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(54) Magnesium alloy and production process thereof

(57) Provided are a magnesium alloy which is inexpensive, can be produced at a high yield, and has both high strength and high ductility; and a production process of the magnesium alloy. The magnesium alloy contains from 1 to 4 atomic % of Zn and from 1 to 4.5 atomic % of Y at a Zn/Y composition ratio ranging from 0.6 to 1.3, and contains both an intermetallic compound $Mg_3Y_2Zn_3$, and $Mg_{12}YZn$ having a long period structure. It may contain from 2 to 3.5 atomic % of Zn and from 2 to 4.5 atomic % of Y at a Zn/Y composition ratio falling within a range of from 0.8 to 1.2. It may contain from 1 to 4 atomic % of Zn, from 1 to 4.5 atomic % of Y and from 0.1 to 0.5 atomic % of Zr and contains, as a remaining portion, Mg and inevitable impurities. An alloy structure having both an intermetallic compound $Mg_3Y_2Zn_3$ and $Mg_{12}YZn$ having a long period structure is available by casting an Mg alloy containing from 1 to 4 atomic % of Zn and from 1 to 4.5 atomic % of Y at a Zn/Y composition ratio ranging from 0.6 to 1.3, followed by plastic processing.

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Description

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates to a magnesium alloy having both high strength and high ductility; and a production process thereof.

Description of the Related Art

[0002] Since magnesium is lighter in weight than iron or aluminum, its use as a light-weight substitute for members made of an iron steel material or aluminum alloy material is under investigation. Ordinary magnesium alloys have, however, lower strength than the other metal structure materials such as iron steel, aluminum alloy and titanium alloy. An AZ91 material for die casting, which is said to have relatively high strength, has strength as low as 160 MPa. In addition, industrial parts are required to have, at a moving part thereof, a percent elongation of at least 4 to 5%, but ordinary magnesium alloys do not have sufficient ductility. Even the above-described AZ91 material has a percent elongation of only about 3%.

[0003] A variety of magnesium alloys equipped with both high strength and high ductility have so far been proposed.

[0004] For example, known is a magnesium alloy having a composition represented by the formula: $Mg_{100-a-b-c}Ca_aZn_bX_c$ (wherein, X represents one or more than one elements selected from the group consisting of Y, Ce, La, Nd, Pr, Sm and Mm (misch metal); and $0.5 \leq a \leq 5$ atomic %, $0 < b \leq 5$ atomic %, and $0 < c \leq 3$ atomic % with the proviso that $1 \leq a+b+c \leq 11$ atomic %), and having a structure in which one or more of Mg-Ca, Mg-Zn and Mg-X intermetallic compounds have been finely dispersed in a Mg mother phase composed of a fine crystalline material. The above-described magnesium alloy having intermetallic compound(s) can be obtained as a high strength magnesium alloy in the powder form by rapid solidification of a molten alloy having the above-described composition by atomization or the like method. It can be molded or formed into even complex shaped products by hot plastic processing (refer to Japanese Patent Laid-Open No. 41065/1997).

[0005] Also known is a magnesium alloy having a composition represented by the formula: $Mg_{100-a-b}Ln_aM_b$ (wherein, M is one or more elements selected from Al and Zn; Ln is one or more elements selected from Y, Ce, La, Nd, Pr, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu and Mm (misch metal), or a mixture of rare earth elements; and $0.5 \leq a \leq 5$ atomic %, and $0.2 \leq b \leq 4$ atomic %, with the proviso that $1.5 \leq a+b \leq 7$ atomic %); having a crystal grain size less than 2,000 nm; and having a long period hexagonal structure in a part or whole region of the crystals. The above-described magnesium alloy having a long period hexagonal structure can be prepared as a high strength and high ductility magnesium alloy in the powder form by rapid solidification of a molten alloy having the above-described composition by atomization or the like method. By subjecting the resulting powder to plastic processing at an extrusion ratio of from 3 to 20, extrusion goods made of the magnesium alloy can be obtained (refer to Japanese Patent Laid-Open No. 2002-256370).

[0006] The above-described magnesium alloys however have a drawback: a yield at the time of rapid solidification of the molten alloy is low, which inevitably leads to a cost rise when the powder obtained by rapid solidification is molded or formed.

[0007] The above-described magnesium alloys each has a percent elongation not greater than 5%, which is almost a limit value when they are used for moving portions of industrial parts. Thus, they do not have sufficient ductility. The industrial parts using the above-described magnesium alloys therefore have a drawback: design freedom is greatly limited and they are not suited for practical use.

[0008] The magnesium alloy having a long period hexagonal structure, on the other hand, is said so that it could be formed into a molded product by casting using a copper mold with a large cooling rate. When the copper mold is used, however, molded products thus obtained must be relatively small in order to raise its cooling rate. Thus, this magnesium alloy has a drawback that any size of a molded product cannot be produced freely.

SUMMARY OF THE INVENTION

[0009] An object of the present invention is to overcome the above-described drawbacks and provide a magnesium alloy which is inexpensive, has a good yield, can be molded or formed into any size, and has both high strength and high ductility; and a production method of the magnesium alloy.

[0010] With a view to attaining the above-described object, the magnesium alloy of the present invention comprises from 1 to 4 atomic % of Zn and from 1 to 4.5 atomic % of Y, each based on the total amount, at a Zn/Y composition ratio falling within a range of from 0.6 to 1.3, and further comprises $Mg_3Y_2Zn_3$ which is an intermetallic compound and $Mg_{12}YZn$

having a long period structure.

[0011] Since the magnesium alloy according to the present invention has, as well as the above-described composition, both the intermetallic compound $Mg_3Y_2Zn_3$ and $Mg_{12}YZn$ having a long period structure, it is able to have both high strength and high ductility. Either one of or both of strength and ductility become insufficient when the content of Zn is less than 1 atomic % or exceeds 4 atomic % and that of Y is less than 1 atomic % or exceeds 4.5 atomic %, based on the total amount of the magnesium alloy.

[0012] Even if Zn and Y both satisfy the above-described ranges based on the total amount of the magnesium alloy, either one or both of strength and ductility becomes insufficient when the magnesium alloy is free of either one or both of the intermetallic compound $Mg_3Y_2Zn_3$ and $Mg_{12}YZn$ having a long period structure.

[0013] In addition, the magnesium alloy of the present invention is required to satisfy the Zn/Y composition ratio which falls within a range of from 0.6 to 1.3 in order to incorporate both the intermetallic compound $Mg_3Y_2Zn_3$ and $Mg_{12}YZn$ having a long period structure in the alloy without failure. When the Zn/Y composition ratio is less than 0.6 or exceeds 1.3, the magnesium alloy does not always contain either one or both of the intermetallic compound $Mg_3Y_2Zn_3$ and $Mg_{12}YZn$ having a long period structure.

[0014] It is known in a rapidly solidified Mg-Zn-Y alloy that an alloy of MgZ_nY_x (X=2 to 4) in which the concentration of Y > the concentration of Zn has an increased long period structure as the concentration of Y becomes greater; in the case of an alloy of $MgZn_xY$ (X=2 to 4) in which the concentration of Zn > the concentration of Y, heat treatment of it causes precipitation of the intermetallic compound $Mg_3Y_zZn_3$; and an alloy of $MgZn_xY_x$ (X=1 to 4) in which the concentration of Y = the concentration of Zn, that is, an equiatomic alloy is heat treated to generate the long period structure (refer to: Masayuki Nagano, Minoru Nishida, and Yoshihito Kawamura, "Influences of concentrations of Zn and Y and heat treatment on the structure formation of rapidly solidified Mg-Zn-Y alloy", *Collected Abstracts of the 2003 meeting of the Japan Institute of Metals,* The Japan Institute of Metals, p187).

[0015] According to the investigation by the present inventors, however, no intermetallic compound $Mg_3Y_2Zn_3$ exists in each of the alloy in which the concentration of Y > the concentration of Z and the equiatomic alloy in which the concentration of Y = the concentration of Zn, while no long period structure exists in the alloy in which the concentration of Zn > the concentration of Y. Accordingly, the long period structure and intermetallic compound $Mg_3Y_2Zn_3$ do not exist simultaneously in the rapidly solidified Mg-Zn-Y alloy.

[0016] The magnesium alloy of the present invention preferably contains from 2 to 3.5 atomic % of Zn and from 2 to 4.5 atomic % of Y, each based on the total amount, at a Zn/Y composition ratio falling within a range of from 0.8 to 1.2, in order to have both higher strength and higher ductility.

[0017] The magnesium alloy of the present invention may contain from 1 to 4 atomic % of Zn and from 1 to 4.5 atomic % of Y, based on the total amount, and contain, as a remaining portion, Mg and inevitable impurities. Alternatively, it may contain from 0.1 to 0.5 atomic % of Zr, based on the total amount, and contain as a remaining portion Mg and inevitable impurities.

[0018] Incorporation of Zr in the magnesium alloy of the present invention within the above-descried range enables to impart a miniaturized alloy structure to the magnesium alloy. Miniaturization effect of the alloy structure cannot be attained when the content of Zr is less than 0.1 atomic % based on the total alloy amount. On the other hand, when the content of Zr exceeds 0.5 atomic % based on the total alloy amount, formation of the intermetallic compound $Mg_3Y_2Zn_3$ is sometimes disturbed.

[0019] The magnesium alloy of the present invention is able to have higher strength by the addition, to the above-described composition, of a small amount of at least one element selected from the group consisting of La, Ce, Nd, Sm and Yb. Moreover, the magnesium alloy of the present invention can be obtained as a composite by adding a reinforcing material such as fibers and particles.

[0020] The magnesium alloy of the present invention can be produced by a process comprising casting an Mg alloy containing from 1 to 4 atomic % of Zn and from 1 to 4.5 atomic % of Y, each based on the total amount, at a Zn/Y composition ratio falling within a range of from 0.6 to 1.3; and plastic processing of the cast product obtained in the above-described step into an alloy structure containing an intermetallic compound $Mg_3Y_2Zn_3$ and $Mg_{12}YZn$ having a long period structure.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0021] Embodiments of the present invention will hereinafter be described more specifically.

[0022] In this Embodiment, a material containing from 1 to 4 atomic % of Zn and from 1 to 4.5 atomic % of Y, each based on the total alloy amount, at a Zn/Y composition ratio falling within a range of from 0.6 to 1.3, preferably further containing from 0.1 to 0.5 atomic % of Zr and, as a remaining portion, Mg and inevitable impurities is charged in a carbon crucible. In an argon atmosphere, the material is melted in a high-frequency melting furnace, for example, at 700°C to yield a molten alloy.

[0023] The molten alloy is poured into a mold, followed by casting. A cooling rate during the casting is preferably 10

K/sec or less. This cooling rate is much lower than that of atomization method or twin-roll method employed for rapid solidification, that is, 10^4 K/sec or greater. It is also much lower than that of roll casting method or quenched copper mold method, that is, 10^3 to 10^2 K/sec. In this Embodiment, ordinarily employed molds such as metal mold, graphite mold and sand mold can be used for casting and a copper mold or water-cooled copper mold is not necessary, which leads to a reduction in the production cost.

[0024] The cast product thus obtained is subjected to plastic processing, whereby a molded or formed product can be obtained. The molded or formed product is a magnesium alloy containing from 1 to 4 atomic % of Zn and from 1 to 4.5% of Y, based on the total alloy amount, at a Zn/Y composition ratio falling within a range of from 0.6 to 1.3. Preferably, it further contains from 0.1 to 0.5 atomic % of Zr and as a remaining portion Mg and inevitable impurities. It contains both an intermetallic compound $Mg_3Y_2Zn_3$ and $Mg_{12}YZn$ having a long period structure. As a result, the molded or formed product is able to have both high strength and high ductility.

[0025] Examples, Comparative examples and Referential Examples of the present invention will next be described.

[Examples]

[0026] In Examples, materials containing, based on the total alloy amount, from 1 to 4 atomic % of Zn and from 1 to 4.5 atomic % of Y at a Zn/Y composition ratio falling within a range of from 0.6 to 1.3, preferably further containing from 0.1 to 0.5 atomic % of Zr, and, as a remaining portion, Mg and inevitable impurities, which materials were however different from each other with their amounts of Zn, Y and Zr varied within the above-described ranges were charged in a carbon crucible. In an argon atmosphere, the materials were melted in a high-frequency melting furnace, for example, at 700°C. The molten alloys thus obtained were poured into metal molds, followed by casting at a cooling rate not greater than 10K/sec, whereby rod materials were obtained. The rod materials were heated to a temperature range of from 350 to 450°C in an electric furnace, and then extruded at an extrusion ratio of 10, whereby extrusion goods were obtained.

[0027] The metal structure of each of the resulting extrusion goods was identified by X-ray diffraction and transmission electron microscope, whereby the presence or absence of an intermetallic compound $Mg_3Y_2Zn_3$ and $Mg_{12}YZn$ having a long period structure was confirmed. Test pieces were cut from the extrusion goods. Their 0.2% proof stress, tensile strength and elongation were measured by conducting a tensile test on them at normal temperature. The results are shown in Table 1.

[Comparative Examples]

[0028] In Comparative Examples, in a similar manner to that employed for the above-described Examples except that materials containing, each based on the total alloy amount, from 0.5 to 5 atomic % of Zn and from 0.5 to 5 atomic % of Y and containing, as a remaining portion, Mg and inevitable impurities, which materials were however different from each other with their amounts of Zn and Y varied within the above-described ranges were used, rod materials were obtained. The rod materials were extruded as in the above-described Examples, whereby extrusion goods were obtained.

[0029] The metal structure of each of the resulting extrusion goods was identified by X-ray diffraction and transmission electron microscope, whereby the presence or absence of an intermetallic compound $Mg_3Y_2Zn_3$ and $Mg_{12}YZn$ having a long period structure was confirmed. Test pieces were cut from the extrusion goods. Their 0.2% proof stress, tensile strength and elongation were measured by conducting a tensile test on them at normal temperature. The results are shown in Table 1.

[Referential Examples]

[0030] In Referential Examples, a metal structure of known magnesium alloys, that is, WE54-T6 material and AZ91 material was identified by X-ray diffraction and a transmission electron microscope, whereby the presence or absence of an intermetallic compound $Mg_3Y_2Zn_3$ and $Mg_{12}YZn$ having a long period structure was confirmed. Test pieces were cut from the WE54-T6 material and AZ91 material, respectively. Their 0.2% proof stress, tensile strength and elongation were measured by conducting a tensile test on them at normal temperature. The results are shown in Table 1.

[Table 1]

	Zn (at %)	Y (at %)	Zr (at %)	Zn/Y	Extrusion at (°C)	Intermetallic Compound $Mg_3Y_2Zn_3$	Long-period phase $Mg_{12}YZn$	0.2% Proof stress (MPa)	Tensile strength (MPa)	Elongation (%)
Example 1	2	2	-	1	350	○	○	395	429	10.2
Example 2	2	2	-	1	375	○	○	415	446	7.8
Example 3	2	2	0.2	1	350	○	○	405	465	8.5
Example 4	2	2	0.2	1	400	○	○	425	471	8.5
Example 5	3	3	-	1	450	○	○	430	487	7.5
Example 6	3	3.5	-	0.86	450	○	○	440	492	6
Example 7	3.5	3	-	1.17	350	○	○	425	490	7.5
Example 8	3.5	3.5	-	1	350	○	○	450	523	4.5
Example 9	2.5	3	-	0.83	350	○	○	407	485	9
Example 10	2	3	-	0.67	350	○	○	370	447	8.3
Example 11	2.5	4	-	0.63	450	○	○	370	450	6
Example 12	1.5	1.5	-	1	350	○	○	374	417	7.7
Example 13	1	1	-	1	350	○	○	373	392	10.3
Example 14	2	2	-	1.3	400	○	○	377	402	5.1
Comparative Example 1	0.5	2	-	0.25	400	×	○	278	329	8.2
Comparative Example 2	1	2	-	0.5	350	×	○	375	420	4
Comparative Example 3	1	3	-	0.33	350	×	○	418	440	2
Comparative Example 4	4	2	-	2	450	○	×	288	338	10.6
Comparative Example 5	5	3	-	1.67	450	○	×	376	383	2.5
Comparative Example 6	3	5	-	0.6	450	×	○	348	451	2.6
Comparative Example 7	0.5	0.5	-	1	350	×	○	323	341	12
Comparative Example 8	5	5	-	1	450	○	○	457	477	0.3
Referential Example 1	WE54-T6 material			-	--	×	×	172	250	2
Referential Example 2	AZ91 material			-	--	×	×	160	230	3

Intermetallic compound $Mg_3Y_2Zn_3$: ○ when it is contained, × when it is not contained

Long-period phase $Mg_{12}YZn$: ○ when it is contained, × when it is not contained

[0031] From Table 1, it is apparent that the magnesium alloys obtained in Examples 1 to 14 containing, based on the total alloy amount, from 1 to 4 atomic % of Zn and from 1 to 4.5 atomic % of Y at a Zn/Y composition ratio falling within a range of from 0.6 to 1.3, and containing both an intermetallic compound $Mg_3Y_2Zn_3$ and $Mg_{12}YZn$ having a long period structure have both high strength and high ductility, because they are markedly superior to known WE54-T6 material and AZ91 material in each of strength (0.2% proof stress, tensile strength) and ductility (elongation).

[0032] Compared with the magnesium alloys obtained in Examples, those obtained in Comparative Examples 1 to 5 containing Zn and Y at a Zn/Y composition ratio outside the range of from 0.6 to 1.3 have only either one of the intermetallic compound $Mg_3Y_2Zn_3$ or $Mg_{12}YZn$ having a long period structure, suggesting that they are not equipped sufficiently with either one or both of strength and ductility. It is apparent that the magnesium alloy obtained in Comparative Example 6 which contained Y in an amount exceeding the invention range of from 1 to 4.5 atomic % does not have the intermetallic compound $Mg_3Y_2Zn_3$ so that it does not have sufficient ductility. It is also apparent that the magnesium alloy obtained in Comparative Example 7 containing Zn in an amount less than the invention range of from 1 to 4 atomic % and Y in an amount less than the invention range of from 1 to 4.5 atomic % does not have the intermetallic compound $Mg_3Y_2Zn_3$ so that it does not have sufficient strength. It is also apparent that the magnesium alloy obtained in Comparative Example 8 containing Zn in an amount exceeding the invention range of from 1 to 4 atomic % and Y in an amount exceeding the invention range of from 1 to 4.5 atomic % contains both the intermetallic compound $Mg_3Y_2Zn_3$ and $Mg_{12}YZn$ having a long period structure but it does not have sufficient ductility.

[0033] Provided are a magnesium alloy which is inexpensive, can be produced at a high yield, and has both high strength and high ductility; and a production process of the magnesium alloy. The magnesium alloy contains from 1 to 4 atomic % of Zn and from 1 to 4.5 atomic % of Y at a Zn/Y composition ratio ranging from 0.6 to 1.3, and contains both an intermetallic compound $Mg_3Y_2Zn_3$, and $Mg_{12}YZn$ having a long period structure. It may contain from 2 to 3.5 atomic % of Zn and from 2 to 4.5 atomic % of Y at a Zn/Y composition ratio falling within a range of from 0.8 to 1.2. It may contain from 1 to 4 atomic % of Zn, from 1 to 4.5 atomic % of Y and from 0.1 to 0.5 atomic % of Zr and contains, as a remaining portion, Mg and inevitable impurities. An alloy structure having both an intermetallic compound $Mg_3Y_2Zn_3$ and $Mg_{12}YZn$ having a long period structure is available by casting an Mg alloy containing from 1 to 4 atomic % of Zn and from 1 to 4.5 atomic % of Y at a Zn/Y composition ratio ranging from 0.6 to 1.3, followed by plastic processing.

Claims

1. A magnesium alloy, which comprises, based on a total alloy amount, from 1 to 4 atomic % of Zn and from 1 to 4.5 atomic % of Y at a Zn/Y composition ratio falling within a range of from 0.6 to 1.3, and includesv an intermetallic compound $Mg_3Y_2Zn_3$ and $Mg_{12}YZn$ having a long period structure.

2. A magnesium alloy according to Claim 1, which comprises at least 3 atomic % of Zn and at least 3 atomic % of Y, each based on a total alloy amount, and as a remaining portion Mg and inevitable impurities.

3. A magnesium alloy according to Claim 1, which comprises from 2 to 3.5 atomic % of Zn and from 2 to 4.5 atomic % of Y, each based on a total alloy amount, at a Zn/Y composition ratio falling within a range of from 0.8 to 1.2.

4. A magnesium alloy according to Claim 3, which comprises at least 3 atomic % of Zn and at least 3 atomic % of Y, each based on a total alloy amount, and as a remaining portion Mg and inevitable impurities.

5. A magnesium alloy according to Claim 1, which comprises from 1 to 4 atomic % of Zn, from 1 to 4.5 atomic % of Y, and from 0.1 to 0.5 atomic % of Zr, each based on a total alloy amount, and as a remaining portion Mg and inevitable impurities.

6. A production process of a magnesium alloy, which comprises casting an Mg alloy comprising from 1 to 4 atomic % of Zn and from 1 to 4.5 atomic % of Y at a Zn/Y composition ratio falling within a range of from 0.6 to 1.3; and plastic processing of the cast product obtained in the above-described step into an alloy structure containing an intermetallic compound $Mg_3Y_2Zn_3$ and $Mg_{12}YZn$ having a long period structure.

7. A production process of a magnesium alloy according to Claim 6, which comprises at least 3 atomic % of Zn and at least 3 atomic % of Y, each based on a total alloy amount, and as a remaining portion Mg and inevitable impurities.

8. A production process of a magnesium alloy according to Claim 6, which comprises from 2 to 3.5 atomic % of Zn and from 2 to 4.5 atomic % of Y, each based on a total alloy amount, at a Zn/Y composition ratio falling within a range of from 0.8 to 1.2.

9. A production process of a magnesium alloy according to Claim 8, wherein the magnesium alloy contains at least 3 atomic % of Zn and at least 3 atomic % of Y, each based on a total alloy amount and contains as a remaining portion Mg and inevitable impurities.

10. A production process of a magnesium alloy according to Claim 6, wherein the magnesium alloy contains from 1 to 4 atomic % of Zn, from 1 to 4.5 atomic % of Y and from 0.1 to 0.5 atomic % of Zr, each based on a total alloy amount and contains as a remaining portion Mg and inevitable impurities.

11. A production process of a magnesium alloy according to Claim 6, wherein the casting is performed at a cooling rate of 10 K/sec or less.

12. A production process of a magnesium alloy according to Claim 6, wherein the plastic processing is carried out by extrusion of the cast product.

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EUROPEAN SEARCH REPORT

Application Number
EP 05 02 0951

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
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A	DATABASE INSPEC [Online] THE INSTITUTION OF ELECTRICAL ENGINEERS, STEVENAGE, GB; January 1989 (1989-01), MURATOVA E V ET AL: "Phase equilibria in the Mg-Y-La-Zn system at temperatures below the solidus" XP002349969 Database accession no. 3606647 * abstract * -& Inorganic Materials USA, vol. 25, no. 1, January 1989 (1989-01), pages 50-54, XP008054202 ISSN: 0020-1685 -----	1-12	
A	DATABASE INSPEC [Online] THE INSTITUTION OF ELECTRICAL ENGINEERS, STEVENAGE, GB; 15 June 1997 (1997-06-15), SUGAMATA M ET AL: "Structures and mechanical properties of rapidly solidified Mg-Y based alloys" XP002349970 Database accession no. 5694945 * abstract * -/--	1-12	TECHNICAL FIELDS SEARCHED (Int.Cl.7) C22C C22F

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	20 October 2005	Vlassi, E

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons
....
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EPO FORM 1503 03.82 (P04C01)

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EUROPEAN SEARCH REPORT

Application Number
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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
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The present search report has been drawn up for all claims

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The Hague	20 October 2005	Vlassi, E

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
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3

EPO FORM 1503 03.82 (P04C01)

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DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
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A	EP 0 575 796 A (NORSK HYDRO TECHNOLOGY B.V; NORSK HYDRO A.S) 29 December 1993 (1993-12-29) * claims 1-10 * * examples 1-5 * * page 2, line 31 - line 57 * -----	1-12	TECHNICAL FIELDS SEARCHED (Int.Cl.7)

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	20 October 2005	Vlassi, E

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 05 02 0951

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