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

MIT EINER QUERAUFHÄNGUNG AUSGESTATTETES SCHIENENFAHRZEUG UND AUFHÄNGUNGSVERFAHREN

VÉHICULE FERROVIAIRE DOTÉ D'UN SYSTÈME DE SUSPENSION TRANSVERSAL ET MÉTHODE DE SUSPENSION

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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.

[0003] A rail vehicle having a car body, which is supported on a running gear by a spring device, and a rolling compensation device, which is coupled to the running gear and the car body, is disclosed in US2012137926. The rolling compensation device may be arranged kinematically in parallel to the spring device. The rolling compensation device counteracts rolling motions of the car body toward the outside of the curve about a rolling axis during travel in curves. The rolling compensation device, in order to increase the tilting comfort, is designed to impose, in a first frequency range and under a first transverse deflection of the car body, upon the car body, a first rolling angle about the rolling axis, which corresponds to a current curvature of a current section of track being travelled.

SUMMARY OF THE INVENTION

[0004] 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.

[0005] According to a first aspect of the invention, there is provided a rail vehicle comprising a car body, having

a weight $2L$ supported on two longitudinally spaced running gears, each of the running gears comprising a running gear frame, a primary suspension between the running gear frame and two sets of wheels, and a secondary suspension between the running gear frame and the car body 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 each running gear in a transverse direction of the running gear over a range of transverse positions including a centred position and each secondary suspension comprises vertical suspension elements, 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.

[0006] 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.

[0007] 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.

[0008] The range of transverse position can be limited by transverse stops.

[0009] The active transverse actuator means are adapted to generate forces in the transverse direction with a maximal magnitude M_{max} such that:

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

[0010] 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:

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

[0011] 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:

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

[0012] 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.

[0013] 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.

[0014] 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.

[0015] 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.

[0016] According to a preferred embodiment, the suspension elements 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.

[0017] 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.

[0018] 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).

[0019] 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.

[0020] 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.

[0021] The one or more sets of wheels can be wheel-sets or independent wheels.

[0022] 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.

[0023] According to another aspect of the invention, there is provided a method of supporting a rail car body having a weight $2L$ on two longitudinally spaced running gears, each comprising a running gear frame, a primary suspension between the running gear frame and two sets of wheels, and a secondary suspension between the running gear frame and the car body for transmitting a load having a static vertical component L from the car body to the running gear, the method comprising providing each secondary suspension with vertical suspension elements, passive transverse suspension means and active transverse actuator means in parallel between the car body and the running gear such that the car body is movable relative to the running gear in a transverse direction of each running gear over a range of transverse positions including a centred position, wherein:

- the transverse suspension means between the car body and each running gear have a stiffness K such that:

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

over said range of transverse positions

- 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

[0024] 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

[0025] 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.

[0026] 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.

[0027] 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.

[0028] 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.

[0029] The active transverse actuator means 26 comprise one or more electro-hydraulic actuators, and preferably only one actuator.

[0030] 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.

[0031] 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:

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

[0032] 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:

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

[0033] The maximal magnitude is preferably such that

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

[0034] 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:

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

[0035] As mentioned before, all or part of this transverse stiffness K can be provided by the vertical suspension elements **22**.

[0036] The invention is not limited to conventional running gears with wheelsets. It can also be applied to 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) having a weight $2L$ supported on two longitudinally spaced running gears (14), each of the running gears (14) comprising 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) 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 each running gear (14) in a transverse direction of the running gear (14) over a range of transverse positions including a centred position and, each secondary suspension comprises vertical suspension elements (22), 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 and **in that** the active transverse actuator means (26) are adapted to generate forces in the transverse direction with a maximal magnitude M_{max} such that:

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

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:

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

3. 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:

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

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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:

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

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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).

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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.

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

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

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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).

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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).

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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 ver-

tical 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. A method of supporting a rail car body (12) having a weight $2L$ on two longitudinally spaced running gears (14), each of the running gears (14) comprising 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) for transmitting a load having a static vertical component L from the car body (12) to the running gear (14), the method comprising providing each secondary suspension with vertical suspension elements (22), passive transverse suspension means (24) and active transverse actuator means (26) in parallel between the car body (12) and the running gear (14) such that the car body (12) is movable relative to the running gear (14) in a transverse direction of each running gear (14) over a range of transverse positions including a centred position, wherein:

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

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

over said range of transverse positions,

- the active transverse actuator means (26) are adapted to generate forces in the transverse direction with a maximal magnitude M_{max} such that:

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

Patentansprüche

1. Schienenfahrzeug (10), das einen Wagenkasten

(12) umfasst, der ein Gewicht $2L$ aufweist, das auf zwei in Längsrichtung beabstandeten Laufwerken (14) getragen wird, wobei jedes der Laufwerke (14) einen Laufwerkrahmen (16), eine primäre Aufhängung (18) zwischen dem Laufwerkrahmen (16) und zwei Radsätzen (20), und eine sekundäre Aufhängung zwischen dem Laufwerkrahmen (16) und dem Wagenkasten (12) zum Übertragen einer Last umfasst, die eine statische vertikale Komponente L vom Wagenkasten (12) zum Laufwerk (14) aufweist, wobei der Wagenkasten (12) relativ zu jedem Laufwerk (14) in einer Querrichtung des Laufwerks (14) über einen Bereich von Querpositionen einschließlich einer zentrierten Position bewegbar ist, jede sekundäre Aufhängung vertikale Aufhängungselemente (22), passive Queraufhängungsmittel (24) und aktive Queraktuatormittel (26) parallel zwischen dem Wagenkasten (12) und dem Laufwerk (14) umfasst, **dadurch gekennzeichnet, dass** die passiven Queraufhängungsmittel (24) eine Steifigkeit K derart aufweisen, dass:

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

über dem Bereich von Querpositionen und dadurch, dass die aktiven Queraktuatormittel (26) angepasst sind, um Kräfte in der Querrichtung mit einer maximalen Größe M_{max} derart zu erzeugen, dass:

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

2. Schienenfahrzeug nach Anspruch 1, wobei die aktiven Queraktuatormittel (26) angepasst sind, um Kräfte in der Querrichtung mit einer maximalen Größe M_{max} derart zu erzeugen, dass:

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

3. Schienenfahrzeug nach Anspruch 1, wobei die aktiven Queraktuatormittel (26) angepasst sind, um Kräfte in der Querrichtung mit einer maximalen Größe M_{max} derart zu erzeugen, dass:

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

4. Schienenfahrzeug nach einem der vorhergehenden Ansprüche, das ferner eine Steuerung (28) zum Steuern der aktiven Queraktuatormittel (26) umfasst, um Querkräfte zu erzeugen, die keine niederfrequente Komponente oder eine niederfrequente

Komponente mit einer Effektivgröße von weniger als 100 daN unter einer Grenzfrequenz / aufweisen, wie folgt definiert:

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

5. Schienenfahrzeug nach einem der vorhergehenden Ansprüche, das ferner einen Wandler (30) zum Messen einer Querbeschleunigung oder einer Quergeschwindigkeit des Wagenkastens (12) und zum Liefern eines Signals an die Steuerung (28) umfasst.
6. Schienenfahrzeug nach einem der vorhergehenden Ansprüche, wobei die aktiven Queraktuatormittel (26) einen oder mehrere elektrohydraulische Aktuatoren umfassen.
7. Schienenfahrzeug nach einem der vorhergehenden Ansprüche, wobei die aktiven Queraktuatormittel (26) aus nur einem Aktuator bestehen.
8. Schienenfahrzeug nach einem der vorhergehenden Ansprüche, wobei die vertikalen Aufhängungselemente (22) wenigstens einen Teil der passiven Queraufhängungsmittel (24) ausbilden.
9. Schienenfahrzeug nach Anspruch 8, wobei die vertikalen Aufhängungselemente (22) pneumatische Aufhängungselemente und/oder Schraubenfedern einschließen.
10. Schienenfahrzeug nach einem der Ansprüche 8 bis 9, wobei die vertikalen Aufhängungselemente (22) mehr als die Hälfte der Quersteifigkeit K über mehr als die Hälfte des Querhubs des Wagenkastens (12) relativ zu dem Laufwerk (14) bereitstellen.
11. Schienenfahrzeug nach einem der vorhergehenden Ansprüche, wobei das Aufhängungssystem Querschlackpuffer umfasst, die wenigstens einen Teil der passiven Queraufhängungsmittel (24) ausbilden.
12. Schienenfahrzeug nach einem der vorhergehenden Ansprüche, wobei jedes des einen oder der mehreren Laufwerke (14) ein Paar Radsätze (20) aufweist, die von einer vertikalen mittleren Querebene (200) äquidistant sind, und die aktiven Queraktuatormittel (26) an dem Laufwerk (14) an einer Stelle näher an der vertikalen mittleren Querebene (200) als an den Radsätzen (20), vorzugsweise in der geometrischen vertikalen mittleren Querebene (200), befestigt sind.
13. Schienenfahrzeug nach einem der vorhergehenden Ansprüche, wobei jedes des einen oder der mehre-

ren Laufwerke (14) ein Paar Radsätze (20) aufweist, die von einer vertikalen mittleren Querebene (200) äquidistant sind, und die passiven Queraufhängungsmittel (24) an dem Laufwerk (14) an einer Stelle näher an der vertikalen mittleren Querebene (200) als an den Radsätzen (20), vorzugsweise in der geometrischen vertikalen mittleren Querebene (200), befestigt sind.

14. Verfahren zum Tragen eines Schienenfahrzeugkörpers (12), der ein Gewicht $2L$ auf zwei in Längsrichtung beabstandeten Laufwerken (14) aufweist, wobei jedes der Laufwerke (14) einen Laufwerkrahmen (16), eine primäre Aufhängung (18) zwischen dem Laufwerkrahmen (16) und zwei Radsätzen (20), und eine sekundäre Aufhängung zwischen dem Laufwerkrahmen (16) und dem Wagenkasten (12) zum Übertragen einer Last umfasst, die eine statische vertikale Komponente L vom Wagenkasten (12) zum Laufwerk (14) aufweist, wobei das Verfahren das Bereitstellen jeder sekundären Aufhängung mit vertikalen Aufhängungselementen (22), passiven Queraufhängungsmitteln (24) und aktiven Queraktuatormitteln (26) parallel zwischen dem Wagenkasten (12) und dem Laufwerk (14) derart umfasst, dass der Wagenkasten (12) relativ zu dem Laufwerk (14) in einer Querrichtung jedes Laufwerks (14) über einen Bereich von Querpositionen einschließlich einer zentrierten Position bewegbar ist, wobei:

- die passive Queraufhängung (24) zwischen dem Wagenkasten (12) und jedem Laufwerk (14) eine derartige Steifigkeit K aufweist, dass:

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

über dem Bereich von Querpositionen,

- die aktiven Queraktuatormittel (26) angepasst sind, um Kräfte in der Querrichtung mit einer maximalen Größe M_{max} derart zu erzeugen, dass:

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

Revendications

1. Véhicule ferroviaire (10) comprenant une caisse de wagon (12) ayant un poids $2L$ supporté sur deux trains roulants espacés de manière longitudinale (14), chacun des trains roulants (14) comprenant un châssis de train roulant (16), une suspension primaire (18) entre le châssis de train roulant (16) et deux essieux (20), et une suspension secondaire entre le châssis de train roulant (16) et la caisse de wagon

(12) servant à transmettre une charge ayant une composante verticale statique L de la caisse de wagon (12) au train roulant (14), dans lequel la caisse de wagon (12) est mobile par rapport à chaque train roulant (14) dans une direction transversale du train roulant (14) sur une plage de positions transversales comportant une position centrée, et chaque suspension secondaire comprend des éléments de suspension verticaux (22), des moyens de suspension transversaux passifs (24) et des moyens d'actionnement transversaux actifs (26) en parallèle entre la caisse (12) et le train roulant (14), **caractérisé en ce que** les moyens de suspension transversaux passifs (24) ont une raideur K telle que :

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

sur ladite plage de positions transversales et **en ce que** les moyens d'actionnement transversaux actifs (26) sont adaptés pour générer des forces dans la direction transversale d'une amplitude maximale M_{max} telle que :

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

2. Véhicule ferroviaire selon la revendication 1, dans lequel les moyens d'actionnement transversaux actifs (26) sont adaptés pour générer des forces dans la direction transversale avec une amplitude maximale M_{max} de telle sorte que :

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

3. Véhicule ferroviaire selon la revendication 1, dans lequel les moyens d'actionnement transversaux actifs (26) sont adaptés pour générer des forces dans la direction transversale avec une amplitude maximale M_{max} de telle sorte que :

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

4. Véhicule ferroviaire selon l'une quelconque des revendications précédentes, comprenant en outre un dispositif de commande (28) servant à commander les moyens d'actionnement transversaux actifs (26) de manière à générer des forces transversales qui n'ont pas de composante basse fréquence ou une composante basse fréquence avec une amplitude efficace inférieure à 100 daN en dessous d'une fréquence de coupure / définie comme suit :

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

5. Véhicule ferroviaire selon l'une quelconque des revendications précédentes, comprenant en outre un transducteur (30) pour mesurer une accélération transversale ou une vitesse transversale de la caisse de wagon (12) et délivrer un signal au dispositif de commande (28).
6. Véhicule ferroviaire selon l'une quelconque des revendications précédentes, dans lequel les moyens d'actionnement transversaux actifs (26) comprennent un ou plusieurs actionneurs électrohydrauliques.
7. Véhicule ferroviaire selon l'une quelconque des revendications précédentes, dans lequel les moyens d'actionnement transversaux actifs (26) sont constitués par un seul actionneur.
8. Véhicule ferroviaire selon l'une quelconque des revendications précédentes, dans lequel les éléments de suspension verticaux (22) constituent au moins une partie des moyens de suspension transversaux passifs (24).
9. Véhicule ferroviaire selon la revendication 8, dans lequel les éléments de suspension verticaux (22) comprennent des éléments de suspension pneumatiques et/ou des ressorts hélicoïdaux.
10. Véhicule ferroviaire selon l'une quelconque des revendications 8 à 9, dans lequel les éléments de suspension verticaux (22) fournissent plus de la moitié de la rigidité transversale K sur plus de la moitié de la course transversale de la caisse de wagon (12) par rapport au train roulant (14).
11. Véhicule ferroviaire selon l'une quelconque des revendications précédentes, dans lequel le système de suspension comprend des butées de suspension transversales, qui constituent au moins une partie des moyens de suspension transversaux passifs (24).
12. Véhicule ferroviaire selon l'une quelconque des revendications précédentes, dans lequel chacun du ou des trains roulants (14) a une paire d'essieux (20) équidistants d'un plan transversal médian vertical (200), et les moyens d'actionnement transversaux actifs (26) sont fixés au train roulant (14) au niveau d'un emplacement plus proche du plan transversal médian vertical (200) que des essieux (20), de préférence dans le plan transversal médian vertical géométrique (200).

13. Véhicule ferroviaire selon l'une quelconque des revendications précédentes, dans lequel chacun du ou des trains roulants (14) a une paire d'essieux (20) équidistants d'un plan transversal médian vertical (200), et les moyens de suspension transversaux passifs (24) sont fixés au train roulant (14) au niveau d'un emplacement plus proche du plan transversal médian vertical (200) que des essieux (20), de préférence dans le plan transversal médian vertical géométrique (200). 5
10
14. Procédé de support d'une caisse de wagon (12) ayant un poids de $2L$ sur deux trains de roulement espacés de manière longitudinale (14), chacun des trains roulants (14) comprenant un châssis de train roulant (16), une suspension primaire (18) entre les châssis de train roulant (16) et deux essieux (20), et une suspension secondaire entre le châssis de train roulant (16) et la caisse de wagon (12) servant à transmettre une charge ayant une composante verticale statique L de la caisse de wagon (12) au train roulant (14), le procédé comprenant la fourniture pour chaque suspension secondaire d'éléments de suspension verticaux (22), de moyens de suspension transversaux passifs (24) et de moyens d'actionnement transversaux actifs (26) en parallèle entre la caisse de wagon (12) et le train roulant (14) de telle sorte que la caisse de wagon (12) est mobile par rapport au train roulant (14) dans une direction transversale de chaque train roulant (14) sur une plage de positions transversales comprenant une position centrée, dans lequel : 15
20
25
30
- les moyens de suspension transversaux passifs (24) entre la caisse de wagon (12) et chaque train roulant (14) ont une raideur K telle que : 35

$$\frac{K}{L} \geq 5m^{-1} \quad 40$$

- sur ladite plage de positions transversales,
- les moyens d'actionnement transversaux actifs (26) sont adaptés pour générer des forces dans la direction transversale d'une amplitude maximale M_{max} telle que : 45

$$\frac{M_{max}}{L} \leq \frac{1}{30} \quad 50$$

55

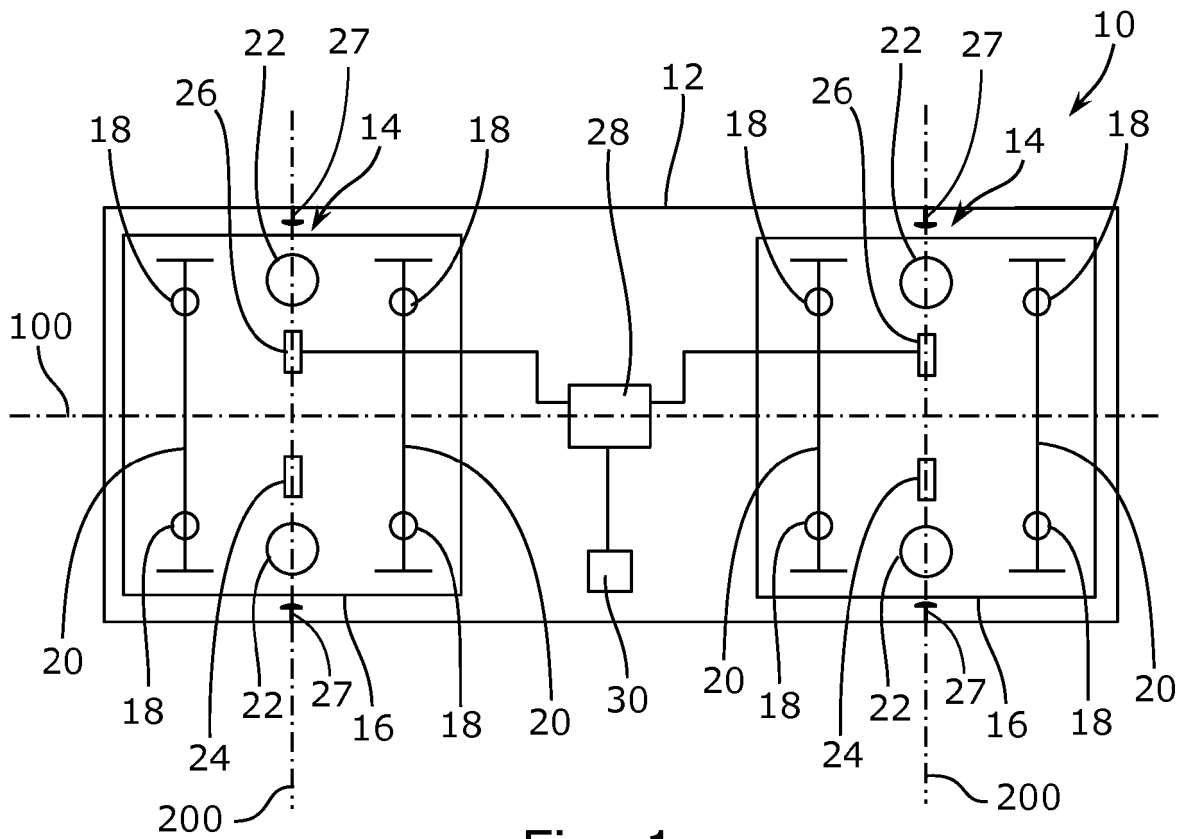


Fig. 1

REFERENCES CITED IN THE DESCRIPTION

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