(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
6 June 2013 (06.06.2013)

WIPO | PCT

(10) International Publication Number
WO 2013/081451 Al

(51) International Patent Classification:
C21D 9/40 (2006.01) *C21D 9/00* (2006.01)
F16G 5/16 (2006.01) *C21D 9/32* (2006.01)
C21D 6/02 (2006.01) *C21D 6/00* (2006.01)
C23C 8/24 (2006.01) *C22C 38/08* (2006.01)
C21D 1/76 (2006.01) *C22C 38/10* (2006.01)

(21) International Application Number:
PCT/NL201 1/000078

(22) International Filing Date:
30 November 201 1 (30.1 1.201 1)

(25) Filing Language: English

(26) Publication Language: English

(71) Applicant *(for all designated States except US)*: **ROBERT BOSCH GMBH** [DE/DE]; Postfach 30 02 20, 70442 Stuttgart (DE).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **PENNINGS, Bert** [NL/NL]; Zonnedauw 30, NL-5052 CH Goirle (NL). **TRAN, Minh-Duc** [NL/NL]; Schering 19, NL-5348 KX Oss (NL).

(74) Agent: **PLEVIER, Gabriel Anton Johan Maria;** Bosch Transmission Technology B.V., Postbus 500, NL-5000 AM Tilburg (NL).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

[Continued on next page]

(54) Title: HEAT TREATMENT PROCESS IN A MANUFACTURING METHOD FOR A DRIVE BELT METAL RING COMPONENT

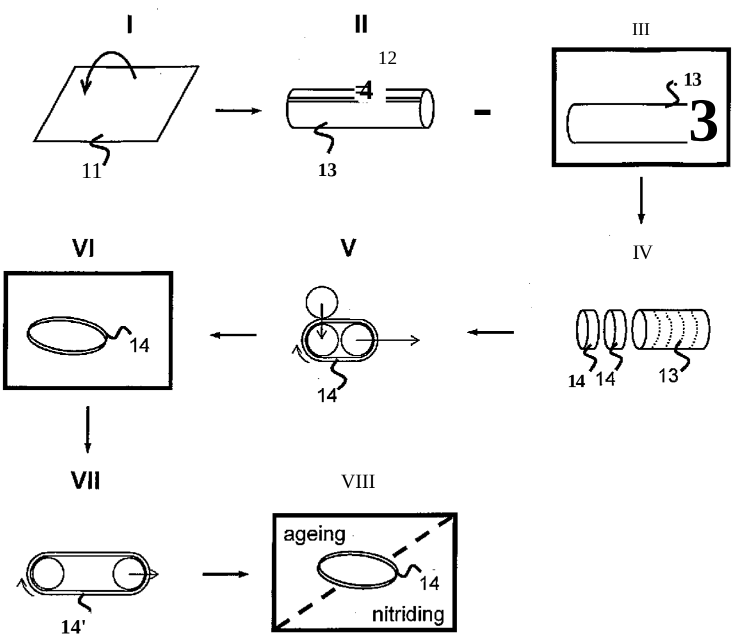

FIG. 3

(57) Abstract: The invention provides for a heat treatment process in a manufacturing method for a metal ring (14) for use in a drive belt (1), wherein the ring (14) is processed in two steps. In the first step the ring (14) is kept for more than 3 hours in an atmosphere that is free from ammonia gas at a temperature in the range from 450 °C to 500 °C and in the second step the ring (14) is kept in an atmosphere containing at least 2, but less than 10 volume-% ammonia at a temperature in the range from 425 °C to 475 °C.

WO 2013/081451 A1

Published:

— *with international search report (Art. 21(3))*

HEAT TREATMENT PROCESS IN A MANUFACTURING METHOD FOR A DRIVE BELT METAL RING COMPONENT

The present invention relates to a manufacturing method for a metal ring to be used in a drive belt, more in particular a heat treatment process part thereof as defined by the preamble of the following claim 1. The drive belt is typically used as the means for power transmission between two adjustable pulleys of the well-known continuously variable transmission that is mainly applied in motor vehicles.

One well known type of drive belt is described in detail in EP-A-1403551 and is composed of a number of relatively thin transverse metal elements that are slideably incorporated on two laminated endless tensile means that are each composed of a set of mutually nested flat metal rings, alternatively denoted endless bands or hoops. Such rings are typically produced from a precipitation hardening steel, such as a maraging steel, that combines a/o the properties of great tensile strength and good resistance against tensile stress and bending fatigue with a relatively favourable possibility to process the steel from sheet material towards the desired shape and material characteristics of the end-product rings, which, preferably, should not vary along the circumference of the rings. The present invention in particular relates to the range of maraging steel alloys having a basic composition with 17 to 19 mass-% nickel, 4 to 6 mass-% molybdenum, 8 to 18 mass-% cobalt, less than 1 mass-% titanium, possibly containing small amounts (e.g. < 1 mass-%) of other alloying elements and/or impurities and with balance iron.

The said desired material characteristics comprise a fair hardness of the ring core material for combining the properties of a great tensile strength together with sufficient elasticity to allow longitudinal bending of the ring and an extremely hard outer surface layer of the ring to provide wear resistance. Additionally, the outer surface layer is provided with a residual compressive stress to provide a high resistance against metal fatigue, which is a significant feature of the rings because of the numerous numbers of load and bending cycles the rings are subjected to during the service lifetime of the belt.

The basics of the known manufacturing method for such rings have become well known in the art and are, for example, described in the European patent publication EP-A-1 753889. The rings are formed out of a sheet base material, which is bent and welded into a cylindrical shape, or tube, which is heat treated, i.e. annealed, to restore the original material properties, i.e. to largely remove changes therein that were introduced by the bending and welding. The tube is then cut into a number of hoops, which are subsequently rolled and elongated to a required thickness, which is typically about 0.185 mm in the end product. After rolling the hoops are usually referred to as rings or bands. The rings are subjected to a further annealing step to remove the internal stresses introduced during rolling. Thereafter, the rings are calibrated, i.e. they are mounted around two rotating rollers and stretched to a predefined circumference length.

Finally in accordance with EP-A-1 753889, the rings are subjected to a single, combined process step that includes both the heat treatments of precipitation hardening, i.e. ageing or core hardening, and of gas soft-nitriding, i.e. of case hardening by the insertion of Nitrogen atoms into the steel lattice of the rings. According to EP-A-1 753889 such combined process step of ageing and nitriding entails keeping the rings in an ammonia gas containing process atmosphere at 440 °C to 480 °C for 45 to 65 minutes.

Over the years the chemistry of, in particular, the nitriding heat treatment has been extensively studied and has become increasingly better understood. The yet unpublished international patent application No. PCT/EP201 0/007783 relies on such newly obtained, detailed understanding and thereby suggests that the effectiveness of the known combined process step of ageing and nitriding can still be significantly improved. In particular, it is proposed therein that the ammonia gas content of the process atmosphere can be reduced to comfortably below 10 volume-%, provided that such process atmosphere is maintained at a temperature of 500 °C or more. The advantage of these latter process settings being that considerably less ammonia is used and thus that the cost of the nitriding heat treatment is favourably reduced and the environmental impact thereof.

As is also recognised in PCT/EP201 0/007783, the above new process settings must be accurately controlled since otherwise, e.g. if an inadvertent increase of the process temperature or of the ammonia concentration occurs, a so-called compound layer of iron-nitrides will form on the surface of the rings, whereby the (metal) fatigue strength of the rings is unacceptably reduced. This phenomenon of compound layer formation is particularly relevant for the present range of maraging steel ring materials including no or only very small non-metallic inclusions such as titanium nitride, which materials tend to ultimately fail from metal fatigue by a fracture initiating from a surface imperfection rather than from such an inclusion. In practice and in particular in a mass-production environment it was found to be very difficult to reliably control the actual process settings inside the narrow window wherein the compound layer and/or other surface imperfection is not formed.

It was found to be a further limitation of these new process settings that they are suitable only for a limited range of maraging steel ring material compositions, namely those with a comparatively high cobalt and/or molybdenum content for realising a required rate of precipitation hardening. These steel types are relatively expensive simply because of the said high cobalt and/or molybdenum content.

It is thus considered advantageous if the aforementioned process settings can be changed (i) to reduce the risk of compound layer formation and (ii) to accommodate a broader range of maraging steel compositions, while maintaining the favourably low ammonia content of the process atmosphere in nitriding.

According to the present invention these objectives are realised by a heat treatment process including separate ageing and nitriding steps, wherein the ageing heat treatment entails keeping the rings in nitrogen gas at a temperature of 450 °C to 500 °C for more than 180 minutes and wherein the nitriding heat treatment entails keeping the rings in a process atmosphere containing a notional amount, but less than 12 volume-%, preferably less than 10 volume-% of ammonia gas at a temperature of 425 to 475 °C for 45 to 90 minutes. Particularly, good results were obtained with the ageing heat treatment being performed at 490 °C for 200 minutes and/or with the nitriding heat treatment being performed at 450 °C for 75 minutes under a process atmosphere containing between 4 and 8 volume-% ammonia.

The above-described basic features of the invention will now be elucidated by way of example with reference to the accompanying figures.

Figure 1 is a schematic illustration of the drive belt the present invention relates to and of the transmission in which such belt is applied.

Figure 2 is a schematic illustration of the manner in which a laminated tensile means and a transverse element are mutually oriented within the drive belt.

Figure 3 diagrammatically represents the known manufacturing method of a metal ring applied in the endless tensile means of the drive belt that includes the process step of combined ageing and nitriding.

Figure 4 diagrammatically represents the ageing and nitriding heat treatment of the drive belt's tensile means ring component in accordance with the invention.

In the drawings, the separate process steps of the known and the new manufacturing method are indicated by way of Roman numerals.

Figure 1 shows schematically a continuously variable transmission (CVT) with a drive belt 1 wrapped around two pulleys 4 and 5, which belt 1 is made up of a laminated, endless tensile means 2 in the form of two sets of mutually nested thin and flat metal rings 14 (Figure 2), alternatively denoted bands 14 and a number of transverse members 3, alternatively denoted transverse elements, that are mounted in an essentially continuous row along the circumference of the tensile means 2 and that are free to slide along such circumference. Such a continuously variable transmission is well-known per se.

Figure 2 is a cross-section of the known belt 1, providing a front view of a transverse member 3 and a cross-section of the tensile means 2. The transverse members 3, on either lateral side thereof, show side faces 6 by which it engages pulley sheaves of the two transmission pulleys 4, 5. The rings 14 of the tensile means 2 are produced of high quality maraging steel. A typical thickness of the rings 14 ranges from 0.15 to 0.25 mm, a typical width thereof ranges from 8 to 35 mm and a typical circumference length thereof ranges from 500 to 1000 mm.

Figure 3 illustrates the presently relevant part of the known manufacturing method for the above described belt 1, in particular for the rings 14 thereof, as is practised since the early years of metal push belt production. In a first process step I a sheet of base material 11 is bend into a cylindrical shape, whereby the sheet ends 12 that meet each other are. welded together in a second process step II to form a tube 13. In a third step III of the process the tube 13 is annealed at a temperature of more than 800 °C in an inert process atmosphere such as a vacuum or nitrogen gas N_2. Thereafter, in a fourth process step IV the tube 13 is cut into a number of hoops 14, which are subsequently -process step five V- rolled and elongated to a desired thickness. After rolling the hoops 14 are usually referred to as rings 14 or bands 14. The rings 14 are subjected to a further annealing process step VI to remove the internal stresses introduced during rolling. Thereafter, in a seventh process step VII, the rings 14 are calibrated, i.e. they are mounted around two rotating rollers and stretched to a predefined circumference length. In this seventh process step VII, also an internal stress distribution is imposed on the rings 14, which defines the so-called curling radius of the respective ring 14. Finally, in the eighth step VIII of the known manufacturing method the rings 14 are subjected to the two heat treatments of precipitation hardening or ageing and of gas soft-nitriding, i.e. of case hardening by the insertion of nitrogen atoms into the steel lattice of the rings. It is known to perform such two heat treatments of ageing and nitriding either separately, i.e. in two separate, sequential process steps, or simultaneously in a single process step.

In nitriding the ring 14 is kept in an ammonia-gas containing process atmosphere. It has been a recent development to successfully apply an unprecedented low amount of less than 10 volume-% ammonia in nitriding. Although such low ammonia content in nitriding is favourable per se, it was found to come with the disadvantages of being less tolerant to variations in the process parameters (i.e. temperature, time and atmosphere) and to set more stringent requirements in relation to the ring material (i.e. maraging steel composition).

The present invention, which is diagrammatically illustrated in figure 4, provides a way to apply such low amount of less than 10 volume-% ammonia in nitriding for a broader range of ring material compositions, while losing the requirements in relation to the accuracy of the control of the process parameters. In accordance with the invention, the heat treatments of ageing and of nitriding the ring 14 involve two separate, i.e. sequential, process steps VIII-A, VIII-B. In the first process step VIII-A according to the invention, the ring 14 is kept in a process atmosphere that is free from ammonia gas and that is solely, or at least mainly, composed of nitrogen gas, at a process temperature of 450 °C to 500 °C and for a process duration of more than 180 minutes. In the second process step VIII-B according to the invention, the ring 14 is kept in a process atmosphere that contains 2 to less than 12 volume-% ammonia gas, at a process temperature of 425 to 475 °C and for a process duration of 45 to 90 minutes.

The invention, apart from the preceding description and all details of the drawing that may not be described, however immediately and unambiguously evident to a person skilled in the art, further relates to all details of the following set of claims.

CLAIMS

1. Heat treatment process in a manufacturing method for a metal ring (14) for use in a drive belt (1) wherein the ring (14) is processed in two steps of ageing and nitriding respectively, wherein in the process step of ageing the ring (14) is kept in an atmosphere that is free from ammonia gas at a temperature in the range from 450 °C to 500 °C and wherein in the process step of nitriding the ring (14) is kept in an atmosphere that contains ammonia gas at a temperature in the range from 425 °C to 475 °C, characterised in that the ring (14) is processed for more than 3 hours in the process step of ageing and in that the ring (14) is processed in an atmosphere containing at least 2, but less than 12 volume-% ammonia in the process step of nitriding.

2. Heat treatment process according to claim 1, characterised in that, in the process step of nitriding the ring (14) is processed in an atmosphere containing between 4 and 8 volume-% ammonia.

3. Heat treatment process according to claim 1, characterised in that, in the process step of nitriding the ring (14) is processed at 450 °C for 75 minutes.

4. Heat treatment process according to claim 1, 2 or 3, characterised in that, in the process step of ageing the ring (14) is processed at 490 °C for 200 minutes.

5. Heat treatment process according to a preceding claim, characterised in that, the ring (14) is made of a maraging steel alloy from the range of maraging steel alloys having a basic composition with 17 to 19 mass-% nickel, 4 to 6 mass-% molybdenum, 8 to 18 mass-% cobalt, less than 1 mass-% titanium and with balance iron.

6. Drive belt (1) for a continuously variable transmission for motor vehicles incorporating a laminated endless tensile means (2) and a number of metal elements (3) slideably provided on the tensile means (2), which tensile means (2) is composed of set of mutually nested metal rings (14) that are subjected to the heat treatment process according to a preceding claim.

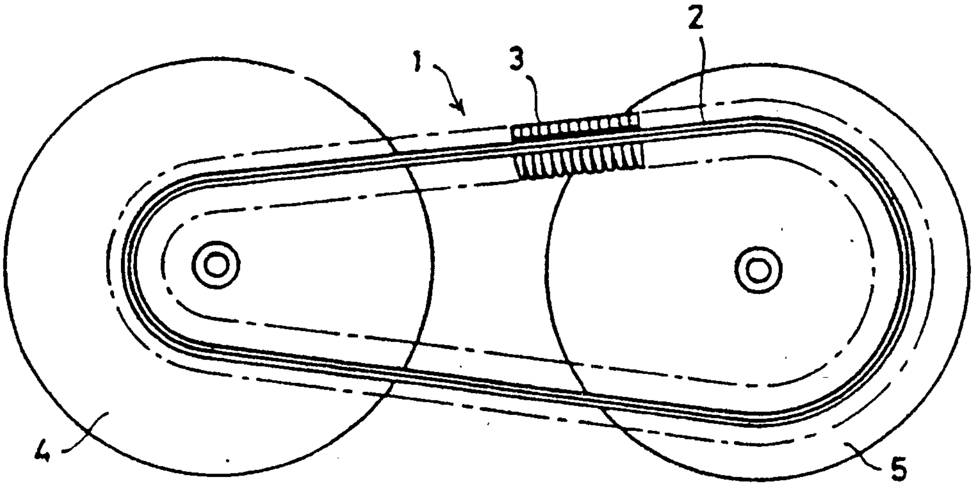

FIG. 1

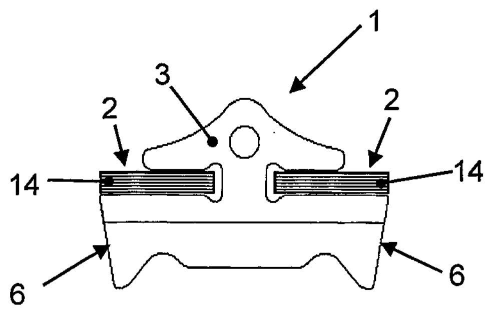

FIG. 2

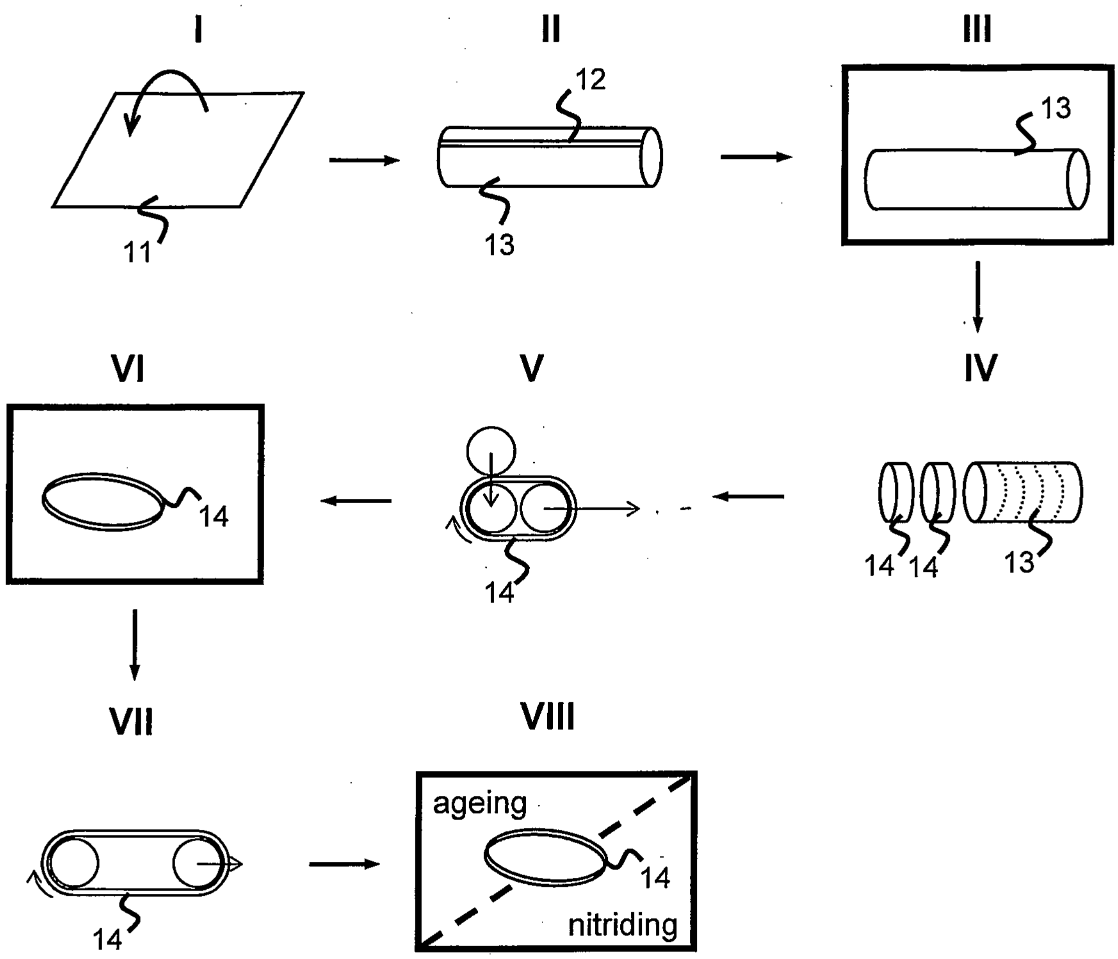
I
II
III
12
13
11
13
VI
V
IV
14
14
14 14
13
VII
VIII
ageing
nitriding
14
14

FIG. 3

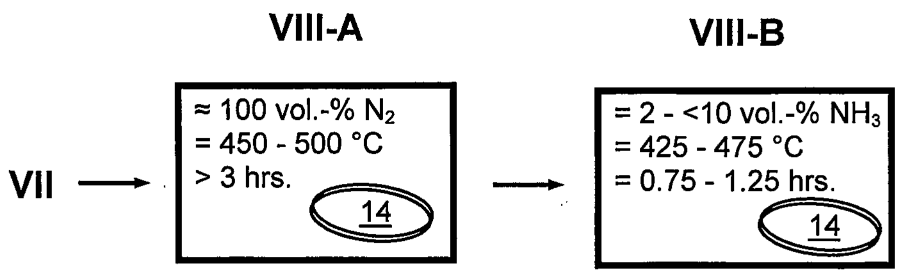
VIII-A
VIII-B
VII
≈ 100 vol.-% N2
= 450 - 500 °C
> 3 hrs.
14
= 2 - <10 vol.-% NH3
= 425 - 475 °C
= 0.75 - 1.25 hrs.
14

FIG. 4

INTERNATIONAL SEARCH REPORT

International application No
PCT/NL2011/0OQ078

A. CLASSIFICATION OF SUBJECT MATTER

INV.	C21D9/40	F16G5/16	C21D6/02	C23C8/24	C21D1/76
	C21D9/Q0	C21D9/32	C21D6/00	C22C38/08	C22C38/10
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)

C21D C23C F16G C22C

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 , WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 1 176 224 Al (NISSAN MOTOR [JP] ; DOWA MINING CO [JP]) 30 January 2002 (2002-01-30) paragraph [0031] ; figure 5 ; examples 1-4 figures 3A,3B paragraph [0020] paragraph [0017] the whole document -----	1-6
A	EP 1 544 317 Al (HONDA MOTOR CO LTD [JP]) 22 June 2005 (2005-06-22) the whole document -----	1-6

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) orwhich is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
27 July 2012	06/08/2012

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Ugarte, Eva

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/NL2011/0OQ078

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 1176224 Al	30-01-2002	EP 1176224 Al	30-01-2002
		US 2002014281 Al	07-02-2002
EP 1544317 Al	22-06-2005	AU 2003266561 Al	19-04-2004
		CN 1685075 A	19-10-2005
		EP 1544317 Al	22-06-2005
		US 2005247375 Al	10-11-2005
		WO 2004029320 Al	08-04-2004