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D E C I S I O N
of 20 December 2002

Case Number: T 0169/00 - 3.2.2

Application Number: 92302106.7

Publication Number: 0505085

IPC: C22C 38/44

Language of the proceedings: EN

Title of invention:

Steel for rotor shafts of electric machines

Patentee:

Hitachi, Ltd.

Opponents:

SAARSTAHL AGi.K.
Siemens Aktiengesellschaft ZT PA 3

Headword:

-

Relevant legal provisions:

EPC Art. 54, 56, 83

Keyword:

"Novelty, inventive step (yes)"

Decisions cited:

T 0624/91

Catchword:

-



Case Number: T 0169/00 - 3.2.2

D E C I S I O N
of the Technical Board of Appeal 3.2.2
of 20 December 2002

Appellant: Hitachi, Ltd.
(Proprietor of the patent) 6, Kanda Surugadai 4-chome
Chiyoda-ku,
Tokyo 101 (JP)

Representative: Stoner, Gerard Patrick
MEWBURN ELLIS
York House
23 Kingsway
London WC2B 6HP (GB)

Respondents: SAARSTAHL AGi.K.
(Opponent) Bismarckstrasse 57-59
D-66333 Völklingen (DE)

Representative: Vièl, Georg, Dipl.-Ing
Patentanwaltskanzlei
Vièl & Wieske
Postfach 65 04 03
D-66143 Saarbrücken (DE)

(Opponent) Siemens Aktiengesellschaft
ZT PA 3
Postfach 22 16 34
D-80506 München (DE)

Representative: -

Decision under appeal: Decision of the Opposition Division of the
European Patent Office posted 9 December 1999
revoking European patent No. 0 505 085 pursuant
to Article 102(1) EPC.

Composition of the Board:

Chairman: W. D. Weiß
Members: R. Ries
U. J. Tronser

Summary of Facts and Submissions

- I. European patent No. 0 505 085 was granted on 19 February 1997 on the basis of European patent application No. 92 302 106.7.
- II. The granted patent was opposed by the present respondents (opponents I and II) on the grounds that its subject matter lacked novelty and did not involve an inventive step with respect to the state of the art (Article 100(a) EPC). Opponent II further objected that the patent at issue did not disclose the invention in a manner sufficiently clear and complete for it to be carried out by a person skilled in the art (Article 100(c) EPC).
- III. With its decision posted on 9 December 1999, the opposition division held that the claimed subject matter lacked an inventive step and revoked the patent.
- IV. An appeal against this decision was filed by the patentee (the appellant) on 11 February 2000. The fee for appeal was paid on the same day and the written statement setting out the grounds of appeal was filed within the time limit given in Article 108 EPC.

In the opposition proceedings, the following documents were relied upon:

D1: M. Kohno, T. Tsuchiyama, et al., "Effect of Alloying Elements on Temper Embrittlement of Superclean 3.5NiCrMoV Steel Forgings", pages 241 to 247; in: Workshop Proceedings Sapporo, Japan, 30 to 31 August 1989, edited by R.I. Jaffee, Electric Power Research Institute, Pergamon Press, EPRI GS-6921,

- D2: K. Forch: "Contribution to the Long Time Isothermal Embrittlement of NiCrMoV Steels in the Temperature Range of 350 to 450°C" pages 5-76 to 5-79; in: Workshop Proceedings: Rotor Forgings for Turbines and Generators, September 1981, EPRS WS-79-235
- D3: K. Forch K. Fischer and K. H. Piehl: "Gezielte Analysevariation zum Stahl 26NiCrMoV 14 5" Stahl und Eisen 101, No. 15, 1981, pages 47 to 50
- D4: K. Forch K. Fischer and K.H. Piehl: "Gezielte Analysevariation zum Stahl 26NiCrMoV 14 5" IFC Düsseldorf 1981, volume, No. 2.6, pages 1 to 16
- D5: EP-A-0 225 425
- D6: US-A-4 985 201
- D7: US-A-3 954 454
- D8: WO 90/04 659
- D9: JP-A-60 224 766 and Abstract
- D10: JP-A-47-25 248 (in Japanese Language)
- D11: JP-A-60 230 965 and Abstract
- D12: EP-A-0 384 181

In the appeal proceedings, the parties further referred to the documents:

D13: R. Jauch, K. Langner, F. Tince: "Forging Ingots with Improved Properties for Turbine and Generator Rotors" in: 11th International Forgemasters Meeting, Terni, 11 to 14 June 1991, II. 5, pages 1 to 9

D14: Investigation Report 483/20/95/Ri September 23, 1994, Saar-Schmiede-GmbH Freiformschmiede Völklingen

D15: Designation A470/89: Standard Specification for Vacuum-Treated Carbon and Alloy Steel Forgings for Turbine Rotors and Shafts, Published December 1989

V. In order to meet the requests of all parties, oral proceedings before the Board were held on 20 December 2002. In a letter dated 12 December 2002 opponent II (Siemens AG) informed the Board that it would not attend the oral proceedings.

- The appellant (patentee) requested that the decision under appeal be set aside and that the patent be maintained in amended form on the basis of the set of claims 1 to 11 submitted with letter of 19 April 2000, the amended description, pages 2 to 6 as submitted at the oral proceedings, and the description, pages 7 to 14 and the Figures as granted.
- The respondents (opponents I and II) requested that the appeal be dismissed.

Independent Claims 1 and 7 read as follows:

"1. An electric machine rotor shaft of steel having the composition (by weight):

C	0.15	to	0.3 %
Si	less than		0.05%

Mn less than 0.5%, at least 0.1%
 Ni 3.5 to 5 %
 Cr at least 2.05%, less than 3.5%
 (Mo+W) 0.1 to 1.0%, W being optional
 V 0.03 to 0.35%
 Al 0.0005% to 0.006%

optionally, from 0.001 to 0.05% of Group IIa or Group IIIa element,
 optionally, up to 0.2% of any of Ti, Zr, Hf, Nd, Ta;
 and the remainder Fe apart from impurities."

"7. An electric machine rotor shaft of steel having the composition:

C 0.15 to 0.3 %
 Si less than 0.05%
 Mn less than 0.5%, at least 0.1%
 Ni 3.5 to 5 %
 Cr at least 2.05%, less than 3.5%
 (Mo+W) 0.1 to 1.0%, W being optional
 V 0.03 to 0.35%
 Al less than 0.006%
 (P + S + Sn + Sb + As) less than 0.03%;
 and the remainder Fe apart from impurities."

VI. The patentee (appellant) argued as follows:

In the general field of electric power generation, a clear distinction should be made between rotor shafts which are (i) used in electric machines, e.g. electric generators, and (ii) those provided for steam turbines in electric power plants. Steam turbine rotor shafts operate at high temperatures of about 300°C or higher and, therefore, these steel alloys should exhibit i.a. a high creep rupture strength and good resistance to high-temperature embrittlement. However, there are no magnetic requirements at all. The documents D1, D2, D7, D8, D9 and D12 specifically relate to such steel alloy

developments addressing the technical problem of high-temperature embrittlement which exclusively arises in steam turbines.

By contrast, the patent under consideration relates to steel developments to produce electric machine rotor shafts operating below 100°C and, consequently, high-temperature embrittlement is not an issue. However, these rotor shafts have crucial magnetic requirements. To this end, document D6 provides a low alloy NiCrMoV steel for generator rotors exhibiting an improved combination of strength and toughness but without reducing the magnetic permeability. The chromium content of this steel alloy is limited to 2.0% at most and, more preferably, should be kept in the range between 1.0 to 1.5% Cr since the magnetic permeability is believed to be adversely affected at higher chromium contents.

Likewise, chromium contents higher than 2.03 % have not been tested in document D1, which relates to steels adapted and selected for steam turbine rotors. Rather more, 1.75% Cr is suggested as an optimum value for this type of shaft. Moreover, manganese should be kept below 0.08% in order to improve the alloy's resistance to isothermal embrittlement. Neither of documents D1 and D6 recognizes the necessity to adhere to an aluminium content within narrow ranges to reduce the FATT and the magnetic field strength of the alloy, as does the disputed patent (see Figures 6 and 9). Consequently, document D1 can neither anticipate the claimed subject matter nor represent a realistic starting point for a skilled person who is seeking a properly balanced alloy composition which exhibits the desired combination of strength, toughness and magnetic

permeability so that the alloy is appropriate for the production of electric machine rotor shafts. The other documents are more remote. Novelty and inventive step of the claimed electric machine rotor shaft set out in claim 1 and 7 are therefore given.

VII. The opponents (respondents) argued as follows:

In their written responses to the appeal, the opponents essentially referred back to the facts and arguments that had been submitted in the opposition proceedings.

At the oral proceedings, opponent I (Saarstahl AG) argued that a person skilled in the field of rotor steel technology would not make a distinction between turbine rotor shafts and electric machine rotor shafts as alleged by the patentee. This evaluation is confirmed in document D1 which does not address different uses of the alloy but is concerned with "large scale rotor forgings" in general. Such rotors must exhibit a specific combination of properties including strength, toughness, hardenability and a high magnetic permeability. The composition of alloy Nr. 13 in Table 1 of document D1 anticipates the steel alloy defined in claim 1. In particular, the chromium content in this alloy (2.03%) is identical with the lower limit of 2.05% Cr claimed in the patent. Although the accuracy of the Mn measurement in the steel is quite high, some variations of the Mn-content around a particular value (e.g. 0.06% Mn) over the length of the structural part must be expected. Having regard to decision T 624/91, point-like disclosures such as for alloy compositions (like Nr. 13) must be interpreted as average or nominal values within a small range in view of known fluctuations in reproducibility and in

analytical results. Hence, the amount of 0.06% Mn in Example 13 of D1 is interpreted by a skilled person as to comply with the lower limit of 0.1% Mn required in claim 1 of the patent. As to the presence of Al it can be learned from document D3, page 50, that the aluminium content in these types of steel is 0.004%, and that chromium can be 2.49% without running the risk of impairing the magnetic properties of the alloy. In view of the combined technical teaching given in documents D1 and D3, the electric machine rotor steel composition claimed in the disputed patent is, therefore, obvious for a person skilled in the art.

Reasons for the Decision

1. The appeal complies with the formal requirements of Articles 106 to 108 and Rules 1(1) and 64 EPC. It is therefore admissible.
2. *Amendments (Article 123(2), (3) EPC)*

Claim 1 results from a combination of claims 1, 2, 5, and 14 as granted and the description, page 5, lines 33, 34. Claims 2 to 6 correspond to claims 3 to 7 as granted. Independent claim 7 is based on former claims 8, 9 and the description page 5, lines 33 to 36 and 48 to 51, whereas dependent claims 8 to 11 comply with the claims 10 to 15 as granted. The description has been suitably adapted to the amended claims.

Hence, there are no formal objections to the amended claims and to the description. The requirements of Articles 123(2), (3) are therefore satisfied.

3. *Sufficiency of disclosure (Article 83 EPC)*

In its most general form the present invention is expressed by independent product claims 1 and 7 which define exactly the elemental ranges of the steel alloy which the electric machine rotor shaft is made of. Preferred embodiments of the claimed steel within these narrow limits are disclosed in Table 1, Examples 2 to 4, 6 and 15. These exemplifying alloy compositions convincingly establish that the design of an alloy comprising low amounts of silicon and aluminium together with chromium contents higher than 2.05% and the remaining components falling within the claimed elemental ranges brings about the desired combination of strength, toughness and magnetic properties. When putting the invention into practice, the skilled reader is led in particular to the passages on page 6, lines 50 to 58 and page 7, embodiment 1, reflecting the process steps that are necessary for producing the claimed steel alloy. Hence, the patent at issue provides enough technical information concerning the effects and interactions of the compulsory components of the claimed steel compositions and the elemental ranges to adhere to so that the skilled metallurgist is enabled to achieve success. The Board is, therefore, unaware of any verifiable facts which could cast a serious doubt on the capability of a metallurgist to carry out the invention. Consequently, the requirements of Article 83 EPC are met.

4. *State of the art*

Document D13 was, published after the priority date of the patent at issue and document D14 represents an internal report that has not been made available to the

public. Document D10 is in the Japanese language without a translation into one of the official languages of the EPO. Therefore, these documents have to be disregarded.

5. *Novelty*

Having regard to composition No. 13 given in Table 1 of D1, it is noted that the content of manganese (0.06%) of alloy Nr. 13 disclosed in Table 1 of D1 falls outside the claimed range (Mn: 0.1 to 0.5%) and this document is silent about the aluminium content. In the alloys given in documents D2 (Table 1: 3.5NiCrMoV), D6, D8 and D11 the upper limit for chromium is defined to be 1.88% or 2.0%, respectively, whereas in documents D2 to D4 (modified NiCrMoV-alloy comprising 2.44% Cr), D7 (Table 1), D9 (Abstract), D11 (Abstract) and D12 (page 6, lines 27 to 30), the nickel content is restricted at maximum to 2.7%, 2.5% or to even lower amounts. Moreover, some of these documents (D1, D5, D7 to D9, D12) are concerned with steam turbine rotor shafts rather than with an electric machine rotor shaft as is the patent at issue.

Consequently, the subject matter of the independent claims 1 and 7 is novel.

6. *The closest prior art*

The independent claims 1 and 7 of the disputed patent relate to an electric machine rotor shaft of a NiCrMoV steel composition which provides an excellent match in high strength, high toughness, low FATT (fracture appearance transition temperature) and adequate magnetic properties. In particular, the magnetic field strength at 21 kG is required to be less than 990 AT/cm so that the rotor shaft can be used in large capacity generators of 900 MVA or higher. Thus, the closest

prior art should be established among those documents which are concerned with an electric machine rotor shaft material consisting of the claimed steel type and matching the previously mentioned combination of properties. Specifically, citation D6 discloses a low alloy steel of the claimed type for use in generator rotors, the steel including 0.1 to 0.28%C - 3.5 to 5.5%Ni - 0.75 to 2.0%Cr - 0.3 to 0.8%Mo - 0.05 to 0.15% V and exhibiting a favourable combination of good strength and impact energy with a high magnetic permeability. By contrast, citation D1 is essentially concerned with a superclean 3.5 NiCrMoV steel which is designed to exhibit a very good resistance to isothermal temper embrittlement at 400 to 450°C but pays no attention to the steel's magnetic properties (cf. D1, page 244, Conclusions). In the Board's view, document D6, therefore, represents the closest prior art.

7. *The problem to be solved*

Starting from this prior art, the problem underlying the patent at issue consists in further improving the strength and toughness of the generator rotor shaft without negatively affecting the magnetic properties and impairing other important properties of the alloy such as the FATT and the resistance to temper embrittlement so that the shaft can be used in a large capacity generator over 900 MVA.

The solution to this problem is represented by a rotor shaft consisting of the carefully balanced steel composition which is set out in independent claims 1 and 7 of the disputed patent.

8. *Inventive step*

8.1 As set out in the patent specification on page 4, lines 14 to 18, page 6, line 49 to page 7, line 5 and Figures 7 to 10, the desired favourable magnetic characteristics are achieved by drastically reducing the level of certain impurities, in particular those of Al and Si and others such as P, S, Sn, Sb and As, although more than 2% Cr is present in the steel to increase its hardenability and toughness. Moreover, Si and Mn are kept within narrow ranges to prevent brittleness due to tempering. It will be shown in the following, that this particular design of the steel composition has not been obviously derivable from the prior art as has been alleged by the opponents.

8.2 Apart from enhancing the tensile strength of the NiCrMoV alloy disclosed in document D6, increased amounts of chromium are said to entail the drawback of adversely affecting the magnetic properties. Therefore, chromium should be kept below 2.0% (cf. D6, column 5, lines 7 to 10; 23 to 29), and more preferably be restricted to 1.0 to 1.5 (cf. D6, claims 1, 7). In addition, document D6 places great emphasis on the proviso that Ni needs to be balanced with Cr, and Cr should be balanced with carbon to obtain the desired combination of properties (cf. D6, Figures 4 and 5). Hence, document D6 dissuades from adding more than 2.0% chromium. Moreover, not any hint is found in this document that a pronounced benefit in terms of improvement to the magnetic properties and to the FATT can be achieved by restricting the amounts of aluminium to a range between 0.0005 to 0.006%, as has been realized in the claimed patent (cf. Figures 6 and 9 of the patent specification).

The teaching given in document D1 does not render the selected alloy composition obvious either, the more so since the magnetic performance of the investigated alloy is not even addressed. Document D1 is rather concerned with improving the temper embrittlement of steel 3.5NiCrMoV which was found to be small for steels with manganese contents lower than 0.08% (cf. D1, page 242, point 3: Test results, second paragraph). Turning to the influence of chromium, the FATT and impact toughness are reported to be improved by increasing the chromium content to up to 1.75%, but at which value the effect on these properties is saturated (see D1, page 243, third paragraph from the bottom). Based on these findings, the optimum chemical composition of the alloy is suggested in D1: C: 0.24%, Si \leq 0.05%, Mn \leq 0.08%, Ni: 3.75%, Cr: 1.75%, V: 0.14%, and $(10P+5Sb+4Sn+As)\times 10^2 \leq 7.0$ (cf. D1, page 243, last paragraph; page 4, Conclusions). Only steel Nr. 13 exhibits a chromium content of 2.03% which is, however, the maximum admissible limit for this component. Like document D6, also document D1 therefore dissuades from adding more than 2% chromium and, in addition thereto, from adding more than 0.08% manganese. Notwithstanding certain variations of the chemical analysis over the product cross sectional area being permissible, as set out in document D15, Table 2, the steel shall conform to the requirements for chemical composition (cf. D15, point 5.1). As to the alloy compositions disclosed in document D1, such variations are tolerated within the specific elemental ranges since outside these ranges a significant deterioration of the desired properties must be expected. To this end, manganese is restricted to $\leq 0.08\%$ in D1 and the exemplifying steel compositions comprising 0.08, 0.07 or even 0.02% confirm that manganese contents below 0.08% are reliably reproducible with known metallurgical techniques. Therefore, the findings of decision T 624/91 do not apply to the present case. Contrary to the opponent's

allegation, it must therefore be concluded that the upper limit of $\leq 0.08\%$ Mn defined in D1 is selected on purpose and cannot be regarded as being identical with the lower limit of $\geq 0.1\%$ claimed in the patent.

Furthermore, document D1 remains silent about the aluminium content in the steel alloy. The opponent's reference to document D3 disclosing an aluminium content of 0.004% in a modified steel grade 26 CrNiMoV 14 5 does not prove beyond any doubt that the same aluminium content is also present in the 3.5 NiCrMoV steel discussed in D1, or in the alloys disclosed in document D6.

- 8.3 The statement in documents D6 and D1 that chromium should not be increased above 2% is confirmed by many other documents irrespective of the intended use of the rotor shaft, cf. D5: examples; D8, D11, D12: examples. If, on the other hand and as proposed in documents D2 to D4, the rotor shaft standard steel composition has been modified by increasing the chromium content beyond this value, for example to about 2.5%, the nickel content needs to be reduced to below 3% to compensate for the alloy's impaired resistance to temper embrittlement which is associated with higher chromium contents (cf. D2, page 48, right hand column, second paragraph). Thus, also the combined teaching of documents D1 with any of D2 to D4 would not lead to the claimed steel composition.
- 8.5 The remaining documents are more remote in that they relate to steel compositions which are even more different to the claimed alloy than those discussed above.
- 8.6 In view of these considerations, the technical teaching given in document D6, taken alone or in combination with that given in any of the remaining documents did

not lead a person skilled in the field of metallurgy in an obvious way to the electric machine rotor shaft stipulated in claims 1 and 7 of the patent at issue. The subject matter of claims 1 and 7, therefore, involves an inventive step.

9. The patent and the invention to which it relates, therefore, meet the requirements of the EPC.

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 maintain the patent in amended form on the basis of
 - Claims 1 to 11 submitted with letter of 19 April 2000;
 - Description pages 2 to 6 submitted at the oral proceedings;
 - Description pages 7 to 14 as granted and
 - Figures as granted.

The Registrar:

The Chairman:

V. Commare

W. D. Weiß