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D E C I S I O N
of 10 November 1994

Case Number: T 1034/93 - 3.2.1

Application Number: 88102038.2

Publication Number: 0303758

IPC: F16C 33/30, F16C 19/52, F16C 35/06

Language of the proceedings: EN

Title of invention:
Rotating member supporting apparatus

Applicants:
(01) Koyo Seiko Co. Ltd.
(02) Kabushiki Kaisha Toshiba

Opponent:
-

Headword:
-

Relevant legal provisions:
EPC Art. 54, 56 and 76(1)

Keyword:
"Novelty (no)"
"Conformity with Article 76(1) - left undecided"
"Inventive step (no)"

Decisions cited:
-

Catchword:
-

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Case Number: T 1034/93 - 3.2.1

D E C I S I O N
of the Technical Board of Appeal 3.2.1
of 10 November 1994

Appellant I: Koyo Seiko Co. Ltd.
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Decision under appeal: **Decision of the Examining Division 2.3.09.115 of the European Patent Office given at the oral proceedings on 25 May 1993 and issued in writing on 2 July 1993 refusing European patent application No. 88 102 038.2 pursuant to Article 97(1) EPC.**

Composition of the Board:

Chairman: F. Gumbel
Members: S. Crane
W. M. Schar

Summary of Facts and Submissions

I. European patent application No. 88 102 038.2, which is a divisional of European patent application No. 85 103 808.3 filed on 29 March 1985, was refused by a decision of the Examining Division given at oral proceedings on 25 May 1993 and issued in writing on 2 July 1993.

II. The reasons given for the decision were that the subject-matter of Claim 1 then on file lacked novelty and the subject-matter of Claims 2 to 5 lacked inventive step (Articles 52(1), 54 and 56 EPC).

The following prior art documents were referred to in the decision:

(D1) Journal of the American Society of Lubrication Engineers, (ASLE, 1981), vol. 37, No. 7, July 1981, pages 407 to 415, US; G. Hamburg et al.: "Operation of an all-ceramic mainshaft roller bearing in a J-402 gas-turbine engine",

(D2) US-A-4 097 293,

(D3) GB-A- 991 421,

(D4) FR-A-2 378 204,

(D5) Machine Design, vol. 51, No. 5, pages 55 to 59, published 8 March, 1979,

(D6) US-A-3 969 125,

(D7) EP-A-0 100 380.

III. An appeal against this decision was filed on 25 August 1993 and the appeal fee paid at the same time. The Statement of Grounds of Appeal was filed on 29 October 1993.

In the Statement of Grounds the Appellants (Applicants) referred to the following publications:

(D8) R. K. Allan, "Rolling Bearings", 1946, pages 294 and 295,

(D9) Japanese Industrial Standards, "How to select and use rolling bearings", (a partial translation),

(D10) Catalogue "Koyo Ball & Roller Bearings" of the Koyo Seiko Co., Ltd., pages A84 and A85,

(D11) SKF General Catalogue, section entitled "Recommended fits".

IV. In a communication of the Board dated 29 July 1994 pursuant to Article 11(2) RPBA the question was raised whether the terms used in relation to the nature of the fits in Claims 1 and 2 filed with the Statement of Grounds found a basis in the earlier (parent) application as originally filed (Article 76(1) EPC). The Board further expressed the view that the subject-matter of these claims was new but that having regard to documents D1 and D5 and the common knowledge of the person skilled in the art, did not involve an inventive step.

V. Oral proceedings were held on 10 November 1994.

At the oral proceedings the Appellants submitted an amended Claim 1 and requested that the wording of Claim 2 be similarly amended. These claims read as follows:

"1. A rotating member supporting apparatus comprising: an outer member (12) having a bore (14) therein; an inner member (10) inserted in the bore and capable of rotation relative to the outer member, said inner member constituting a rotating member, and said outer member

constituting a supporting member for supporting the rotating member; and a rolling bearing (20) interposed between the outer and inner member and rotatably supporting the rotating member, said rolling bearing including a ceramic inner ring (22) fitted on the outer peripheral surface of the inner member, a ceramic outer ring (24) fitted in the bore so as to face the inner ring, and a plurality of ceramic rolling elements (28) rollably arranged between the outer peripheral surface of the inner ring and the inner peripheral surface of the outer ring;
c h a r a c t e r i z e d in that
said inner ring (22) is fitted on the outer peripheral surface of the inner member (10) by a loose fit, said outer ring (24) is fitted in the bore (14) of the outer member (12) by a tight fit, and said inner and outer rings and rolling elements (28) are formed of a pressure sintered compact mainly composed of silicon nitride."

"2. A rotating member supporting apparatus comprising: an outer member (12) having a bore (14) therein; an inner member (10) inserted in the bore and capable of rotation relative to the outer member, said inner member constituting a rotating member, and said outer member constituting a supporting member for supporting the rotating member; and a rolling bearing (20) interposed between the outer and inner member and rotatably supporting the rotating member, said rolling bearing including a ceramic inner ring (22) fitted on the outer peripheral surface of the inner member, a ceramic outer ring (24) fitted in the bore so as to face the inner ring, and a plurality of ceramic rolling elements (28) rollably arranged between the outer peripheral surface of the inner ring and the inner peripheral surface of the outer ring;
c h a r a c t e r i z e d in that

said inner ring (22) is fitted on the outer peripheral surface of the inner member (10) by a loose fit, said outer ring (24) is fitted in the bore (14) of the outer member (12) by a tight fit, and said inner and outer rings and rolling elements (28) are formed of a pressure sintered compact mainly composed of silicon carbide."

The Appellants requested the grant of a patent on the basis of these Claims 1 and 2 and the dependent Claims 3 to 5, description and drawings as published.

VI. The representative of the Appellants stated that despite his efforts he had not yet been able to obtain any reply from them concerning the possible infringement of Article 76(1) EPC. He was however confident that there was no intended difference in meaning between the terms "loose fit" and "tight fit" as used in the present Claims 1 and 2 and the corresponding terms "clearance fit" and "transition fit" as used in the parent application as originally filed. He therefore requested that the Board hear the arguments on the substantive question of inventive step and if it came here to a positive conclusion but still had reservations on the Article 76(1) issue to return to the written procedure in order to give the Appellants a further opportunity to amend the claims.

The main arguments presented with respect to inventive step can be summarised as follows:

Document D1 proposed a complete and no doubt effective solution to the problems caused by the relatively different coefficients of thermal expansion when mounting ceramic roller bearing rings on a metallic shaft or in a metallic housing. As taught there the inner bearing ring has at room temperature an internal diameter larger than the external diameter of the shaft

and is supported on the shaft by rings which are fixed to the shaft. Thus although there could be said to be a clearance between the shaft and the bearing ring that ring was clearly not fitted by a "clearance" or "loose" fit as this would be understood by the skilled person, since this implied the possibility of lateral movement between the bearing ring and the shaft.

The Appellants had surprisingly found that it was possible to obtain good results by the use of a true clearance or loose fit of the inner ring thus dispensing with the need for the relatively complex arrangement of support rings proposed in document D1. Nothing in the art could suggest this possibility to the person skilled in the art, indeed it could be seen from documents D8 and D9 that loose fits were considered detrimental so that he would have had a prejudice against using one. Generally, as could be seen from documents D10 and D11, the accepted arrangement was to use a transition fit for the inner bearing ring and a clearance fit for the outer bearing ring, which was the opposite of what the invention proposed.

Reasons for the Decision

1. The appeal applies with Articles 106 to 108 and Rules 1(1) and 64 EPC. It is therefore admissible.

2. *Conformity with Article 76(1) EPC*

As far as the features set out in the preamble of independent Claims 1 and 2 are concerned the requirement of Article 76(1) EPC that the subject-matter of a divisional application should not extend beyond the content of the parent application poses no problems

since the rotation member supporting apparatus defined therein is clearly disclosed in the parent application. The same is true of the statement in the characterising clause of Claim 1 that the inner and outer rings and rolling elements are formed of a pressure sintered compact mainly composed of silicon nitride, and the equivalent statement in the characterising clause of Claim 2 that these components are formed of a sintered compact mainly composed of silicon carbide.

A problem does however arise with the identical requirements of the characterising clauses of both Claims 1 and 2 that the inner ring is fitted on the outer peripheral surface of the inner member by a loose fit and the outer ring is fitted in the bore of the outer member by a tight fit. No equivalent statement in these terms is to be found in the parent application as originally filed. Instead, it is stated there in Claim 4 that the inner member and the inner ring are coupled by a clearance fit and the outer member and the outer ring are coupled by a transition fit. The same definition of the fits used, i.e. "clearance" and "transition", is to be found in the only relevant passage of the description at page 6, line 21 to page 7, line 9.

The term "fit" in the present context can be equated to the difference between the external diameter of one part and the internal diameter of a bore in a second part within which the first part is mounted. If the external diameter is larger than the internal diameter then there is interference between the two parts, if on the other hand the external diameter is smaller than the internal diameter there is play between the two parts. Clearly, the higher the degree of interference the more force is required to bring the two parts together and the stronger the connection between the two. In the reverse direction, that is with increasing play, it becomes

easier to assemble the two parts but the stability of the connection between them decreases. The term "transition fit" as found in the parent application is a well-defined term of the art (see for example documents D10 and D11) which refers to a minimal degree of interference between the parts to be mated. The term "tight fit" as used in present Claims 1 and 2 has no such precise meaning and could thus readily be interpreted as extending to fits having a higher degree of interference such as locational interference, drive or force fits. Similar considerations apply to the terms "clearance fit" and "loose fit", the first also being a term of the art, see again documents D10 and D11, and the second not. The Board is therefore by no means convinced that the terms "loose fit" and "tight fit" as used in present Claims 1 and 2 should be considered as synonymous with the terms "clearance fit" and "transition fit" to be found in the parent application, and that therefore the relevant condition of Article 76(1) EPC is met.

However, it was decided at the oral proceedings that for procedural economy it would only be necessary to come to a final conclusion on this question, if necessary after further written communication with the Appellants as requested by their representative, if the subject-matter of the application could be seen to involve an inventive step. Since, as follows from what is said below, this was not the case, a final decision on the conformity of the application to the requirements of Article 76(1) EPC could be left in abeyance.

3. *State of the art*

3.1 Document D1 concerns the design and use of a ceramic mainshaft roller bearing for a gas turbine engine. The bearing comprises an inner ring, an outer ring and

rollers disposed therebetween, all of these components being made of pressure sintered silicon nitride. As stated in the right-hand column of page 408 special mounting means for the inner ring were necessary to accommodate the 3.72-to-1 differential in thermal expansion coefficients of silicon nitride and the steel shaft. Thus, two steel rings are press fitted onto the shaft on either side of the silicon nitride bearing ring, which at room temperature is 0.079 mm loose on the shaft, but is supported concentrically thereto by opposing conical interfaces on the steel rings and on the bearing ring. The specific conical angle is a function of the bore diameter and width of the bearing ring. As the steel shaft expands axially and radially relative to the bearing ring the latter is supported on the conical seats until the maximum design temperature (482°C) is reached where the shaft and bore should attain a line fit. The outer bearing ring is stated to be mounted in a compliant ring of unspecified construction. With respect to this outer ring it is also stated that this was originally finished with a 0.1 mm larger diameter than the steel bearing ring which it replaced in order to provide an equivalent fit at the maximum design temperature. However, difficulties encountered during assembly made it necessary to eliminate this oversize condition.

3.2 Document D5 is a general article concerning the potential future uses of ceramic rolling bearings, especially those made of sintered silicon nitride. In the middle column of page 57 it is stated that "Silicon nitride has a thermal expansion rate about 4 times lower than that of steel; thus, the material is highly resistant to changes in operating temperature. The low expansivity might be a problem if ceramic bearings were mounted on steel shafts without making provisions for the difference in expansion rates."

3.3 Documents D8 and D9 both relate to a phenomenon known as creep which can occur if a bearing inner ring is mounted loosely on a shaft and can therefore rotate with respect thereto. This movement in turn leads to fretting corrosion.

3.4 Documents D10 and D11 both concern recommended fits for mounting the inner and outer rings of rolling bearings. Depending on the nature of the expected load, operating temperature, and other conditions the recommended fits range from clearance fits through transition fits to interference fits.

4. *Novelty and inventive step*

4.1 For the purpose of evaluation of the novelty and inventive step of the claimed invention the terms "loose fit" and "tight fit" as used in the claims will be interpreted as being equivalent in meaning to the terms "clearance fit" and "transition fit" as used in the parent application. Clearly, this cannot be disadvantageous to them since for the reasons given in point 2 above it would not be possible for the Appellants to argue that there was some potentially significant distinction intended.

4.2 Although it is stated in document D1 that the inner bearing ring is 0.079 mm "loose" on the shaft this must be read in the circumstances merely as meaning that the internal diameter of the ring, see Figure 1, is larger by that amount than the external diameter of the shaft. The ring is not "loose" on the shaft in the sense that it can undergo limited radial movement with respect to the shaft since it is supported on the shaft by the support rings. Accordingly, it cannot be fairly said, as required by Claim 1, that the inner ring is fitted on the outer peripheral surface of the shaft ("inner

member") by a loose fit. Thus, the subject-matter of present Claim 1 is novel with respect to the disclosure of document D1.

The only other prior art document in the proceedings which specifically relates to a ceramic bearing with inner ring, outer ring and rolling elements formed of pressure sintered silicon nitride is document D5. Although this document mentions the problems associated with mounting the inner ring on a steel shaft it does not propose any particular solutions. It is therefore apparent that the subject-matter of present Claim 1 is also novel with respect to the remaining state of the art.

4.3 It is evident from what is said above that the technical problem with which the claimed invention is concerned and which results from the difference in the coefficients of thermal expansion between ceramic, e.g. silicon nitride, materials and metals had been recognised in the art. Furthermore, since it is well known that such materials are more liable to fracture under tensile stress than compressible stress it is apparent that it is the mounting of the inner bearing ring on the metal shaft that is critical as the expansion of the latter within the former will lead to tensile stresses therein.

In this respect the invention proposes fitting the inner ring to the shaft ("inner member") by a loose fit. Accordingly, at least part of the relation expansion of the shaft with respect to the inner ring as these parts are heated from ambient to operating temperature is taken up by elimination of the clearance between them so that the resulting stresses in the ring are correspondingly reduced.

This basic principle is to be found in document D1. There, however, the inner bearing ring is supported by further support rings attached to the shaft (see point 4.2 above). In the opinion of the Board the skilled person would recognise that the particular arrangement disclosed in document D1 is predicated upon the special field of use to which it relates where accurate positioning of the inner ring is required at very high speeds of revolution (of the order of 40000 rpm), and that in situations where such accurate positioning was not required then the basic principle of using a loose fit without further support would be sufficient. In this respect it is to be noted that the only example given in the application of supporting apparatus which still corresponds to what is defined in the preamble of present Claim 1 is that for supporting a sink roller in an electroplating bath. It is evident that accurate positioning at high speeds is not a requirement that prevails there. The argument of the Appellants that the skilled person would have a prejudice against using a loose fit for the inner ring because of the danger of creep cannot be accepted by the Board since it overlooks the fact that at operating temperatures the clearance between the inner ring and the shaft will be substantially reduced or fully eliminated.

As far as the outer bearing ring is concerned it would be ideal (as discussed in both the present application and document D1) if this had an outer diameter greater than that of the bore in the outer member by an extent sufficient to compensate for the greater expansion of the outer member. Since, however, that requirement would necessitate the use of significant force to press fit the inner ring into the bore and could readily lead to fracture of the outer ring it is obvious for the skilled person to fit the outer ring by means of a "tight" (i.e.

transition) fit, which provided a suitable compromise between ease of assembly and compensation for thermal expansion.

Accordingly, the Board comes to the conclusion that the subject-matter of Claim 1 lacks inventive step (Article 56 EPC).

4.4 The subject-matter of independent Claim 2 differs from that of Claim 1 solely in that the bearing rings and rolling elements are of sintered silicon carbide instead of sintered silicon nitride.

Although in any case the application has to be refused for lack of inventive step of the subject-matter of Claim 1 it is noted for completeness that sintered silicon carbide is a well known ceramic material already proposed for use in rolling bearings, see for example document D3. Thus nothing of inventive significance can be seen in the replacement of sintered silicon nitride parts by sintered silicon carbide parts in a rotating member supporting apparatus as disclosed in document D1, nor has this viewpoint been put forward at any stage by the Appellants.

4.5 In view of the above negative findings with respect to inventive step the procedural request of the Appellants for return to the written procedure, see point VI, paragraph 1, above, is no longer relevant and is accordingly refused.

Order

For these reasons it is decided that:

The appeal is dismissed.

The Registrar: The Chairman:

S. Fabiani F. Gumbel