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D E C I S I O N
of 2 December 1996

Case Number: T 0177/94 - 3.2.4

Application Number: 89310588.2

Publication Number: 0365253

IPC: F01D 5/02

Language of the proceedings: EN

Title of invention:
Ceramic-metal joined composite bodies

Applicant:
NGK INSULATORS, LTD.

Opponent:
-

Headword:
Composite body/NGK

Relevant legal provisions:
EPC Art. 56

Keyword:
"Inventive step (yes)"

Decisions cited:
-

Catchword:
-

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Case Number: T 0177/94 - 3.2.4

D E C I S I O N
of the Technical Board of Appeal 3.2.4
of 2 December 1996

Appellant: NGK INSULATORS, LTD.
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Decision under appeal: **Decision of the Examining Division of the European Patent Office posted 8 October 1993 refusing European patent application No. 89 310 588.2 pursuant to Article 97(1) EPC.**

Composition of the Board:

Chairman: C. A. J. Andries
Members: P. Petti
J. P. B. Seitz

Summary of Facts of Submissions

I. The European patent application No. 89 310 588.2 filed on 16 October 1989 was refused by a decision of the examining division dispatched on 8 October 1993.

The reason the examining division gave for the refusal was that the subject-matter of the independent Claim 1 according to each of the six requests submitted by the appellant (applicant), which are defined on pages 4 and 5 of the decision under appeal, did not involve an inventive step within the meaning of Article 56 EPC.

II. The appellant lodged an appeal against this decision on 6 December 1993 and simultaneously paid the appeal fee. The statement setting out the grounds of appeal was filed on 14 February 1994.

III. In response to a communication of the board, the appellant filed with the letter dated 7 October 1996 an amended set of Claims 1 to 6 upon which its main request was based. Claim 1 of this set reads as follows:

"1. A ceramic-metal joined composite body comprising a ceramic member (1) having a projection (2) formed thereon and a metallic member (3) having a recess (4) formed therein, the projection (2) being fitted into the recess (4) by a fitting method which causes stress in the regions at which the outer surface of the projection (2) contacts the recess of the metallic member, the projection (2) being of solid cylindrical shape of diameter D over its length where its peripheral outer surface contacts the side of the recess of the metallic member, and the corner of the bottom of the recess of the metallic member being rounded where the bottom of the recess joins the side of the recess, characterised in that the bottom of said recess is unpierced, the diameter of the projection (2) is not more than 15 mm and R/D is

in the range 0.04 to 0.20 wherein R is the radius of the corner (5) of the bottom of the recess (4) where the bottom of the recess (4) joins the side of the recess."

IV. As a main request the appellant requested that the impugned decision be set aside and a patent be granted on the basis of the following documents:

Claims 1 to 6, pages 1 to 9 of the description and Figures 1 and 2 of the drawings as filed with the letter dated 7 October 1996.

The appellant also submitted six subsidiary requests.

Reasons for the Decision

1. The appeal is admissible.

2. Amendments (main request)

2.1 Claim 1 of the main request differs from Claim 1 of the application as originally filed in that

the expression "the projection being fitted into the recess" is followed by the expression

(a) "by a fitting method which causes stress in the regions at which the outer surface of the projection contacts the recess of the metallic member";

the features that

(b) "the diameter of the projection is not more than 15 mm" and

(c) "the bottom of the recess is unpierced", have been added;

and the feature that "R/D is greater than or equal to 0.04" has been replaced by the feature that

(d) "R/D is in the range 0.04 to 0.20".

Moreover, the features that "R and D are the rounded dimension of the corner of the bottom of the recess and an outer diameter of the projection, respectively" have been replaced by the features:

(e) "R is the radius of the corner of the bottom where the bottom of the recess joins the side of the recess", and

(f) "the projection is of cylindrical shape of diameter D over its length where its outer surface contacts the recess of the metallic member".

The amendments according to items (e) and (f) can be considered as clarifications of the original features which clarifications have a basis in the original drawings. Also feature (c) can be unambiguously derived from the original drawings (Figures 1a and 2).

Features (b) and (d) have an explicit basis in the original description (page 6, lines 1 to 5).

Feature (a), although not explicitly mentioned in the application as filed, can be implicitly derived from the description of the original application, in so far as the original description refers to "conspicuous stress concentration [occurring] at the bottom corner of the recess ... due to fitted forces" of ceramic-metal joined composite bodies according to the prior art (see page 1, lines 14 to 23) and the aim of the

invention is to reduce the stress concentration occurring at the corner of the recess (see page 2, line 22 to page 3, line 1).

2.2 The features specified in dependent Claims 2 and 5 correspond to the features of the original Claims 2 and 4. The features specified in dependent Claims 3, 4 and 6 can be unambiguously derived from the description and the drawings of the application as filed, namely: Figures 1A and 2 (Claim 3); page 4, lines 9 to 12 (Claim 4); page 8, lines 9 to 13 and Figure 2 (Claim 6).

2.3 The amendments of the description consist essentially in its adaptation to the amended claims, in the correction of some linguistic errors and in the citation of the document EP-A-139 406 (D6).

2.4 The board is satisfied that these amendments do not contravene Article 123(2) EPC.

3. *Novelty (main request)*

The subject-matter of independent Claim 1 is novel with respect to each of the documents cited in the search report and/or in the description of the application as filed.

4. *The closest prior art*

4.1 With respect to the subject-matter of the present Claim 1, documents JP-A-58-223 675 (D2), JP-A-61-26501 (D3), EP-A-139 406 (D6) and EP-A-161 081 (D1) are considered to be more relevant than the other available documents.

4.1.1 The appellant filed translations (D'2) in the English language of some passages of document (D2). It is clear from the translations (D'2) that document D2 relates to a ceramic-metal joined composite body comprising a ceramic shaft 1 and a metallic member 2 having a recess (metallic sleeve 3) formed therein. Moreover, since the Figures 2 and 4 of document D2 show the stress distribution at the interface between the ceramic shaft and the metallic sleeve, it can be derived that the shaft is fitted into the sleeve by a fitting method which causes stress in the regions at which the outer surface of the shaft contacts the recess of the metallic member. Furthermore, it is clear that the shaft is of a solid cylindrical shape of a certain diameter D over its length where its outer surface contacts the recess of the metallic sleeve.

According to each of Figures 1 to 4 the ceramic shaft has a rounded tip portion and the recess has a rounded bottom corner. Moreover it is clear from each of the figures that the radius R of the corner of the bottom of the recess (where the bottom joins the side of the recess) is smaller than the radius r of the rounding of the tip portion of the shaft.

However, no quantitative information can be derived either from the drawings of document D2 or from the translations (D'2) concerning the diameter D of the shaft or the ratio R/D.

4.1.2 Document D3 is also cited in the description of the application. The appellant filed translations (D'3) in the English language of some passages of this document. For this document there is also an abstract (D''3) in English language.

It is clear from the translations (D'3) as well as from the abstract (D''3) that document D3 concerns a ceramic-metal joined body which comprises a rotary shaft for a turbocharger rotor, comprising a ceramic member 2 having a projection 2a formed thereon and a metallic member 3 having a recess formed therein, the projection being fitted into the recess by a fitting method which can cause stress concentrations in the regions in which the outer surface of the shaft contacts the recess of the metallic member, the projection being of a solid cylindrical shape of diameter D over its length where its outer surface contacts the recess of the metallic member, the bottom of the recess being unpierced.

No information can be derived from document D3 concerning the presence of a rounding at the bottom corner of the recess. The sole figure shows a projection having a flat end portion contacting the bottom of the recess.

4.1.3 Document D6 discloses (see particularly Figure 3) a ceramic-metal joined body which comprises a rotary shaft for a turbocharger rotor, comprising a ceramic member 11 having a projection 14 formed thereon and a metallic member 12 having a recess 13 formed therein, the projection being fitted into the recess by a fitting method which can cause stress concentrations in the regions in which the outer surface of the shaft contacts the recess of the metallic member (press fitting, see page 12, lines 24 and 25), the projection being of a solid cylindrical shape of diameter D over its length where its outer surface contacts the recess of the metallic member, the bottom of the recess being unpierced. According to the drawings, the bottom of the

recess of the metallic member is connected to cylindrical portion of the recess by a conical surface. Moreover, the projection 14 of the ceramic member has a frusto-conical tip portion.

4.1.4 Document D1 discloses (see particularly Figure 2) a ceramic-metal joined composite body comprising a ceramic member having a projection 90 formed thereon and a metallic member 86 having a recess, the projection being fitted into the recess. However, the projection is not of solid cylindrical shape but hollow and frusto-conical.

4.2 The metal-ceramic joined composite body disclosed in the document D2 cited in the description of the application as filed is considered to be the closest prior art, especially because it comprises a ceramic projection of solid cylindrical shape fitted into a recess having a rounded bottom.

Each of documents D3 and D6 relates to a ceramic projection of solid cylindrical shape fitted into a recess. However, the corner of the bottom of the recess of the metallic member according to either document D3 or document D6 is not rounded. According to document D3 the said corner is shaped at right angles and according to document D6 it is tapered. Therefore, these documents are considered as less relevant than document D2.

Due to the hollow frusto-conical shape of the projection of the ceramic member according to document D1, the stress, induced by fitting forces, in the regions at which the outer surface of the projection contacts the recess cannot be compared with the stress induced by fitting forces in the case of a

projection of solid cylindrical shape. Therefore, having regard to the problem to be solved as specified in the description of the application as filed, document D1 is considered as less relevant than document D2.

5. *Problem and solution (main request)*

5.1 The subject-matter of the present Claim 1 differs from the prior art according to document D2 substantially in that

(1) the bottom of the recess is unpierced,

(2) the diameter D is no more than 15 mm and

(3) the ratio R/D is in the range 0.04 to 0.20.

5.2 The problem to be solved as described in the present application relates to reliability of the ceramic-metal joined body (see page 2, lines 1 to 4), and more particularly it consists in avoiding cracks occurring in a ceramic-metal joined composite body according to the prior art (see page 1, lines 14 to 23).

5.3 Having regard inter alia to the results in Table 1 of the application as filed, it is credible that the combination of features specified in Claim 1 represents a solution of the above mentioned problem. It is also clear that the definition of the ranges for the parameters D and R/D according to features (2) and (3) represents the main contribution to the solution of this problem.

6. *Inventive step (main request)*

6.1 Feature (1) relates to the shaping of the metallic member. As submitted by the appellant in the letter dated 14 May 1992 (see page 2, fourth paragraph, lines 5 to 10), "the solid cross section ceramic projection ... combines with the unpierced bottom of the recess ... and means that there is much greater stress concentration at the region of the base of the recess in the metallic part".

Feature (2) represents the choice of a dimension range of the ceramic projection of the composite body, such that the ceramic-metal joint can be applied in turbocharger rotors where small size is highly desirable. This feature introduces a maximum diameter for the ceramic projection and thus limits the area of contact between the ceramic projection and the metallic member. Due to the limitation of the contact area, if the strength of the joint is maintained, the fitting forces at the contact area have to increase, and thus the stress caused in the contact area by these fitting forces (see feature a in section 2.1 above) will increase.

Therefore, both features (1) and (2) result in increasing the risk of stress-induced cracking at the region of the base of the recess in the metallic part. In other words, these features render the problem to be solved more critical.

Feature (3) represents the relationship between two dimensions of the composite body, namely the diameter D of the ceramic projection and the radius R of the corner of the recess bottom. This feature is linked to feature (2) in so far as it relates to the diameter D, whose range is defined by feature (2).

In spite of the critical situation with respect to the above mentioned problem of stress, feature (3) results in reducing cracking at the region of the base of the recess in the metallic part.

6.2 A skilled person, when confronted with the problem of avoiding cracks in the metal-ceramic joined composite bodies according to the prior art, would probably realize that the cracks were due the concentration of stress occurring at the corner of the bottom of the recess. However, in order to find the solution to this problem, the skilled person would need firstly to realize that the parameter R/D was decisive for reducing stress concentration in this region. Only after this parameter R/D has been identified could the skilled person try to optimise it in order to reduce stress concentration.

The documents cited in the search report and/or in the description of the application as filed do not contain any element pointing towards the importance of the parameter R/D in relation to the bottom of a cylindrical recess of a metallic shaft.

Moreover, according to the board, a skilled person on the basis of its general knowledge would not immediately realize that the parameter to be optimised for reducing stress concentration is R/D.

From the book of G. NIEMANN, *Maschinenelemente*, Band I, *Konstruktion und Berechnung von Verbindungen, Lagern, Wellen*. Springer-Verlag, Berlin Heidelberg New York 1981, (see particularly page 70, point 3) it is known that in a shaft of diameter D having a cylindrical protrusion of diameter d (d<D) with a rounding of radius r at the interface between shaft and protrusion the ratio r/d influences the stress concentration at the corner between shaft and protrusion. This

information relates to the stress concentration occurring when there is a change of outside diameter of a shaft, the stresses being caused by torsional and bending forces.

However, the problem to be solved in the present case relates to stress concentration occurring at the corner of the bottom recess of a metallic member as a consequence not only of torsional and bending forces but also of the fitting forces. Therefore, this situation cannot be considered as closely analogous to the stress concentration occurring in a shaft when there is a change of outside diameter.

Thus, the information from the above mentioned book would not guide a skilled person to realize that the parameter R/D is decisive for the solution of the indicated problem.

Therefore, without having realized the importance of the parameter R/D, the skilled person would never try to exercise routine methods of trial and error in order to optimize this parameter.

6.3 Thus, having regard to the prior art mentioned above, a skilled person would not arrive at the subject-matter of Claim 1 without exercising inventive skill. The subject-matter of Claim 1 according to the main request of the appellant meets, therefore, the requirements of Article 56 EPC.

7. A patent can be granted on the basis of this independent Claim 1 of the main request and of dependent Claims 2 to 6 which concern particular embodiments of the invention defined in Claim 1.

8 The main request of the appellant having been allowed, there is no need to consider the subsidiary requests.

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 the following documents:

   Claims 1 to 6, as filed with the letter dated 7 October 1996

   Description, pages 1 and 9, as filed with the letter dated 7 October 1996 and

   Figures 1 and 2, as filed with the letter dated 7 October 1996.

The Registrar: The Chairman:

N. Maslin C. Andries