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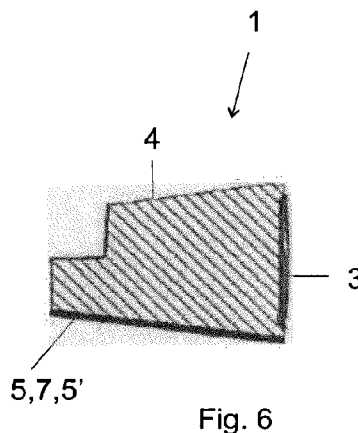
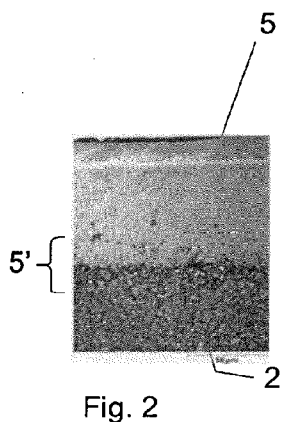
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(54) Title: PISTON RING AND HEAT TREATMENT PROCESS



(57) Abstract: The present invention relates to a piston ring, in particular a compression ring, provided with a base (2) of carbon steel whose cross-section defines an outer lateral surface (3) slidably associable to the wall (D) of a cylinder, an upper surface (4) as-sociable to the groove (C) of a piston (P), facing the piston crown and a lower surface (5) associable to the groove (C) of a piston (P), facing the piston skirt (S), wherein at least a portion of the lower surface (5) comprises a carbonitrided layer (7) that has a thick-ness between 100pm and 300pm and hardness between 700HV and 1000HV.

Specification of the Patent for **"PISTON RING AND
HEAT TREATMENT PROCESS"**.

5 The present invention relates to a piston ring,
being in particular a first-groove ring, which meets
the performance requirements without having any type of
coating on its lower surface. The ring is based on
carbon steel and its lower surface is hardened by a
process of cementation or laser carbonitriding.

10 **Description of the prior art**

The first-groove piston ring, also known as
compression ring, is the one that is subjected to the
largest forces and stresses when the engine is in
operation. When mounted in the first groove of the
15 piston, the ring moves slightly in the axial direction,
causing wear on its upper and lower surfaces, and not
only wear on the surface of the external diameter,
facing the cylinder wall.

One of the most critical situations for wear
20 occurs at the moments when the piston moves towards top
dead centre (TDC), which generates interference of the
lower surface of the ring with the cylinder groove,
potentiating wear in that region. Another fairly
critical situation occurs at the beginning of the
25 expansion stroke (PCP), i.e. when the piston moves
towards bottom dead centre (BDC), also generating
interference on the lower surface.

One way of reducing this wear consists of applying
coatings on the ring. As a rule, these coatings have
30 advantageous properties with respect to hardness, which
allows good performance of the ring with respect to
wear; however, the low ductility of these hard coatings
causes undesirable fractures, often with the occurrence
of detachment, which reduces the useful life of the
35 piston ring.

As another aspect, there are coatings that have
good ductility values and as a corollary resist
detachment quite well, but conversely they do not give
the desired performance with respect to wear
40 resistance.

Various solutions for piston ring coating have been proposed by experts in this area, some of which are described below.

Japanese patent JP4452641 relates to a piston ring comprising a ferrous-metal or aluminium base, a nitrided layer and a coating in the form of a film of a Cr-B-Ti-N alloy, applied by the PVD (*physical vapour deposition*) process. This coating was designed so as to offer good properties of hardness and ductility, however its application generates an increase in the cost of manufacture of the ring that may not be commercially viable in some applications.

Japanese patent JP 3239610 relates to a piston ring for use in the groove of a piston made of an aluminium alloy (metal matrix composite - MMC). The ring comprises a nitrided coating layer or a coating formed only on the outer lateral surface. The hardness of the upper and lower surfaces of the ring is from about 400HV to 600HV, obtained by the cementation or hardening process.

US patent 4,531,985 relates to a piston ring whose outer surfaces are treated in a chamber with a gaseous mixture of a gas with carbon and a gas with nitrogen, at a temperature between 450°C and 650°C. The proportions of the gases have values between 25:75 and 75:25 and this gas mixture provides carbonitriding of the surfaces of the ring. The surfaces of the ring are finished mechanically before the treatment.

A piston ring based on carbon steel whose lower lateral surface has a cemented or carbonitrided layer with thickness between 100µm and 300µm and hardness between 700HV and 1000HV has not yet been developed and described.

Aims of the invention

One aim of the present invention is a piston ring based on carbon steel whose lower surface is hardened by a process of cementation or laser carbonitriding.

Another aim of the present invention is a piston ring based on carbon steel whose lower surface is

hardened by a process of cementation or laser carbonitriding to give a cemented or carbonitrided layer with thickness between 100µm and 300µm and hardness between 700HV and 1000HV.

5 Brief description of the invention

The aims of the present invention are achieved with a piston ring, in particular a compression ring, provided with a carbon steel base whose cross-section defines an outer surface slidably associable to the
10 wall of a cylinder, an upper surface associable to the groove of a piston, facing the piston crown and a lower lateral surface associable to the groove of a piston, facing the piston skirt, wherein at least a portion of the lower surface comprises a carbonitrided layer that
15 has a thickness between 100µm and 300µm and hardness between 700HV and 1000HV.

The aims of the present invention are also achieved by a heat treatment process for treating at least a portion of the lower surface of the piston ring
20 defined in the preceding paragraph, comprising the following steps:

Step (i): covering at least a portion of the lower surface of the ring with a covering of carbon black or any other carbon-based compound; and
25 Step (ii): application of a laser beam on the covering of carbon black applied with precise control of location and depth.

The laser beam is applied and heats the spot until the austenitizing temperature is reached, promoting
30 diffusion of carbon atoms present in the covering of carbon black from the surface towards the interior of the base.

Step (ii) comprises rapid cooling of the region where the laser beam is applied for formation of
35 martensite.

Brief description of the drawings

The present invention will be described in more detail below, based on an embodiment example represented in the drawings. The figures show:

Fig. 1 - is a schematic partial view of a compression ring mounted on an engine piston that moves towards TDC, illustrating a critical situation of wear of its lower surface.

5 Fig. 2 - is an enlarged photograph of a section of the piston ring according to the present invention, on its lower surface.

Fig. 3 - is a schematic view of equipment for the process of laser carbonitriding applied to the piston
10 ring according to the present invention.

Fig. 4 - is a schematic comparative view of the lower surface of the piston ring before and after the process of laser carbonitriding.

Fig. 5 - is a schematic sectional view of the
15 piston ring according to the present invention before the process of laser carbonitriding.

Fig. 6 - is a schematic sectional view of the piston ring according to the present invention after the process of laser carbonitriding.

20 Fig. 7 - is a chart of wear of the piston ring according to the present invention compared with other piston rings of the prior art.

Detailed description of the figures

The piston ring according to the present invention
25 was developed after long studies with the objective of providing a long useful life and a cost of production that makes it viable for commercial application for engines.

Piston rings undergo wear not only on their outer
30 surface that faces the cylinder wall. The constant friction of the ring with the piston groove leads to wear on its upper surfaces (facing the piston top or crown) and lower surfaces (facing the piston skirt).

The first-groove piston ring, also known as
35 compression ring, is the one that is subjected to the largest forces and stresses when the engine is in operation. When the engine is running, the compression ring, which is mounted in the (first) piston groove, moves slightly in the axial direction, causing wear on

its upper and lower surfaces. One of the most critical wear situations occurs at the moment when the piston moves towards top dead centre (TDC), which generates interference of the lower surface of the ring with the piston groove, potentiating wear in that region. This situation occurs thousands of times per minute in normal operation of an engine and is shown schematically in Fig. 1.

Preferably, but not necessarily, piston ring 1 according to the present invention is a compression ring, but it is obvious that it may assume other configurations, such as that of a second-groove ring or of an oil scraper ring, without the resultant invention leaving the scope of protection of the appended claims.

Regardless of its specific constitution, ring 1 according to the present invention meets the performance requirements without having any type of coating or nitriding on its lower surface, but does have hardening on at least a portion of this surface by means of a process of cementation or laser carbonitriding. Another imperative characteristic for this carbonitriding process to be effective is that the base material from which ring 1 is constituted is carbon steel, with any required or desirable composition.

Describing essentially, ring 1 according to the present invention is provided with a base 2 of carbon steel whose cross-section may assume the most varied configurations provided that they define an outer lateral surface 3 slidably associable to the wall D of a cylinder, an upper surface 4 associable to the groove C of a piston P, facing the piston crown and a lower surface 5 associable to the groove C of a piston P, facing the skirt S of the piston.

This is the basic geometry for a compression ring to perform its required function. A non-limiting configuration of the cross-section of the ring 1 may be seen in Fig. 6.

It is precisely a portion of the lower surface 5, or all of it, that undergoes the process of laser carbonitriding that will be described hereunder, and that increases the surface hardness in that region, greatly reducing the wear of the ring in constant friction with the piston groove.

Cementation or carbonitriding is a thermochemical treatment that consists of introducing carbon and/or nitrogen into the surface of a carbon-steel component with the aim of increasing the surface hardness. The carbon and/or nitrogen atoms supplied by a source material are inserted on the basis of heating of the region that is to undergo cementation, as will be described below. Then the surface is cooled rapidly, and the higher carbon content in the surface layers leads to an increase in surface hardness, increase in wear resistance and increase in tensile fatigue strength. Another characteristic feature resulting from this process is a change (generally increase) in grain size.

The rapid temperature drop and the higher carbon content adjacent to the surface lead to transformation of austenite to martensite, whereas the area not cemented still has a ferrite and/or pearlite microstructure, which is predominant in carbon steel, with higher ductility.

More specifically, ring 1 according to the present invention undergoes a process of cementation or laser carbonitriding. For this, the equipment employed for carrying out the process comprises a source that emits laser rays, which serve as a heat source of high power and precision, activating the transfer of carbon and/or nitrogen from a source material.

The great advantage of this process, relative to the existing technologies, besides the intrinsic disadvantages/characteristics of a coating that may crack and spall, lies in the possibility of careful control of the variables of this process so as to obtain the desirable tribological characteristics in

the treated region. More specifically, the ability to manipulate the source of laser rays for treating very small areas with great precision, with appropriate thermal control, of the depth to which diffusion of carbon and/or nitrogen is desired, and of the path of the laser beam combined with high capacity for automation of this process makes its use extremely advantageous.

In this connection, in extensive investigations, the applicant worked on all the variables until the ideal strength properties of the treated lower surface 5 were achieved.

Fig. 3 shows, schematically, the equipment 10 for carrying out the process of carbonitriding with the laser beam 13. It comprises a source that emits laser rays 11, an optional mirror 12 for guiding this beam and one or more focusing lenses 14 to allow focusing of the entire spectrum of the laser beam 13 on quite a small area or point, thereby ensuring both high heating power and very precise control of the area to be treated.

Preferably, the surface to be treated 5 is applied in an environment in the presence of a gas based on nitrogen, for the purpose of making diffusion of this element possible.

Describing essentially, the heat treatment process for treating at least a portion of the lower surface 5 of the piston ring according to the present invention is an invention included in the scope of protection of the appended claims and comprises step (i), of covering at least a portion of the lower surface 5 of the ring with a covering of carbon black 6 or any other carbon-based compound; and step (ii), of application of a laser beam 13 on the covering of carbon black 6 applied with precise control of location and depth.

In step (ii), the laser beam 13 is applied and heats the surface 5 until the austenitizing temperature is reached, promoting diffusion of carbon atoms present in the covering of carbon black (6) and the nitrogen atoms present in the gaseous atmosphere from the

surface 5 towards the interior of the base. Step (ii) further comprises rapid cooling of the region where the laser beam is applied for formation of martensite. Formation of the carbonitrided layer 7 is illustrated schematically in Fig. 4.

Describing in more detail, the laser beam causes rapid melting of the material, but as it is applied for a short time and only on the surface, the rest of the material remains at its initial temperature, called cold temperature hereinafter, and functions as a heat barrier. Thus, there is a large temperature gradient in the transition region between the molten material and the rest of the material that remained at the cold temperature. The result is rapid solidification as soon as application of the laser beam ceases.

For all sources emitting laser rays, the exposure time (or pulse) has a considerable influence on the depth of material that will be melted. Of course, long exposure times provide deeper fusion. Since a material melted to a greater depth obviously means a longer time that it remains in the molten state, there will be more time available for diffusion of one or more alloying elements (such as carbon or nitrogen) there. Thus, a material melted to a greater depth and for a longer time results in the formation of more dilute alloys, and vice-versa.

Other variables in the process are the power of the laser beam, the thickness of the covering of carbon black and the nature of the gaseous atmosphere in which the process takes place.

Regardless of its specific configuration, the resultant ring 1 has, finally, a lower surface 5 in which the portion treated comprises a carbonitrided layer 7 that has a thickness between 100µm and 300µm and hardness between 700HV and 1000HV. More preferably, the carbonitrided layer 7 has a thickness of substantially 100µm and also has a transition layer 5' with a thickness of substantially 200µm, which begins

at a depth of 100µm and reaches a depth of 300µm reckoned from the outer surface.

Use of the laser carbonitriding technique is quite advantageous as it offers benefits in comparison with the coating processes when it is desired to confer strength on specific surfaces of the piston ring. To summarize, the advantages are as follows:

- increase in toughness on the surface treated by diffusion of carbon, when compared with the prior art;
- increase in the useful life of the piston ring (and, by inference, of the engine as a whole) through the increase in wear resistance in the place treated;
- possibility of extending the use of piston rings of carbon steel to more demanding applications (engines where the rings must meet more exacting performance requirements); and
- possibility of localized treatment, minimizing the undesirable influence of the temperature in other regions of the component.

The chart shown in Fig. 7 illustrates the values of wear resistance of the present ring 1 when compared to rings currently in use. Tests confirmed that ring 1 according to the present invention displays reduced wear values, almost as good as that displayed by rings of nitrided stainless steel (GNS) with 60µm and rings of grey cast iron (GCI), and far more advantageous than that displayed by rings of nodular cast iron (NCI) and by rings of Cr-Si steel.

A preferred embodiment example having been described, it must be understood that the scope of the present invention comprises other possible variations, thus being limited only by the content of the appended claims, including possible equivalents.

CLAIMS

1. Piston ring provided with a base (2) of carbon steel whose cross-section defines an outer lateral surface (3) slidably associable to the wall (D) of a cylinder, an upper surface (4) associable to the groove (C) of a piston (P), facing the piston crown and a lower surface (5) associable to the groove (C) of a piston (P), facing the piston skirt (S), characterized in that at least a portion of the lower surface (5) comprises a carbonitrided layer (7) that has a thickness between 100µm and 300µm and hardness between 700HV and 1000HV.

2. Ring according to Claim 1, characterized in that the carbonitrided layer (7) has a thickness of substantially 100µm.

3. Ring according to Claim 2, characterized in that it comprises a transition layer (5') with a thickness of substantially 200µm.

*4. Ring according to Claim 5, characterized in that the transition layer (5') begins at a depth of 100µm and reaches a depth of 300µm reckoned from the outer surface.

5. Ring according to Claim 1 or 2, characterized in that the carbonitrided layer (7) consists of an austenite matrix retained with martensite platelets incorporated.

6. Ring according to any one of the preceding claims, characterized in that the carbonitrided layer (7) is obtained by the process of laser carbonitriding.

7. Ring according to any one of the preceding claims, characterized in that the outer surface (3) has a coating applied by the process of physical vapour deposition (PVD).

8. Heat treatment process for treating at least a portion of the lower surface (5) of the piston ring defined in Claims 1 to 7, characterized in that it comprises the following steps:

Step (i): covering at least a portion of the lower surface (5) of the ring with a covering of carbon black (6) or any other carbon-based compound; and

5 Step (ii): application of a laser beam on the covering of carbon black (6) applied with precise control of location and depth.

9. Process according to Claim 8, characterized in that, in step (ii), the laser beam is applied and heats the spot until the austenitizing temperature is
10 reached, promoting diffusion of carbon atoms present in the covering of carbon black (6) from the surface towards the interior of the base.

10. Process according to Claim 8 or 9, characterized in that step (ii) comprises rapid cooling
15 of the region where the laser beam is applied for formation of martensite.

11. Process according to Claim 8, 9 or 10, characterized in that, in step (ii), the laser beam is applied in an environment in which a gas containing
20 nitrogen predominates.

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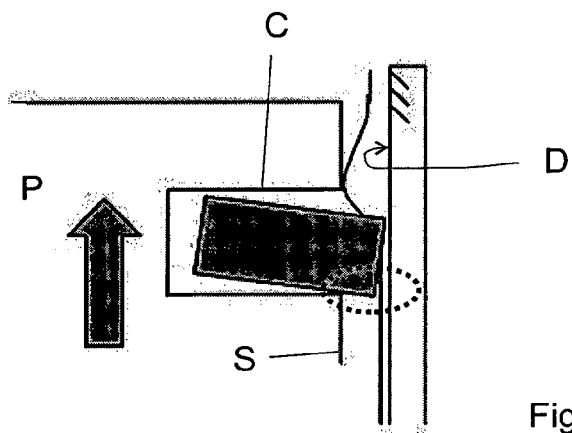


Fig. 1

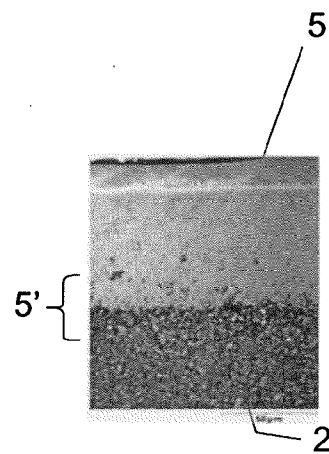
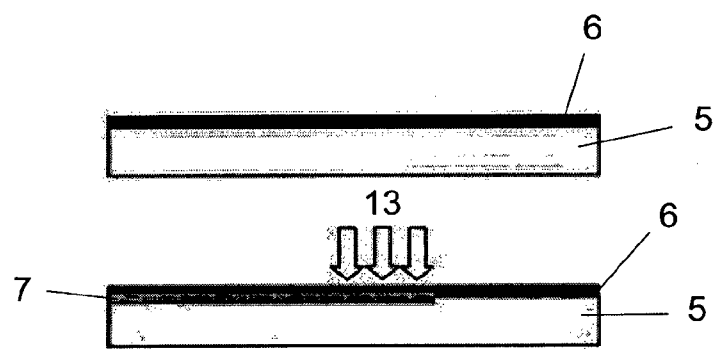
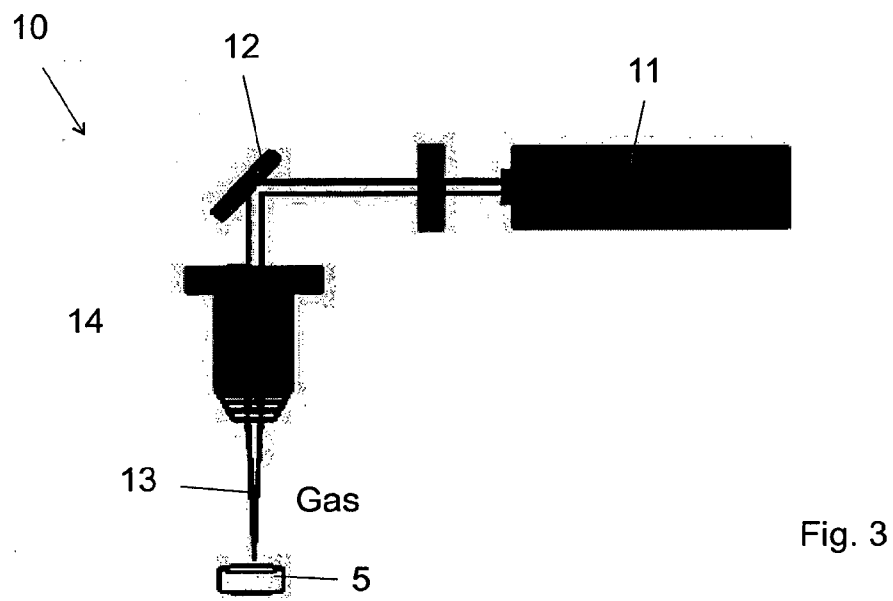
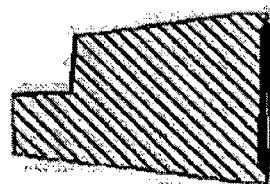


Fig. 2

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Prior Art

Fig. 5

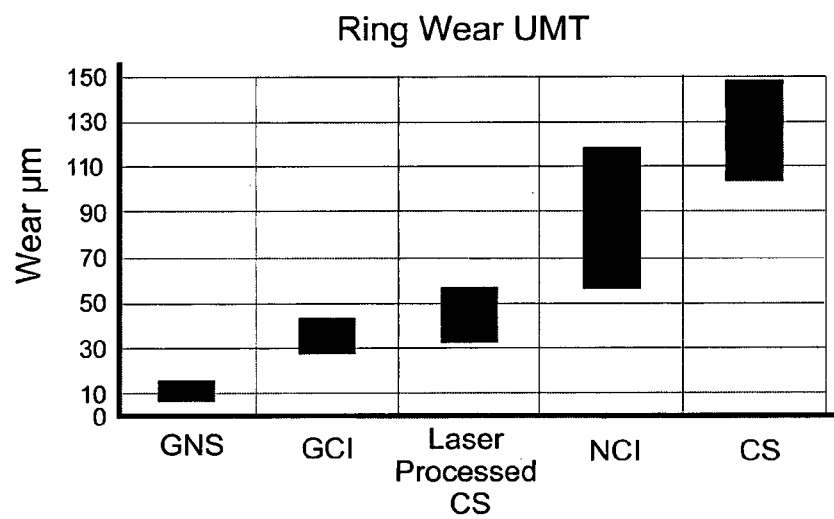
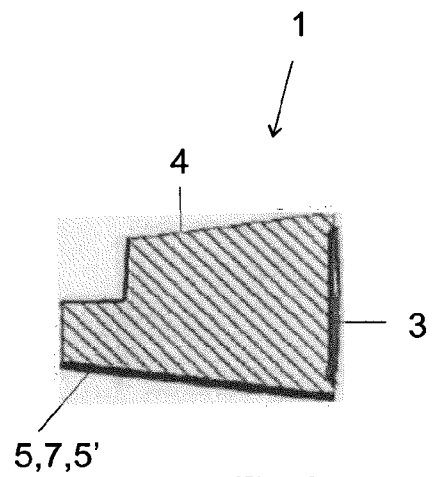


Fig. 7

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2014/075413

A. CLASSIFICATION OF SUBJECT MATTER

INV. F16J9/26

ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F16J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	GB 1 320 902 A (WELLWORTHY LTD) 20 June 1973 (1973-06-20) page 1, lines 13-45; figure 1 page 2, lines 23-36; claims 1, 2, 13, 15; table 1	1-11
X	----- US 6 508 473 B1 (TANAKA SHOJI [JP] ET AL) 21 January 2003 (2003-01-21) column 2, lines 6-21; claims 9-10; figures 1a-3b	1-11
X	----- US 5 295 696 A (HARAYAMA AKIRA [JP] ET AL) 22 March 1994 (1994-03-22) column 2, lines 23-36, 49-50; figure 3 column 6, lines 13-24 ----- -/-	1-11



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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Date of the actual completion of the international search

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16/02/2015

Name and mailing address of the ISA/

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INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2014/075413

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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