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(54) **Title**: SUSPENSION SYSTEM

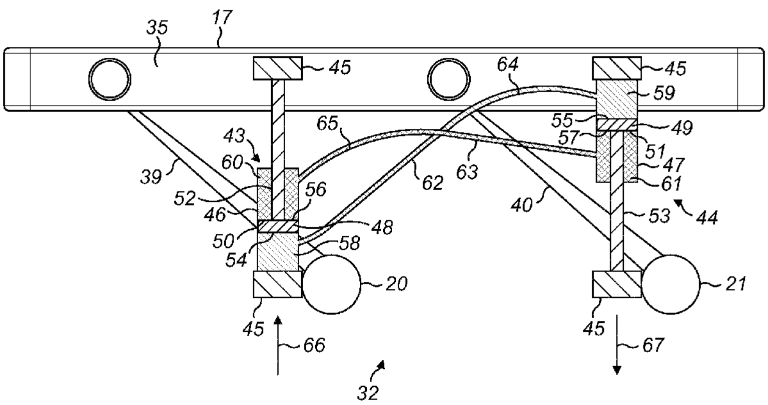

FIG. 3

(57) **Abstract**: This disclosure is directed towards a suspension system which is suitable for an articulated vehicle. A suspension system comprises a chassis, first and second axles each having first and second ends, two first actuators and two second actuators. The first actuator is connected between each of the first and second ends of the first axle and the chassis. The second actuator is connected between each of the first and second ends of the second axle and the chassis. The first and second actuators are arranged such that when one end of a first axle moves in one direction, the corresponding end of the second axle moves in the opposite direction.

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SUSPENSION SYSTEM

Technical Field

This disclosure is directed towards a suspension system which is suitable for an articulated vehicle.

Background

Vehicles, including work machines such as articulated trucks, excavators, dozers, loaders and the like, often have a centre of mass relatively high above the ground. This may be as a result of loading during operation, for example where a dump body holds a large mass of material. Work machines are often equipped with work tools which can be raised for safety when not in use and when the vehicle is travelling, which also affects the centre of mass of the vehicle. Such work machines are also typically operated on rough and uneven terrain. As a result, there is a risk that the work machine may tip over as it travels over uneven terrain.

This risk is increased for articulated vehicles, in that these typically comprise a first frame (such as a tractor in which the power unit is usually mounted) and a second frame (such as a trailer which may have a container for holding a mass of material or goods for transportation) connected to one another via an articulation joint. The articulation joint enables the frames to roll and yaw relative to one another. When operated on uneven terrain, one of the frames may become positioned at an unsafe roll and/or yaw angle and may cause the entire machine to turn over. Alternatively, if the articulated vehicle has an open container, such as a bucket or body mounted on one of the frames, any materials or goods held in the open container may fall out when one of the frames is positioned above certain roll and/or yaw angle thresholds.

In order to reduce the likelihood of this from occurring, some work machines such as articulated vehicles typically have a special suspension arrangement.

The front frame of an articulated vehicle typically comprises a single axle, denoted herein as the front axle, with wheels attached at either end of the axle. The rear frame typically comprises two axles, denoted herein as the central and rear axles, with wheels attached at either end of each axle. In addition to enabling the front and rear frames to be orientated at different roll and yaw angles relative to one another, the articulation joint may enable the power unit to provide power simultaneously to all of the wheels on the front and rear frames.

One suspension arrangement which is commonly used on an articulated vehicle, to reduce the likelihood of the rear frame tipping over, is disclosed in US-B-4324417. In this arrangement there is a bogie beam on either side of the rear frame. The centre of each bogie beams is pivotally attached to the rear frame. The front ends of the two bogie beams are attached to the ends of the central axle and the rear ends of the bogie beams are attached to the ends of the rear axle. Each bogie beam thus extends between the two axles on the same side of the vehicle. When one end of one of the centre or rear axle rises, the end of the other axle on the same side of the vehicle will lower. It is not possible for both of the adjacent ends of the axles to rise together. Thus as a pair of adjacent wheels on one side of the rear frame travels over a bump in the terrain, one wheel will rise, whilst the other lowers. The upwards vertical displacement of the side of the rear frame resulting from the bump is reduced by the downwards vertical displacement of the lowering wheel. Such a suspension arrangement effectively provides the frame with a very high roll stiffness and, therefore, the rear frame will only roll insubstantially as the vehicle passes over a bump. As a result, the rear frame will be less likely to tip onto its side.

However, in such a suspension arrangement, the rear frame loading passes entirely through the pivot attaching the bogie beams to the rear frame. This creates high localised stresses and requires the arrangement around the pivot to be sufficiently sized to be able to resist these stresses. The arrangement may therefore add significant additional mass to the machine, resulting in higher emissions and increased cost of manufacture. Furthermore the bogie beams must be constructed to be strong enough to withstand the forces generated, which means that they tend to be heavy, which adds to the mass of the vehicle.

Summary

The disclosure provides a suspension system for a vehicle, said suspension system comprising; a chassis; first and second axles each having first and second ends; two first actuators; and two second actuators, a first actuator being connected between each of the first and second ends of the first axle and the chassis, and a second actuator being connected between each of the first and second ends of the second axle and the chassis; wherein the first and second actuators are arranged such that when one end of a first axle moves in one direction, the corresponding end of the second axle moves in the opposite direction.

The disclosure further provides a vehicle comprising the aforementioned suspension system.

The disclosure further provides a method of stabilising the chassis of a vehicle, said vehicle having first and second axles, comprising the steps of hydraulically connecting a first end of the first axle with a first end of the second axle and connecting a second end of the first axle with a second end of the second axle such that when one end of a first axle moves in one direction, the corresponding end of the second axle moves in the opposite direction.

By way of example only, embodiments of a suspension arrangement suitable for an articulated vehicle are now described with reference to, and as shown in, the accompanying drawings.

Brief Description of the Drawings

Figure 1 is a side elevation of an exemplary articulated vehicle comprising the suspension arrangement of the present disclosure;

Figure 2 is a perspective representation of a rear frame of the articulated vehicle of Figure 1 with parts removed for ease of reference; and

Figure 3 is a side elevation of part of the rear from of Figure 2 illustrating the hydraulic system of the suspension arrangement of the present disclosure.

Detailed Description

The present disclosure is generally directed towards a suspension system suitable for a vehicle and in particular an articulated vehicle.

Figure 1 illustrates an exemplary articulated vehicle 10 in which the suspension system of the present disclosure may be used. The articulated vehicle 10 may comprise a front frame 11 and a rear frame 12. The front frame 11 may be a tractor unit and may comprise a cab 13 and a power unit (not shown). The power unit may be of any suitable type, such as an internal combustion engine, a micro-turbine or an electric motor. A front axle (not shown) may be provided to support the front frame 11 having one or more ground engaging means 14 mounted at either end of the front axle. The front frame 11 may comprise more than one axle and more than two ground engaging means 14 attached to each axle.

The front frame 11 may be connected to the rear frame 12 via a coupling 15, which may be an articulation joint. The coupling 15 may allow each of the frames 11, 12 to be orientated at a different yaw, pitch and/or roll angle to the other frame 12, 11. The yaw angle of the first frame 11 may be different to the yaw angle of the second frame 12 about an axis of articulation 16. The articulated vehicle 10 may be steered by adjusting the yaw angle of the front and rear frames about the axis of articulation 16 utilising actuators, for example hydraulic cylinders, suitably attached to each of the frames 11, 12 on either side of the coupling 15.

The rear frame 12 comprises a chassis 17 and may comprise a body 18 adapted to carry a load, such as a dump or ejector body. The body 18 may be attached to the chassis 17 at a pivot point (not shown) and a tipping system may be provided to rotate the body 18 about the pivot point. The tipping system may comprise at least one hydraulic actuator 19 connected to the body 18 and the chassis 17. The body 18 may comprise an ejector mechanism, having an actuator which may move a plate within the body 18 to eject any material contained therein.

Figure 2 shows the rear frame 12 with the body 18 removed to expose the chassis 17. The rear frame 12 comprises a central axle 20 and a rear axle 21. Ground engaging means 22, 23 (not shown in Figures 2 and 3) may be mounted by suitable mounting means 24, 25, 26, 27 located at each end of the central and rear axles 20, 21 of the rear frame 12.

The ground engaging means 14, 22, 23 may provide support between the terrain 31, over which the articulated vehicle 10 travels, and the front and rear frames 11, 12. The ground engaging means 14, 22, 23 may be of any suitable type, for example wheels or tracks, and may be operably connected via the axles 20, 21 to, and thus receive power from, the power unit.

Power may be transferred from the power unit located in the front frame 11 to the rear and central axles 20, 21 by a drive shaft 28 via the coupling 15. An end of the drive shaft 28 may be operably connected to receive power from the coupling 15. Transmission devices 29, 30, such as differentials or universal joints, may transfer torque from the drive shaft 28 to the central and rear axles 20, 21.

The central and rear axles 20, 21 may be attached to the chassis 17 by a suspension arrangement 32. The chassis 17 may have two longitudinal chassis members 35, 36 and a rear and a front cross member 33, 34 may be attached between the two chassis members 35, 36. At least one rigid support member 37, 38, 39, 40 may extend between each cross member 33, 34 and an end of each axle 20, 21. This may be arranged so that the front cross member 34 is pivotably connected to each end of the central axle 20 and the rear cross member 33 is pivotably connected to each end of the rear axle 21. The ends of a pair of rigid support members 37, 38, 39, 40 may be fixed to an axle 20, 21 on either side of the transmission devices 29, 30. The other ends of each pair of rigid support members 37, 38, 39, 40 may be joined to one another and pivotally attached to a cross member 33, 34 by a pivotable coupling 68, 69 such as a ball joint. Such an arrangement is commonly known as an ‘A-frame’.

Other arrangements of the at least one support members 37, 38, 39, 40 may be provided. For example, a single cross member 33, 34 may extend longitudinally between the chassis members 35, 36 and may be located midway between the axles 20, 21. A support member 37, 38, 39, 40 may be pivotally attached by a coupling to the outer casing of each transmission device 29, 30 on each axle 20, 21 and pivotally attached by a coupling to the centre of the cross member 33, 34. An end of each of a pair of support members 37, 38, 39, 40 may be pivotally attached to either end of each axles 20, 21, and the other ends of the support members 37, 38, 39, 40 may be pivotally attached to either end of the cross member 33, 34. Such an arrangement is commonly known as a ‘multi-link’ arrangement.

The support members 37, 38, 39, 40 and axles 20, 21 may form support means for supporting the rear frame 12 on the ground engaging means 22, 23. Furthermore, the support members 37, 38, 39, 40 may react against the fore or aft forces resulting from power being provided to the ground engaging means 22, 23 (i.e., the reactive force acting against the movement of the vehicle 10).

Actuators 41, 42, 43, 44, operable to be compressed or extended, may be attached by suitable attachment means 45 at one end to the chassis members 35, 36. The other ends of the actuators 41, 42, 43, 44 are attached by suitable attachment means 45 on either side of the transmission devices 29, 30 to an axle 20, 21 or the support members 37, 38, 39, 40. The attachment means 45 may comprise any suitable means, such as a fixed joint, a rotatable joint or the like.

The actuators 41, 42, 43, 44 may be hydraulic actuators and a hydraulic arrangement for the first and second hydraulic actuators 43, 44 on one side of the rear frame 12 is shown in Figure 3. The hydraulic arrangement illustrated, and described below, is the same as that for the first and second hydraulic actuators 41, 42 on the other side of the rear frame 12.

Each of the hydraulic actuators 41, 42, 43, 44 may comprise at least one cylinder 46, 47 in which a piston 48, 49 is mounted. Each piston 48, 49 may be attached to a rod 52, 53. Each piston 48, 49 may comprise a first face 54, 55 and an opposing second face 56, 57. Each rod 52, 53 may be attached to the second face 56, 57 of the piston 48, 49 and may extend out of one end of the cylinder 46, 47. A first chamber 58, 59 may be formed on one side of the piston 48, 49, in the space between the first face 54, 55 and the inside of the cylinder 46, 47. A second chamber 60, 61 may be formed on the opposing side of the piston 48, 49, in the space between the second face 56, 57, the rod 52, 53 and the inside of the cylinder 46, 47. Each piston 48, 49 may be operable to move relative to the cylinder 46, 47 when a physical force is applied to the exposed end of the rod 52, 53 or an hydraulic force is applied to either face 54, 55, 56, 57.

The first actuators 41, 43 may be mounted in a reverse manner to the second actuators 42, 44. As shown in Figure 3, the end of the rod 52, which projects from a first end of the cylinder of the first hydraulic actuator 43, may be connected to the chassis 17. The second (opposing) end of the cylinder 46 of the first hydraulic actuator 43 may be connected to the central axle 20 or support member 39. The end of the rod 53 which projects from a first end of the cylinder of the second hydraulic actuator 44 may be connected to the rear axle 21 or support member 40 and the second (opposing) end of the cylinder 47 of the second hydraulic actuator 44 may be connected to the chassis 17.

First hydraulic lines 62 may be provided to fluidly connect the first chamber 58 of the first hydraulic actuator 43 to the first chamber 59 of the second hydraulic actuator 44. Second hydraulic lines 63 may be provided to fluidly connect the second chamber 60 of the first hydraulic actuator 43 to the second chamber 61 of the second hydraulic actuator 44. Hydraulic fluid may thus be transferred between the pairs of first chambers 58, 59 and between the pairs of second chambers 60, 61 thereby adjusting the positions of the pistons 48, 49.

The first hydraulic line 62 and the first chambers 58, 59 may define a first volume 64 and the second hydraulic line 63 and the second chambers 60, 61 may define a second volume 65. The first and second volumes 64, 65 may each contain a substantially constant volume of hydraulic fluid. A charge pump hydraulic circuit (not shown) may be connected to the hydraulic lines 62, 63 and/or chambers 58, 59, 60, 61 to supply hydraulic fluid to compensate for any fluid leakages, thereby maintaining a substantially constant volume of hydraulic fluid in each of the first and second volumes 64, 65.

When one piston 48, 49 is moved relative to the cylinder 46, 47, hydraulic fluid may be transferred between the chambers 58, 59, 60, 61 such that the other piston 49, 48 moves in the opposite direction. For example, as shown in Figure 3, if a force is applied in an upwards direction 66 to the first actuator 43, the cylinder 46 may move upwards and relative to the piston 48 such that the first actuator 43 compresses. Hydraulic fluid is forced from the first chamber 58 of the first actuator 43 to the first chamber 59 of the second actuator 44 and from the second chamber 61 of the second actuator 44 to the second chamber 60 of the first actuator 43. The piston 49 of the second actuator 44 will move in the downwards direction 67 and the second actuator 44 will extend. Therefore, if the central axle 20 moves in the upwards direction 66, the rear axle 21 will move in the downwards direction 67 and vice-versa.

The magnitude of the displacement of each of the axles 20, 21 may be substantially the same. In particular, this may be a result of the area exposed to hydraulic fluid on each of the first faces 54, 55 being the same and the area exposed to hydraulic fluid on each of the second faces 56, 57 being the same. Therefore, for example, as the axle 20 moves in the upwards direction 49 the pressure applied to the hydraulic fluid by the first face 54 of the first actuator 43 will be the same as the pressure applied by the hydraulic fluid to the first face 55 of the second actuator 44. As a result the movement of the rear axle 21 is the inverse of the central axle 20.

In alternative embodiments, each hydraulic actuator 41, 42, 43, 44 may comprise more than one hydraulic cylinder and more than one first and second chambers.

Industrial Applicability

As an articulated vehicle 10 with the suspension system of the present disclosure passes over uneven terrain 31, the suspension system prevents both axles from rising together on the same side, and reduces the risk of the vehicle 10 from tipping over. The suspension system redistributes the resulting loads on the rear frame 12 and thereby also reduces the stress on the rear frame 12. As a pair of adjacent ground engaging means 22, 23 on one side of the rear frame 12 travel over a bump in the terrain 31, one ground engaging means 22 may rise whilst the other ground engaging means 23 lowers. The upwards vertical displacement of the side of the rear frame 12 resulting from the bump may be reduced by the downwards vertical displacement of the lowering ground engaging means 23. Therefore, the suspension system may provide the rear frame 12 with an effectively very high roll stiffness and the rear frame 12 may roll insubstantially as it passes over the bumps in the terrain.

The hydraulic actuators 41, 42, 43, 44 may be connected in a passive arrangement, wherein no additional force, other than that caused by a bump in the terrain 31, is required to raise and lower the axles 20, 21. However whilst the suspension system described herein is a passive suspension system, it may be adapted to provide active suspension.

The weight of the suspension system may be less than the weight of the aforementioned prior art bogie system. Therefore, efficiency of the articulated vehicle 10 may be relatively higher and the operating fuel costs relatively lower. Furthermore, in the prior art arrangement all of the rear frame loads are directed through the central pivot point. This requires a locally strong rear frame. This is not the case in the suspension system of the present disclosure, as the loading is distributed across a greater number of points.

CLAIMS:

1. A suspension system for a vehicle, said suspension system comprising;

a chassis;

first and second axles each having first and second ends;

two first actuators; and

two second actuators,

a first actuator being connected between each of the first and second ends of the first axle and the chassis, and a second actuator being connected between each of the first and second ends of the second axle and the chassis;

wherein the first and second actuators are arranged such that when one end of a first axle moves in one direction, the corresponding end of the second axle moves in the opposite direction.

2. A suspension system as claimed in claim 1 wherein each axle further comprises at least one rigid support member pivotably connected between each of the first and second ends of each axle and the chassis.

3. A suspension system as claimed in any one of the preceding claims wherein the first and second actuators are hydraulic actuators and wherein the first actuator, which is connected to the first end of the first axle, is fluidly connected to the second actuator, which is connected to the first end of the second axle, and the first actuator, which is connected to the second end of the first axle, is fluidly connected to the second actuator, which is connected to the second end of the second axle.

4. A suspension system as claimed in any one of the preceding claims in which the actuators comprise a cylinder and a piston mounted on a piston rod, the cylinder and piston being movable relative to each other.

5. A suspension system as claimed in claim 4 wherein

the piston of the first actuator is connected to the chassis;

the cylinder of the first actuator is connected to the first axle;

the piston rod of the second actuator is connected to the axle; and

the cylinder of the second actuator is connected to the chassis.

6. A suspension system as claimed in claim 4 or claim 5 wherein each cylinder defines a first chamber formed on one side of the piston and a second chamber formed on the opposing side of the piston, wherein the first chambers of each cylinder are fluidly connected, and the second chambers of each cylinder are fluidly connected.

7. A suspension system as claimed in any one of the preceding claims wherein the suspension arrangement is a passive or an active suspension arrangement.

8. A vehicle comprising the suspension system as claimed in any one of the preceding claims, ground engagement means attached to each end of each axle and a power unit arranged to drive the ground engagement means.

9. A vehicle as claimed in claim 8 being an articulated vehicle comprising a first frame and a second frame, the

first and second frames being connected by a coupling and being movable relative to each other in at least one direction, wherein the second frame is provided with the suspension system.

10. A method of stabilising the chassis of a vehicle, said vehicle having first and second axles, comprising the steps of hydraulically connecting a first end of the first axle with a first end of the second axle and connecting a second end of the first axle with a second end of the second axle such that when one end of a first axle moves in one direction, the corresponding end of the second axle moves in the opposite direction.

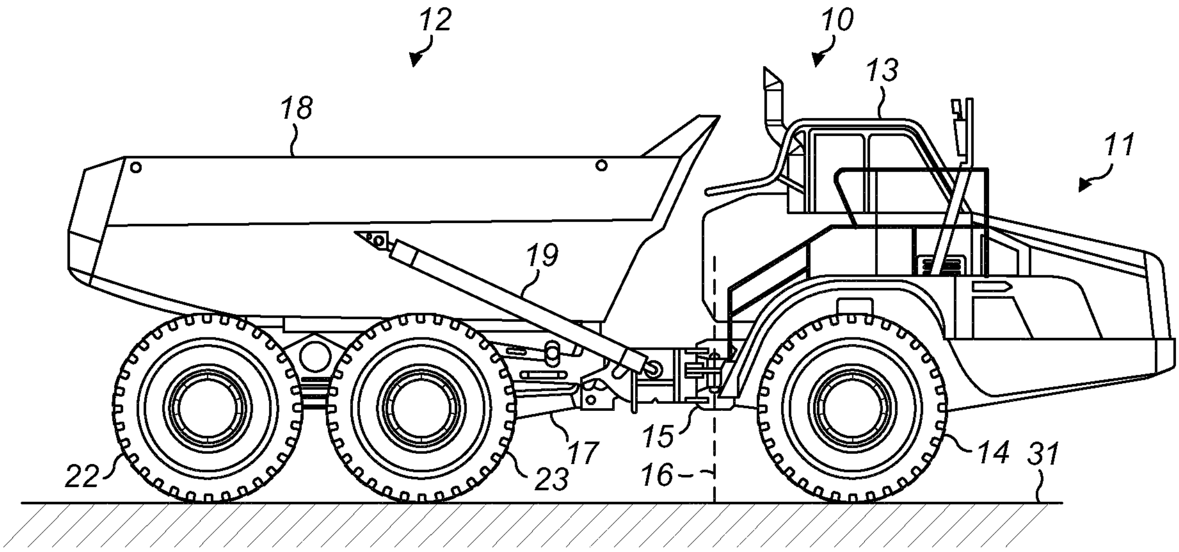

FIG. 1

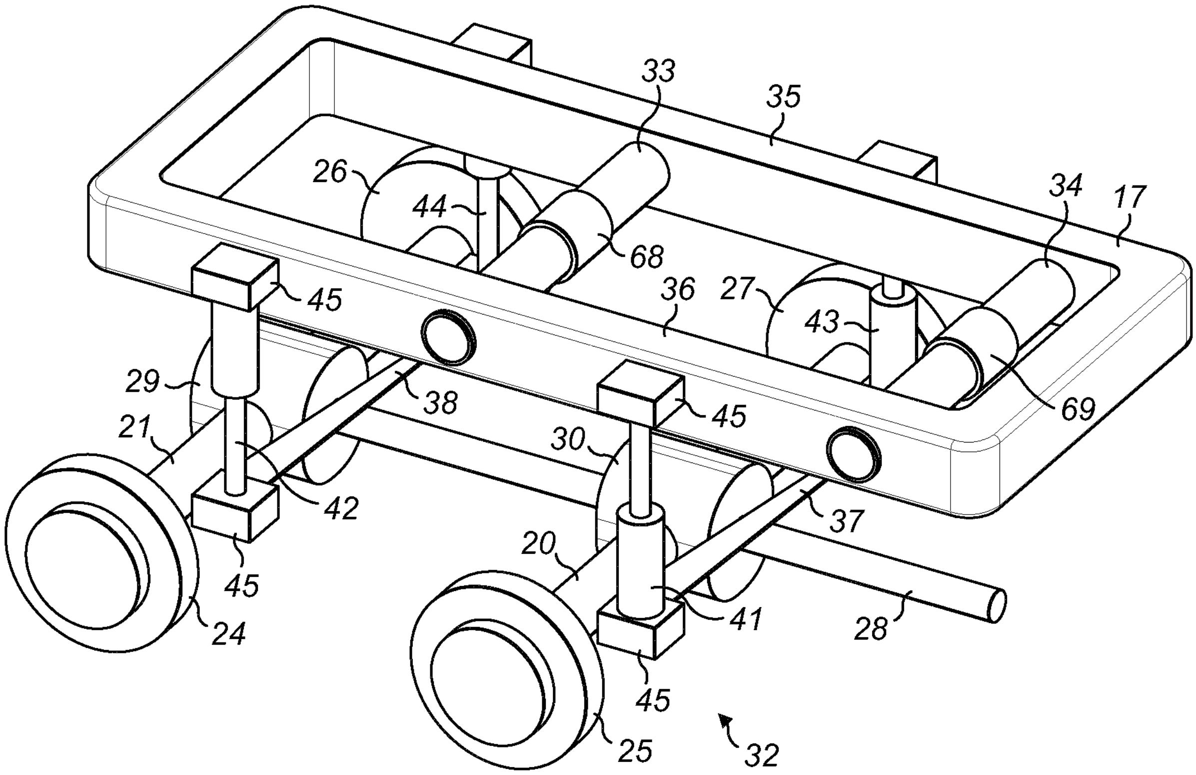
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FIG. 2

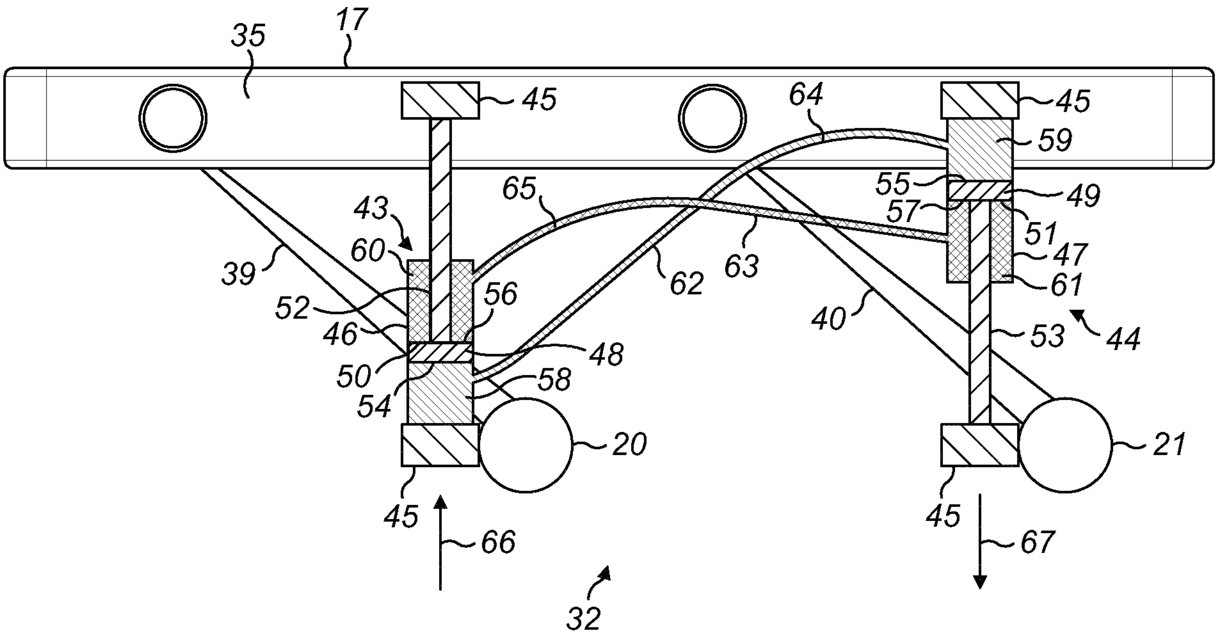
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FIG. 3

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2013/067491

A. CLASSIFICATION OF SUBJECT MATTER
INV. B60G21/067
ADD. B60G5/04 B60G9/00

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)
B60G

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

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
6 November 2013	18/11/2013

Name and mailing address of the ISA/	Authorized officer
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INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2013/067491

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INTERNATIONAL SEARCH REPORT

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International application No
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