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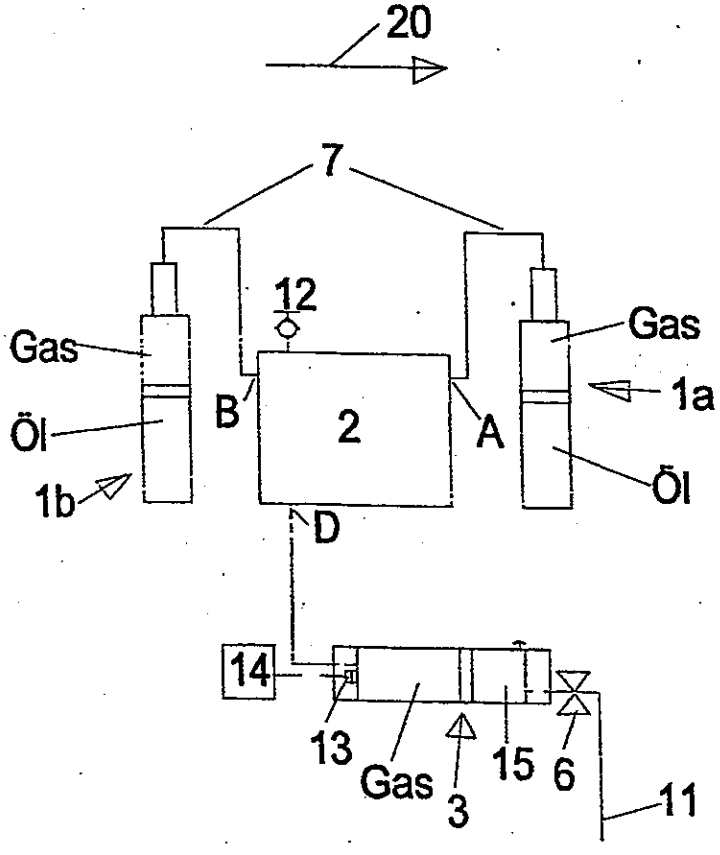
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(54) Title: HYDROPNEUMATIC SUSPENSION SYSTEM

(54) Bezeichnung: HYDROPNEUMATISCHE FEDERUNG



(57) Abstract: The invention relates to a hydropneumatic suspension system and the method of controlling said hydropneumatic suspension system, as used, in particular, for off-road vehicles. Said hydropneumatic suspension system permits allowance to be made for both static and dynamic factors, as well as both a manual and automatic control, despite being of a simple and cheap construction which is easy to repair. An inventive hydropneumatic suspension system, in particular for vehicles, comprises at least two hydraulic springs, which are hydraulically connected to each other and to a regulating cylinder via a load distribution unit. Said hydropneumatic suspension system is characterised by the following switching possibilities for the load distribution unit: hydraulic separation of the hydraulic springs, hydraulic connection of just the two linked hydraulic springs and hydraulic connection of both hydraulic springs and the regulating cylinder.

(57) Zusammenfassung: Die Erfindung betrifft eine hydropneumatische Federung bzw. das Verfahren beim Steuern einer solchen hydropneumatischen Federung, wie sie insbesondere bei geländegängigen Kraftfahrzeugen verwendet wird, welches trotz einfachem und kostengünstigem sowie reparaturfreudlichem Aufbau die Berücksichtigung sowohl statischer als auch dynamischer Faktoren erlaubt und darüber hinaus sowohl eine manuelle als auch eine automatische Steuerung ermöglicht.

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Hydropneumatic suspension

1. Field of use

The invention concerns a hydropneumatic suspension or the operating procedure in controlling such a hydropneumatic suspension, as is used in particular in cross-country motor vehicles.

The travel characteristics of cross-country vehicles depend on the one hand on the static conditions involved such as for example weight and distribution of load and on the other hand dynamic factors, for example the speed of travel, the size and frequency of irregularities of the ground and so forth.

The advantage of hydropneumatic suspension is in principle that, by varying for example the volume of oil in the individual hydropneumatic springs, it is possible to vary the spring characteristics of the individual hydropneumatic springs and thus of the entire suspension system, in dependence on static and/or dynamic factors.

II. Technical background

In this context, systems are already known which by means of a plurality of sensors continuously detect those static and dynamic parameters and by way of a complex computer set the optimum prestressing of the individual hydropneumatic springs, that is to say the oil volume thereof.

Those systems however are expensive to manufacture and, because of the large number of in particular electrical and electronic components, under rough conditions of use, for example in military situations, on the one hand are severely exposed to the risk of failure and on the other hand are not very repair-friendly as restoration in a purely mechanical fashion is generally not possible. In order to arrive at a simple hydropneumatic suspension system which is also easy to repair, it is moreover already known from DE 195 05 712 to either increase or reduce the volume of the

individual hydropneumatic springs by means of a fixed additional volume, in dependence on the load condition, that is to say a static factor. That arrangement does not involve automatic adaptation nor can the size of the additional volume be changed. Adaptation of the suspension system to dynamic factors is also not possible in that fashion.

III. Statement of the invention

a) Technical object Therefore the object of the present invention is to provide a hydropneumatic suspension system and a control method for same, which, in spite of being of a simple, inexpensive and repair-friendly structure, makes it possible to take account of both static and also dynamic factors and in addition permits both manual and also automatic control.

b) Attainment of the object

That object is attained by the feature of claims 1 and 16.

Accordingly, in an aspect of the present invention, there is provided a hydropneumatic suspension, in particular for motor vehicles, comprising at least one front hydropneumatic spring and at least one rear hydropneumatic spring which are in flow communication

- by way of a load distribution with each other and also with a metering cylinder, wherein the load distribution unit has at least the following switching positions:

a) flow separation of the hydropneumatic springs,

b) flow communication only of the two connected hydropneumatic springs to each other, and

c) flow communication of the two hydropneumatic springs and the metering cylinder to each other, wherein

- load distribution unit has in the compensating line between the connections for the hydropneumatic springs a compensating circuit,

- the metering connection of the load distribution unit, which is in communication with the metering cylinder, is connected to both arms of the compensating line, that is to say on both sides of the compensating circuit,

- a metering circuit is arranged between the metering connection of the load distribution unit and the branch point to the arms of the compensating line, and

- the compensating circuit and also the metering circuit have no sensors and electrical or electronic control or regulating elements for converting the signals thereof.

In another aspect of the present invention, there is provided a method of controlling a hydropneumatic suspension, in particular the suspension of a motor vehicle, having a plurality of hydropneumatic springs which can be brought into flow communication with each other and also with a metering cylinder, in particular a hydropneumatic suspension according to the preceding paragraph, characterised in that

a) with low dynamic influences on the vehicle, in dependence on static factors, fluid is introduced from the metering cylinder into the assembly comprising the hydropneumatic springs and thereafter the hydropneumatic springs are separated from each other in respect of flow,

b) in the case of moderate dynamic influences on the vehicle, in dependence on static factors, fluid is added from the metering cylinder into the assembly comprising the hydropneumatic springs and the connection between the two hydropneumatic springs and also the connection to the metering cylinder remains open, and

c) in the case of heavy dynamic influences, fluid is introduced from the metering cylinder into the assembly comprising the hydropneumatic springs and the connection between the hydropneumatic springs and the metering

volume remains open, but a rapid transfer flow between the two hydropneumatic springs or between the hydropneumatic springs and the metering cylinder is prevented.
Advantageous embodiments are set forth in the appendant claims.

In this respect, the volumes of two respective mutually corresponding hydropneumatic springs at the front and the rear on the vehicle, that is to say in the case of a four-wheel vehicle, for example the left front and rear hydropneumatic springs of the vehicle, are coupled together. Besides the volumes of the two hydropneumatic springs involved, there is further the metering volume of a metering cylinder, wherein those three components are connected together by way of a load distribution unit which can assume three different switching positions:

- connecting the volumes of the two hydropneumatic springs together and also to the metering cylinder,

- connecting only the volumes of the two hydropneumatic springs to each other, and

- separating the three component units from each other, that is to say separate action of each individual hydropneumatic spring.

In that arrangement, the metering volume of the metering cylinder is not a fixed volume but rather, by means of the metering cylinder, as required, an amount which is to be ascertained of metering volume is introduced into the system, that is to say into the coupled volume of the

two hydropneumatic springs involved, or is removed by means of the metering cylinder.

The entire invention is described hereinafter in the form of a variation in the oil volume of the hydropneumatic springs involved and therewith also a metering volume of the metering cylinder in the form of hydraulic oil.

The variation in the oil volume of a hydropneumatic spring displaces the working point along the spring characteristic of the hydropneumatic spring upwardly, that is to say in the direction of a higher degree of prestressing.

Instead of the variation in the oil volume however, or supplemental to the variation in the oil volume, it is also possible to influence the gas volume, in which case the metering volume of the metering cylinder obviously also contains gas.

The for example increase in the gas volume of a hydropneumatic spring however - while maintaining the current working point - causes a displacement of the entire spring characteristic upwardly.

Independently thereof, the effects of the variation, which can be perceived on the vehicle, are not dissimilar so that the two options which are fundamentally afforded, that is to say influencing the oil volume and/or the gas volume of the hydropneumatic springs of a hydropneumatic suspension system, can certainly be used substitutively or in mutually supplemental relationship.

In addition to the three described switching positions of the load distribution unit the hydrodynamic connection of the two hydropneumatic springs has a compensating circuit which influences the nature of the transfer flow and likewise the connection of the metering cylinder to the two hydropneumatic springs has a metering circuit which also influences the nature of the transfer flow. The compensating circuit and the metering circuit provide for adaptation of the hydropneumatic suspension system to the dynamic parameters without using sensors and converting control or regulating elements.

The load distribution unit includes for example a non-return valve which permits a fast transfer flow from the rear to the front hydropneumatic spring, but blocks that in the opposite direction and can only be by-passed by way of a throttle so that a return flow can only take place at a much slower rate.

The metering circuit can be of an identical structure, with a passage direction from the metering cylinder to the hydropneumatic springs, but it includes at least one throttle which cannot be by-passed, in order to prevent an excessively rapid subsequent flow or discharge flow of metering volume out of the hydropneumatic springs.

In addition, it is possible to arrange in a by-pass in relation to the compensating circuit, a pressure-limiting valve disposed between the front hydropneumatic spring and the rear hydropneumatic spring or the metering cylinder respectively, which on the one hand serves as a safety valve for the front hydropneumatic spring (opening of the pressure-limiting valve at an excessively high pressure in the front hydropneumatic spring) and which on the other hand serves for the flow of metering volume from the metering cylinder directly into the front hydropneumatic spring, that is to say by-passing the throttles of the compensating circuit, in order to provide additional volume in the front hydropneumatic spring more quickly and thus to 'stiffen' the front hydropneumatic spring more quickly than the rear hydropneumatic spring.

Both measures serve to avoid the damage which occurs in the case of overloaded hydropneumatic suspensions almost always firstly at the front axles and thus steering arrangements of motor vehicles, and they also serve to be able to stiffen primarily the front hydropneumatic springs quickly and adequately, while in the case of the rear hydropneumatic springs that is generally still sufficient if a certain time delay is involved.

That affords the following options:

Travelling on smooth or relatively uneven ground with or without a slight gradient:

a) When the vehicle is uniformly loaded: the hydropneumatic springs are separated from each other; depending on the magnitude of the loading,

prior to separation, metering volume is introduced to the required amount into the hydropneumatic springs when they are still connected together;

b) With an uneven loading: after the metering volume has been introduced into the coupled hydropneumatic springs, the connection to the metering cylinder is shut off and only the two hydropneumatic springs remain connected. That increases the working point for carrying the load, at the heavily loaded hydropneumatic spring.

Travelling on a moderate gradient:

Possibly after a metering volume has been introduced, the connection to the metering cylinder is shut off, but the hydropneumatic springs remain connected together in order particularly when travelling down a hill to be able to rapidly stiffen the heavily loaded front axle whenever a dynamic loading occurs.

Travelling on flat ground with a moderate frequency in terms of the occurrence of dynamic loadings due to irregularities of the ground, that is to say the speed of travel is not excessively high, in comparison with the distance between the irregularities in the ground:

In order to improve the level of travelling comfort the metering volume remains in flow communication with both hydropneumatic springs in order to increase the total available volume and to permit volume to flow to and back from the metering cylinder, in a manner which is limited in respect of speed but continuous.

High frequency in terms of the occurrence of dynamic loadings due to ground irregularities in relation to the speed of travel:

By virtue of the throttles in the compensating circuit and the metering circuit, a subsequent flow of volume from the metering circuit into the two hydropneumatic springs at the necessary speed in order to compensate for the dynamic loadings which occur is not possible in any case. Nonetheless the connection between the metering cylinder and/or the hydropneumatic springs remains open in order to permit at least a rapid return flow of volume from the first hydropneumatic spring if an excessively high pressure builds up there.

It may also be pointed out that the static factors include not only the loading of the vehicle but for example also the temperature, in particular in the gas of the hydropneumatic spring, which can be very different either by virtue of the external temperature or also by virtue of friction when the hydropneumatic spring is constantly extending and retracting, but the increase in temperature produces the same effect as an increase in the volume of gas, that is to say a displacement of the spring characteristic further upwardly, that is to say in the direction of a higher level of prestressing, and thus also requires compensation.

c) Embodiments

An embodiment of the invention is described in greater detail with reference to the Figures in which:

Figure 1 is a circuit diagram showing the principle of the hydropneumatic suspension, and

Figure 2 shows the load distribution unit 2 of that suspension in the form of a block circuit diagram.

Figure 1 shows the circuitry in principle of the components of the suspension according to the invention.

The hydropneumatic spring 1a which is at the front in the direction of travel 20 and the rear hydropneumatic spring 1b are in this arrangement each connected with their gas volume by way of compensating lines 7 to the load distribution unit 2 which is only symbolically illustrated, wherein the front hydropneumatic spring 1a is connected to the connection A and the rear hydropneumatic spring 1b is connected to the connection B.

The load distribution unit 2 also has a connection D which is connected to the metering volume 9 of a metering cylinder 3 which in this case is also a gas volume.

A metering plunger 10 is disposed in the metering cylinder 3 between the gas-filled metering volume 9 and the adjacent working chamber 15. By virtue of applying pressure in the working chamber 15 which can be connected to the working pressure 11 by way of a for example regulatable control valve 6, the pressure in the working chamber 15 can be controlled, that is to say increased or reduced, which results in a

displacement of the metering plunger 10 and thus expels parts of the metering volume 9 out of the metering cylinder or allows them to flow back therein.

The pressure obtaining in the metering volume 9 is preferably checked by means of a pressure sensor 13 which is arranged thereon and which is in communication with a suitable testing device 14.

As is known the hydropneumatic springs 1a, 1b have a gas volume and an adjacent oil volume which are separated from each other by a diaphragm or a plunger in such a way that the relation of the gas volume to the oil volume within the total volume can alter, for example by virtue of compression of the gas volume.

The gas volume is loaded by the plunger rod to which the wheel (not shown) is secured.

In this respect it should again be pointed out that, instead of the gas volumes of the hydropneumatic springs 1a, 1b and the metering cylinder 3, the respective oil volumes thereof can also be connected to the load distribution unit and thus brought into communication with each other.

Figure 2 shows the internal structure of the load distribution unit 2 in the form of a block circuit diagram. The two connections A and B for the hydropneumatic springs 1a, 1b are in communication with each other by way of a compensating circuit 4. It has on the one hand a non-return valve 24 through which a flow can pass in a direction towards the connection A, that is to say in the direction of the front hydropneumatic spring 1a, but which is closed in the opposite direction. Connected in series with the non-return valve 24 is a throttle 21 in the compensating line 7 between the connections A and B, which limits the through-flow in both directions of flow, to the degree of opening of that throttle 21.

In addition, arranged in parallel with the non-return valve 24 is a further throttle 22 whose opening diameter thus determines only the through-flow in the direction of flow from the connection A in the direction of the connection B or D, in which the non-return valve 24 is closed.

The arm of the compensating line 7 to the connection B, that is to say towards the rear hydropneumatic spring, is further connected to a

metering circuit 5 which on the other hand is connected to the connection D for the metering cylinder 3. In the simplest case, that metering circuit 5 merely comprises a throttle 23 which limits the flow speed in both directions from or to the metering cylinder 3.

In addition, a pressure relief valve 26 is arranged between that metering circuit 5 and the arm of the compensating line 7, which is connected to the connection A, in such a way that, after the set pressure is exceeded, a through-flow from the connection A to the branch point 8 is possible. As the branch point 8 is arranged immediately upstream of the metering circuit 5 and is in communication with the arm of the compensating line 7, which is associated with the connection B, the fluid then flows both in the direction of the connection B and also through the metering circuit 5 to the connection D.

The pressure-relief valve 26 which is preferably adjustable in terms of its opposing pressure cannot in contrast allow a flow therethrough, in a direction towards the connection A.

That pressure-relief valve 26 thus serves primarily as a safety valve to prevent the gas volume of the hydropneumatic spring 1a connected to the terminal A coming under an excessively high pressure.

The load distribution unit 2 also has a filling connection 12 which is connected to the arm of the compensating line 7, which is associated with the connection B.

In the above-described cases, two respective hydropneumatic springs 1a, 1b, being a front one and a rear one, can be connected together and to a metering cylinder 3 by way of a compensating circuit 2.

When there are more than two hydropneumatic springs or axles which are arranged one behind the other, each two successive hydropneumatic springs can be connected together by means of a compensating circuit 2 as described above. In that case also each pair of hydropneumatic springs can be connected to a separate or a common metering cylinder 3, as described above.

LIST OF REFERENCES

1	hydropneumatic spring
2	load distribution unit
3	metering cylinder
4	compensating circuit
5	metering circuit
6	control valve
7	compensating line
8	branch point
9	metering volume
10	metering plunger
11	working pressure
12	filling connection
13	pressure sensor
14	test device
15	working chamber
20	direction of travel
21	throttle
23	throttle
24	non-return valve
26	pressure-relief valve

CLAIMS

1. A hydropneumatic suspension, in particular for motor vehicles, comprising at least one front hydropneumatic spring (1a) and at least one rear hydropneuamtic spring (1b) which are in flow communication

- by way of a load distribution (2) with each other and also with a metering cylinder (3), wherein the load distribution unit (2) has at least the following switching positions:

a) flow separation of the hydropneumatic springs (1a, 1b),

b) flow communication only of the two connected hydropneumatic springs (1a, b) to each other, and

c) flow communication of the two hydropneumatic springs (1a, b) and the metering cylinder (3) to each other, wherein

- load distribution unit (2) has in the compensating line (7) between the connections (A, B) for the hydropneumatic springs (1a, b) a compensating circuit (4),

- the metering connection (D) of the load distribution unit (2), which is in communication with the metering cylinder (3), is connected to both arms of the compensating line (7), that is to say on both sides of the compensating circuit (4),

- a metering circuit (5) is arranged between the metering connection (D) of the load distribution unit (2) and the branch point (8) to the arms of the compensating line (7), and

- the compensating circuit (4) and also the metering circuit (5) have no sensors and electrical or electronic control or regulating elements for converting the signals thereof.

2. A hydropneumatic suspension according to claim 1 characterised in that the gas volumes of the hydropneumatic springs (1a, 1b) can be brought into communication with the gas-filled volume of the metering cylinder (3).

3. A hydropneumatic suspension according to one of the preceding claims characterised in that the oil volumes of the hydropneumatic springs (1a, 1b) can be brought into communication with the oil-filled volume of the metering cylinder (3).

4. A hydropneumatic suspension according to one of the preceding claims characterised in that the compensating circuit (4) has a throttle (21).

5. A hydropneumatic suspension according to one of the preceding claims characterised in that the compensating circuit (4) is such that a transfer flow from the connection (B) for the rear hydropneumatic spring (1b) to the connection (A) for the front hydropneumatic spring (1a) is possible more quickly than vice-versa.

6. A hydropneumatic suspension according to one of the preceding claims characterised in that the compensating circuit (4) has a non-return valve (24) which is openable in the direction from the connection (B) for the rear hydropneumatic spring (1b) towards the connection (A) for the front hydropneumatic spring (1a) and which is connected in particular in series with the throttle (21).

7. A hydropneumatic suspension according to one of the preceding claims characterised in that a further throttle (22) is conneeted in the compensating circuit (4) in by-pass relationship with the non-return valve (24).

8. A hydropneumatic suspension according to one of the preceding claims characterised in that the metering circuit (5) of the load distribution unit (2) is identically equipped to the compensating circuit (4), in particular with an opening direction of a non-return valve from the metering connection (D) to the compensating line (7).

9. A hydropneumatic suspension according to one of the preceding claims characterised in that the metering circuit (5) includes a throttle (23), in particular only one throttle (23).

10. A hydropneumatic suspension according to one of the preceding claims characterised in that a pressure-relief valve (26) is arranged between the metering circuit (5) and the arm of the compensating line (7), which is connected to the front axle connection (A), in such a way that, with an excessively high pressure on the side of the connection A), opening is possible with diversion to the branch point (8) between the metering connection (D) and the rear axle connection (B).

11. A hydropneumatic suspension according to one of the preceding claims characterised in that the metering connection (D) can be completely shut off.

12. A hydropneumatic suspension according to one of the preceding claims characterised in that the compensating line (7) and in particular the connections (A, B) can be completely shut off.

13. A hydropneumatic suspension according to one of the preceding claims characterised in that actuation of the metering plunger (10) of the metering cylinder (3) on the side which is remote from the metering volume (9) can be determined manually and/or automatically by the vehicle control system.

14. A method of controlling a hydropneumatic suspension, in particular the suspension of a motor vehicle, having a plurality of hydropneumatic springs (1a, b) which can be brought into flow communication with each other and also with a metering cylinder (3), in particular a hydropneumatic suspension according to one of the preceding claims,

characterised in that

a) with low dynamic influences on the vehicle, in dependence on static factors, fluid is introduced from the metering cylinder into the assembly comprising the hydropneumatic springs and thereafter the hydropneumatic springs are separated from each other in respect of flow,

b) in the case of moderate dynamic influences on the vehicle, in dependence on static factors, fluid is added from the metering cylinder into the assembly comprising the hydropneumatic springs and the connection between the two hydropneumatic springs and also the connection to the metering cylinder remains open, and

c) in the case of heavy dynamic influences, fluid is introduced from the metering cylinder into the assembly comprising the hydropneumatic springs and the connection between the hydropneumatic springs and the metering volume remains open, but a rapid transfer flow between the two hydropneumatic springs or between the hydropneumatic springs and the metering cylinder is prevented.

15. A method according to claim 14 characterised in that a static factor is the load state of the vehicle.

16. A method according to one of the preceding method claims characterised in that a static factor is the temperature of the gas in the suspension system, in particular in the hydropneumatic springs.

17. A method according to one of the preceding method claims characterised in that the dynamic factors are ascertained directly at the wheel mountings, in particular those of the front axle, in particular directly at the hydropneumatic springs, and in dependence thereon in an automatic mode the procedure in accordance with the variants a, b and c of claim 14 is selected and in particular the magnitude of the feed metering from the metering cylinder (3) is selected.

18. A method according to one of the preceding method claims characterised in that with high dynamic loadings a fast return flow from the

front hydropneumatic spring (1a) is possible by way of opening of the pressure-relief valve into the rear hydropneumatic spring (B) and/or the metering cylinder (3), in particular without passing through a throttle.

ABSTRACT

The invention concerns a hydropneumatic suspension and the method involved in controlling such a hydropneumatic suspension, as is used in particular in relation to cross-country motor vehicles, which, in spite of being of a simple, inexpensive and repair-friendly structure, makes it possible to take account of both static and also dynamic factors and which in addition permits both manual and also automatic control. A hydropneumatic suspension according to the invention, in particular for motor vehicles, having at least two hydropneumatic springs which are in flow communication with each and also with a metering cylinder by way of a load distribution unit, is distinguished in that the load distribution unit has at least the following switching positions: flow separation of the hydropneumatic springs, flow communication only of the two connected hydropneumatic springs with each other, and flow communication of the two hydropneumatic springs and the metering cylinder with each other.