 810\text{K},$$

wherein the hot forging has a bainite structure in an
amount of at least 80% by volume, and exhibits a
tensile strength of at least 1000 MPa."

"2. A method for producing a microalloyed hot forging
having a bainite structure comprising the steps of:

hot forging a microalloyed steel having a composition
comprising, in terms of weight%, at a temperature of at
least 1270K,

from 0.15 to 0.40% of C,
from 0.9 to 3.00% of Si,
from 1.20 to 3.00% of Mn,
from 0.10 to 0.50% of Cr,
from 0.03 to 0.10% of S,

from 0.05 to 0.50% of V,
from 0.0080 to 0.0200 of N,
optionally at least one of the following elements:
from 0.005 to 0.050% of Al and from 0.002 to 0.050% of
Ti,
from 0.05 to 1.00% of Mo and from 0.01 to 0.05% of Nb,
and balance Fe and unavoidable impurities,

having a carbon equivalent (Ceq.) represented by the
formula

$$\text{Ceq. (\%)} = \text{C} + 0.10(\% \text{Si}) + 0.18(\% \text{Mn}) + 0.21(\% \text{Cr}) + \\ 0.155(\% \text{Mo})^{1/2} + 0.328(\% \text{V} + \% \text{Nb}) \text{ of at least } 0.82, \text{ and}$$

exhibiting a bainite starting point Bs represented by
the formula

$$\text{Bs (K)} = 1152 - 618(\% \text{C}) - 25(\% \text{Si}) - 76(\% \text{Mn}) - 55(\% \text{Cr}) - \\ 69(\% \text{Mo}) - 127(\% \text{V} + \% \text{Nb}) \text{ of up to } 810\text{K},$$

allowing the hot forged product to cool and
optionally, after allowing the hot forged product to
cool, further aging the cooled product at a temperature
of 450 to 900K,

whereby the hot forging has a bainite structure in an
amount of at least 80% by volume, and exhibits a
tensile strength of at least 1000 MPa."

- IV. An appeal against this decision was filed on 10 June
2002 and the fee for appeal paid at the same date. The
notice of appeal was also accompanied by the statement
of grounds filed on 20 August 2002 in which the
following document was referred to:

D6: Yoshiro Koyasu et al.: "Development of Special Steel Bars and Wire Rods for High-Strength Automobile Parts", Nippon Steel Technical Report No. 53, April 1992, pages 35 to 43

V. Oral proceedings were held before the Board on 11 November 2004, at the end of which the requests were as follows:

- The appellant (opponent) requested that the decision under appeal be set aside and the patent be revoked.
- The respondent (patentee) requested that the appeal be dismissed.

VI. The appellant argued as follows:

The concept of the micro-alloyed bainite steel forgings claimed in the patent at issue was amply disclosed in document D6. The "typical bainite steel composition" listed in Table 1 only failed to disclose a range for nitrogen. The beneficial effect of nitrogen by forming precipitations such TiN or AlN or V(CN) which acted as nuclei for the transformation of intragranular ferrite was already described in point 2.1 of D6 and, therefore, known to the skilled metallurgist. Moreover, nitrogen amounts ranging from 0.01 to 0.02% were said in document D5, page 13 to inhibit the formation of coarse austenite grains upon heating to high temperatures or during forming. Toughness, however, generally improved with a finer grained microstructure. It was therefore indispensable to include appropriate amounts of nitrogen. This was confirmed in particular by Figures 3

and 4 of document D6 showing that the mechanical properties stipulated in claim 1 of the disputed patent were also achieved by the known alloy.

Hence, the technical features of the bainite steel forgings set out in claim 1 did not involve an inventive step.

VII. The respondent argued as follow:

Document D6 dealt with micro-alloyed bainite steel forgings but failed to mention the presence of nitrogen as a compulsory ingredient of the typical bainite steel composition referred to in Table 1. It was only the ferrite-perlite steels discussed in D6, paragraph 2.1 which appeared to comprise nitrogen to the extent that TiN was formed. This prior knowledge relating to ferrite-perlite steels could, however, not be assumed also to relate to bainite steels where nitrogen had a fundamental effect on the microstructure.

Moreover, the superior mechanical properties of the claimed steel alloy, in particular its high tensile strength of >1000 MPa in combination with the high toughness, were believed to be partly due to the presence of Si at a minimum of 0.9% and partly due to the low bainite start (Bs) temperature. An overlap between 0.9 to 1.25% happened to exist for the silicon content between the "typical" air-cooled micro-alloyed forging steels known from D6 and the claimed alloy. There was, however, no disclosure of any particular alloy of this type on the basis of which it could be said categorically that a particular steel of D6 fell within the scope of the present claims. Accordingly, it

could not be said that a teaching existed in D6 to the use of silicon in the range of overlap, nor to the selection of the claimed Bs-temperature range.

The claimed steel alloy further comprised sulphur in amounts between 0.03 and 0.1% in order to improve its toughness and machinability. The inventors had also found that above a level of 0.1% S the toughness is adversely affected. In particular the surprising improvement on the toughness that sulphur provided in the claimed steels had been neither known in the art nor had been obvious thereof, the more so since at least in D5 the effect of sulphur in bainite steels was described to decrease the toughness rather than to improve it.

Document D5 pointed the skilled person towards the necessity of including B and Zr to stabilise the bainite microstructure and to improve both the steel's toughness and strength. The examples in D5, however, showed that, as the Si-content was increased, the toughness values decreased significantly without a drastic fall above 2% Si which might be inferred from page 10 of the description.

D1 on the other hand related to ferrite-perlite forgings, i.e. a totally different type of steel.

Thus, neither document D6 alone nor its teaching read in combination with that given in any of documents D5 or D1 could lead to the claimed micro-alloyed forgings. The subject matter set out in claims 1 and 2, was therefore novel and involved an inventive step with respect to the cited prior art.

Reasons for the Decision

1. The appeal complies with Rule 65(1) EPC and is, therefore, admissible.

2. *The prior art*
 - 2.1 The patent at issue relates to micro-alloyed steel forgings of a specific composition which are used in the as-hot worked or aged condition as driving related parts of automobiles. It also relates to a process for producing such forgings. As set out in claim 1, the steel forgings comprise a bainite structure of at least 80 volume% and exhibit in the as-hot forged state a tensile strength (TS) exceeding 1000 MPa and a high toughness of preferably 55 J/cm² or more. The paragraphs [0009] and [0010] of the patent specification further reflect that a high yield ratio (TS/YS) is also aimed at. Due to the improved mechanical properties of the steel forgings the production of small and light automobile parts which are less costly is possible since i.a. a subsequent heat treatment is not needed.

 - 2.2 Likewise, document D6 is concerned with high strength micro-alloyed forging steels that can be used, with or without subsequent heat treatment or aging step, for the production of functional parts of automobiles with a reduced automobile body weight and an improved fuel mileage (cf. D6, abstract, introduction; point 2). The problem addressed by the patent at issue and by D6 is, therefore, the same. If forgings with a tensile strength of more than 90 kgf/mm² (883 MPa) in

combination with a high toughness are required, a bainite microstructure is indispensable which is obtained by adding alloying elements and/or by increasing the cooling rate (cf. D6, page 36, first column, 3. and 4. full paragraph). A typical composition of an air-cooled bainite micro-alloyed forging steel comprising 0.24 to 0.32%C, 0.25 to 1.25% Si, 1.50 to 2.30% Mn, 0.20 to 0.80%Cr and 0.15% vanadium as the micro-alloying element is disclosed in D6, Table 1. Figure 8 of document D6 further points out that the addition of 0.065% sulphur improves significantly the machinability of the bainite micro-alloyed forging, and Figure 2 depicts that the tensile strength can be adjusted between 90 and 130 kgf/mm² (883 to 1275 MPa) by selecting the appropriate carbon equivalent in the same way as with ferrite-perlite steel. As shown in Figures 3 and 4, a high yield ratio of 0.7 to 0.8 can be secured over a tensile strength range of 90 to 130 kgf/mm², and a marked increase in toughness up to about 6 Kgfm/cm² = 58.9 J/cm² or higher is achieved by annealing the steels at 300°C (572 K). The comparison shows that the steel composition given in Table 1 of D6 overlaps the claimed composition and that the mechanical properties of the known bainite steel satisfy the minimum limits specified in claim 1 of the patent at issue. Given this situation, it has been common ground to all parties and to the Board that document D6 represents the closest prior art.

However, document D6 is silent about the nitrogen content and fails to disclose a specific exemplifying composition of the air-cooled bainite micro-alloyed forging steel.

- 2.3 Document D1 differs from the claimed forgings set out in claim 1 in that it relates to heat treatment-free steels exhibiting a ferrite-perlite rather than a bainite structure, and none of the examples attains a tensile strength of 1000 MPa or higher. The hot formed steel are used for the production of automotive engine components such as crank shafts or connecting rods.
- 2.4 The bainite steel forgings disclosed in document D5 are provided for the production of automotive components which exhibit a TS > 90 kgf/mm² (883 MPa) and a toughness σ_{E20} > 5 kgfm/mm² (> 49 J/mm²) in the heat-treatment free condition. The fine bainite structure of the forgings is promoted by adding appropriate amounts of zirconium and/or boron as grain-fining elements to the basic composition, i.e. alloying components which are excluded from the claimed steel composition.
- 2.5 The bainite micro-alloyed hot forgings stipulated in claim 1 and the process for their production according to claim 2 are therefore novel over the disclosure given in any of documents D1, D5 and D6.
3. *Inventive step*
- 3.1 It is evident from the considerations above that, in the light of the closest prior art according to document D6, the problem underlying D6 and the patent at issue is the same. This finding has not been disputed by the parties at the oral proceedings. The identified problem is also addressed in the documents D1 and D5.

3.2 The patentee argued that document D6 did not disclose the presence of nitrogen and that a skilled person had no incentive to add this element in the claimed amounts.

The beneficial influence of nitrogen upon the mechanical properties, in particular on the toughness, and its grain fining effect upon the microstructure are, however, well known to the metallurgist. Although document D6 fails to mention a particular nitrogen range, it can be duly assumed that the steel composition listed in Table 1 likewise comprises this component in appropriate amounts. This can be concluded from point 2.1 of document D6, stating that in micro-alloyed forging steels nitrogen combines with Ti, Al and V to form nitrides (TiN; AlN) or carbonitrides (V(CN)) which form nuclei to promote the transformation of intra-granular ferrite. Nitrogen, therefore, constitutes an indispensable component in micro-alloyed steels. Contrary to the appellant's allegations, this finding is not restricted exclusively to ferrite-perlite steels but likewise applies to micro-alloyed steel forgings in general and to bainite steel forging in particular. To corroborate this estimation, reference is made to document D1, page 5, paragraphs 4, 6 and 7 as well as to document D5, page 13, last paragraph to page 14, line 2. In particular the latter document teaches that in bainite steel forgings the (austenite) micro-structure becomes very coarse unless nitrogen is present in amounts of 0.01% or higher and that an upper limit of 0.02% N should not be exceeded for other reasons, in particular to avoid an interaction with boron. Despite the presence of Zr and/or B in the steel alloy set out in document D5, this teaching complies with the statement appearing in

[0021] of the patent at issue according to which at least 0.008% N is required to prevent the austenite structure of the steel from coarsening during hot forging and that above 0.02% the effect of nitrogen becomes saturated.

3.3 The patentee's argument with respect to the beneficial influence of 0.03 to 0.1% sulphur on the toughness of the claimed bainite steel forgings is not disputed. It has, however, no bearing on the matter since document D6 mentions in Figure 8 the addition of 0.065% S in order to improve the machinability of the bainite micro-alloyed forging steel, an effect that is also addressed in paragraph [0019] of the patent. The improvement on the level of toughness of the claimed forgings provided by the presence of sulphur has, therefore, to be considered merely as a bonus effect.

3.4 The patentee further pointed to the excellent match of the mechanical properties of the claimed forgings, in particular of strength and toughness, which was achieved partly due to the presence of silicon at a minimum of at least 0.9% and partly due to the low bainite transformation starting temperature B_s of ≤ 810 K. It also argued that the skilled person had no incentive to work in the area of overlap, that is to say in particular in the range of 0.9 to 1.25% Si.

It is, however, noted that document D6 does not give any warning or hint that could lead a skilled person to avoid or even exclude higher amounts of silicon close to the maximum limit of 1.25%. To the contrary, silicon in amounts up to 2%, and more preferably up to 1.5%, is known to be a suitable element for increasing

effectively the strength of bainite steel forgings without running the risk of impairing its toughness significantly (cf. document D5, page 10, last paragraph). Hence, a pointer existed in the art to include higher amounts of Si in the steel if a higher ultimate tensile strength was required. It is noted in this context that a plethora of examples according to the patent at issue (No. 6, 17, 21, 24, 25, 33, 34) likewise comprise a silicon content of 1.25% or lower thus falling within the Si-range of the typical composition specified in document D6.

As to the Bs-temperature, it is true that document D6 does not give a specific example on the basis of which the Bs-temperature could be accurately calculated. Based on the limits of the elemental ranges of the typical steel composition given in Table 1 of D6, the Bs temperatures of the known steel could, however, be calculated to fall within the range of 853 to 685 K which broadly overlaps the claimed range of less than 810 K. Besides, the examples given in the patent do not appear to demonstrate unambiguously that the Bs temperature actually represents an independent parameter which strongly influences the mechanical properties of the steel. So sample 4 (Bs: 844 K) also comprises an extremely low carbon content (0.10%) and a low Ceq. of 0.80. Bearing in mind Figure 2 of document D6 it cannot be surprising that due to the low carbon equivalent a TS > 1000 MPa is not obtained. Moreover, sample 10 (Bs = 830 K) also comprises very high amounts of Si (3.21%) which, on the one hand, contribute to the increase the tensile strength but, on the other hand, are known to adversely affect the toughness when exceeding 2%. Given the broad overlap of the claimed Bs

temperature range with the range calculated on the basis of the typical composition given in document D6, Table 1 and the considerations made above, the subject matter of claim 1 amounts to nothing more than that which results by a skilled person putting into practice the technical teaching given in D6 alone or in combination with his background knowledge or, alternatively, the teaching given in D5.

4. It is therefore concluded that the subject matter of claim 1 does not involve an inventive step.

Order

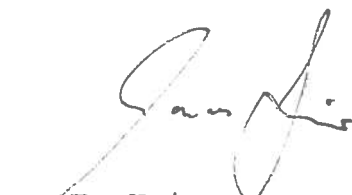
For these reasons it is decided that:

1. The decision under appeal is set aside.
2. The patent is revoked.

The Registrar:


V. Commare

The Chairman:


T. Kriner

R.R

