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(54) **RAIL VEHICLE PROVIDED WITH A TRANSVERSE SUSPENSION SYSTEM AND SUSPENSION METHOD**

(57) A rail vehicle (10) comprises a car body (12), at least one running gear (14) and a suspension for transmitting a load having a static vertical component L from the car body to the running gear (14), wherein the suspension comprises passive transverse suspension means (24) and active transverse actuator means (26) in parallel between the car body (12) and the running gear (14). The passive transverse suspension means (24) have a relatively high stiffness *K* such that:

$$\frac{K}{L} \geq 5m^{-1}$$

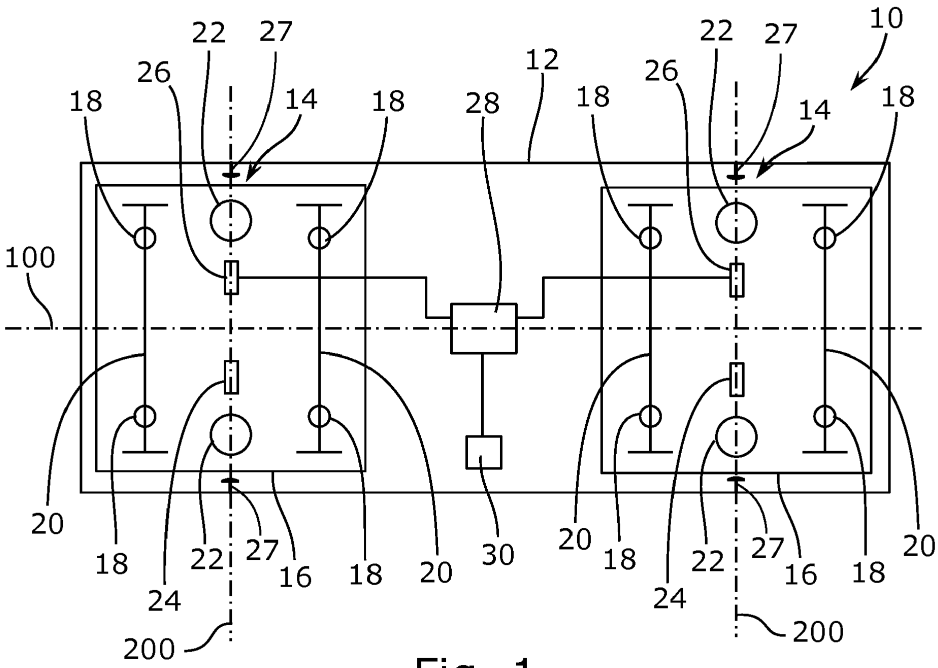

Fig. 1

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Description

TECHNICAL FIELD OF THE INVENTION

[0001] The present invention relates to a transverse suspension system for a rail vehicle and to a rail vehicle including a transverse suspension system.

BACKGROUND ART

[0002] In order to reduce vibration of a rail car body, it has been proposed in GB 2 025 572 to add various pneumatic actuators to a conventional secondary suspension provided with air springs. More specifically, two vertical pneumatic actuators and one transverse pneumatic actuator are provided between the car body of a rail vehicle and each of the front and rear running gears on which the car body is supported. The pneumatic actuators are controlled based on acceleration signals measured on the car body of the vehicle. The yawing vibrations are controlled mainly by the transverse pneumatic actuators provided on the two rolling gears while the pitching and rolling vibrations are controlled mainly by the vertical pneumatic actuators. With such an arrangement, the front and rear transverse pneumatic actuators are used to counteract vibrations and quasi-static transverse loads. These actuators must therefore be adapted to generate quasi-static forces of high magnitude and dynamic forces at high frequencies. To meet these conflicting requirements, the actuators have to be oversized in terms of both power and volume. High power actuators require external cooling and result in an overall bulky, heavy and complex system. Moreover, no fail-safe mode is available in case of malfunction of the transverse actuators.

SUMMARY OF THE INVENTION

[0003] The invention aims to address the above-identified problems of the prior art and to provide a simplified suspension system that achieves good results in terms of ride comfort.

[0004] According to a first aspect of the invention, there is provided a rail vehicle comprising a car body, at least one running gear and a suspension for transmitting a load having a static vertical component L from the car body to the running gear, wherein the car body is movable relative to the running gear in a transverse direction of the running gear over a range of transverse positions including a centred position and the suspension comprises passive transverse suspension means and active transverse actuator means in parallel between the car body and the running gear, characterized in that the passive transverse suspension means have a stiffness K such that:

$$\frac{K}{L} \geq 5m^{-1}$$

over said range of transverse positions.

[0005] Unlike the suspension systems of the prior art, the suspension system of the invention combines a stiff passive transverse suspension and transverse actuator means. The particular combination enables to substantially downsize the transverse actuator means without negatively affecting the ride comfort. In case of malfunction, the transverse suspension system of the invention operates as a passive suspension and provides a fail-safe operating mode.

[0006] A typical secondary suspension of the prior art has a transverse stiffness per bellow of about 200 kN/m. This value is a compromise between ride comfort (which favours soft springs) and relative displacements (which favours stiff springs). In contrast, the transverse stiffness of the passive transverse suspension of the invention is substantially greater, in the range of 400 kN/m or 500 kN/m over the whole range of transverse positions, including the centre position. The stiffer passive transverse suspension reduces the relative transverse displacement.

[0007] The range of transverse position can be limited by transverse stops.

[0008] According to a preferred embodiment, the active transverse actuator means are adapted to generate forces in the transverse direction with a maximal magnitude M_{max} such that:

$$\frac{M_{max}}{L} \leq \frac{1}{30}$$

[0009] This contributes to the downsizing of the transverse actuator means, which do not have to generate great forces. Preferably, the active transverse actuator means are adapted to generate forces in the transverse direction with a maximal magnitude M_{max} such that:

$$M_{max} \leq 10kN$$

and preferably:

$$M_{max} \leq 5kN$$

[0010] According to one embodiment, the rail vehicle further comprises a controller for controlling the active transverse actuator means such as to generate transverse forces that have no low frequency component or a low frequency component with a rms magnitude of less than 100 daN below a cut-off frequency *f* defined as follows:

$$f = \frac{1}{2\pi}\sqrt{\frac{K}{L}}$$

[0011] At very low frequencies below the cut-off frequency, the suspension reacts as a stiff passive suspension. Less energy is required to power the actuator. Such low frequency transverse displacement occurs when the rail vehicle negotiates a curve or runs through a switch or crossing.

[0012] Advantageously, the rail vehicle further comprises a transducer for measuring a transverse acceleration or transverse velocity of the car body and delivering a signal to the controller. The transverse velocity can be obtained by integration of an acceleration signal.

[0013] According to an embodiment, the active transverse actuator means comprise one or more electro-hydraulic actuators. Other kinds of actuators are also envisaged, e.g. electro-pneumatic actuators. The actuators should be able to follow low frequency transverse relative movements between the car body and the running gear, i.e. to retract and expand, without generating reacting forces.

[0014] In principle, the transverse actuator means can comprise more than one transverse actuator, e.g. two transverse actuators. According to a preferred embodiment, however, the active transverse actuator means consist of only one actuator.

[0015] According to a preferred embodiment, the suspension system comprises vertical suspension elements, which constitute at least part of the passive transverse suspension means. The vertical suspension elements support the vertical static and dynamic components of the load applied by the car body on the running gear. In particular, the vertical suspension elements include pneumatic suspension elements and/or coil springs.

[0016] According to a preferred embodiment, the vertical suspension elements provide more than half the transverse stiffness K over more than half the transverse stroke of the car body relative to the running gear. Additional passive transverse suspension means can be used. They can include transverse springs operational throughout the transverse stroke or bump stops only operational at the ends of the transverse stroke.

[0017] The suspension system may also include a passive transverse damper. Alternatively or additionally, the active transverse actuator means can be controlled to generate a transverse damping force, i.e. a force proportional to the transverse velocity of the vehicle body, which can be a reactive force (in a direction opposite to the direction of movement) or pro-active, i.e. in the direction of the relative movement).

[0018] According to one embodiment, each of the one or more running gears has a pair of wheel sets equidistant from a vertical median transverse plane, and the active transverse actuator means are attached to the running gear at a location closer to the vertical median transverse plane than to the wheel sets, preferably in the geometric vertical median transverse plane. The active transverse actuator means should not be affected by the relative rotation between the running gear and the car body about a vertical axis.

[0019] For similar reasons, each of the one or more the running gears has a pair of wheel sets equidistant from a vertical median transverse plane, and the passive transverse suspension means are attached to the running gear at a location closer to the vertical median transverse plane than to the wheel sets, preferably in the geometric vertical median transverse plane.

[0020] According to one embodiment the suspension comprises a secondary suspension between the car body and a frame of the running gear. The running gear may also be provided with a primary suspension between the running gear frame and one or more sets of wheels, which may be wheelsets or independent wheels.

[0021] According other embodiments, the suspension is arranged between the car body and a running gear without primary suspension, or a running gear without frame, or a running gear with independent wheels, or a running gear with only one set of wheels, e.g. a portal axle.

[0022] According to another aspect of the invention, there is provided a method of supporting a rail car body on at least one running gear provided with a running gear and a suspension for transmitting a load having a static vertical component *L* from the car body to the running gear, the method comprising:

- providing passive transverse suspension means between the car body and the running gear, with a stiffness *K* such that:

$$\frac{K}{L} \geq 5m^{-1}$$

- providing active transverse actuator means in parallel with the passive transverse suspension means between the car body and the running gear; wherein the active transverse actuator means are adapted to generate forces in the transverse direction with a maximal magnitude M_{max} such that:

$$\frac{M_{max}}{L} \leq \frac{1}{30}$$

BRIEF DESCRIPTION OF THE FIGURES

[0023] Other advantages and features of the invention will then become more clearly apparent from the following description of a specific embodiment of the invention given as non-restrictive examples only and represented in the accompanying drawings in which figure 1 is a diagrammatic illustration of a rail vehicle according to one embodiment of the invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0024] Referring to Fig 1, a rail vehicle **10** comprises a car body **12** supported on two longitudinally spaced running gears **14.** The car body defines a vertical longitudinal plane **100.** Each of the running gears **14** comprises a running gear frame **16,** a primary suspension **18** between the running gear frame **16** and two sets of wheels **20,** and a secondary suspension between the running gear frame **16** and the car body **12,** which comprises vertical suspension elements **22,** e.g. pneumatic suspension elements or coil springs, as well as passive transverse suspension means **24** and active transverse actuator means **26** in parallel between the car body and the running gear frame.

[0025] In the centred position depicted in Figure **1,** the rail vehicle is stationary on a straight track, and the longitudinal vertical plane **100** of the car body **12** coincides with a longitudinal vertical median plane **150** of each running gear frame. The two wheel sets **20** of each running gear **14** are equidistant from a vertical median transverse plane **200** of the running gear frame **16.** The intersection between each vertical median transverse plane **200** and the vertical longitudinal plane **150** defines a vertical axis of rotation of the associated running gear. The car body **12** can also move relative to each running gear **14** in a transverse direction perpendicular to the longitudinal vertical median plane **150** of the running gear frame **16** on each side of the centred position. The secondary suspension system may also comprise transverse bump stops **27,** which may constitute an additional part of the passive transverse suspension means **24** and become active at the ends of the transverse stroke of the car body **12** relative to each running gear frame **16.** to limit the range of transverse positions of the car body **12** relative to the running gear frame **16.**

[0026] Both the passive transverse suspension means **24** and the active transverse actuator means **26** are preferably attached to the running gear frame **16** at a location closer to the vertical median transverse plane **200** than to the wheel sets **20,** preferably in the geometric vertical median transverse plane **200.**

[0027] In the schematic view of figure 1, the passive transverse suspension means **24** have been depicted as an individualised separate means. However, the vertical suspension elements **22** may have a transverse stiffness and may constitute at least part of the passive transverse suspension means **24,** preferably a preponderant part, i.e. more than half of the transverse stiffness. The bump stops **27** can also be individualised or incorporated to the passive transverse suspension means **24.**

[0028] The active transverse actuator means **26** comprise one or more electro-hydraulic actuators, and preferably only one actuator.

[0029] The active transverse actuator means **26** of the two running gears **14** are connected to a common controller **28.** A transducer **30** for measuring a transverse acceleration or transverse velocity of the car body **12** is connected to the controller **28.**

[0030] If *L* denotes the static vertical load on each running gear (i.e. *2L* is the weight of the car body), the passive transverse suspension means **24** have a high stiffness K such that:

$$\frac{K}{L} \geq 5m^{-1}$$

[0031] As a result, the transverse actuator means are adapted to generate forces in the transverse direction with a relatively low maximal magnitude $M_{\max}$ such that:

$$\frac{M_{max}}{L} \leq \frac{1}{30}$$

[0032] The maximal magnitude is preferably such that

$$M_{max} \leq 10kN \text{ or } M_{max} \leq 5kN$$

[0033] Moreover, the active transverse actuator means **26** is controlled by the controller **28** such as to generate transverse forces that have no low frequency component or a low frequency component with a rms magnitude of less than 100 daN below a cut-off frequency *f* defined as follows:

$$f = \frac{1}{2\pi}\sqrt{\frac{K}{L}}$$

[0034] As mentioned before, all or part of this transverse stiffness K can be provided by the vertical suspension elements **22.**

[0035] The invention is not limited to conventional running gears with a frame, a primary suspension between the frame and the wheelsets and a secondary suspension between the frame and the car body. It can also be applied to less convention layouts, running gears without primary suspension, running gears without frame, running gears with independent wheels, or running gears with only one set of wheels, e.g. portal axles.

Claims

1. A rail vehicle (10) comprising a car body (12), at least one running gear (14) and a suspension for transmitting a load having a static vertical component L from the car body (12) to the running gear (14), wherein the car body (12) is movable relative to the running gear (14) in a transverse direction of the running gear (14) over a range of transverse positions including a centred position and the suspension comprises passive transverse suspension means (24) and active transverse actuator means (26) in parallel between the car body (12) and the running gear (14), **characterized in that** the passive transverse suspension means (24) have a stiffness *K* such that:

$$\frac{K}{L} \geq 5m^{-1}$$

over said range of transverse positions.

2. The rail vehicle of claim 1, wherein the active transverse actuator means (26) are adapted to generate forces in the transverse direction with a maximal magnitude $M_{\max}$ such that:

$$\frac{M_{max}}{L} \leq \frac{1}{30}$$

3. The rail vehicle of any one of the preceding claims, wherein the active transverse actuator means (26) are adapted to generate forces in the transverse direction with a maximal magnitude $M_{\max}$ such that:

$$M_{max} \leq 10kN$$

and preferably:

$$M_{max} \leq 5kN$$

4. The rail vehicle of any one of the preceding claims, further comprising a controller (28) for controlling the active transverse actuator means (26) such as to generate transverse forces that have no low frequency component or a low frequency component with a rms magnitude of less than 100 daN below a cut-off frequency *f* defined as follows:

$$f = \frac{1}{2\pi}\sqrt{\frac{K}{L}}$$

5. The rail vehicle of any one of the preceding claims, further comprising a transducer (30) for measuring a transverse acceleration or transverse velocity of the car body (12) and delivering a signal to the controller (28).

6. The rail vehicle of any one of the preceding claims, wherein the active transverse actuator means (26) comprise one or more electro-hydraulic actuators.

7. The rail vehicle of any one of the preceding claims, wherein the active transverse actuator means (26) consist of only one actuator.

8. The rail vehicle of any one of the preceding claims, wherein the suspension system comprises vertical suspension elements (22), which constitute at least part of the passive transverse suspension means (24).

9. The rail vehicle of claim 8, wherein the vertical suspension elements (22) include pneumatic suspension elements and/or coil springs.

10. The rail vehicle of any one of claims 8 to 9, wherein the vertical suspension elements (22) provide more than half the transverse stiffness K over more than half the transverse stroke of the car body (12) relative to the running gear (14).

11. The rail vehicle of any one of the preceding claims, wherein the suspension system comprises transverse bump stops, which constitute at least part of the passive transverse suspension means (24).

12. The rail vehicle of any one of the preceding claims, wherein each of the one or more running gears (14) has a pair of wheel sets (20) equidistant from a vertical median transverse plane (200), and the active transverse actuator means (26) are attached to the running gear (14) at a location closer to the vertical median transverse plane (200) than to the wheel sets (20), preferably in the geometric vertical median transverse plane (200).

13. The rail vehicle of any one of the preceding claims, wherein each of the one or more the running gears (14) has a pair of wheel sets (20) equidistant from a vertical median transverse plane (200), and the passive transverse suspension means (24) are attached to the running gear (14) at a location closer to the vertical median transverse plane (200) than to the wheel sets (20), preferably in the geometric vertical median transverse plane (200).

14. The rail vehicle of any one of the preceding claims, wherein the suspension comprises a secondary suspension between the car body (12) and a frame (16) of the running gear (14).

15. A method of supporting a rail car body (12) on at least one running gear (14) provided with a running gear (14) and a suspension for transmitting a load having a static vertical component L from the car body (12) to the running gear (14), the method comprising:

- providing passive transverse suspension means (24) between the car body (12) and the running gear (14), with a stiffness K such that:

$$\frac{K}{L} \geq 5m^{-1}$$

- providing active transverse actuator means (26) in parallel with the passive transverse suspension means (24) between the car body (12) and the running gear (14); wherein the active transverse actuator means (26) are adapted to generate forces in the transverse direction with a maximal magnitude $M_{\max}$ such that:

$$\frac{M_{max}}{L} \leq \frac{1}{30}$$

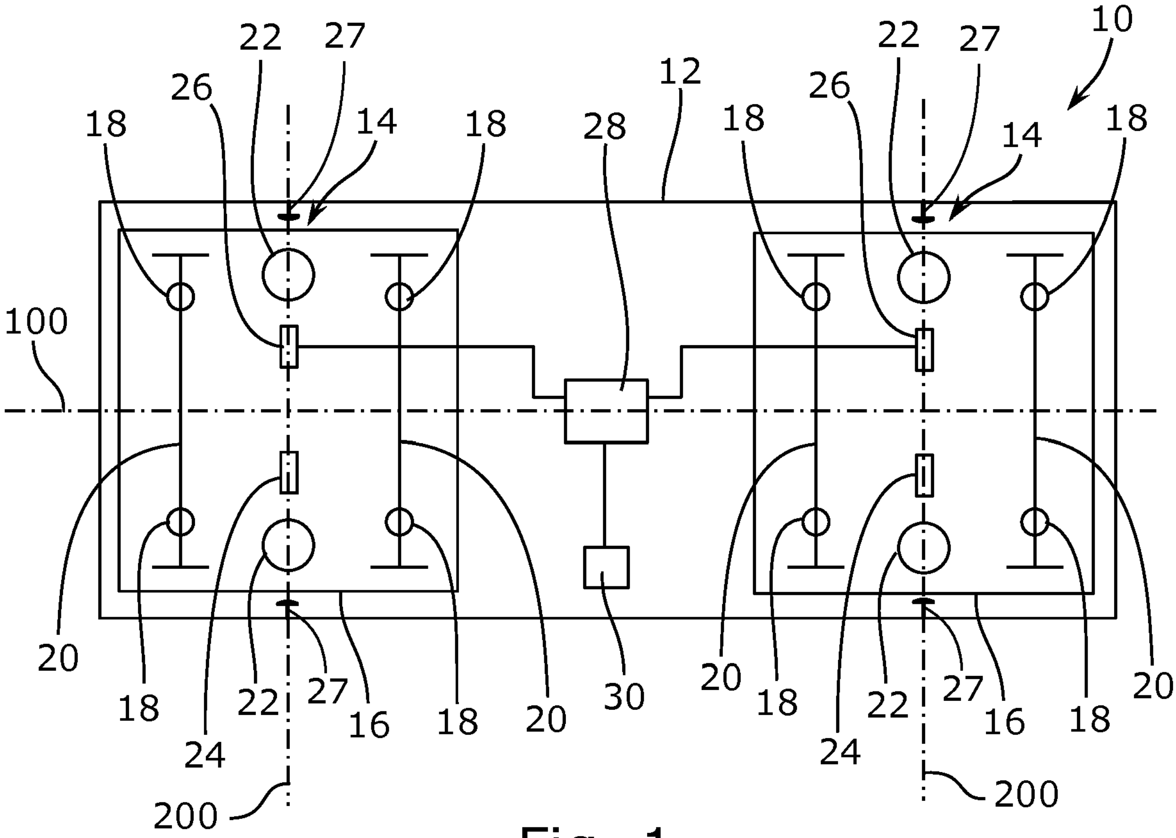
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Fig. 1

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EUROPEAN SEARCH REPORT

Application Number
EP 17 20 4598

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2012/137926 A1 (SCHNEIDER RICHARD [CH]) 7 June 2012 (2012-06-07) * paragraphs [0013], [0064], [0066], [0081], [0082], [0090], [0093], [0095], [0099]; figures * -----	1-15	INV. B61F5/04 B61F5/22 B61F5/24
A	US 2005/087098 A1 (STREITER RALPH [DE]) 28 April 2005 (2005-04-28) * paragraphs [0043], [0044], [0064]; figures * -----	1,15	
A	US 2015/183443 A1 (IWAMURA TSUTOMU [JP] ET AL) 2 July 2015 (2015-07-02) * paragraph [0217]; figures * -----	1,15	
A	FR 2 689 476 A1 (FAIVELEY TRANSPORT [FR]) 8 October 1993 (1993-10-08) * figures * -----	1,11,15	
A	JP H06 247299 A (SUMITOMO METAL IND) 6 September 1994 (1994-09-06) * abstract; figures * -----	1,11,15	TECHNICAL FIELDS SEARCHED (IPC)
A	FR 2 633 577 A1 (DURAND CHARLES [FR]; DURAND JEROME [FR]) 5 January 1990 (1990-01-05) * the whole document * -----	1,15	B61F
A	JP 2006 327529 A (KAWASAKI HEAVY IND LTD) 7 December 2006 (2006-12-07) * abstract; figures * -----	1,15	

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	17 May 2018	Schultze, Yves

CATEGORY OF CITED DOCUMENTS

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 17 20 4598

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17-05-2018

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2012137926 A1	07-06-2012	AT 11080 U2	15-04-2010
		AU 2010230407 A1	27-10-2011
		AU 2010230991 A1	27-10-2011
		CA 2756252 A1	07-10-2010
		CA 2756399 A1	07-10-2010
		CN 102448790 A	09-05-2012
		CN 102448791 A	09-05-2012
		DE 102009014866 A1	28-10-2010
		DE 202009015736 U1	29-04-2010
		EP 2414207 A1	08-02-2012
		EP 2414208 A2	08-02-2012
		IT MI20090372 U1	30-09-2010
		JP 2012521925 A	20-09-2012
		JP 2012521931 A	20-09-2012
		KR 20110138264 A	26-12-2011
		KR 20120024574 A	14-03-2012
		RU 2011143761 A	10-05-2013
		RU 2011143762 A	10-05-2013
		US 2012118194 A1	17-05-2012
		US 2012137926 A1	07-06-2012
		WO 2010112306 A1	07-10-2010
		ZA 201106990 B	30-05-2012
		ZA 201106991 B	31-10-2012
US 2005087098 A1	28-04-2005	AT 325720 T	15-06-2006
		AU 2002351979 A1	10-06-2003
		CN 1610621 A	27-04-2005
		DE 10157368 A1	12-06-2003
		DK 1451030 T3	11-09-2006
		EP 1451030 A1	01-09-2004
		ES 2262873 T3	01-12-2006
		JP 2005509553 A	14-04-2005
		KR 20050044595 A	12-05-2005
		PT 1451030 E	31-08-2006
		US 2005087098 A1	28-04-2005
		WO 03043840 A1	30-05-2003
US 2015183443 A1	02-07-2015	CN 104487733 A	01-04-2015
		DE 112013003296 T5	26-03-2015
		JP 5778344 B2	16-09-2015
		JP WO2014002981 A1	02-06-2016
		US 2015183443 A1	02-07-2015
		WO 2014002981 A1	03-01-2014
FR 2689476 A1	08-10-1993	NONE	

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17-05-2018

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP H06247299 A	06-09-1994	NONE	
FR 2633577 A1	05-01-1990	NONE	
JP 2006327529 A	07-12-2006	JP 4845426 B2	28-12-2011
		JP 2006327529 A	07-12-2006

EPO FORM P0459

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- GB 2025572 A **[0002]**