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(54) **Lifting vehicle comprising mobile lifting arm and control device**

Hubfahrzeug mit Hubarm und Steuervorrichtung

Véhicule élévateur avec bras de levage et dispositif de commande

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Description

[0001] The present invention relates to a control method for a vehicle comprising a telescopic lifting arm provided at one end thereof with a piece of working equipment such as a platform, a fork-shaped tool, or a shovel.

[0002] The lifting arm is preferably telescopic and is moved by an operator via a joystick for moving weights carried by the piece of working equipment.

[0003] The movement is executed by an operator via an open-loop control system, which activates a power circuit, for example a hydraulic power circuit, via a control element, for example a joystick. The movement of a lifting arm must be executed by the operator with the maximum care in order not to jeopardize stability of the vehicle within an admissible working space in which the machine can operate safely. Furthermore, sudden commands, for example sudden arrests of the arm, can cause accelerations and dynamic overloads that are equally dangerous for the stability of the vehicle, which, in the case of particularly sharp manoeuvres, can lose adherence or even turn over.

[0004] US-A-2005177292 discloses a vehicle according to the preamble of claim 1.

[0005] The aim of the present invention is to provide a lifting vehicle comprising a control device for a lifting arm that will be free from the drawbacks referred to above.

[0006] The aim of the present invention is achieved via a vehicle according to Claim 1 and a method according to Claim 10.

[0007] For a better understanding of the present invention, a preferred embodiment thereof is now described, purely by way of non-limiting example, with reference to the annexed drawings, wherein:

- Figure 1 is a perspective view of a vehicle according to the present invention;
- Figure 2 is a diagram of a hydraulic control circuit mounted on the vehicle of Figure 1;
- Figure 3 is a graph that illustrates the variation of the first natural frequency of a lifting arm of the vehicle of Figure 1 as a function of the weight lifted and of the extension of the lifting arm; and
- Figures 4a, 4b and 4c illustrate, respectively, experimental results of measurements of residual oscillations following upon an input signal (Figure 4c) comparing the case without control with the case where the control forming the subject of the present invention is adopted.

[0008] With reference to Figure 1, designated as a whole by 1 is a lifting vehicle comprising a frame, a preferably telescopic arm 3 hinged to the frame, a fork-shaped tool 4 mounted to a free end portion of the arm 3, and a driving cab 5.

[0009] The vehicle 1 is moreover provided with tyred wheels 6 set on two axles and stabilizing arms 7 both front and rear (illustrated in Figure 1 are only the front arms). In particular, the front and rear stabilizing arms 7 are actuated via respective hydraulic cylinders 8 and are mobile between a raised position and a resting position. When the stabilizing arms 7 are in the raised position, the tyred wheels 6 rest on the ground and the vehicle 1 can circulate. When the stabilizing arms 7 are in the resting position, the latter are lowered via the hydraulic cylinders 8 and rest by means of purposely provided plates 9 on the ground.

[0010] The hydraulic cylinders 7 are sized for raising the vehicle 1 also in conditions of maximum load and consequently, at the discretion of the operator sitting in the driving cab 5, for raising the tyred wheels 6 off the ground. The arm 3 can consequently be actuated both when the tyred wheels 6 rest on the ground and the stabilizing arms 7 are in the raised position and when the stabilizing arms 7 are in the resting position and the tyred wheels 6 are raised off the ground.

[0011] The arm 3 has an angular degree of freedom, i.e., the angle of lifting with respect to a plane passing through the axes of the tyred wheels 6, and can have a variable length due to the extension of the arm 3.

[0012] The angle of lifting and the extension of the arm 3 are powered via a hydraulic circuit (illustrated schematically in Figure 2) comprising a pump 10, a plurality of actuators 11 (only one of which is illustrated), and means for adjusting the capacity 12, for example, one or more servo valves, preferably of the continuous-positioning type, for governing the actuators 11.

[0013] According to the present invention, the vehicle 1 further comprises a automatic electronic control device 13 connected to the valve 12 and configured for reducing or eliminating the oscillations of the arm 3 due to the movement of lifting.

[0014] The control device 13 receives at input an electric signal SJ, for example a voltage signal, from an electronic joystick 14 and processes a control signal SV for governing the valve 12. In particular, the signal SJ governs the speed of lifting of the arm 3 by means of the valve 12.

[0015] Furthermore, the control device 13 receives at input the signals coming, respectively, from a load cell 15 mounted on the vehicle 1 for detecting the weight of a load lifted by the arm 3 and from a position sensor 16 mounted on the vehicle 1 for detecting the extend of extraction of the arm 3.

[0016] For example, the load cell 15 is mounted between the head of the hydraulic cylinder 11 and the arm 3, whilst the position sensor 16 is mounted directly on the arm 3.

[0017] In particular, the control device 13 processes the signal SJ and generates a signal SV defined by the convolution

of the signal SJ with a plurality of pulses set apart by a predetermined time interval and having a predetermined amplitude, in which the time interval and the amplitude are defined on the basis of the signals received from the load cell 15 and from the position sensor 16.

[0018] The control device 13 implements an open-loop control, known as "feed-forward control", comprising the steps of:

- estimating the kinetic energy associated to the mode of vibration of the system comprising the arm 3 for deriving at least the first natural frequency of the system itself in the conditions of load and in the geometrical conditions detected via the load cell 15 and/or the position sensor 16;
- processing a plurality of pulses, or of pulsations having a finite duration, appropriately spaced apart by a time interval defined on the basis of the first natural frequency and sized in amplitude so as to provoke corresponding responses on the system, which, added together according to an appropriate phase shift, generate by interference an overall response having an oscillation that is substantially small or zero at the moment when the last pulse has terminated; and
- carrying out a convolution of the plurality of pulses with the signal SJ set by the user for generating the signal SV; for example, in the case of a non-damped linear system, the input signal can be a pulse of unit amplitude which, applied to a mechanical system, causes a vibration having a first natural frequency of period T; a signal SV compensated on the basis of the control described previously, is constituted by a first pulse of amplitude 0.5 and by a second pulse of amplitude 0.5 at a time T/2, i.e., at the half-period.

[0019] As may be readily noted, the free oscillations generated by the system in response, respectively, to the first and second pulses cancel out by interference at the end of the second pulse. Furthermore, the energy content of the two pulses is equivalent to that of the pulse SJ since the sum of the two amplitudes of the signal SV is equal to that of the signal SJ.

[0020] The result that is valid for a non-damped linear system can be extended to a damped linear system. In this case, the overall response is once again constituted by the sum of the free response of the system to the first pulse and of the free response of the system to the second pulse. The equation of constraint for determining the phase and the amplitude of the pulses is defined by the condition that the overall amplitude of the response of the system to the two pulses is zero at the moment in which the last pulse has terminated. The expressions of the amplitude and of the phase in the case of two pulses are respectively

$$A_1 = \frac{1}{1 + k} \quad A_2 = \frac{k}{1 + k}$$

where

$$k = e^{\frac{-\xi\omega_0}{\sqrt{1-\xi^2}}}$$

$$\Delta T = \frac{\pi}{\omega_0 \sqrt{1 - \xi^2}}$$

where

ω_0 is the first natural frequency

ξ is the dimensional modal damping associated to the first natural frequency. The damping can be calculated via the logarithmic-decrement formula.

[0021] As may be noted, appearing in the denominator in the expression of the interval of time previously given is the first natural frequency of the free oscillation of the arm 3 having modal damping ξ . Consequently, the delay to which the second pulse and all the subsequent pulses must be applied corresponds to a half-period of free oscillation of the arm 3. In the case of more than two pulses, the delay is an integer multiple of the ΔT given previously.

[0022] The convolution of a pair of pulses with any input signal SJ enables 'forming', i.e., modification, of the signal SJ so as to obtain a compensated signal SV.

[0023] For example, if the signal SJ is a ramp speed signal, the signal SV given by the convolution of SJ with the two pulses described previously is a broken line having three segments delimited by four singular points of which the first is spaced apart from the second and the third is spaced apart from the fourth by ΔT .

[0024] If SJ is a step, i.e., a sharp signal, SV is defined by two consecutive and superimposed steps.

[0025] In any case, the signal SV 'formed' is able to reduce or substantially eliminate to zero the oscillations of the arm 3 after the second singular point.

[0026] In the case where it is necessary to increase the effectiveness of the control in regard, for example, to errors of evaluation of the first natural frequency, it is possible to use more than two pulses. In this case, for each pulse m beyond the second, the equation of constraint is defined so that the derivative with respect to the frequency of order $n = m - 2$ of the overall response referred to previously and adapted to m pulses vanishes.

[0027] On the basis of the formulas appearing above, the form of the signal SV depends upon the first natural frequency of the arm 3. However, the first frequency depends directly upon the weight of the load lifted by the fork-shaped equipment 4.

[0028] In order to 'form' the signal SV on the basis of the effective working conditions of the arm 3, the control device 13 stores a matrix within which the natural frequency of the arm 3 is indexed as the weight of the load applied to the arm 3 varies.

[0029] Furthermore, the value of the first natural frequency changes, as illustrated in Figure 3, also as the extent of extraction of the arm 3 varies. In this case, the matrix stored in the control device 13 is structured for identifying a single value of the first resonance frequency of the arm 3 for each pair of values of the weight of the load and of the extent of extraction of the arm.

[0030] Furthermore, the natural frequencies of the arm 3 can depend upon numerous other working parameters of the vehicle 1, as, for example, in the case where the vehicle 1 is lifted on the stabilizing arms 7 or else in the case where the stabilizing arms 7 are in the raised position when a command is sent to the arm 3 for lifting a load. For instance, there has been found a substantial decrease of the value of the first natural frequency, given the same weight of the load applied to the fork-shaped equipment 4 and of extent of extraction of the arm 3, when the vehicle 1 rests directly on the tired wheels 6 as compared to when the tired wheels 6 are raised off the ground via the stabilizing arms 7.

[0031] In this case, the indexing matrix is multidimensional and is structured so as to enable a single value of the first resonance frequency to be obtained also on the basis of whether the vehicle 1 is resting or otherwise on the stabilizing arms 7.

[0032] In addition, it is possible to store in the control device 13 a second multidimensional matrix for indexing the variation of the modal damping on the basis of one or more of the working parameters of the vehicle 1. For example, the working parameters are one or more of the parameters previously indicated for variation of the first natural frequency.

[0033] According to a preferred embodiment of the present invention, the indexing matrix is constructed by performing a purposely devised calibration, for example at the end of the production process or else in the step of definition of the prototype of the vehicle. In particular, a plurality of pairs of values of weight and extent of extraction of the arm 3 is identified. For each pair the value of the first natural frequency of the arm 3 is measured when the vehicle 1 rests both on the stabilizing arms 7 and directly on the tired wheels 7, and the indexing matrix to be stored in the control device 13 is thus constructed.

[0034] The value of the first natural frequency and of the higher-order frequencies can be detected via an accelerometer 17 mounted on the arm 3 and connected to the control device 13 that enables analysis of the signal both in the time domain and in the frequency domain.

[0035] As described above for construction of the indexing matrix of the first natural frequency, an automatic control device 13 according to the present invention can comprise a matrix for indexing the damping coefficient for the first mode of vibration in order to store the different values as the load applied on the arm 3 varies and/or the extent of extraction of the arm 3 varies and/or according to whether the lifting vehicle 1 rests or otherwise on the stabilizing arms 7.

[0036] The calibration step further comprises a subsequent compensation stage in order to take into account the delay with which the hydraulic cylinder 11 responds to the variations of capacity governed via the signal SV and the valve 12.

[0037] On the basis of the foregoing, it is important for the pulses subsequent to the first to be synchronized in order for the oscillations of the arm 3 to be reduced or substantially eliminated after the second singular point of the signal SV.

[0038] However, phase shifts with respect to the half-period enable in any case more than satisfactory reductions of the oscillations to be obtained. Preferably, the pulses can be set apart by a ΔT^* such that $0.5\Delta T < \Delta T^* < 1.5\Delta T$ to obtain a decrease in the oscillations of the arm 3. Even more preferably, $0.75\Delta T < \Delta T^* < 1.25\Delta T$ to reduce further the oscillations of the arm 3.

[0039] Furthermore, it should be considered that the arm 3 is governed by a hydraulic circuit that affects the response time of the cylinder 11 with respect to the signal SV that governs the valve 12. In this connection, it has been found that the hydraulic circuit downstream of the valve 12 tends to respond with a delay that differs according to whether it is the

first or second singular point and according to the type of command, i.e., for example according to whether the command is to cause the arm 3 to start to rise or else to cause the arm 3 to start to descend.

[0040] In particular, a measurement in the time of the capacity of the hydraulic circuit superimposed on the signal SV in relation to a command for causing the arm 3 to start to rise shows that the delay in the variation of capacity in response to the first singular point of the signal SV is shorter than the delay of the variation of capacity in response to the second singular point of the signal SV.

[0041] Consequently, it is preferable for the second pulse to be delayed with respect to the first pulse of ΔT^* such that $\Delta T^* + C = \Delta T$ with $C > 0$ so that said modified delay is present, in the convoluted signal SV, between the first two singular points. In this way, it is possible to apply the desired command to the cylinder 11 taking into account the effect of the hydraulic circuit.

[0042] From the foregoing, the time constant C is characteristic of the hydraulic circuit and is consequently not linked to the period of free oscillation of the arm 3 according to the first natural frequency.

[0043] Compared in Figures 4a are the measurements made on the vibrations of the arm 3 respectively in the case of a command compensated with respect to the first natural frequency with two pulses illustrated in Figure 4b) and in the case of a non-compensated command (illustrated in Figure 4a).

[0044] As may be noted, the maximum peak is generated in response to a non-compensated step control signal. The response of the system in the case of compensated signal presents a considerably lower peak and subsequently the oscillations are considerably lower.

[0045] The advantages that the lifting vehicle 1 equipped with the control device 13 affords are described in what follows.

[0046] The control system 13 compensates the dynamic behaviour of the arm 3 and adapts to the variable weight of the load applied in use to the equipment 4. In this way, the dynamic overload of the arm 3 is reduced significantly. Said result is particularly appreciable because the majority of cases of overturning are due to the energy associated to said overload and in this way it is possible to reduce considerably the occurrence of said accident.

[0047] The step of calibration enables compensation of the control device 13 on the basis of the coupled system comprising also the hydraulic circuit.

[0048] The step of calibration can moreover be executed on each lifting vehicle 1 so as to guarantee the maximum precision of operation of the control device 13.

[0049] Finally, it is clear that modifications and variations may be made to the lifting vehicle 1 described and illustrated herein, without thereby departing from the sphere of protection of the present invention, as defined in the annexed claims.

[0050] The natural frequencies may also be measured via an analysis of the signal of the load cell 15 in the case where the latter is, for example, of a strain-gauge type.

[0051] The arm 3 may even not be telescopic.

[0052] The variation of the damping with respect to the extent of extraction of the arm 3 and to the load can be neglected in order to offer a control that is simpler to implement.

[0053] A lifting vehicle already in use can be updated via the installation of a control unit 13 and of the corresponding sensors, i.e., at least of the load cell 15 and of the position sensor 16.

[0054] The vehicle may further comprise a platform that can turn about a vertical axis and on which the arm 3 is hinged.

[0055] Furthermore, the control device 13 can be programmed for executing the convolution with the plurality of pulses only for portions of signal SJ. For example, it is possible for the convolution, and hence the control proper, to be executed only for that part of the signal SJ that is constituted by a step command. The step command corresponds to a sharp command, and in this way the control is applied selectively, and in particular only in the conditions deemed critical for stability of the lifting vehicle 1.

[0056] The lifting vehicle 1 may also be provided with tracks.

Claims

1. A lifting vehicle (1) comprising a mobile lifting arm (3) and first measuring means (16) for measuring at least one working parameter of said arm (3) and a control device (13) receiving an input signal (SJ) and configured for deriving the value of at least one first natural frequency of said arm (3) at least on the basis of said at least one working parameter and for determining a control, signal (SV) for actuating said arm (3), **characterized in that** said signal (SV) is defined at least partially by the convolution of said input signal (SJ) with a plurality of pulses having a time delay between one another and an amplitude defined as a function at least of said first natural frequency.
2. The vehicle according to Claim 1, **characterized in that** said control device (13) comprises storage means for storing a matrix that indexes a value of said first natural frequency with respect to each value of said working parameter.

3. The vehicle according to either Claim 1 or Claim 2, **characterized in that** said working parameter comprises at least one from among:

- a weight of the load acting on said arm (3);
 - an extension of said arm (3); and
 - an index that signals whether said lifting vehicle (1) rests on tyred wheels (6) or else on stabilization means (7).

4. The vehicle according to any one of the preceding claims, **characterized in that** said control device (13) is configured for deriving the value of a damping coefficient of the mode of vibration corresponding to said at least one first natural frequency at least on the basis of said working parameter, said time delay and amplitude being defined also as a function of said damping coefficient.

5. The vehicle according to any one of the preceding claims, **characterized in that** it comprises second measuring means (16) connected to said control device (13) for measuring said at least first natural frequency.

6. The vehicle according to Claim 5, **characterized in that** said second measuring means comprise at least one between an accelerometer and a load cell (16).

7. The vehicle according to any one of the preceding claims, **characterized in that** it comprises at least one fluidic actuator (11) for actuating said arm (3), means for adjusting the lifting capacity (12) connected to said fluidic actuator (11), wherein a second pulse of said control signal (SV) is phase-shifted with respect to a first pulse of said control signal (SV) by a time comprised between 0.5 and 1.5 times the period of said first natural frequency.

8. The vehicle according to Claim 7, **characterized in that** said second pulse is phase-shifted with respect to said first pulse by a time comprised between 0.75 and 1.25 times the period of said first natural frequency.

9. The vehicle according to any one of the preceding claims, **characterized in that** a first pulse and a second pulse of said plurality of pulses are set apart by ΔT^* such that:

$$\Delta T^* + C = \Delta T \text{ with } C > 0$$

$$\Delta T = \frac{\pi}{\omega_0 \sqrt{1 - \xi^2}}$$

where

ω_0 is the first natural frequency; and

ξ is the dimensional modal damping associated to said first natural frequency.

10. An automatic control method for a vehicle (1) comprising a mobile lifting arm (3), comprising the steps of:

- measuring at least one working parameter of said arm (3);
 - deriving the value of at least one first natural frequency of said arm (3) at least on the basis of said at least one working parameter; and
 - determining a control signal (SV) for actuating said arm (3), said signal (SV) being defined at least partially by the convolution of an input signal (SJ) with a plurality of pulses having a temporal delay between one another and an amplitude defined as a function at least of said first natural frequency.

Patentansprüche

1. Hubfahrzeug (1) mit einem mobilen Hubarm (3) und einem ersten Messmittel (16) zum Messen von mindestens einem Arbeitsparameter des Arms (3) und einer Steuereinrichtung (13), welche ein Eingangssignal (SJ) empfängt

und eingerichtet ist, den Wert von zumindest einer ersten natürlichen Frequenz des Arms (3) zumindest auf der Grundlage des mindestens einen Arbeitsparameters abzuleiten und ein Steuersignal (SV) zum Betätigen des Arms (3) zu bestimmen,

dadurch gekennzeichnet,

dass das Signal (SV) zumindest teilweise durch die Faltung des Eingangssignals (SJ) mit einer Mehrzahl von Pulsen definiert ist, welche eine Zeitverzögerung zueinander aufweisen und eine Amplitude, welche als eine Funktion zumindest von der ersten natürlichen Frequenz definiert ist.

2. Fahrzeug nach Anspruch 1,

dadurch gekennzeichnet,

dass die Steuereinrichtung (13) ein Speichermittel zum Speichern einer Matrix aufweist, welche einen Wert der ersten natürlichen Frequenz mit Bezug auf jeden Wert des Arbeitsparameters indexiert.

3. Fahrzeug nach Anspruch 1 oder Anspruch 2,

dadurch gekennzeichnet,

dass der Arbeitsparameter zumindest eines der folgenden aufweist:

- ein Gewicht der auf den Arm (3) wirkenden Last;
- eine Ausdehnung des Arms (3); und
- einen Index, welcher signalisiert, ob das Hubfahrzeug (1) auf bereiften Rädern (6) oder auf Stabilisierungsmitteln (7) ruht.

4. Fahrzeug nach einem der vorangehenden Ansprüche,

dadurch gekennzeichnet,

dass die Steuereinrichtung (13) zum Ableiten des Wertes eines Dämpfungskoeffizienten des Vibrationsmodus eingerichtet ist, welcher der mindestens einen ersten natürlichen Frequenz entspricht, auf zumindest der Grundlage des Arbeitsparameters, wobei die Zeitverzögerung und Amplitude auch als eine Funktion des Dämpfungskoeffizienten definiert sind.

5. Fahrzeug nach einem der vorangehenden Ansprüche,

dadurch gekennzeichnet,

dass es zweite Messmittel (16) aufweist, die mit der Steuereinrichtung (13) zum Messen der zumindest ersten natürlichen Frequenz verbunden sind.

6. Fahrzeug nach Anspruch 5,

dadurch gekennzeichnet,

dass die zweiten Messmittel zumindest eines zwischen einem Beschleunigungsaufnehmer und einem Kraftaufnehmer (16) umfassen.

7. Fahrzeug nach der vorangehenden Ansprüche,

dadurch gekennzeichnet,

dass es zumindest einen Fluidaktuator (11) zum Betätigen des Arms (3), Mittel zum Anpassen der Hubkapazität (12), welche mit dem Fluidaktuator (11) verbunden sind, aufweist, wobei ein zweiter Puls des Steuersignals (SV) mit Bezug auf einen ersten Puls des Steuersignals (SV) um eine Zeit, welche zwischen 0,5 und 1,5 mal der Periode der ersten natürlichen Frequenz liegt, phasenverschoben ist.

8. Fahrzeug nach Anspruch 7,

dadurch gekennzeichnet,

dass der zweite Puls mit Bezug auf den ersten Puls um eine Zeit, welche zwischen 0,75 und 1,25 mal der Periode der ersten natürlichen Frequenz liegt, phasenverschoben ist.

9. Fahrzeug nach einem der vorangehenden Ansprüche,

dadurch gekennzeichnet,

dass ein erster Puls und ein zweiter Puls der Mehrzahl von Pulsen durch ΔT^* getrennt sind, so dass:

$$\Delta T^* + C = \Delta T \text{ mit } C > 0$$

$$\Delta T = \frac{\pi}{\omega_0 \sqrt{1 - \xi^2}}$$

wobei

ω_0 die erste natürliche Frequenz ist; und

ξ die mit der ersten natürlichen Frequenz verbundene dimensionale modale Dämpfung ist.

10. Automatisches Steuerverfahren für ein Fahrzeug (1) mit einem mobilen Hubarm (3), aufweisend die Schritte:

- Messen zumindest eines Arbeitsparameters des Arms (3);
- Ableiten des Wertes zumindest einer ersten natürlichen Frequenz des Arms (3) zumindest auf der Grundlage des mindestens einen Arbeitsparameters; und
- Bestimmen eines Steuersignals (SV) zum Betätigen des Arms (3), wobei das Signal (SV) zumindest teilweise durch die Faltung eines Eingangssignals (SJ) mit einer Mehrzahl von Pulsen definiert ist, welche eine zeitliche Verzögerung zueinander aufweisen und eine Amplitude, welche als eine Funktion zumindest von der ersten natürlichen Frequenz definiert ist.

Revendications

1. Véhicule de levage (1) comprenant un bras de levage mobile (3) et un premier moyen de mesure (16) destiné à mesurer au moins un paramètre de fonctionnement dudit bras (3), et un dispositif de commande (13) recevant un signal d'entrée (SJ) et configuré pour dériver la valeur d'au moins une première fréquence propre dudit bras (3) au moins sur la base dudit au moins un paramètre de fonctionnement et pour déterminer un signal de commande (SV) pour actionner ledit bras (3), **caractérisé en ce que** ledit signal (SV) est défini au moins partiellement par la convolution dudit signal d'entrée (SJ) avec une pluralité d'impulsions présentant un temps de retard entre elles et une amplitude définie en tant que fonction d'au moins ladite première fréquence propre.
2. Véhicule selon la revendication 1, **caractérisé en ce que** ledit dispositif de commande (13) comprend un moyen de stockage destiné à stocker une matrice qui indexe une valeur de ladite première fréquence propre par rapport à chaque valeur dudit paramètre de fonctionnement.
3. Véhicule selon la revendication 1 ou 2, **caractérisé en ce que** ledit paramètre de fonctionnement comprend au moins l'un parmi :
 - un poids de la charge agissant sur ledit bras (3) ;
 - une extension dudit bras (3) ; et
 - un indice qui indique si ledit véhicule de levage (1) s'appuie sur des roues à bandage (6) ou bien sur un moyen de stabilisation (7).
4. Véhicule selon l'une quelconque des revendications précédentes, **caractérisé en ce que** ledit dispositif de commande (13) est configuré pour dériver la valeur d'un coefficient d'amortissement du mode de vibration correspondant à ladite au moins une première fréquence propre au moins sur la base dudit paramètre de fonctionnement, ledit temps de retard et ladite amplitude étant définis également en tant que fonction dudit coefficient d'amortissement.
5. Véhicule selon l'une quelconque des revendications précédentes, **caractérisé en ce qu'il** comprend un deuxième moyen de mesure (16) relié audit dispositif de commande (13) pour mesurer ladite au moins une première fréquence propre.
6. Véhicule selon la revendication 5, **caractérisé en ce que** ledit deuxième moyen de mesure comprend au moins un élément parmi un accéléromètre et une cellule de charge (16).
7. Véhicule selon l'une quelconque des revendications précédentes, **caractérisé en ce qu'il** comprend au moins un actionneur fluide (11) destiné à actionner ledit bras (3), un moyen destiné à régler la capacité de levage (12) relié audit actionneur fluide (11), où une deuxième impulsion dudit signal de commande (SV) est déphasée par rapport à une première impulsion dudit signal de commande (SV) par un temps compris entre 0,5 et 1,5 fois la période de ladite première fréquence propre.

8. Véhicule selon la revendication 7, **caractérisé en ce que** ladite deuxième impulsion est déphasée par rapport à ladite première impulsion par un temps compris entre 0,75 et 1,25 fois la période de ladite première fréquence propre.

9. Véhicule selon l'une quelconque des revendications précédentes, **caractérisé en ce qu'**une première impulsion et une deuxième impulsion de ladite pluralité d'impulsions se distinguent par ΔT^* tel que :

$$\Delta T^* + C = \Delta T \text{ avec } C > 0$$

$$\Delta T = \frac{\pi}{\omega_0 \sqrt{1 - \xi^2}}$$

où

ω_0 est la première fréquence propre ; et

ξ est l'amortissement modal dimensionnel associé à ladite première fréquence propre.

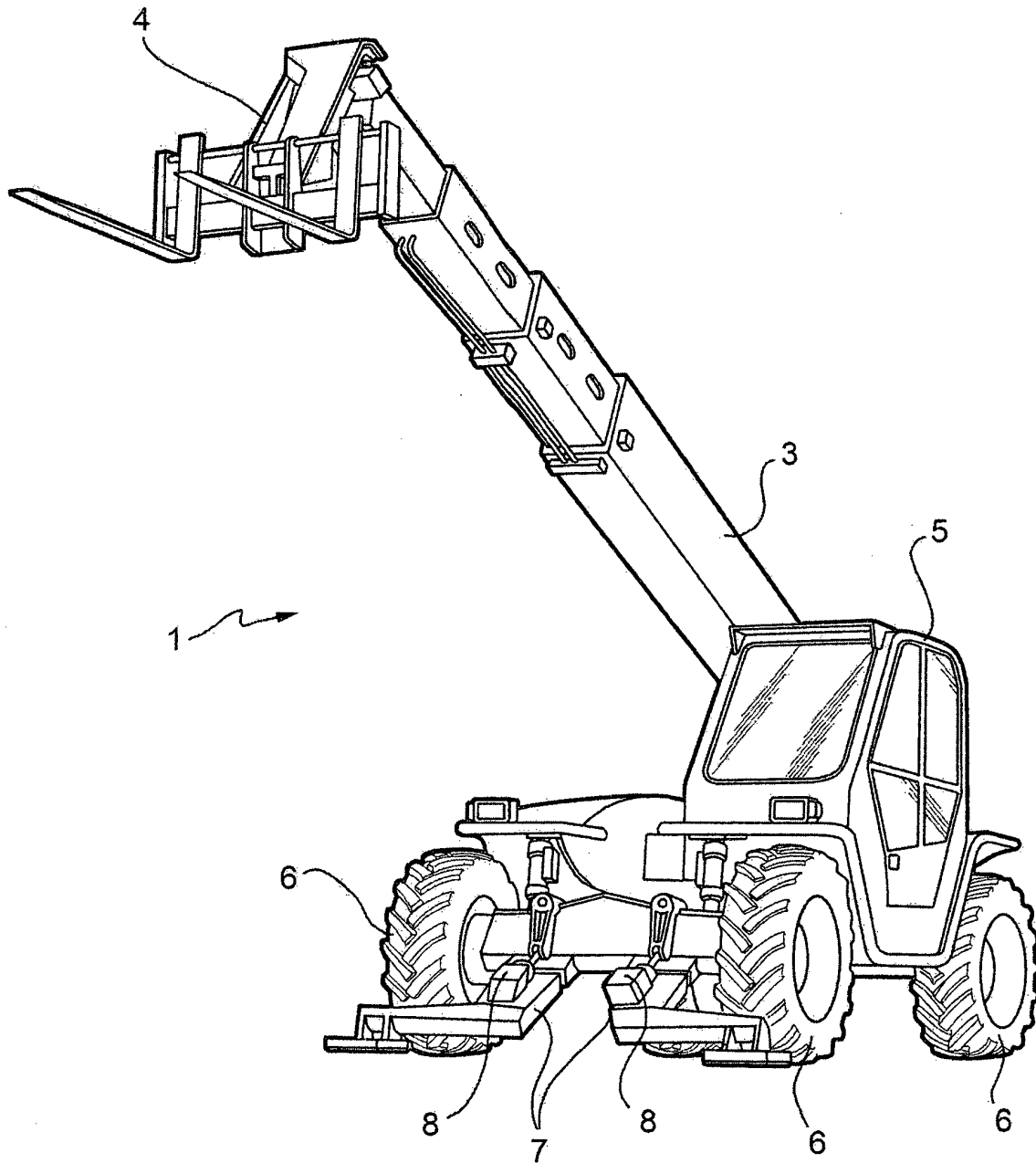
10. Procédé de commande automatique destiné à un véhicule (1) comprenant un bras de levage mobile (3), comprenant les étapes consistant :

à mesurer au moins un paramètre de fonctionnement dudit bras (3) ;

à dériver la valeur d'au moins une première fréquence propre dudit bras (3) au moins sur la base dudit au moins un paramètre de fonctionnement ; et

à déterminer un signal de commande (SV) afin d'actionner ledit bras (3), ledit signal (SV) étant défini au moins partiellement par la convolution d'un signal d'entrée (SJ) avec une pluralité d'impulsions ayant un retard temporel entre elles et une amplitude définie en tant que fonction d'au moins ladite première fréquence propre.

FIG. 1



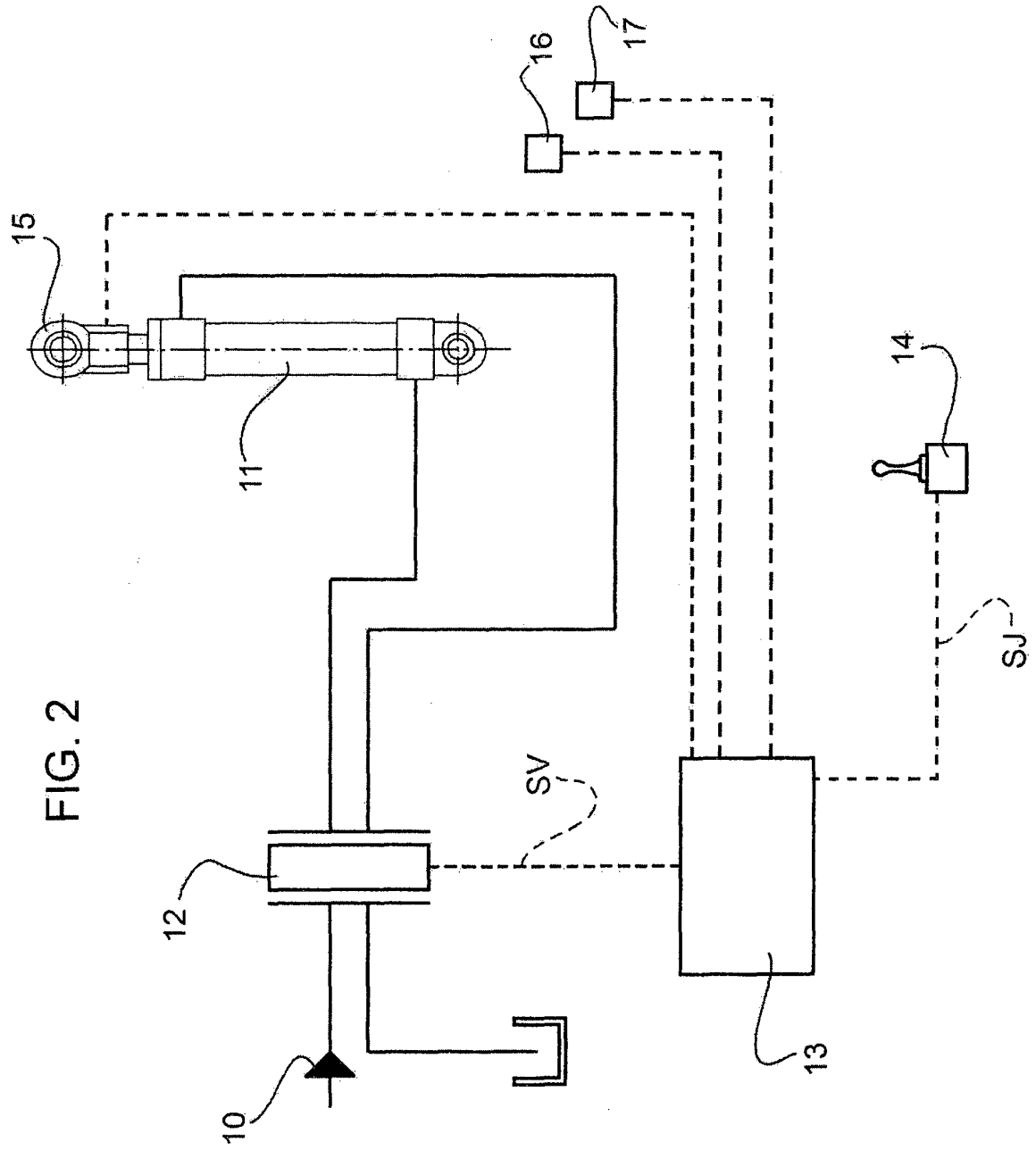


FIG. 3

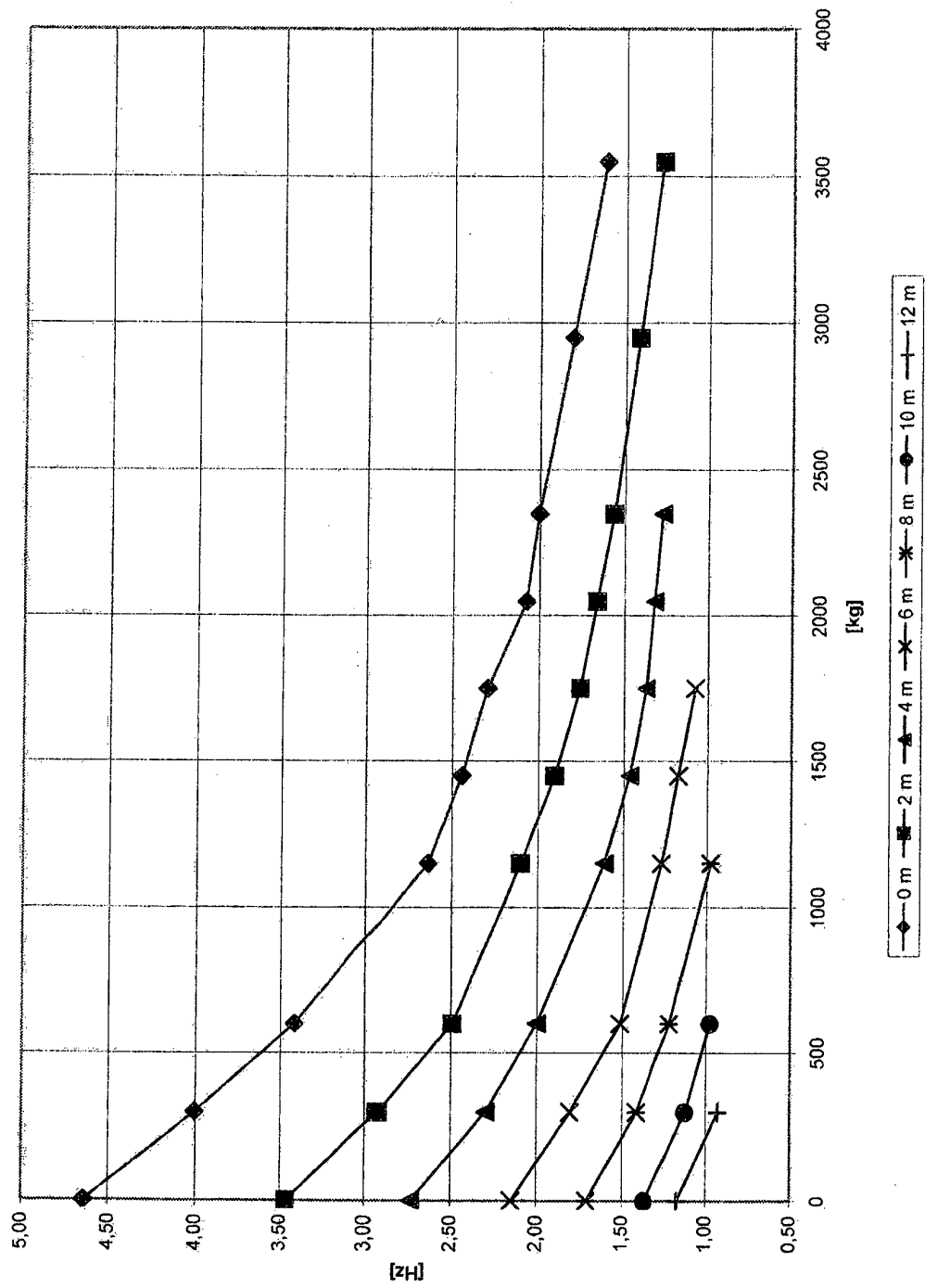


FIG. 4a

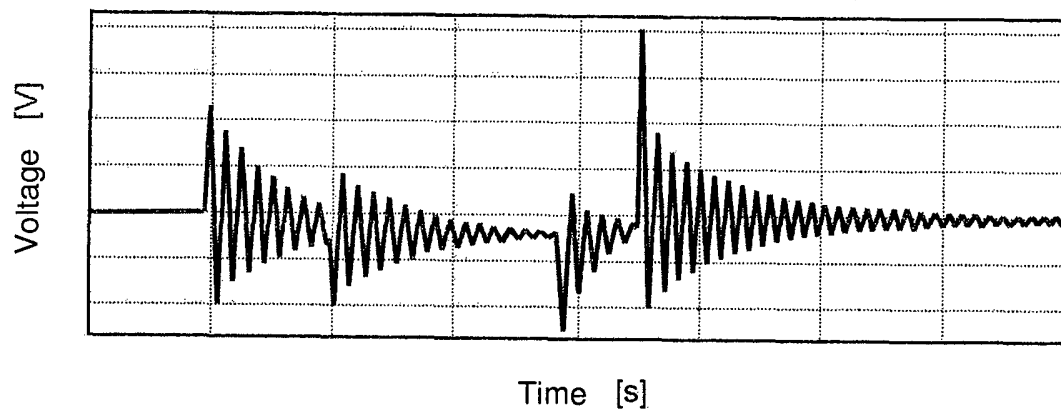


FIG. 4b

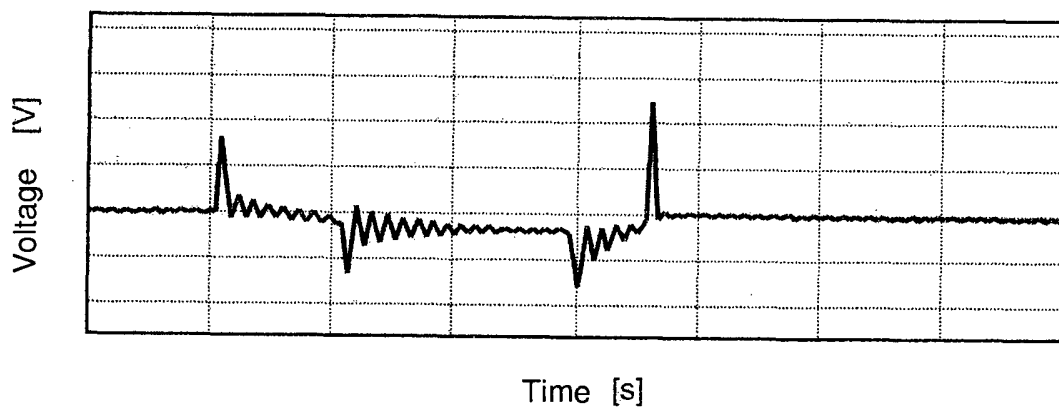
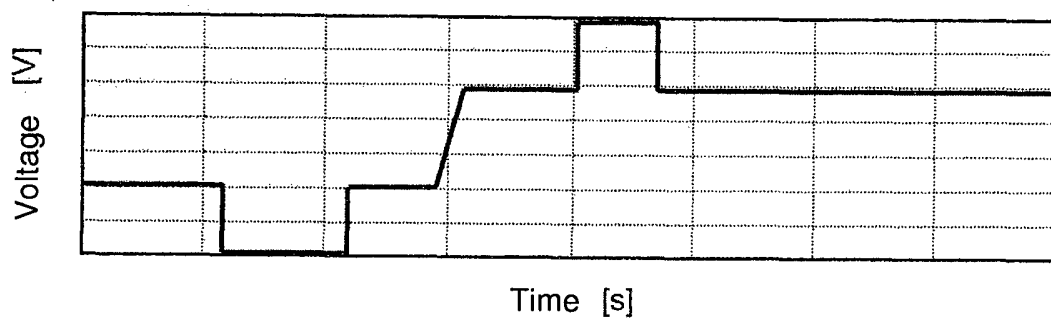


FIG. 4c



REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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