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Datasheet for the decision of 21 January 2010

Case Number: T 0862/08 - 3.2.08

Application Number: 00936186.6

Publication Number: 1198605

IPC: C22C 45/02

Language of the proceedings: EN

Title of invention:
Methods of forming steel

Patentee:
Bechtel BWXT Idaho, LLC

Opponent:
DURUM, Verschleiss-Schutz GmbH

Headword:
-

Relevant legal provisions:
-

Relevant legal provisions (EPC 1973):
EPC Art. 56

Keyword:
"Inventive step (no)"

Decisions cited:
-

Catchword:
-

Case Number: T 0862/08 - 3.2.08

D E C I S I O N
of the Technical Board of Appeal 3.2.08
of 21 January 2010

Appellant:
(Patent Proprietor)

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Decision under appeal:

Decision of the Opposition Division of the European Patent Office posted 21 January 2008 revoking European patent No. 1198605 pursuant to Article 102(1) EPC.

Composition of the Board:

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

Summary of Facts and Submissions

I. This appeal is against the decision of the opposition division dated 21 January 2008 to revoke the European patent No. 1 198 605. The opposition division held among other things that the subject matter of none of the independent claims 1 according to the main request and the auxiliary requests 1 to 5 then on file was novel over the technical disclosure of document

D6: H. Monstadt and U. Zander: "Anlaßverhalten von laserstrahlverglasten eutektischen $Fe_{83}B_{17}$-Legierungen", Metall, volume 44, No. 1, January 1990, pages 57 to 59.

II. The appellant (the patent proprietor) lodged an appeal against the decision. The appeal was received at the European Patent Office on 27 March 2008 and the appeal fee was paid on the same date. The statement setting out the grounds of appeal was received on 2 June 2008.

III. In addition to document D6, the following documents have played a major role on appeal:

D1: US-A-4 576 653 which was acknowledged as technical background in the patent specification;

D12: E. Hornbogen and S. Stanlek: "The Origin of the Three-Zone Structure at the Surface of Laser Melted Eutectic Fe-B-C Alloys", Zeitschrift Metallkunde, volume 79, (1988), No. 6, pages 375 to 380;

D20: Yongqiang Yang et al.: "Multi-pass overlapping laser glazing of FeCrPC and CoNiSiB alloys", Thin Solid Films, 323, (1998), pages 199 to 202.

D21: Statements of Professor Jeffrey Shield and of Dr S. Kureti of Karlsruhe University, both enclosed with the appellant's letter dated 2 June 2008

IV. Oral proceeding before the Board took place on 21 January 2010.

The appellant requested that

- the decision under appeal be set aside and that

- the patent be maintained on the basis of claims 1 to 9 according to the main request filed on 4 January 2010, or alternatively, on the basis of claims 1 to 8 according the auxiliary request 1 submitted during the oral proceedings.

The respondent (opponent) requested that the appeal be dismissed.

V. Independent claim 1 of the main request reads as follows:

"A method of forming a steel, comprising:
forming a metallic glass by forming a molten alloy and cooling the alloy at a rate which forms the metallic glass ***(step 1)***;

converting at least a portion of the glass to a crystalline steel material having a nanocrystalline scale grain size by devitrifying the at least a portion of the metallic glass*(step 2)*;
and transforming at least a portion of the crystalline steel material to metallic glass *(step 3)*, wherein the molten alloy comprises:
at least 50% Fe;
at least one element selected from the group consisting of Ti, Zr, Hf, V, Nb, Ta, Cr, Mo, W, Al, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, and Lu; and
at least one element selected from the group consisting of C."

Claim 1 of the auxiliary request 1 differs from the main request by the following wording (in bold letters)

"A method of forming...to metallic glass,
wherein the converting comprises heating the metallic glass to a temperature of at least about 500°C and less than the melting temperature of the glass,
wherein the molten alloy comprises....of C."

It is noted that the terms *(step 1), (step 2), (step 2)* have been added to claim 1 by the Board.

VI. The appellant's arguments can be summarized as follows:

The process described in document D6 was entirely different from the process of the patent. Looking firstly at the chemistry, D6 was concerned with the binary eutectic alloy $Fe_{83}B_{17}$ which neither included carbon nor a constituent of the group of elements set out in claim 1.

With respect to the composition, the document D12, published earlier than D6 by the same institute, clearly stated that the glass formation during laser reheating was drastically impaired or even destroyed by adding carbon or by substituting boron in part with carbon. When looking for an iron alloy as an alternative to the $Fe_{83}B_{17}$ binary alloy used in D6, the skilled person was dissuaded from considering Fe-alloys comprising carbon by the disclosure of document D12. For that reason, the skilled person would not at all turn to document D20 which dealt with FeCrPC alloys.

In the section "Materials and Methods" of document D6, the surface of the Fe-B material was melted and transformed into a glassy state with overlapping laser beams (called technique A). This first laser glazing was followed by a second non-overlapping re-melting (technique B) or, alternatively, by a second re-melting with single pulsed laser spots (technique C; see D6, page 57, right hand column). In case of technique A, only the first step of the method set out in claim 1 was fulfilled, and with techniques B and C at best only the steps 1 and 2 of the claimed method was met. There was, however, no indication whatsoever that the binary alloy $Fe_{83}B_{17}$ in D6 or the FeCrPC alloy in D20, respectively, comprised a nanocrystalline structure, and that a portion thereof was re-transformed into metallic glass by a further laser glazing treatment, as defined in step 3 of the claimed method. Hence, none of D6 and D20 disclosed step 3 of the claimed method.

Turning to claim 1 of the auxiliary request 1, document D1 described Fe-based boron and carbon containing transition metal alloys containing at least two metal components. The method used in D1 for forming these alloys disclosed the steps of forming the alloy in a glassy state, compacting the powder into bodies and heat treating to devitrify the material into an ultrafine crystalline structure. Although D1 mentioned in column 4, lines 65 to 68 the possibility of an additional thermal or thermo-mechanical treatment to achieve an optimum microstructure and properties of the alloy, this document failed to disclose claimed step 3 of re-transforming at least a portion of the crystalline steel material into a metallic glass. If such a further treatment to improve the anti-corrosion and anti-wear properties of the surface was actually considered, the skilled person had a plurality of different methods at his disposal to do so. Only on the basis of hindsight was it possible to focus on the method of multi-pass overlapping laser-glazing, as described in D20, and to apply it to the compacted bodies referred to in document D1.

The subject matter of claim 1 of the main request and of claim 1 of the auxiliary request therefore involved an inventive step.

VII. The respondent's arguments can be summarized as follows:

The claimed method defined in claim 1 of the main request was obvious from the combined technical teaching of documents D6 and D20. D6 as the closest prior art disclosed the steps of forming a metallic glass by laser glazing, converting in the zone affected by the heat of the overlapping laser beam at least a portion of the metal glass into a nanocrystalline structure, and transforming at least a portion of the crystalline structure steel material into a metallic glass by a second non-overlapping laser treatment (technique (A) and (B) disclosed in D6, page 57, right hand column and page 59, right hand column, lines 10 to 15). Although D6 focussed on investigating a binary $Fe_{83}B_{17}$ alloy, it was close at hand for a skilled person to treat other promising Fe-alloys in the same manner to solve the problem underlying the patent, provided that these alloys exhibited a high glass-forming capability and reliably formed a corrosion resistant surface coating, as did the alloys referred to in document D20.

The method of claim 1 of the main request was therefore obvious from the combination of the technical disclosure of documents D6 and D20.

As to the auxiliary request, document D1 disclosed all the technical features of the claimed method, except for step (3) of re-transforming a portion of the crystalline steel to a metallic glass. If the problem arose to improve the anti-corrosive and anti-friction properties of the surface of the material disclosed in document D1, multi-pass laser glazing was known to the skilled person as representing a highly effective method to provide the material with a corrosion resistant coating, as was evident from document D20.

Hence the subject matter of claim 1 of the auxiliary request also lacked an inventive step.

Reasons for the Decision

1. The appeal is admissible.

2. *Admissibility of documents D1 and D20*

The Board considered the technical teaching given in documents D1 and D20, which were referred to after the expiry of the opposition period, as being highly relevant to the present decision and thus admitted these documents to the appeal proceedings.

3. *Amendments:*

Claim 1 of the main request results from a combination of claims 1, 4 and 8 as granted (claims 1, 3, 4 and 8 of the application as originally filed).

In claim 1 of auxiliary request 1, the subject matter of claim 2 as granted (originally filed claim 2) has been incorporated in claim 1 of the main request.

Hence, there are no formal objections to the amended claims with respect to Article 123 EPC.

4. *The patent at issue:*

4.1 As previously mentioned, the method of forming the steel material of the composition set out in claim 1 of the main request can be subdivided into the following process steps:

(1) forming a molten alloy and cooling the alloy at a rate which forms a metallic glass,

(2) devitrifying at least a portion of the metallic glass into a steel material having a nanocrystalline scale grain size,
(3) transforming at least a portion of the nanocrystalline steel material into metallic glass.

4.2 According to the embodiment set out in claim 1 of the auxiliary request, the devitrifying step (2) is to be carried out at a temperature ranging from 500°C to less than $T_{melting}$.

5. *Main request*

5.1 Novelty

Document D6 is concerned with laser-glazing of a binary eutectic $Fe_{83}B_{17}$ alloy. This process comprises remelting at least in part the surface of the material through a laser-glazing pass to produce a track of an amorphous structure (see D6, Figures 1 and 2 and page 58, first column, paragraphs 1 and 2). This first laser-glazing pass complies with the step (1) of the claimed method.

The second laser-beam pass according to the known process overlaps part of the first laser-glazed pass so that the overlapping zone is re-crystallized at least in part because of heat affecting. As a consequence thereof, ultra-fine precipitations of primary crystals are formed in the heat affected zone (HAZ) which satisfies claimed step (2) of devitrifying at least a portion of the metallic glass to a nanocrystalline grain size (see D6, page 58, column 1, third full paragraph to column 2, first paragraph).

The appellant's argument that document D6 did not disclose explicitly the formation of nanocrystalline grain sized material cannot be followed for the following reasons. Firstly, the term "nanocrystalline" as such is open to interpretation in that it does not clearly define a specific range for the grain size. The patent itself explains that the nanocrystalline grains can be "in the order of 10^{-9} m", (see page 2, line 46), or "below 1 µm", (see page 3, lines 35 to 37; Figure 10; page 6, lines 42, 43 of the patent specification). Hence, the term "nanocrystalline" fails to permit a clear distinction from the "ultra-fine precipitations of primary crystals" identified in the HAZ according to document D6.

The appellant referred to the definition of "nanocrystalline" which was accepted as being below 100 nanometres in the professional community, as confirmed by statements of Mr Jeffrey E. Shield and Dr Kureti of the University of Karlsruhe (D21). Since however the patent specification itself gives the above mentioned meaning of the term "nanocrystalline", the statements of Mr Shield and Dr Kureti cannot lead to a different explanation of this term.

However, the appellant' argument that document D6 is concerned with a binary eutectic $Fe_{83}B_{17}$ alloy which neither comprises carbon nor a metal of the group of elements specified in claim 1 is agreed with. The subject mater of claim 1 of the main request is therefore novel.

5.2 Problem and Solution, inventive step

Starting from the technical disclosure of document D6, the objective problem underlying the present patent thus resides in looking for an appropriate steel as an alternative material which likewise forms a glassy state during the transformation from liquid to solid at rather low cooling rates when applying the overlapping laser glazing technique. Moreover, the alternative material should suitably provide an amorphous (glassy) surface layer having anti-corrosion properties and a low coefficient of friction (see in this context the patent specification, paragraphs [0023] and [0025]).

5.3 In his search for technical assistance to solve this problem, the skilled person would turn to D20 because this document, like D6, deals with multi-pass overlapping laser glazing of FeCrPC alloys which form a glassy state at rather low cooling rates. The glassy surface layer formed on the FeCrPC alloy has been found to be crack-free, completely amorphous and corrosion resistant in erosive environment (see D20, page 199, Introduction, last paragraph; Figure 2; page 200, last line, to page 201, line 3). Choosing the FeCrPC alloy mentioned in D20 as a very promising material was therefore close at hand for a person skilled in the art to solve the identified problem.

5.4 The appellant argued that document D12, published earlier than D6 by the same institute, would dissuade a skilled person from using Fe-C alloys given that he was taught in D12, page 378, point 4: Discussion, second paragraph that the glass forming ability during laser reheating was destroyed by the addition of carbon or by partly substituting boron with carbon. In consequence of this technical finding, the later investigations for producing amorphous layers described in document D6 focussed on eutectic binary Fe-B alloys rather than Fe-C or Fe-C-B alloys. Starting from D6 and bearing in mind the earlier disclosure of document D12, the skilled person was prompted to disregard the technical teaching of document D20 rather than to seriously consider it.

To the Board's understanding of the cited prior art, this line of arguments is misleading. It is not disputed that in their capability of forming amorphous structures, Fe-B alloys are superior to Fe-C alloys (see D12, Table 1 and Figures 4a and 4b). In that respect, however, document D12 mentions in point 3: Experimental results, first paragraph that the glass formation ability is significantly impaired if 50 at% or more of B are replaced by carbon. This means that Fe-B-C alloys comprising boron in amounts higher than carbon still could be expected to form metallic glass. More importantly, however, it is noted that the steel used for laser-glazing in document D20 is not restricted to Fe-C, Fe-B or Fe-B-C alloys but consists of a different composition, i.e. of a FeCrPC steel. This steel alloy, which does not include boron at all as a glass-forming constituent, comprises 10 at% chromium and the metalloids carbon (7 at%) and phosphorus (13 at%) which is known in the art as effective glass-forming element. The document D20 confirms that by multi-pass laser glazing of the FeCrPC alloys, amorphous layers are created on the surface which provide anti-corrosion properties in an erosive environment. These surface properties are also aimed at for the material referred to in the patent at issue. Faced with the identified problem, the skilled person had therefore no reason to disregard the teaching of D20 even after having considered the teaching of document D12. On the contrary, since the FeCrPC alloy actually was highly promising to solve the problem of providing a corrosion resistant coating on the surface of the material, the skilled person was prompted to turn to document D20.

5.5 In conclusion, the subject matter of claim 1 of the main request is obvious from the combined technical teaching given in documents D6 and D20.

6. Auxiliary request 1

6.1 Apart from the problem-solution approach to assess inventive step applied for claim 1 of the main request, in a second approach the technical disclosure of document D1 is chosen as most promising springboard towards the claimed process set out in claim 1 of the auxiliary request.

6.2 Novelty

Like the method claimed in the patent at issue, document D1 discloses glass forming alloys having the composition

$R_u R_v' Cr_w M_x B_y (P,C,Si)_z$ wherein

R is one of Fe, Co, Ni,

R' is one or two of Fe, Co, Ni other than R,

M is one of Mo, W, V, Nb, Ti, Ta, Al, Sn, Ge, Sb, Be, Zr, Mn and Cu;

and u, v, w, x, y and z represent atomic percent of R, R', Cr, M, B and (P, C, Si), respectively, (see D1, column 3, lines 28 to 56). Preferred compositions of the known "steel alloy" satisfying the claimed definition of at least 50% Fe, as for example alloy (F): $Fe_{58-84}Cr_{5-15}Mo_{5-15}B_{5-10}(C,Si)_{1-5}$, are disclosed in D1, column 8, lines 7 to 23 or in column 32, line 48 to column 33, line 36.

The known alloys are obtained in the glassy (amorphous) state by using conventional processes, consolidated and formed into three-dimensional bodies (see e.g. D1, abstract). The compacted bodies are heat treated at temperatures ranging from 0.6 to 0.95 of $T_{solidus}$ to be converted into a devitrified crystalline multiphase alloy having ultrafine grains of less than 1 µm, in particular less than 0.5 µm (see D1, column 3, line 56 to column 4, line 6; lines 12 to 36; lines 52 to 65). Within the explanations given in the patent, this range for the grain size is rated as being "nanocrystalline". Steps (1) and (2) of the claimed process defined in section 3.1 and 3.2 are therefore satisfied.

Document D1 further mentions in column 4, lines 65 to 69 that the consolidated devitrified parts can be given an additional thermal and/or thermo-mechanical treatment to achieve optimum microstructure and mechanical properties in the final product.

The claimed method differs from that given in claim 1 of the auxiliary request it that it does not comprises the step of re-transforming at least a portion of the nanocrystalline steel material into a metallic glass.

6.3 Problem and solution; inventive step

6.4 Starting from the disclosure of document D1 the skilled person, faced with the problem of providing the devitrified material with a surface having anti-corrosive properties and a low coefficient of friction, would look for a final thermal treatment which satisfies these needs.

6.5 It is generally known to the expert in material science and metallurgy that amorphous surface layers, obtained by laser glazing, actually provide the material with a corrosion and wear resistant coating. Bearing in mind this technical background knowledge, it is close at hand for the skilled person to use this technique in order to solve the identified problem. As a particular promising example for this technique, multi-pass overlapping laser glazing of FeCrPC alloys, i.e. of the same type of steels claimed in the patent at issue, to produce a corrosion and erosion resistant crack-free amorphous surface layer is disclosed in document D20 (see D20, page 199, 1. Introduction, last paragraph; page 201, Figures 2 and 3).

6.6 The appellant argued that a plethora of other surface treatments and coating processes was at the disposal of the skilled person to create a surface having anti-corrosive and low friction properties. In his view, the selection of the laser-glazing process described in document D20 to provide the consolidated devitrified products known from D1 with an amorphous corrosion resistant surface coating was based on hindsight.

The Board cannot agree. Metallic glasses are long-known in the art to exhibit a unique combination of properties, including extreme hardness and excellent resistance to corrosion and wear. This general background knowledge is at least in part also reflected in paragraph [0007] of the patent at issue. If, as in case of document D1, a corrosion and wear resistant surface is required on a consolidated product of an alloy already exhibiting due to its particular composition, a high glass-forming ability it would not involve inventive thinking to choose a metallic glass producing method, as for instance the laser glazing technique described in D20, to produce an amorphous coating on the surface of a specimen. The appellant's arguments on that point are therefore not convincing.

6.7 In view of these considerations, the subject matter of claim 1 of the auxiliary request 1 does not involve an inventive step since it is obvious from the technical teaching of document D1 and the technical background knowledge of a person skilled in the art or, alternatively, from the combination of the technical teaching of documents D1 and D20.

7. It is noted that on the basis of this second problem-solution approach, if applied, the subject matter of claim 1 of the main request would not involve an inventive step either for the same reasons.

Order

For these reasons it is decided that:

The appeal is dismissed.

The Registrar: The Chairman:

V. Commare T. Kriner