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CA 2199500 C 2002/02/19

(11)(21) 2 199 500

(12) BREVET CANADIEN
CANADIAN PATENT

(13) C

(86) Date de dépôt PCT/PCT Filing Date: 1995/09/11
(87) Date publication PCT/PCT Publication Date: 1996/03/14
(45) Date de délivrance/Issue Date: 2002/02/19
(85) Entrée phase nationale/National Entry: 1997/03/07
(86) N° demande PCT/PCT Application No.: DE 1995/001234
(87) N° publication PCT/PCT Publication No.: 1996/007882
(30) Priorité/Priority: 1994/09/10 (P 44 32 286.0) DE

(51) Cl.Int.^{6}/Int.Cl.^{6} G01M 17/04
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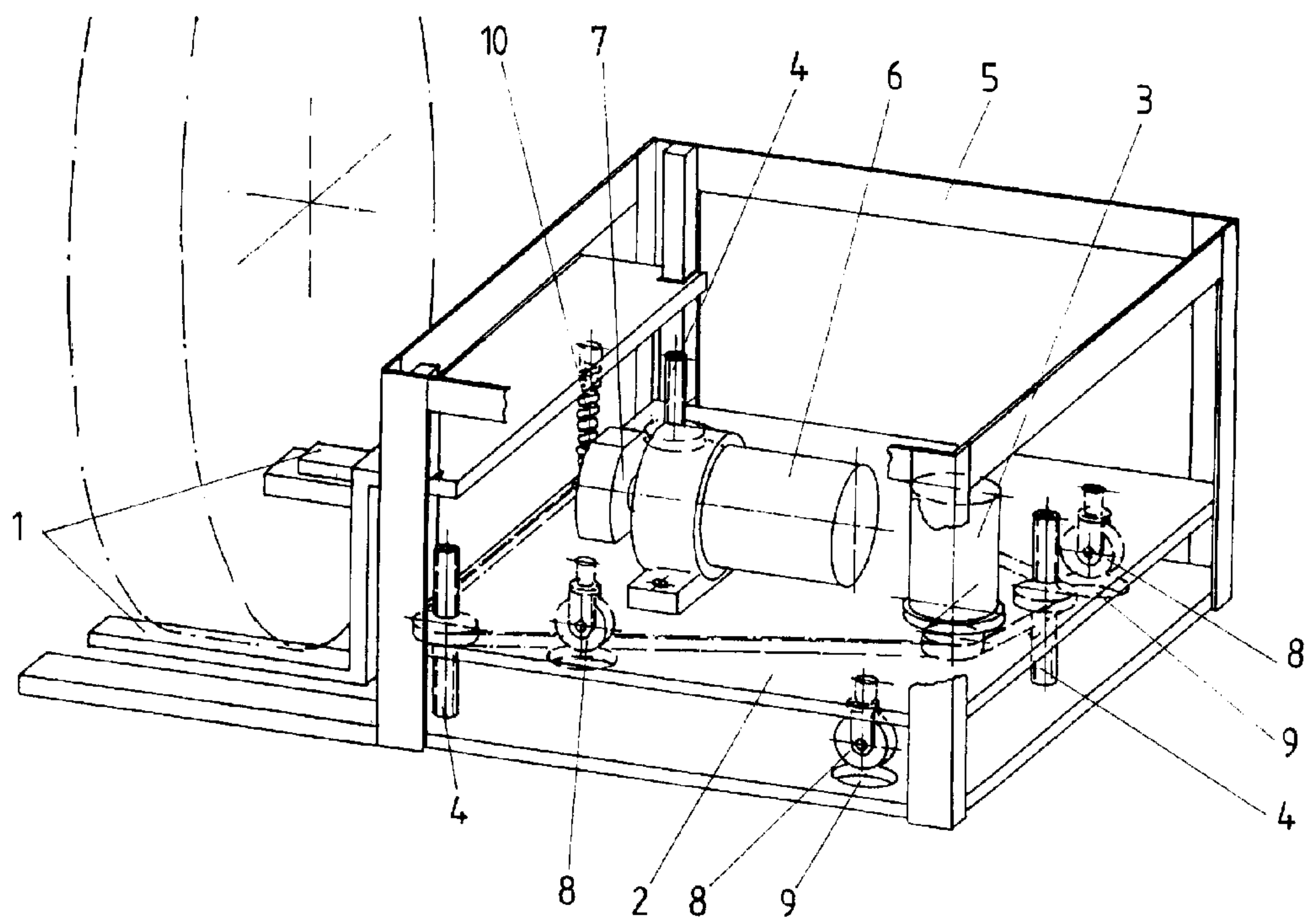
(54) Titre : PROCEDE ET DISPOSITIF DE CONTROLE D'AMORTISSEUR DE VEHICULES
(54) Title: DEVICE AND METHOD FOR TESTING VEHICLE SHOCK ABSORBERS



(57) Abrégé/Abstract:
In known devices for testing vehicle shock absorbers, the tires, which have a dampening effect, are not taken into account, so that the measurement results may be falsified by up to about 30 %, depending on the tire pressure. In addition, when the wheels are mounted on the vehicle, no shock absorber characteristic curve may be measured, only individual values. In the disclosed device, the actuating variable "tire" is eliminated by a regulation process that consists in normalising the resonance amplitude, a considerably more accurate measurement being thus obtained. In addition, the spring constant of the wheel suspension is determined before actually testing the shock absorbers, allowing defective springs to be detected. Finally, car body oscillations may also be determined, causing an additional precision gain. For the first time it becomes possible to determine a shock absorber characteristic curve without having to dismount the shock absorbers.

ABSTRACT

In known devices for testing vehicle shock absorbers, the tires, which have a dampening effect, are not taken into account, so that the measurement results may be falsified by up to about 30%, depending on the tire pressure. In addition, when the wheels are mounted on the vehicle, no shock absorber characteristic curve may be measured, only individual values. In the disclosed device, the actuating variable "tire" is eliminated by a regulation process that consists in normalising the resonance amplitude, a considerably more accurate measurement being thus obtained. In addition, the spring constant of the wheel suspension is determined before actually testing the shock absorbers, allowing defective springs to be detected. Finally, car body oscillations may also be determined, causing an additional precision gain. For the first time it becomes possible to determine a shock absorber characteristic curve without having to dismount the shock absorbers.

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DEVICE AND METHOD FOR TESTING VEHICLE SHOCK ABSORBERS

The invention relates to a device for testing vehicle shock absorbers with at least one receiving means for receiving a wheel of a vehicle, means for exciting oscillations in the received wheel, and means for determining the amplitude of the oscillations at various frequencies as well as an evaluation and output unit.

The invention also relates to a method for testing vehicle shock absorbers.

Devices according to the preamble are known, e.g. from the booklet "BOGE SHOCKTESTER." There, a stationary test station is described onto which a vehicle can drive with two wheels simultaneously. A wheel receiving means adapted to oscillate vertically up and down initiates movement of the axle mass. After disconnecting the drive, the oscillation of the axle diminishes gradually and passes through the resonance of the axle. The amplitude of the oscillation at resonance is physically and mathematically related to the damping. The oscillation amplitude is received by a distance sensor and displayed or recorded, respectively. The measurement has the disadvantage that the result depends strongly on the tire pressure; a change in tire pressure of 1 bar may distort the measurement result by up to 30%.

A shock absorber test station operating according to the above principle is also known from the German utility model G 93 03 201. Here, too, a wheel is oscillated via a spring and the maximum oscillation amplitude is measured at the resonance frequency. The change in the oscillation amplitude correspond to a change of the force. The peak amplitude of the force is subtracted from the static force which had been determined before the start of the oscillations. The disadvantage here is, too, that different tire pressures significantly influence the measurement result.

In addition, both devices include only a single sensor for measuring the oscillation amplitude and the force amplitude. Furthermore, there is no provision for testing the spring of the oscillating system which adversely affects the operating safety. Finally, both devices are designed as stationary test stations which small repair shops can often not afford or which take up too much floor space. Consequently, there exists a need for a handy, portable unit for testing shock absorbers.

From DE-A-43 05 048, there is known a method for testing a shock absorber of an automobile, wherein the values designated as damping coefficient is determined through a parameter estimation method. The estimated damping coefficient is compared to a reference value for determining if the deviation lies within a certain tolerance range.

This method is therefore restricted to the determination of a single value and to a comparison between this single value and with a reference value, wherein furthermore the evaluation is based on an estimation method. It is therefore not possible to use this method for effectively assessing the condition of a shock absorber over a wider operating range.

It is therefore the object of the invention to provide a device for testing shock absorbers according to the preamble while eliminating the afore described disadvantages and testing the shock absorbers adequately essentially independent of the tire pressure and the masses.

This object is solved by the invention in that there are means provided for determining the characteristics of the shock absorber while a wheel is positioned on a vehicle.

Until now, the characteristics of a shock absorber, i.e. a force-velocity diagram, can only be tested in special test stations on shock absorbers that have been removed from the vehicle. On installed shock absorbers, it is only possible to measure separate quantities and to compare those quantities with reference values, which is not sufficient to assess the state of a shock absorber.

In one embodiment of the invention, the means for determining the characteristics of a shock absorber include means for determining the power supplied by the wheel receiving means to the oscillating system comprising the shock absorber and the spring of the vehicle.

This embodiment is advantageous in that measurement values can be obtained easily and inexpensively and that uncontrolled side effects (oscillating engine mass) have only an insignificant impact on the measurement results.

In another embodiment of the invention, the means for determining the characteristics of a shock absorber include means for determining the acceleration of the masses in the oscillating system comprising the shock absorber and the spring of the vehicle.

This modification does not have the advantages of the embodiment mentioned first, but provides a generally useful approach. In this case, the acceleration is measured with acceleration sensors, while the accelerated masses are measured or known.

In an improvement of the invention, there are disposed sensors on the wheel hub and on the chassis of the vehicle, and the excitation stroke of the means for exciting wheel oscillations is variable.

In this way, the spring constant of the wheel suspension can be measured before testing the shock absorber and the amplitude at the resonance frequency can be accurately determined.

According to the invention, the spring constant of the elements of the wheel suspension can be measured using the sensors disposed on the wheel hub and on the chassis of the vehicle.

This method also provides the values for determining the resonance frequency of the chassis and the relative movement between the chassis and the wheel hub, respectively.

There are also provided means for adjusting the level of the vehicle chassis.

Advantageously, the device is portable.

The embodiment of the invention is characterized in that a controllable eccentric cam is provided for varying the excitation stroke.

The output unit is preferably provided with a display and/or a printer.

The invention also relates to a method for testing vehicle shock absorbers, the method comprising the following steps:

- Raising a wheel of the vehicle and determining the spring constant of the wheel suspension

- Varying the excitation frequency and determining the response frequency of the wheel suspension

- Adjusting the resonance amplitude of the wheel hub at the determined response frequency

- Determining the characteristics of the shock absorber

The measurement of the spring constant of the wheel suspension ensures that the measurement results of the shock absorber test are accurate and not affected by defective springs. It is, however, possible to determine if a spring is broken or begins to tear, since then the spring constant is different from the reference value, i.e. is larger or smaller. By normalizing the resonance amplitude in the third method step, the influence quantity "Tire" representing an unknown additional spring, is eliminated in the calculation from the measurement result. Consequently, accurate values for the effect of the shock absorber can be obtained.

According to the invention, there is provided that the values so obtained are conveyed to an evaluation and output unit.

In the following, an embodiment of the device of the invention representing an example is described with reference to the drawings. It is shown in:

FIG. 1 a device for determining the power supplied to the oscillating system,

FIG. 2 a schematic representation of the oscillation model,

FIG. 3 a schematic representation relating to the mechanical advantage of the wheel suspension.

Since the method which is based on determining the power supplied to the oscillating system, is the preferred measurement method, the procedure will be described hereinafter with reference to a device adapted for said method. It will be assumed that the power supplied to the system comprising the shock absorber and the spring is transferred to the shock absorber which is indeed the case, except for small friction losses.

As shown in FIG. 1, the device comprises at least one receiving means 1 for receiving a wheel of a vehicle, with the receiving means 1 shaped like a fork and disposed on the outside of housing 5 of the device. The receiving means 1 are movable in a vertical direction for raising and lowering the wheel. This is accomplished with the depicted device by raising the inside plate 2 connected to the receiving means 1. For this purpose, there is provided a servo motor 3 for vertically moving the inside plate 2 which is held in the respective position by, for example, threaded rods 4. For the purpose of rendering the device portable, there may be provided on the underside of the inside plate 2 casters 8 adapted to protrude from holes 9 in the bottom of housing 5 when the inside plate 2 is positioned in its lowest position.

There is provided a main motor 6 driving an eccentric cam 7 for causing oscillating of the raised wheel. The eccentricity of the eccentric cam 7 can be continuously adjusted. The eccentric cam 7 is connected to the receiving means 1 for the wheel through spring means 10, for example through a coil spring. In this fashion, the wheel can be made to oscillate by way of a variable excitation stroke.

The device may, of course, be implemented in other ways; it may be provided with a hydraulic drive unit for operating, on one hand, hydraulic cylinders for raising and lowering the inside plate 2 and, on the other hand, for operating a hydraulic cylinder for adjusting the eccentricity of the variable eccentric cam 7. In this way, a functional device according to the invention for testing vehicle shock absorbers may be implemented with just the hydraulic drive unit and a main motor 6.

In addition, there are provided sensors for determining the oscillation amplitude at different frequencies, i.e. for measuring the excitation force (difference amplitude of spring means 10) and the oscillation amplitude of the wheel hub and the vehicle chassis. By using the latter two sensors, it is possible to measure the spring constant of the wheel suspension. In addition to the afore described sensors for measuring the position of the body (chassis), of the wheel hub and of the wheel receiving means 1, with the sensors capable of measuring the absolute movement of these measurement points and the relative movement between the measurement points, there are also provided means for determining the power supplied to the oscillating system. This can be done, for example, by measuring the force and velocity on the excitation spring 10.

All obtained results relate to the tire contact point. If values for the quantities acting directly on the measured objects (chassis spring, shock absorber) are required, then the mechanical advantage i_0 (FIG. 3) will have to be taken into account which is governed by the formula $i_0 = b : (a * \cos \alpha)$.

The measured results are conveyed to an evaluation unit which may be either a built-in computer or an external computer. The evaluation unit is in turn connected to a output unit which may be a display and/or a printer.

In order to better analyze the physical relationships, the oscillation system is mapped onto an oscillation model (FIG. 2), incorporating several permissible simplifications. For example, it will be assumed that the effect of the other springs which are not excited, may be neglected if the body of the vehicle remains at the same level during the measurement and if the amplitude of the body oscillation is negligibly small. If the body is motionless, then the coupling of the tested spring- shock absorber system to the other systems may be neglected. It will be discussed later how these conditions can be met.

An additional permitted assumption is to neglect damping by the tires which is small compared to the damping by the shock absorber.

In the oscillation model depicted in FIG. 2, the masses are labeled m, the spring constants c and the excursions s. The mass m1 is the oscillating mass of the vehicle body (body mass) which can be determined from the static tire contact force and the mass of the tire. The spring constant c1 of the body spring is determined at the onset of the measurements, including possible nonlinear spring characteristics. The shock absorber which represents the actual object of the measurement, is labeled k1.

The mass m2 is the oscillating mass of the wheel and the wheel suspension (wheel mass) which can be determined from the dynamic characteristics of the system. The spring-like effect of the tire (tire spring) c2 (and possibly also the wheel mass) can be determined for a specific vehicle from the approved tires with the highest spring constant (e.g. provided by the manufacturer). These values, if known, may be stored in the evaluation unit and recalled when needed.

The mass m3 is the mass of the wheel receiving means 1 (excitation mass) which is known. The spring 10 used for exciting the oscillations, labeled c3 in FIG. 2, provides coupling of the excitation power into the oscillating system. Spring 10 is designed as probe spring for determining the excitation force acting thereon. The excitation itself is provided by the variable excitation stroke having an adjustable frequency. The center position of the exciting oscillation may be adjusted. In this way, the vehicle body can be controllably maintained, for example, via a control circuit, at a constant level during the entire measurement. Consequently, the parameters frequency, stroke, and center position for the excitation may be preset. The damping is measured at a fixed, previously selected frequency which is held constant during the entire measurement. It is feasible, by way of the variable excitation stroke, to vary the power supplied to the oscillating system and to record the characteristics of the shock absorber.

The method for testing the shock absorber with the method of the invention is as follows:

1. First, the device is wheeled on casters 8 proximate to the wheel of a vehicle and the receiving means 1 are positioned around the wheel on both sides of the contact surface of the tire. Subsequently, the inside plate 2 of the device is raised by the servo motor 3, whereby the casters 8 are also raised and the housing 5 settles on the floor. Simultaneously, as a safety test before the actual testing of the shock absorber, the spring constant c1 of the body spring (wheel suspension) is determined in order to detect and prevent damage to the spring, so that the measurement results are not distorted by defective springs. The spring constant may also be compared directly to a stored reference value, with a message to be displayed in the event of significant deviations. Also determined and stored during raising is the static contact force of the tire and the distance between the wheel hub and the chassis. In addition, the friction of the wheel suspension is determined during raising. The contact force of the tire increases slowly when the wheel is raised, while the chassis is not yet moving because of the friction forces. The chassis only moves when the friction force is exceeded. In this way, the friction of the wheel suspension can be determined from the contact force of the tire and the distance between the wheel hub and the chassis.

2. The receiving means 1 is adjusted to a certain initial level. The static contact force of the tire is now measured at rest and the position of the chassis is recorded.

3. At this time, the main motor 6 is operated, sweeping the frequency through the region of the eigenfrequencies, for example, from the minimum to the maximum excitation frequency, with a preferably small excitation stroke of the variable eccentric cam 7 for finding the resonance frequency of the wheel suspension. Hereby, the oscillation amplitude between chassis and wheel hub is observed. There will be several resonances with increasing frequency. The first resonance is called body resonance; it typically lies between 0.5 and 2.5 Hz and is not meaningful as a measurement since the body exhibits a large oscillation amplitude and can consequently not be considered at rest, as would be required. The second oscillation maximum is typically in the range between about 7 Hz and 15 Hz. This value is the desired measurement frequency, where the vehicle body exhibits only very small, negligible oscillation amplitudes. This frequency is also advantageous for the transmission of power from the excitation to the shock absorber (the wheel resonance is here about equal to the power resonance).

4. In the next step, the previously determined resonance frequency is preset and the excitation stroke is increased step-by-step by adjusting the

eccentric cam starting at zero. Each time, when a new oscillation state has stabilized (response time), a possible displacement of the chassis with respect to the reference level is countered by a level adjustment of the wheel receiving means (readjustment). At this point, the power supplied to the probe spring and the resulting oscillation amplitude between the body and the wheel hub are measured. The velocity can be derived from this amplitude and from the known frequency. The shock absorber force can be determined from the power supplied to the system (and absorbed by the shock absorber) and the velocity. The shock absorber force is the average value of the shock absorber force between the pull stage and the push stage.

In general, the pull stage and the push stage in shock absorbers are designed differently in that the pull force is larger than the push force at the same velocity. This feature of a shock absorber causes the chassis to come closer to the wheel hub since the shock absorber is easier compressed than pulled apart. The resulting difference force thus pre-biases the body spring. Since the decrease in chassis level resulting from the difference between the pull and push stage is compensated, as described above, by the level control means (in general: raising of the receiving means 1), this level adjustment can be used to determine the spring excursion used to pre-bias the body spring. The force difference between the pull and push stage can be determined from the measured spring constant and the spring excursion. The characteristics of the shock absorber can consequently be determined separately for the pull and the push stage point by point up to the power limit of the excitation.

This characteristics can then be compared with a given set point characteristics. The damping constant for the vehicle body can be determined from the mass of the body m1, the spring constant c1 and the shock absorber characteristics k1 according to the formula

$D = k1 : (2 * (c1 * m1)^{-2})$

5. The wheel mass is now determined from the quantities which have been determined thus far, and from the oscillation dynamics of the system. The damping of the wheel damping is calculated for a specific vehicle by assuming a certain tire spring constant (worst-case scenario) from the values for the wheel mass m2, tire spring c2, body spring c1 and the shock absorber characteristics k1 using a formula similar to the formula given under 4.

6. It can thus be determined if the body and/or wheel of the vehicle complies with a certain specified minimum damping value.

It is feasible to test only the shock absorber of one wheel or all shock absorbers of a vehicle and to display or print the individual or combined result(s) on the output unit. The display may, of course, also be provided with a complete menu-driven graphic user interface.

The characteristics of the shock absorber can be determined from the acceleration of the oscillating masses as follows:

The forces acting on the oscillating masses can be determined from the values of the acceleration of these masses according to the formulas F = m * a. The force acting on the mass m1 (body) is then apportioned to both the spring and the shock absorber, and the characteristics of the spring and the shock absorber are recorded, whereby the values for the masses have to be known. The masses are also determined beforehand from the movement of the masses.

In this method, the accelerations of all oscillating masses as well as the excitation force have to be measured. From the accelerations, the velocities and the excursions of the masses can be calculated. Since each of these quantities alone characterizes the movement of a mass, the term "movement" will be used hereinafter as a general term without referring to a specific quantity. The excitation force is determined through a probe spring by measuring its length. The force on the probe spring with the vehicle at rest is called the static force. The excitation force F is the force on the probe spring when the system is moving. All quantities are recorded as a function of time.

The static force, the excitation force and the mass accelerations are required for determining the masses. By using the designations of FIG. 2 and F1, F2 and F3 for the forces acting on the masses m1, m2 and m3 and Fg1, Fg2 and Fg3 as the weights of the masses m1, m2 and m3, the following system of equations is obtained:

$$m_1x_1'' = F1 - Fg1$$

$$m_2x_2'' = F2 - F1 - Fg2$$

$$m_3x_3'' = F3 - F2 - Fg3$$

$$F3 = F$$

wherefrom the following equation GL1 can be derived:

$$m_1x_1' + m_2x_2' + m_3x_3' = F - (Fg1 + Fg2 + Fg3) = F - Fg$$

The sum of all forces acting on the masses is the excitation force minus the static weight. For calculating the masses, the accelerations and the excitation force are measured at three different points in time and inserted into the above equation. The result is a system of equations for the three unknown masses.

The force F1 acting on mass m1 is the sum of the spring force and the damping force. The force F1 is given by the equation F1 = c * x + k * v. When the velocity v is equal to zero, then the entire force is absorbed by the spring. The spring stiffness c is given by the instantaneous displacement and the spring force. If the spring displacement is zero, then the force is supplied by the shock absorber. This force and the velocity then determine the characteristics k of the shock absorber. The various zero crossings occur twice during an oscillation, once for the push phase and once for the pull phase. This yields the different characteristics for the pull and push phase.

The oscillation amplitude can be changed by changing the supplied power or the excitation frequency, thus enabling the characteristics to be examined point by point. The spring characteristics can also be measured beforehand, and the shock absorber force may be determined later by apportioning the forces directly.

The assumption underlying the measurement is that the chassis executes only very small oscillation amplitudes and that the level is maintained. In order to accomplish this, the measurement is performed when the wheel is at resonance and the level is controlled to a constant level by a level-dependent excitation.

CLAIMS:

1. A device for testing vehicle shock absorbers, comprising:

at least one receptacle for receiving a wheel of a vehicle;

means for exciting oscillations in the received wheel;

means for determining the amplitude of the oscillations at different frequencies;

an evaluation and output unit; and

means for determining the characteristics of a shock absorber of the wheel while the wheel is mounted on the vehicle;

wherein the means for determining the characteristics of the shock absorber include means for determining a force applied by the wheel receptacle to the oscillating system comprising the shock absorber and the spring of the vehicle.

2. The device of claim 1, and further comprising means for determining a power applied by the wheel receptacle to the oscillating system comprising the shock absorber and the spring of the vehicle.

3. The device of claim 1, and further comprising sensors disposed on the wheel hub, the receptacle and the body of the vehicle.

4. The device of claim 1, and further comprising a force sensor disposed on the wheel receptacle and at least one of an

excursion sensor or angle sensor disposed on the exciting means.

5. The device of claim 1, and further comprising means for recording and evaluating measurement data separately as pull stage values and as push stage values.

6. The device of claim 1, wherein an excitation stroke of the exciting means is variable.

7. The device of claim 3, wherein the sensors disposed on the wheel hub, the receptacle and the body can be used to measure a spring constant of elements of the wheel suspension.

8. The device of claim 1, and further comprising means for adjusting the level of the body.

9. The device of claim 1, wherein the device is movable.

10. The device of claim 6, and further comprising a controllable eccentric cam for varying the excitation stroke.

11. The device of claim 1, wherein the output unit comprises at least one of a display and a printer.

12. A method for use with a device for testing vehicle shock absorbers in accordance with claim 1, wherein the determined values are conveyed to an evaluation and output unit.

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PATENT AGENTS

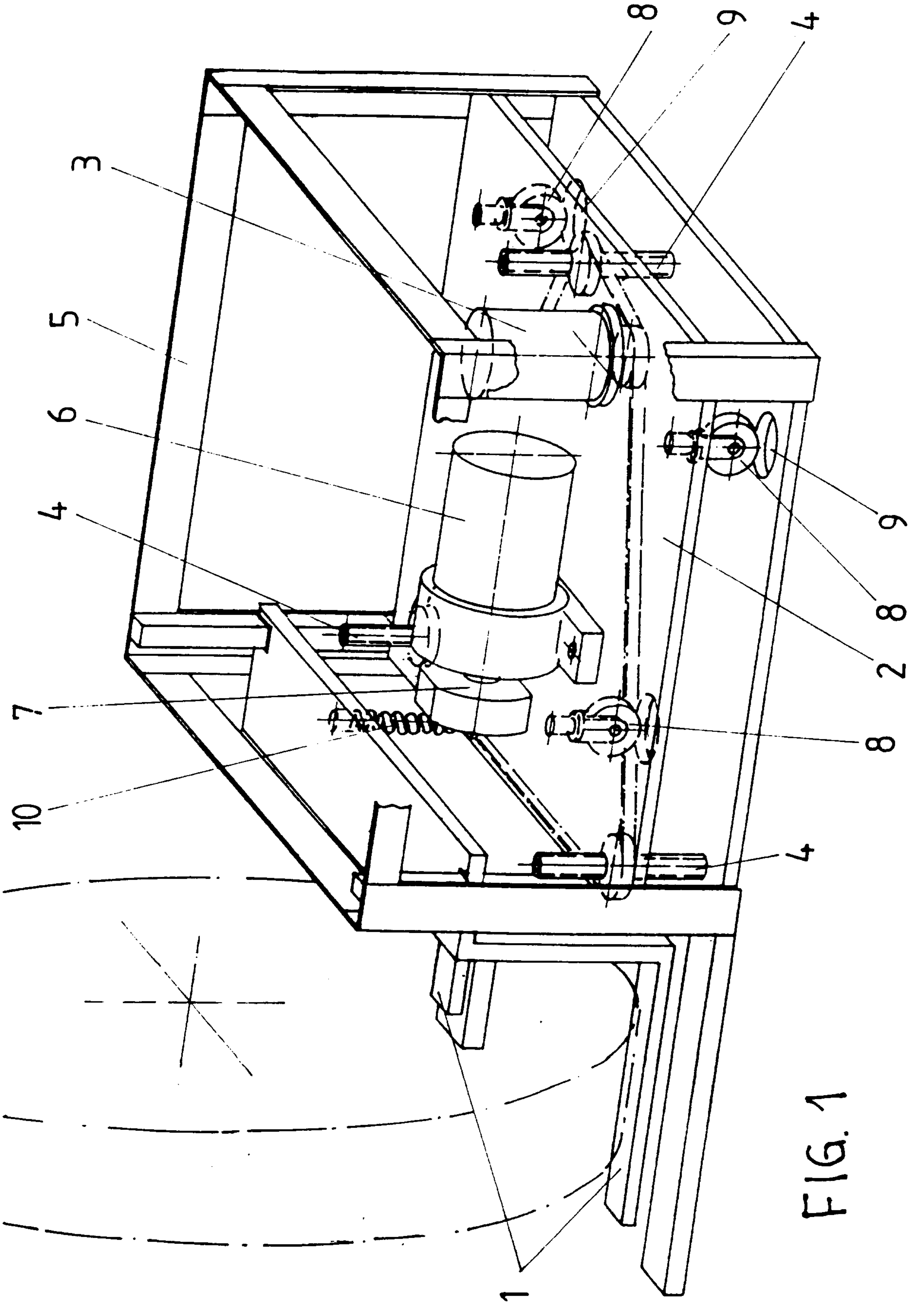


FIG. 1

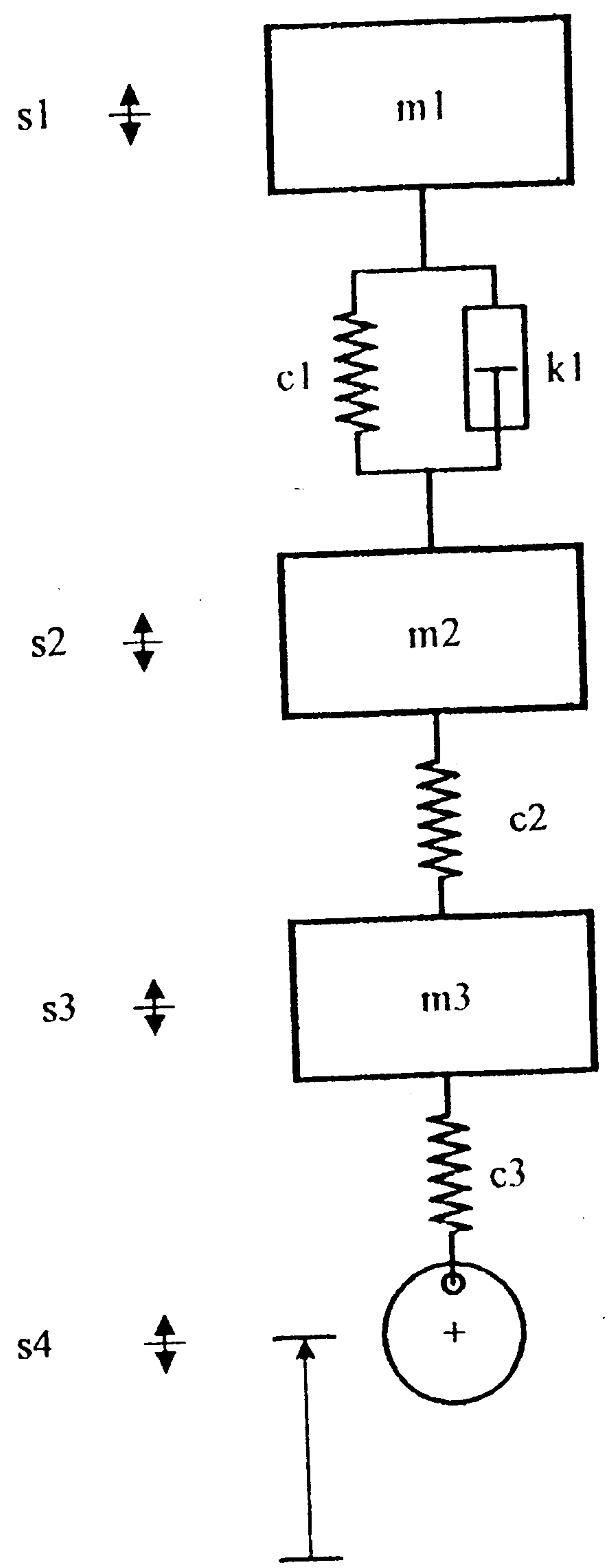
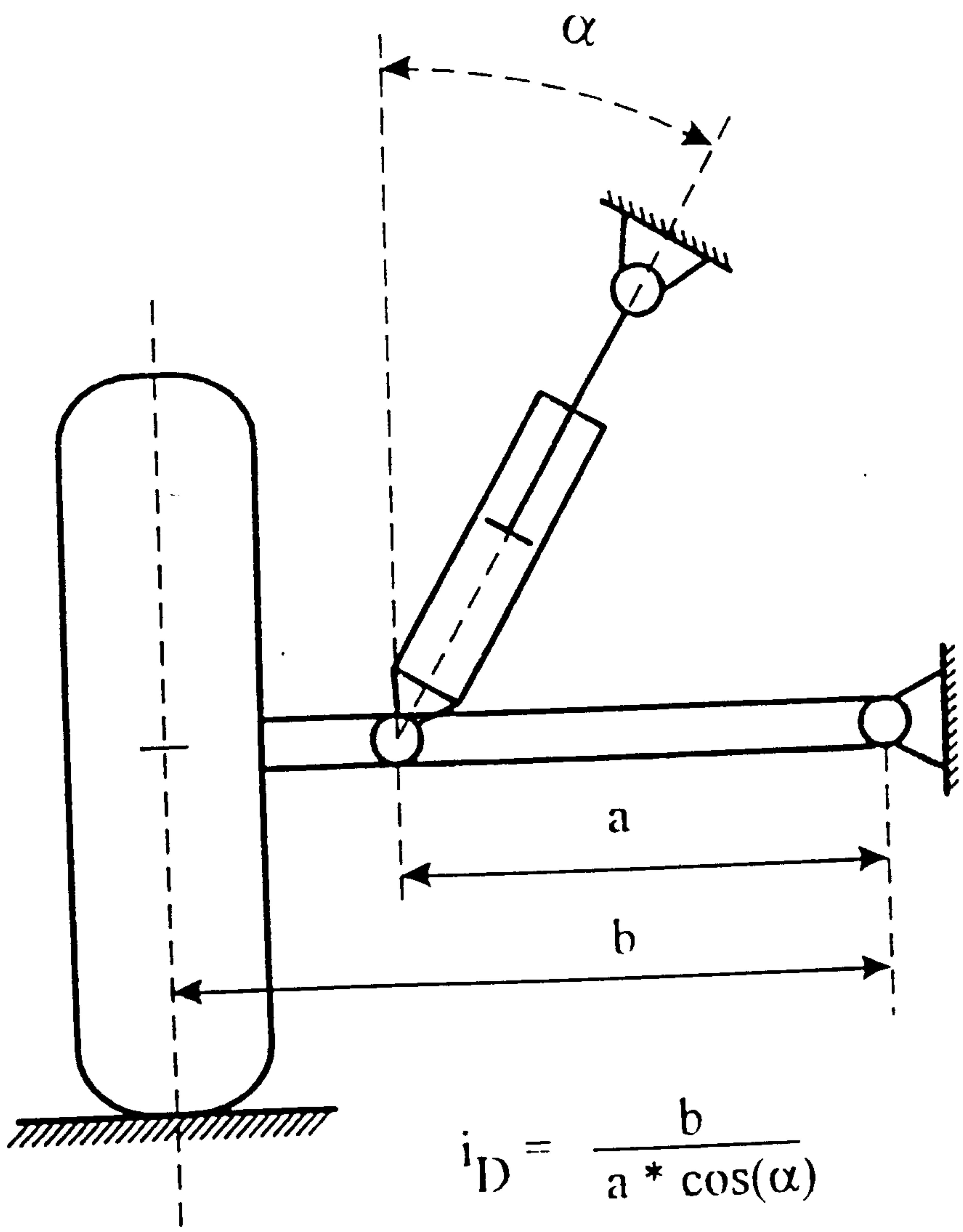
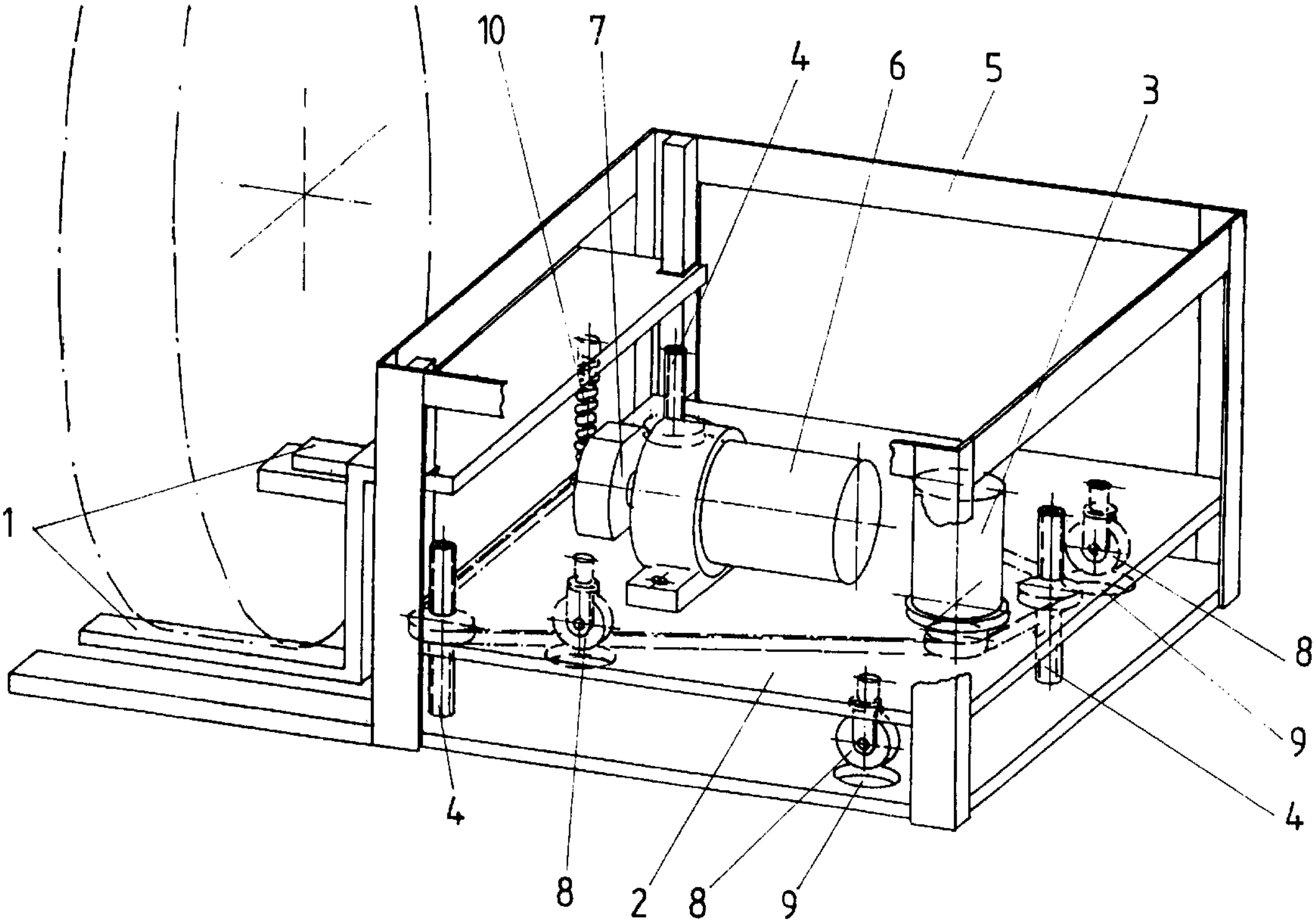


FIG. 2



$$i_D = \frac{b}{a * \cos(\alpha)}$$

FIG. 3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