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(54) A METHOD FOR DETECTING MANUFACTURING DEFECTS OF HYDRAULIC DAMPERS, ESPECIALLY SHOCK ABSORBERS, AND A DEVICE FOR DETECTING MANUFACTURING DEFECTS OF HYDRAULIC DAMPERS, ESPECIALLY SHOCK ABSORBERS

(57) The method for detecting manufacturing defects of hydraulic dampers, especially hydraulic shock absorbers, consists in recording a vibration acceleration signal by means of an accelerometer secured to the end of the piston rod of a forcing actuator, and in that sample hydraulic dampers used in the phase of determining boundary characteristics are standard dampers, wherein automatic clipping of the signal in the time domain by the range of t_0-t_s is applied, wherein the t_0 point is determined by the instant the accelerometer comes into contact with the end of the hydraulic damper piston rod, and in order to determine the boundary characteristics an iteratively determined maximum correction factor of the standard deviation a_{max} and adjusted standard deviation σ_{c_j} are used.

The device for detecting manufacturing defects of hydraulic dampers, especially shock absorbers, has a shock absorber seat in which the shock absorber's end is placed, and the seat is made of plastic of Shore A hardness 93-98. The front side of the plate (12) located in the front part of the machine (7) has its upper edge inclined from the vertical of the machine towards the inside of the machine so as to enable placing a shock absorber in the axis of forcing actuator (9d) operation.

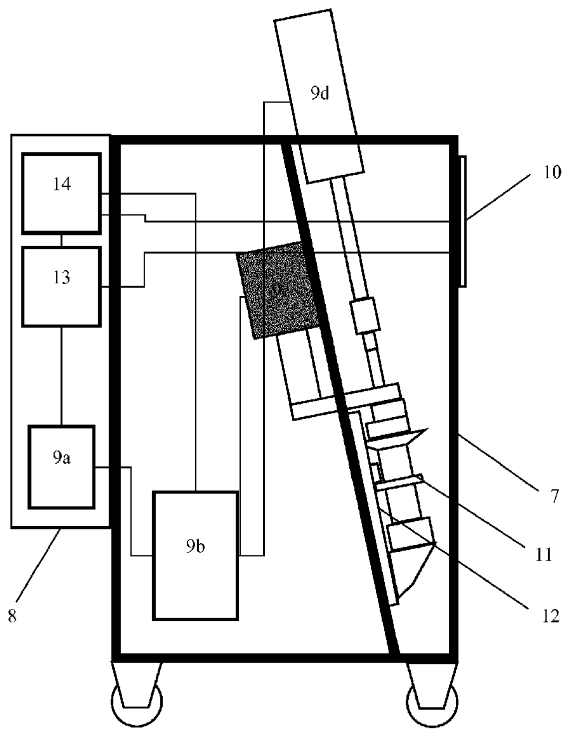

Fig 2.

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Description

[0001] The invention relates to a method and device for detecting manufacturing defects of hydraulic dampers, said method enabling classification of the condition, particularly in the case of a single stroke of the piston rod of a hydraulic damper. The present invention enables detecting defects in piston rod guide, piston rod packing, base valve, piston valve, plate valves, valve plates. The invention is applicable to hydraulic single tube and twin tube shock absorbers.

[0002] The known methods of testing shock absorbers, the examples of which are those described in patent applications EP 86302935 A2, EP 86402253 B1, EP86402254 B1, EP 89907781 B1, EP 94102441 B1, EP 94115944 A2, EP 95930380 B1, EP 98122896 B1, maybe classified into two basic groups which include the following categories:

- bench methods of testing shock absorbers installed in vehicle suspension:
    - forced vibration method,
    - free vibration method:
        - with variable vibration amplitude,
        - with constant vibration amplitude,
    - test platform methods,
    - method of vibration analysis as a measure of the technical condition of vehicle suspension components,
- methods of testing shock absorbers not installed in a vehicle:
    - on indicator test rigs,
    - on servo-hydraulic machines,
    - on test rigs with manual forcing of shock absorber motion.

[0003] Solutions applied to test shock absorbers installed in vehicle suspensions have numerous limitations which make them useless for testing shock absorbers on production lines. First of all, they are intended for diagnostic and control tests of the overall shock absorber capacity to damp vibrations, they do not provide information about the type of shock absorber damages and manufacturing defects of the tested shock absorber. The equipment may measure parameters that determine the operating condition of the shock absorber. Moreover, in the case of this type of equipment, the information provided on the condition of the shock absorber is of qualitative nature primarily. Measurements on devices of this type strongly depend on the value of tyre pressure, which affects the determined characteristics, and are characterized by the lack of adjustment of the test parameters to the variable properties of the tested shock absorbers. Equipment of this type cannot be used on shock absorber production lines because of the manner of effecting the measurement.

[0004] At the stage of designing and manufacture of hydraulic shock absorbers, the characteristics and technical condition of hydraulic dampers are determined by methods for testing shock absorbers not installed in vehicle suspensions. In these methods use is made of mechanical electrically-driven actuators that compress and decompress the shock absorber, of electromechanical vibration inducers or of servo-hydraulic machines.

[0005] Testing of shock absorbers not installed in a vehicle typically includes:

1. determination of operating characteristics (damping force vs. speed of shock absorber piston rod, damping force vs. displacement of shock absorber piston rod),
2. determination of reference vibration characteristics,
3. detection of defects resulting from manufacturing errors,
4. checking the reliability and durability of dampers under conditions as close as possible to operating conditions.

[0006] The major disadvantages of the other bench methods of testing shock absorbers not installed in vehicles include:

1. on electromechanical test stands:
    - high degree of structural complexity of the test stand,
    - lack of the ability to quickly assess the condition of hydraulic shock absorbers,
    - lengthy installation and dismantling of the tested component,
    - long measurement time,
    - need to involve highly qualified operators,

- long test preparation time,
- high cost of test,

2. on servo-hydraulic machines:

- high degree of structural complexity of the test stand,
- lack of the ability to quickly assess the condition of hydraulic shock absorbers,
- high cost of test stand,
- lengthy installation and dismantling of the tested component,
- long measurement time,
- need to involve highly qualified operators,
- high cost of test,

3. manual forcing of shock absorber motion (dedicated test stands on quality control production lines):

- moving the rod of a hydraulic shock absorber under unrepeatable values of force and time,
- processing of measurement results is not automated,
- classification of the condition depends on the test stand operator's expertise. So far, no definitive procedures of classifying the condition of vehicle shock absorbers have been developed for the bench test methods presented above of shock absorbers not installed in vehicles.

[0007] The method according to the invention for detecting manufacturing defects of hydraulic dampers, especially hydraulic shock absorbers, includes at least one of two phases, wherein phase one consists of subsequent operations of the measurement procedure, followed by automatic pre-processing of the vibration acceleration signal. Next, the vibration acceleration signal is processed; then the signal is processed using an FFT algorithm; then statistical characteristics of the spectrum, such as the mean, variance and standard deviation, are determined; then the values of boundary characteristics for each of the *n* spectral domain ranges are determined. Phase two includes, in sequence, the measurement procedure, automatic pre-processing of the vibration acceleration signal, additional processing of the vibration acceleration signal, processing of the signal using the FFT algorithm, determination of the values of upper and lower number of exceedance of boundary characteristics, comparison of the sum of the upper and lower number of exceedance of boundary characteristics with the boundary value and, based on that, indication of the classification result in the form of one of two conditions: working or defective. The measurement procedure consists of the following steps: first, the hydraulic damper is placed on a fixing plate and fixed in place; then the forcing actuator moves down at a speed controlled by the control system and attains a position in which the accelerometer fastened to the piston rod of the forcing actuator makes contact with the end of the piston rod of the hydraulic damper, after that the movement at the speed controlled by the control system is continued until the forcing actuator attains the set outward working position h_{TH}, whereas the vibration acceleration signal is recorded throughout the duration of the outward movement of the piston rod of the forcing actuator. Above all, however, the hydraulic damper is fixed in place during the measurement by clamping it with a hydraulic damper blocking actuator, and the hydraulic damper is positioned so that the longitudinal axis of the hydraulic damper piston rod is directed upwards, whereby the vibration acceleration is recorded by the accelerometer which is secured to the end of the piston rod of the forcing actuator, and by using standard sample hydraulic dampers in the phase of determining boundary characteristics, said standard sample hydraulic dampers being of a design identical to that of the tested hydraulic damper. In the process above automatic clipping of the signal is effected in the time domain by the range of t_0-t_s, wherein the t_0 point is determined by the instant the accelerometer comes into contact with the end of the hydraulic damper piston rod, and in order to determine the boundary characteristics an iteratively determined maximum correction factor of the standard deviation a_{max} and adjusted standard deviation σ_{c_j} are used.

[0008] In the iterative determination of the standard deviation correction factor a_{max} in every step of the iteration algorithm the value of the standard deviation correction factor is incremented by the value of the parameter Δa within the range of (0.. a_{max}), where a_{max} takes the value of ,a_k , which for each of the *n* frequency intervals satisfies the condition that for each value w_{ji} where $j \in \langle 1..n \rangle$ and $i \in \langle 1..k_{th} \rangle$:

$$(w_{j_i} < \mu_j + a_k \cdot \sigma_j) \; and \; (w_{j_i} > \mu_j - a_k \cdot \sigma_j)$$

where:

$j \in \langle 1{:}n \rangle$

w_{ji} - i-th measured value in the set of k_{TH} measurements within the defined frequency interval,
a_k - current value of the standard deviation correction factor for the k-th iteration,
k - successive iteration number,
σ_j - value of standard deviation in the set of k_{TH} measurements within the given frequency interval,
μ_j - mean value in the set of k_{TH} measurements within the given frequency interval.

[0009] The adjusted standard deviation is determined from the function:

$$\sigma_{c_j} = \left(a_{max} \cdot \left(1 - x_j\right) + b\right) \cdot \sigma_j$$

where:

$j \in \langle 1{:}n \rangle$
σ_{c_j} - adjusted standard deviation for the given frequency interval,
a_{max} - maximum standard deviation correction factor,
x_j - ratio of the value of variance to the value of maximum variance for the given frequency interval, $x_j = \frac{\sigma_j^2}{\sigma_{max}^2}$
b - basic deviation adjustment multiplication factor selected by the user, preferably equal to 3,
σ_j - standard deviation for the given frequency interval

[0010] The device for detecting manufacturing defects of hydraulic dampers, especially shock absorbers, comprises a frame, to the rear part of which is attached a control cabinet which houses a control system and a measuring computer of the control panel which is attached to the front part of the frame, a fixing plate mounted in the inner space of the frame, actuating system in the rear part of the inner space of the frame, the said actuating system driving the forcing actuator which pushes the piston rod, an accelerometer attached to the end of the piston rod of the forcing actuator in such manner that the axis of the piston rod of the hydraulic damper and the axis of the accelerometer are parallel to each other, preferably arranged in one axis. The shock absorber seat, in which the shock absorber's end opposite the piston rod is placed, is made of plastic of Shore A hardness 93-98 and is designed to isolate vibrations of the hydraulic damper from vibrations transmitted by the machine frame from the machine surroundings. The front side of the plate located in the front part of the machine has its upper edge inclined from the vertical of the machine towards the inside of the machine so as to enable placing a shock absorber in the axis of forcing actuator operation and to prevent falling out of the shock absorber under gravity.

[0011] The proposed method and device for detecting manufacturing defects of hydraulic dampers, especially hydraulic shock absorbers, enable bench testing on a shock absorber production line within a production tact in an automatic cycle, and enables fast classification of the condition of hydraulic dampers without engaging complex measuring systems while maintaining measurement repeatability and based on developed algorithms and structural design. Moreover, the method disclosed enables testing irrespective of the stand operator's expertise and experience.

[0012] The subject of the invention is illustrated in an example embodiment shown in the figures, where: Fig. 1 shows a diagram of a hydraulic damper comprising the following components: 1 - end piece of the piston rod of the hydraulic damper, 1a - longitudinal axis of the hydraulic damper piston rod, 2 - hydraulic damper piston rod, 3 - cover of hydraulic damper seal, 4 - spring seat, 5 - hydraulic damper tube, 6 - hydraulic damper base; Fig. 2 shows a diagram of the device for detecting manufacturing defects of hydraulic dampers, especially hydraulic shock absorbers, comprising the following components: 7 - frame, 8 - control cabinet, 9a-d - parts of the actuating system, where 9a - electrical part of the actuating system, 9b - pneumatic part of the actuating system, 9c - fixing actuator, 9d - forcing actuator; 10 - control panel, 11 - hydraulic damper, 12 - fixing plate, 13 - control system, 14 - measuring computer; Fig. 3 shows a diagram of the forcing actuator (9d) comprising the following components: 15 cylinder of forcing actuator, 16 - piston rod of forcing actuator, 17 - accelerometer, 18 - displacement sensor; Fig. 4 shows a diagram of the fixing actuator comprising the following components: 19 - cylinder of blocking actuator, 20 - piston rod of blocking actuator (9c), 21 - pressure plate, 22 - flexible lining; Fig. 5 shows a diagram of the fixing plate (12) comprising the following components: 23 - base plate, 24 - seat base, 25 - seat, 26 - upper support, 27 - pressure arms; Fig 6 shows a flow diagram of the method of detecting manufacturing defects in hydraulic dampers, especially vehicle shock absorbers; Fig. 7 shows a diagram of the movements made during the measurement procedure; Fig. 8 shows an example of preliminary and additional clipping of the vibration acceleration signal; Fig. 9 shows the algorithm for determining the maximum value of the standard deviation correction factor a_{max}; Fig. 10 shows a graphic representation of the correction curve; Fig. 11 shows the algorithm for determining the upper δ_g and lower δ_d boundary characteristics in the discrete frequency domain;

Fig. 12 shows a graphic representation of the curves used for determining the boundary characteristics; Fig. 13 shows the algorithm for computing the number of incidents of lower and upper boundary characteristics exceedance; Fig. 14 shows a graphic representation of the principle of calculating the number of incidents of lower and upper boundary characteristics exceedance; Fig. 15 shows the algorithm for classifying a hydraulic damper.

[0013] The method is used for detecting manufacturing defects in hydraulic dampers, especially hydraulic shock absorbers of tube design, and it consists in comparing a frequency spectrum of a recorded and processed vibration acceleration signal in the time domain with the value of upper δ_g and lower δ_d boundary characteristics. The method comprises two phases where measurement procedure is applied:

1. Phase of determining the boundary characteristics

2. Phase of classifying the condition of hydraulic dampers

[0014] The phase of determining the upper δ_g and lower δ_d boundary characteristics takes place in stages in the following steps:

1. Recording, effected using the measurement procedure, of vibration acceleration signal waveforms of hydraulic dampers with sample size of k_{TH}, the dampers being preferably identical in construction with the tested one and having no defects, where k_{TH} is preferably greater than 30;
2. Preliminary automatic clipping of the signal and additional clipping of the automatically clipped vibration acceleration signal;
3. Preparation of the frequency spectrum using a fast Fourier transform (FFT) algorithm for each of the k_{TH} recorded vibration acceleration signal waveforms with the splitting of the frequency domain in the 0-f_{max} range into *n* intervals;
4. Computation of the values of the mean μ_j, standard deviation σ_j and variance σ_j^2 for each of the *n* intervals, where $j \in \langle 1..n \rangle$;
5. Determination the upper δ_{gj} and lower δ_{dj} boundary characteristics based on the values of the mean μ_j, standard deviation σ_j and variance σ_j^2 for each of the *n* intervals, where $j \in (1..\ n)$, using the algorithms, described below, for determining the maximum value of the standard deviation correction factor and for determining the correction curve.

[0015] The measurement procedure comprising the measurement of vibration signal waveforms is effected with the use of the device for detecting manufacturing defects of hydraulic dampers being the object of this invention and includes the following subsequent stages:

- Stage 0 (E0) - hydraulic damper (11) is placed on the fixing plate (12) so that its base (6) is located in the seat (25), and the tube (5) rests against the upper support (26) and is supported by arms (27); the piston rod of the blocking actuator (20) moves down and by means of pressure plate (21) presses the cover of the hydraulic damper seal (3) through flexible lining (22); the piston rod of the forcing actuator (16) is in its upper end position P0 at the time t_0,
- Stage I (E1) - the piston rod of the forcing actuator (16) moves down at a speed regulated by the control system (13) and attains position P1, at the time t_s, in which the accelerometer (17) makes contact with the end of the piston rod of the hydraulic damper (1). After that the movement at the speed regulated by the control system (13) is continued until the forcing actuator (9d) controlled by the displacement sensor (18) attains the set outward working position h_{TH} - position P2, at the time t_k. Recording of the vibration acceleration signal by the accelerometer (17) is initiated by the start of movement from position P0 and terminated by reaching the position P2.
- STAGE II (E2) - the forcing actuator (9d) makes a return movement from position P2 to initial position P0, the blocking actuator (9c) moves up and releases the hydraulic damper (11).
- STAGE III (E3) - the shock absorber is classified according to the method described below and the result of classification is displayed;
- STAGE IV (E4) - the hydraulic damper (11) is removed from the device for detecting manufacturing defects of hydraulic dampers.

[0016] In the phase of determining reference characteristics the signal recorded in step 2 is subjected to two-stage preprocessing. The first stage consists in automatic clipping of the signal in the time domain by the range of t_0-t_s, wherein the t_s point is determined by the instant the accelerometer (17) comes into contact with the end of the hydraulic damper piston rod (1). The instant corresponding to the contact of the accelerometer (17) holder with the end of the hydraulic damper piston rod (1) corresponds to the maximum amplitude of the vibration acceleration recorded in the signal exceeding the set amplitude level, preferably equal to half of the measuring range of the accelerometer (1). Moreover, after preliminary automatic clipping of the signal, it can be clipped additionally by the range of t_s-t_l or by the range of t_p-t_k, where the values t_l, t_p are freely definable by the user. Recording is performed according to the sequence above for each of the k_{TH} hydraulic dampers.

[0017] Then all recorded signal waveforms are processed using an FFT algorithm into a signal spectrum in the frequency domain, wherein the frequency domain in the range 0-f_{max} is split into n intervals of equal length, where n is specified by the user. For each of the n intervals of the frequency domain of the vibration acceleration signal spectrum a mean value is calculated:

$$\mu_j = \frac{\sum_{i=1}^{k_{TH}} w_{j_i}}{k_{TH}}$$

[0018] Where:

$j \in \langle 1{:}n \rangle$
μ_j - mean value in the set of k_{TH} measurements within the given frequency interval,
w_{ji} - i-th measured value in the set of k_{TH} measurements within the defined frequency interval,
k_{TH} - number of measurements (number of hydraulic dampers used to determine the reference characteristics),

[0019] Value of the standard deviation:

$$\sigma_j = \sqrt{\frac{\sum_{i=1}^{k_{TH}} (w_{j_i} - \mu_j)^2}{k_{TH}}}$$

[0020] Where:

$j \in \langle 1{:}n \rangle$
σ_j - value of standard deviation in the set of k_{TH} measurements within the given frequency interval,
w_{ji} - i-th measured value in the set of k_{TH} measurements within the defined frequency interval,
k_{TH} - number of measurements (number of hydraulic dampers used to determine the reference characteristics),

[0021] And the value of variance:

$$\sigma_j^2 = \frac{\sum_{i=1}^{k_{TH}} (w_{j_i} - \mu_i)^2}{k_{TH}}$$

[0022] Where:

$j \in \langle 1{:}n \rangle$
σ_j^2 - value of variance in the set of k_{TH} measurements within the given frequency interval, w_{ji} - i-th measured value in the set of k_{TH} measurements within the defined frequency interval,
k_{TH}- number of measurements (number of hydraulic dampers used to determine the reference characteristics).

[0023] In addition, from the designated set of variance values σ_j^2, where j ∈ (1: n), the maximum value $\sigma_{max}^2 = (\sigma_1^2, \ldots, \sigma_n^2)$ is determined.

[0024] Afterwards, based on mean values μ_j, values of standard deviation σ_j and values of variance σ_j^2 for each of the *n* intervals, where j ∈ ⟨1:n⟩, the maximum value of the standard deviation correction factor is determined. Determination of the correction factor is done iteratively, where in every step of the iteration the value of the standard deviation correction factor is incremented by the value of the parameter Δa within the range of (0.. a_{max}), where a_{max} takes the value of a_k, which for each of the *n* frequency intervals satisfies the condition that for each value w_{ji}, where j ∈ ⟨1..n) and i ∈ ⟨1..k_{th}⟩:

$$(w_{j_i} < \mu_j + a_k \cdot \sigma_j)\ and\ (w_{j_i} > \mu_j - a_k \cdot \sigma_j)$$

where:

$j \in \langle 1{:}n \rangle$
w_{ji} - *i*-th measured value in the set of k_{TH} measurements within the defined frequency interval;
a_k - current value of the standard deviation correction factor for the *k*-th iteration,
k - successive iteration number;
σ_j - value of standard deviation in the set of k_{TH} measurements within the given frequency interval,
μ_j - mean value in the set of k_{TH} measurements within the given frequency interval.

[0025] Then, based on the determined values of the variance and of the maximum variance, the ratio of the variance and the maximum variance is determined according to the formula:

$$x_j = \frac{\sigma_j^2}{\sigma_{max}^2}$$

[0026] In addition, based on the determined maximum value of the standard deviation correction for each j ∈ ⟨1..n⟩, the values of the adjusted standard deviation are determined which are given by the formula, taking into account the base adjustment multiplication factor which is specified by the user and is preferably equal to 3:

$$\sigma_{c_j} = \left(a_{max} \cdot \left(1 - x_j\right) + b\right) \cdot \sigma_j$$

[0027] Where:

j ∈ *(1: n)*
σ_{cj} - adjusted standard deviation for the given frequency interval
a_{max} - maximum standard deviation correction factor
x_j - ratio of the value of variance to the value of maximum variance for the given frequency interval
b - basic deviation adjustment multiplication factor
σ_j standard deviation for the given frequency interval

[0028] Then the lower and upper boundary characteristics are determined from the following formulas:

$$\delta_{g_j} = \mu_j + \sigma_{c_j}$$

$$\delta_{d_j} = \mu_j - \sigma_{c_j}$$

where:

$j \in \langle 1{:}n \rangle$
δ_{gj} - upper boundary characteristics;
δ_{dj} - lower boundary characteristics;
σ_{cj} - adjusted standard deviation for the given frequency interval;

μ_j -mean value in the set of k_{TH} measurements within the given frequency interval,

[0029] The determined values of the lower and upper level of acceptability are used in the phase of classifying the condition of hydraulic dampers. The phase of classifying the condition of hydraulic dampers takes place in the following steps:

1. Recording of the vibration acceleration signal waveform from the tested hydraulic damper using the measurement procedure;
2. Preliminary automatic clipping of the signal and additional clipping of the automatically clipped vibration acceleration signal;
3. Preparation of the frequency spectrum using a fast Fourier transform (FFT) algorithm for each of the k_{TH} recorded vibration acceleration signal waveforms with the splitting of the frequency domain in the 0-f_{max} range into n intervals;
4. Comparison of the recorded vibration acceleration signal with the determined values of lower and upper level of acceptability and computation of the number of incidents of lower and upper boundary characteristics exceedance.
5. Indication of the result of comparison

[0030] In the 4th step the number l_d of intervals is computed for which the following inequality is true:

$$w_j < \delta_{d_j}$$

[0031] Where:

$j \in (1: n)$
w_j - measurement value for the j-th frequency interval under consideration
δ_{dj} - value of the acceptance level for the j-th frequency interval under consideration then the number l_d of intervals is computed for which the following inequality is true:

$$w_j > \delta_{g_j}$$

[0032] Where:

$j \in \langle 1:n \rangle$
w_j - measurement value for the j-th frequency interval under consideration
δ_{gj} value of the acceptance level for the j-th frequency interval under consideration

[0033] A hydraulic damper is classified as fit when the sum of l_g and l_d is less than the limit value l_{gr} defined by the user, meaning that the following condition is met:

$$l_{gr} > l_g + l_d$$

[0034] Measurements are made using a device for detecting manufacturing defects of hydraulic dampers, especially hydraulic shock absorbers, said device enabling recording and processing of signals from an accelerometer (1). The device for detecting manufacturing defects of hydraulic dampers, especially hydraulic shock absorbers, has a frame (7), a control cabinet (8), a control system (13), a measuring computer (14), a control panel (10), a fixing plate (12) and an actuating system (9a-d), the said actuating system including an electrical part of the actuating system (9a), a pneumatic part of the actuating system (9b), a blocking actuator (9c) and a forcing actuator (9d). The control cabinet (8) is attached to the rear part of the frame (7). The control cabinet (8) houses the electrical part of the actuating system (9a), the control system (13) and the measuring computer (14). The measuring computer (14) and the control system (13) are connected with each other by means of a cable. The connection is designed for exchanging data between the measuring computer (14) and the control system (13). The control system (13) sends to the measuring computer (14) information on the start and end of actuator movements (9c and 9d). The measuring computer (14) sends to the control system (13) information on the result of classification. The control panel (10) is connected with the measuring computer (14) and with the control system (13) and it serves the purpose of entering setup parameters: h_{TH}, t_l, t_p, n, f_{max}, l_{gr}, Δa, b and displaying the result of classification and the measurement results. The forcing actuator (9d) has a forcing actuator piston rod (16), a displacement sensor (18), an accelerometer (17). The forcing actuator (9d) pushes the piston rod of the hydraulic damper (2). The accelerometer (17) is attached to the end of the piston rod of the forcing actuator (9d) in such manner that the axis of the piston rod of the hydraulic damper (1a) and the axis of the accelerometer (17) are parallel to each other, preferably arranged in one axis. Moreover, the accelerometer (17) is attached in such manner that it remains in contact with the end of the hydraulic damper piston (1) throughout the duration of movement P1-P2. The displacement sensor (18) is located on the cylinder of the forcing actuator (15). The blocking actuator has a pressure plate (21) with flexible lining (22) made of plastic of Shore A hardness 93-98. The blocking actuator (9c) blocks the hydraulic damper (11) in the fixing plate (12) and secures it firmly by pressing the hydraulic damper (11) through the cover of the hydraulic damper seal (3). The actuating system (9a-d), with the forcing (9d) and blocking (9c) actuators, is connected with the control system (13). The control system (13) controls the actuating system (9a-d) and allows the execution of movements by the forcing (9d) and blocking (9c) actuators, and in addition it maintains the repeatable characteristics of speed as a function of the displacement of the forcing actuator piston rod (16). The fixing plate (12) has a base plate (23), a seat base (24), an upper support (26), pressing arms (27) and seat (25).

[0035] The fixing plate (12) is attached in the front part of the frame (7) and is preferably inclined rearwards in order to facilitate mounting of the hydraulic damper (11) in seat (25). The hydraulic damper (11) is positioned parallel to the fixing plate (12). The upper support (26) is below the spring seat (4) and it ensures axial position of the hydraulic damper (11) in relation to the forcing actuator piston rod (16). The pressing arms (27) are attached symmetrically on both sides of the upper support (26) and they ensure stable and repeatable positioning of the hydraulic damper (11) in relation to the forcing actuator (9d) and prevent its sideways movement during the pushing of the hydraulic damper piston rod (2). The seat base (24) is located in the lower part of the fixing plate (12) and it serves as a supporting member for seat (25). The seat (25), matched to the base of hydraulic damper (6), is attached to the seat base (24). Moreover, the seat (25) is made of a vibration damping material, which together with flexible lining (22) isolate the hydraulic damper (11) from vibrations from the surroundings.

Claims

1. A method for detecting manufacturing defects of hydraulic dampers, especially hydraulic shock absorbers, which method includes at least one of two phases, wherein phase one consists of subsequent operations of the measurement procedure, followed by automatic pre-processing of the vibration acceleration signal, processing of the vibration acceleration signal, processing of the signal using an FFT algorithm, determination of statistical characteristics of the spectrum, such as mean, variance and standard deviation, followed by the determination of the values of boundary characteristics for each of the *n* intervals of the spectrum domain, whereas phase two includes, in sequence, the measurement procedure, automatic pre-processing of the vibration acceleration signal, additional processing of the vibration acceleration signal, processing of the signal using an FFT algorithm, determination of the values of upper and lower number of exceedance of boundary characteristics, comparison of the sum of the upper and lower number of exceedance of boundary characteristics with the boundary value and, based on that, indication of the classification result in the form of two conditions: fit or unfit, wherein the measurement procedure consists of the following steps: first, the hydraulic damper is placed on a fixing plate and fixed in place; then the forcing actuator moves down at a speed controlled by the control system and attains a position in which the accelerometer fastened to the piston rod of the forcing actuator makes contact with the end of the piston rod of the hydraulic damper, after that the movement at the speed controlled by the control system is continued until the forcing actuator attains a set outward working position h_{TH}, whereas the vibration acceleration signal is recorded throughout the duration of the outward movement of the piston rod of the forcing actuator, **characterized in that** the hydraulic damper is fixed in place during the measurement by clamping it with a hydraulic damper blocking actuator, and **in that** the hydraulic damper is positioned so that the longitudinal axis of the hydraulic damper piston rod is directed upwards, whereby the vibration acceleration is recorded by the accelerometer which is secured to the end of the piston rod of the forcing actuator, and by using standard sample hydraulic dampers in the phase of determining boundary characteristics, said standard sample hydraulic dampers being of a design identical to that of the tested hydraulic damper; and **in that** automatic clipping of the signal is effected in the time domain by the range of t_0-t_s, wherein the t_0 point is determined by the instant the accelerometer comes into contact with the end of the hydraulic damper piston rod, and **in that** in order to determine the boundary characteristics an iteratively determined maximum correction factor of the standard deviation a_{max} and adjusted standard deviation σ_{c_j} are used.

2. A method according to claim 1 **characterized in that** the iterative determination of the standard deviation correction factor a_{max} consists **in that** in every step of the iteration algorithm the value of the standard deviation correction

factor is incremented by the value of the parameter Δa within the range of (0.. a_{max}), where a_{max} takes the value of a_k, which for each of the *n* frequency intervals satisfies the condition that for each value w_{ji}, where $j \in \langle 1..n \rangle$ and $i \in \langle 1..k_{th} \rangle$:

$$(w_{j_i} < \mu_j + a_k \cdot \sigma_j) \; and \; (w_{j_i} > \mu_j - a_k \cdot \sigma_j)$$

where:

$j \in (1: n)$
w_{ji} - *i*-th measured value in the set of k_{TH} measurements within the defined frequency interval,
a_k - current value of the standard deviation correction factor for the *k*-th iteration,
k - successive iteration number,
σ_j - value of standard deviation in the set of k_{TH} measurements within the given frequency interval,
- mean value in the set of k_{TH} measurements within the given frequency interval,

3. The method according to claim 1 **characterized in that** the adjusted standard deviation is determined from the function:

$$\sigma_{c_j} = \left(a_{max} \cdot \left(1 - x_j\right) + b\right) \cdot \sigma_j$$

where:

$j \in (1: n)$
σ_{c_j} - adjusted standard deviation for the given frequency interval,
a_{max} - maximum standard deviation correction factor.

x_j - ratio of the value of variance to the value of maximum variance for the given frequency interval, $x_j = \frac{\sigma_j^2}{\sigma_{max}^2}$

b - basic deviation adjustment multiplication factor selected by the user, preferably equal to 3,
σ_j - standard deviation for the given frequency interval

4. A device for detecting manufacturing defects of hydraulic dampers, especially shock absorbers, comprising a frame (7), to the rear part of which is attached a control cabinet (8) which houses a control system (13) and a measuring computer (14) of the control panel (10) which is attached to the front part of the frame, a fixing plate (12) mounted in the inner space of the frame, actuating system (9a-d) in the rear part of the inner space of the frame, the said actuating system driving a forcing actuator (9d) which pushes the piston rod, accelerometer (17) attached to the end of the piston rod of the forcing actuator (9d) in such manner that the axis of the piston rod of the hydraulic damper (1a) and the axis of the accelerometer (17) are parallel to each other, preferably arranged in one axis, **characterized in that** the shock absorber seat (25) in which the shock absorber's end opposite the piston rod is placed, is made of plastic of Shore A hardness 93-98 and **in that** the front side of the plate (12) located in the front part of the machine (7) has its upper edge inclined from the vertical of the machine towards the inside of the machine so as to enable placing a shock absorber in the axis of forcing actuator (9d) operation.

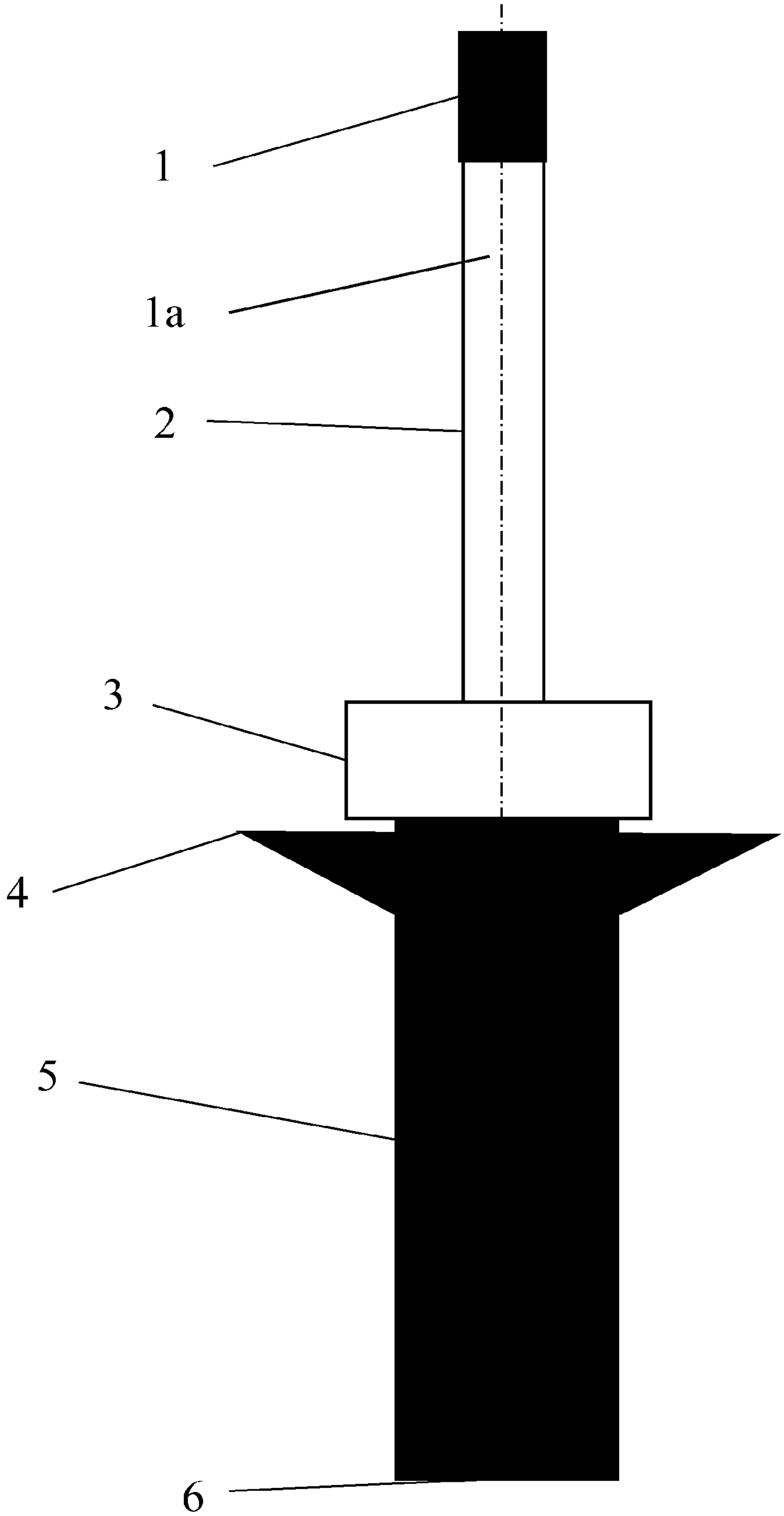


Fig 1.

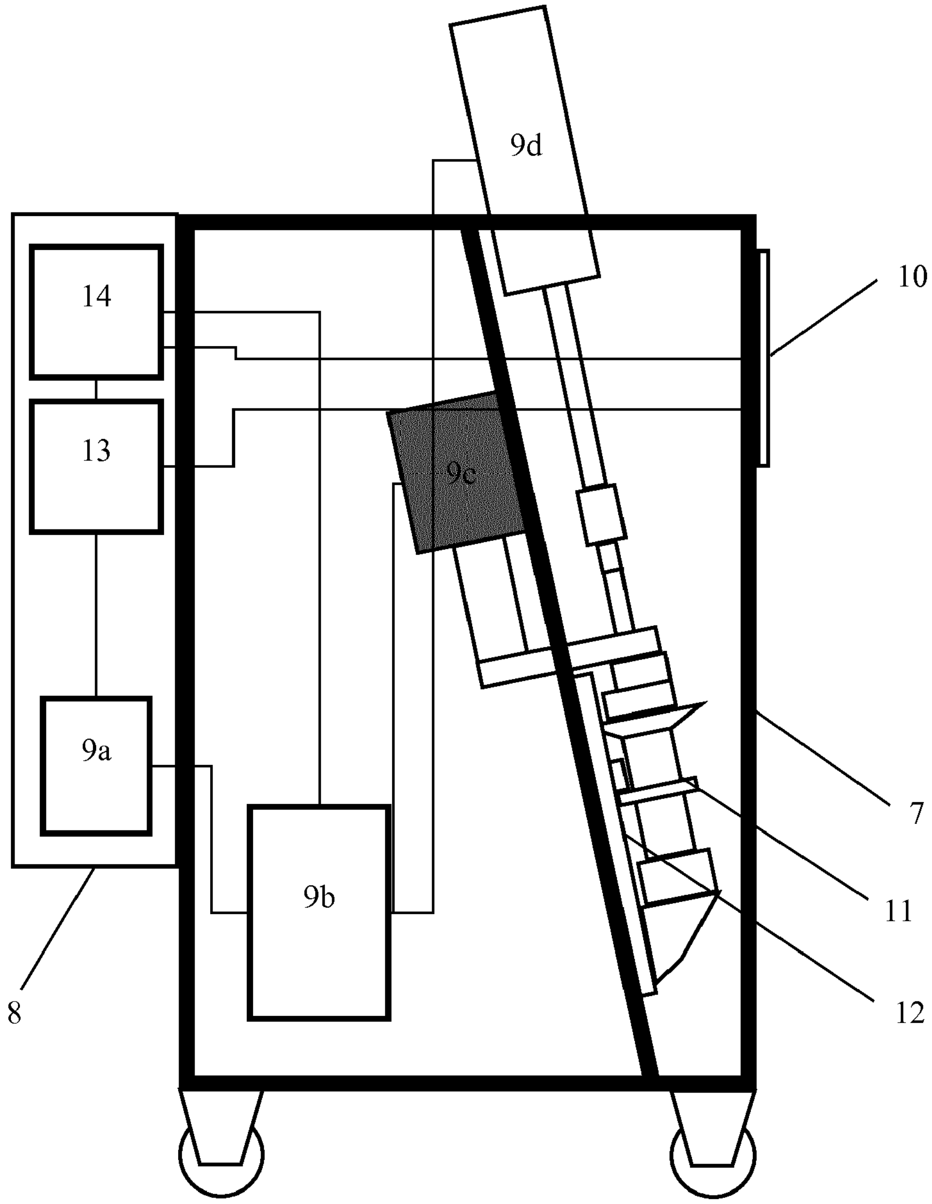


Fig 2.

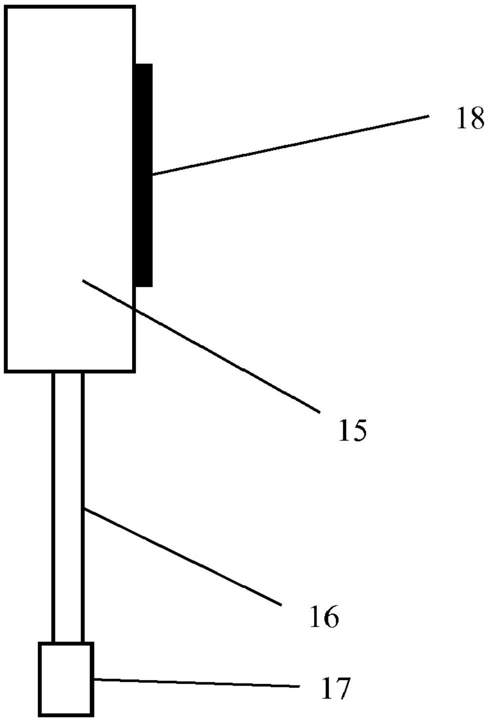


Fig 3.

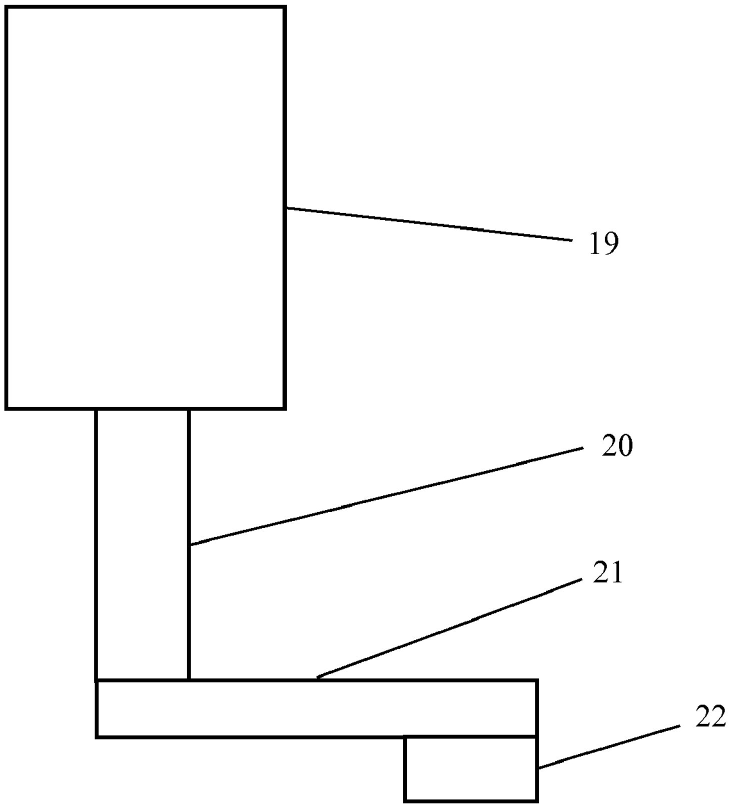


Fig 4.

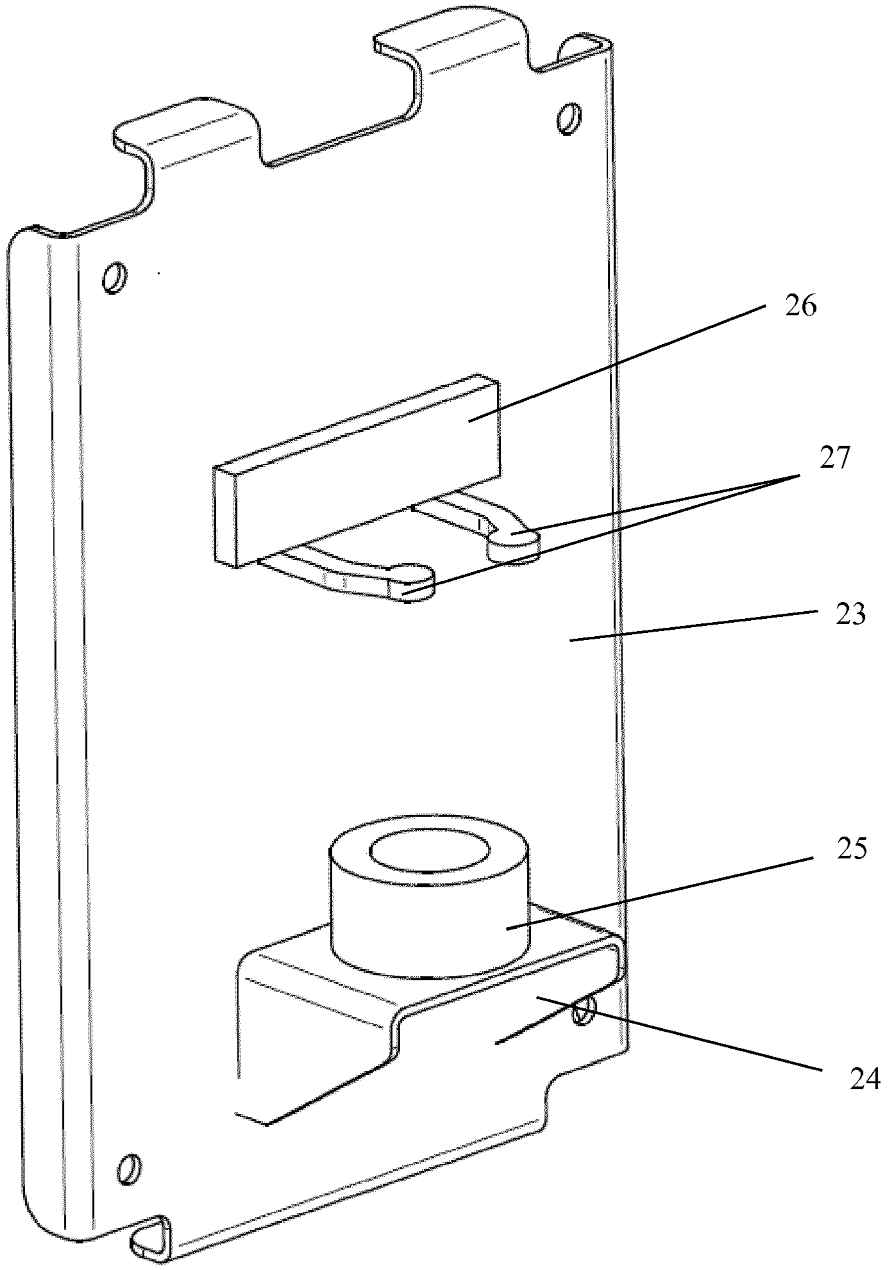
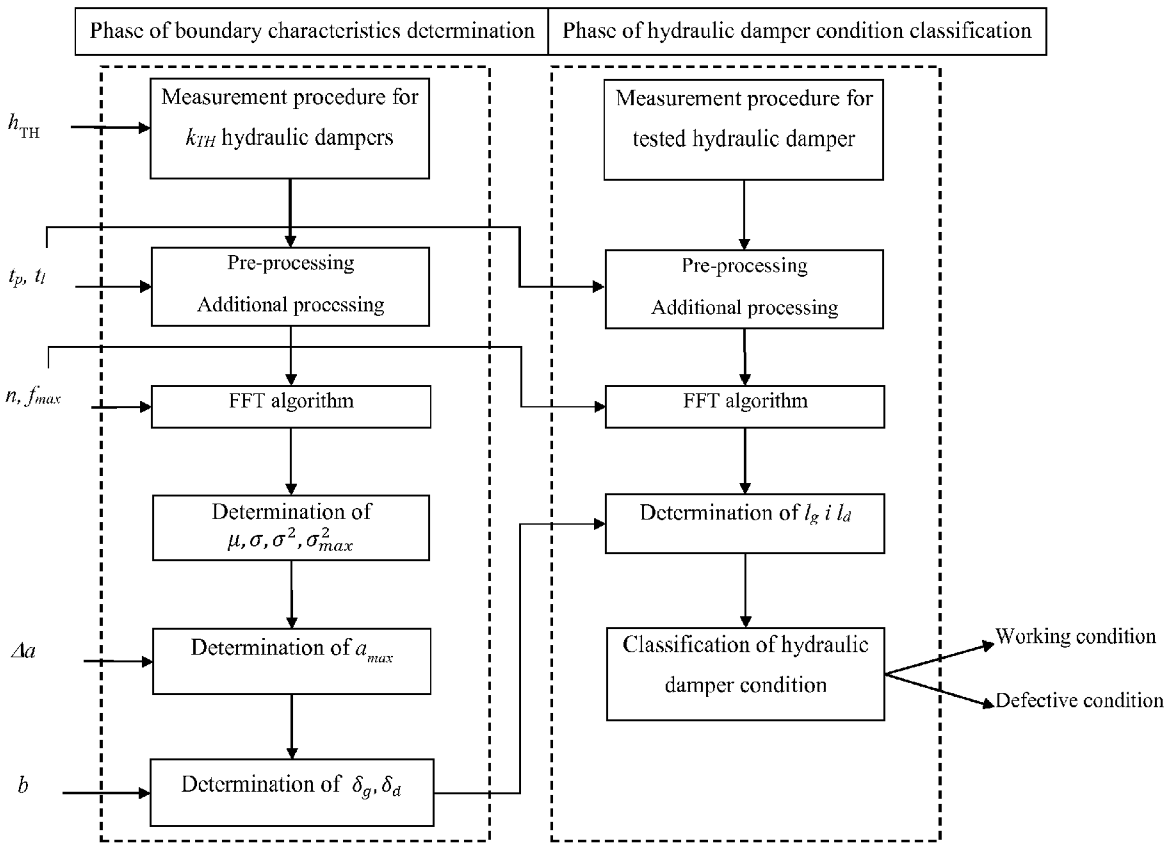


Fig 5.



Phase of boundary characteristics determination
Phase of hydraulic damper condition classification
h_{TH}
Measurement procedure for k_{TH} hydraulic dampers
t_p, t_l
Pre-processing
Additional processing
n, f_{max}
FFT algorithm
Determination of $\mu, \sigma, \sigma^2, \sigma^2_{max}$
Δa
Determination of a_{max}
b
Determination of δ_g, δ_d
Measurement procedure for tested hydraulic damper
Pre-processing
Additional processing
FFT algorithm
Determination of l_g i l_d
Classification of hydraulic damper condition
Working condition
Defective condition

Fig 6.

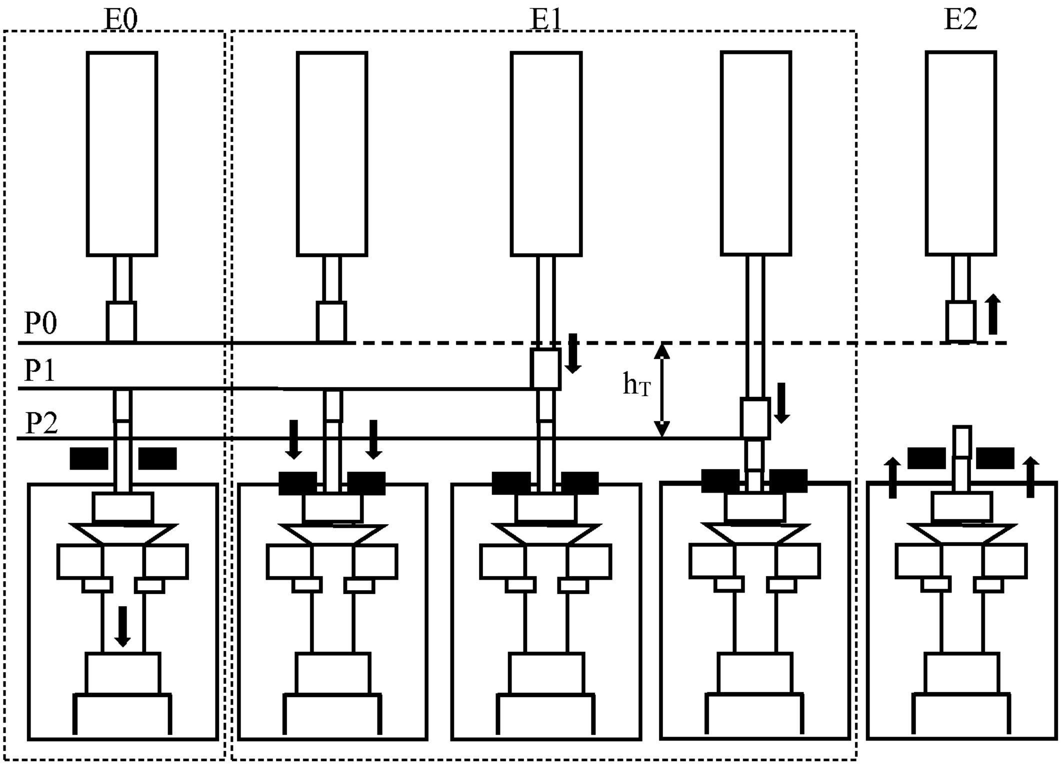


Fig 7.

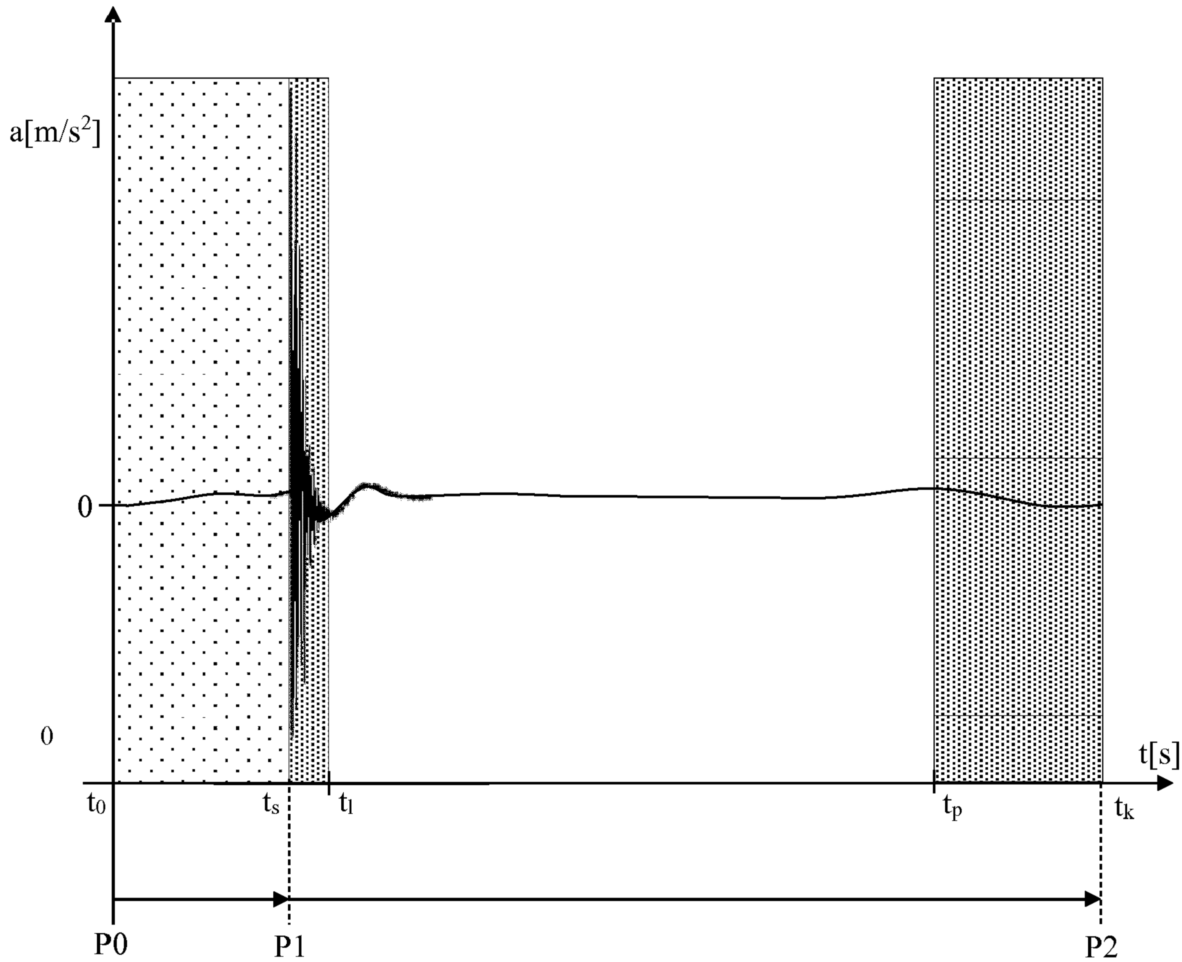


Fig 8.

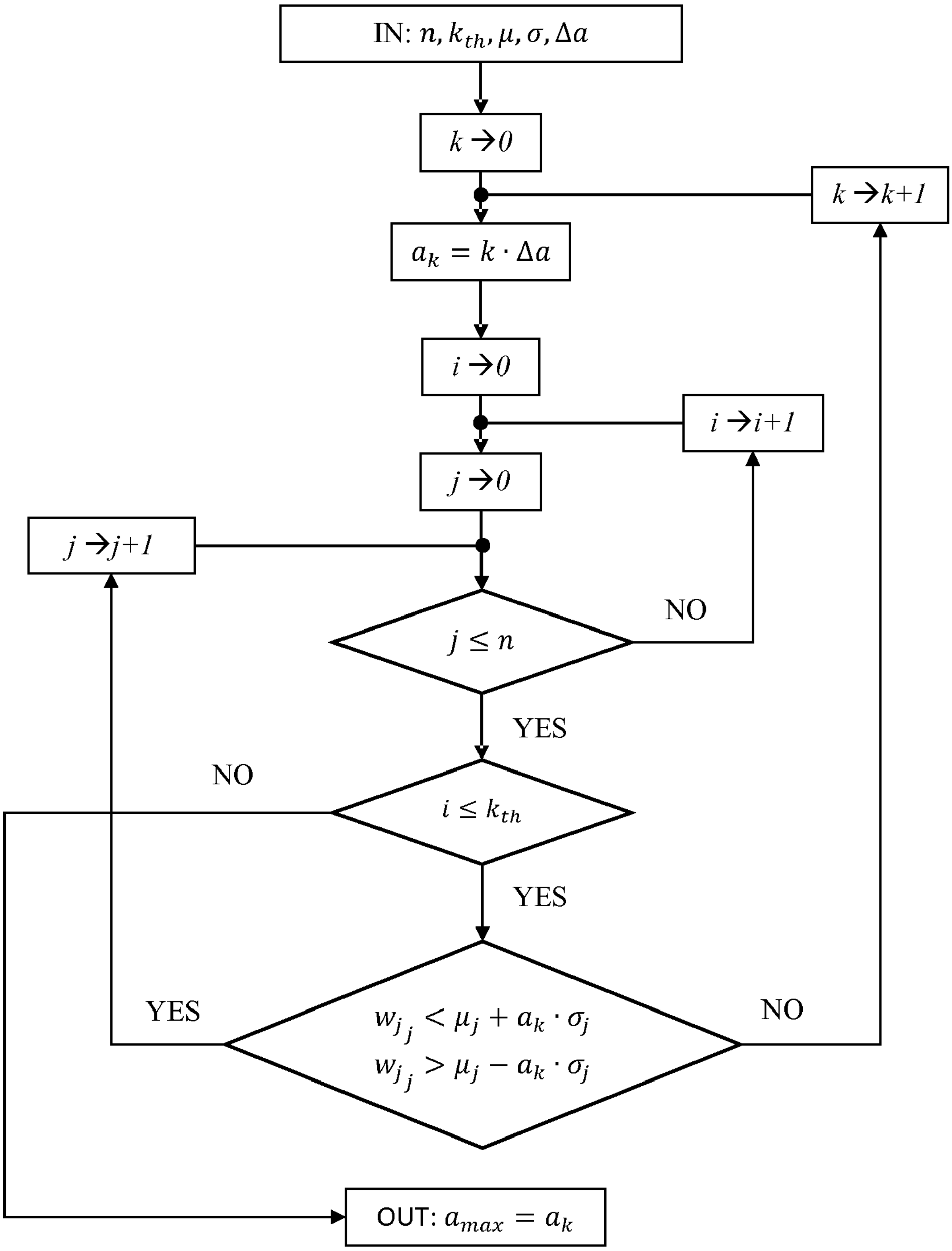

IN: $n, k_{th}, \mu, \sigma, \Delta a$
$k \rightarrow 0$
$k \rightarrow k+1$
$a_k = k \cdot \Delta a$
$i \rightarrow 0$
$i \rightarrow i+1$
$j \rightarrow 0$
$j \rightarrow j+1$
$j \leq n$
NO
YES
NO
$i \leq k_{th}$
YES
YES
$w_{j_j} < \mu_j + a_k \cdot \sigma_j$
$w_{j_j} > \mu_j - a_k \cdot \sigma_j$
NO
OUT: $a_{max} = a_k$

Fig 9.

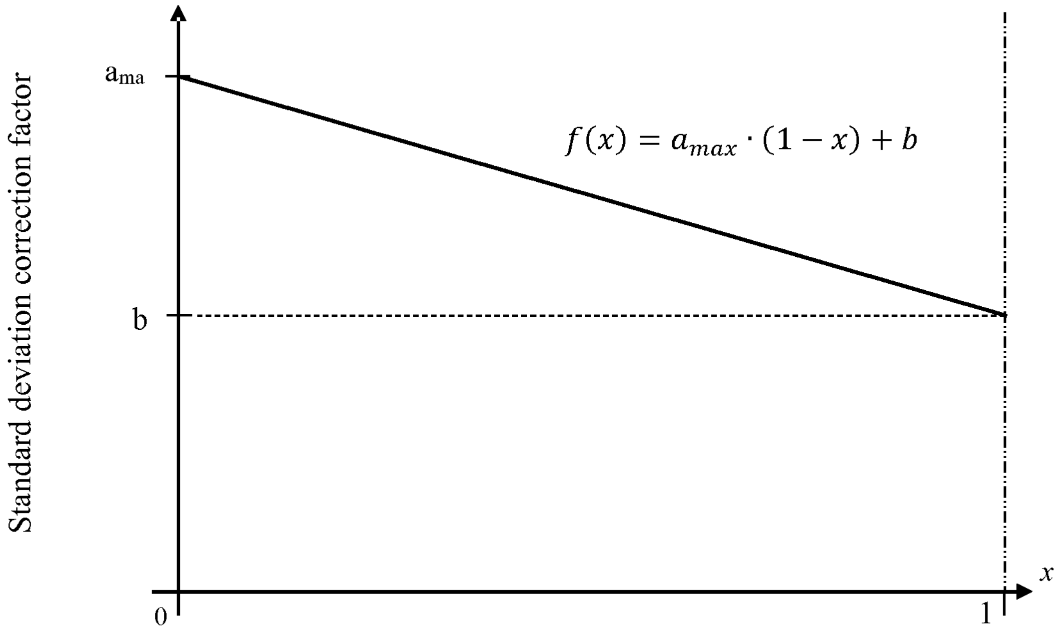


Fig 10.

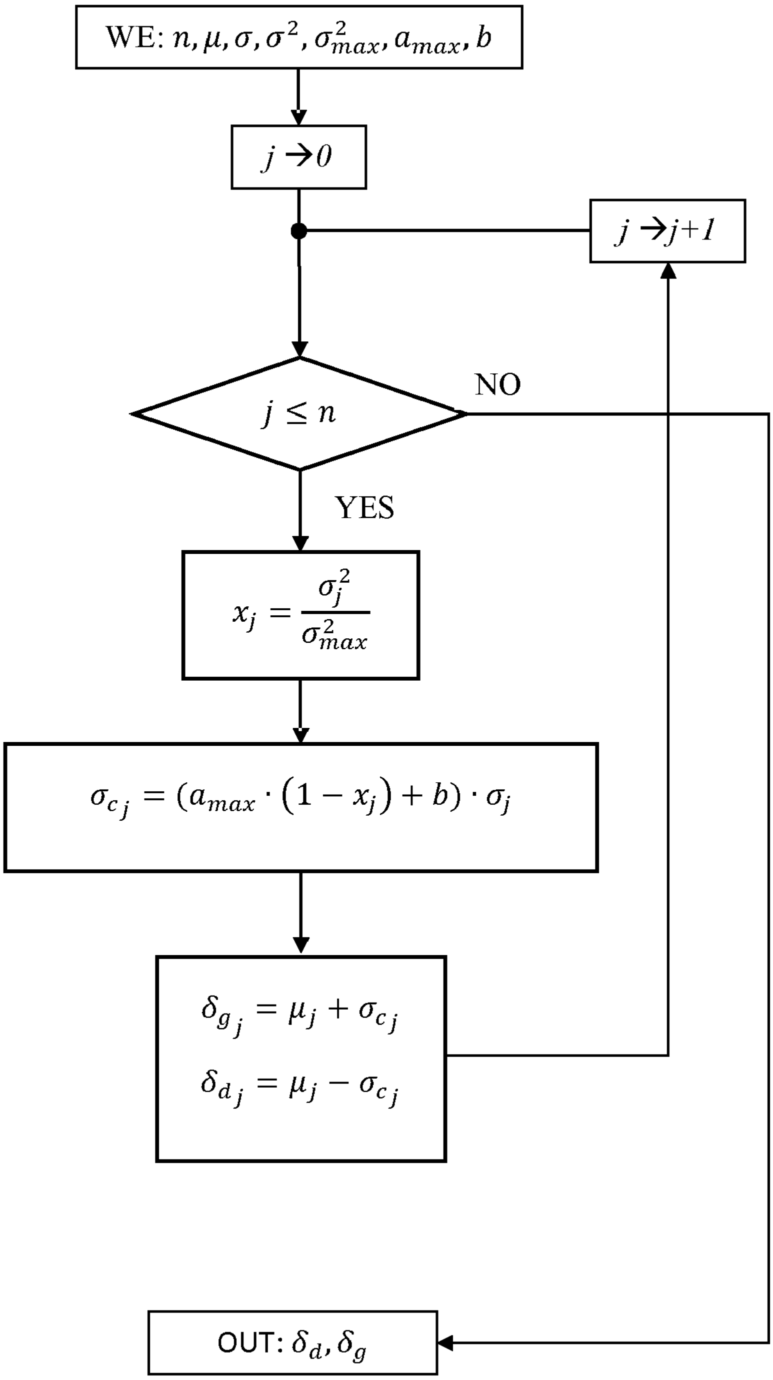

WE: $n, \mu, \sigma, \sigma^2, \sigma_{max}^2, a_{max}, b$
$j \rightarrow 0$
$j \rightarrow j+1$
$j \leq n$
NO
YES
$x_j = \frac{\sigma_j^2}{\sigma_{max}^2}$
$\sigma_{c_j} = (a_{max} \cdot (1 - x_j) + b) \cdot \sigma_j$
$\delta_{g_j} = \mu_j + \sigma_{c_j}$
$\delta_{d_j} = \mu_j - \sigma_{c_j}$
OUT: δ_d, δ_g

Fig 11.

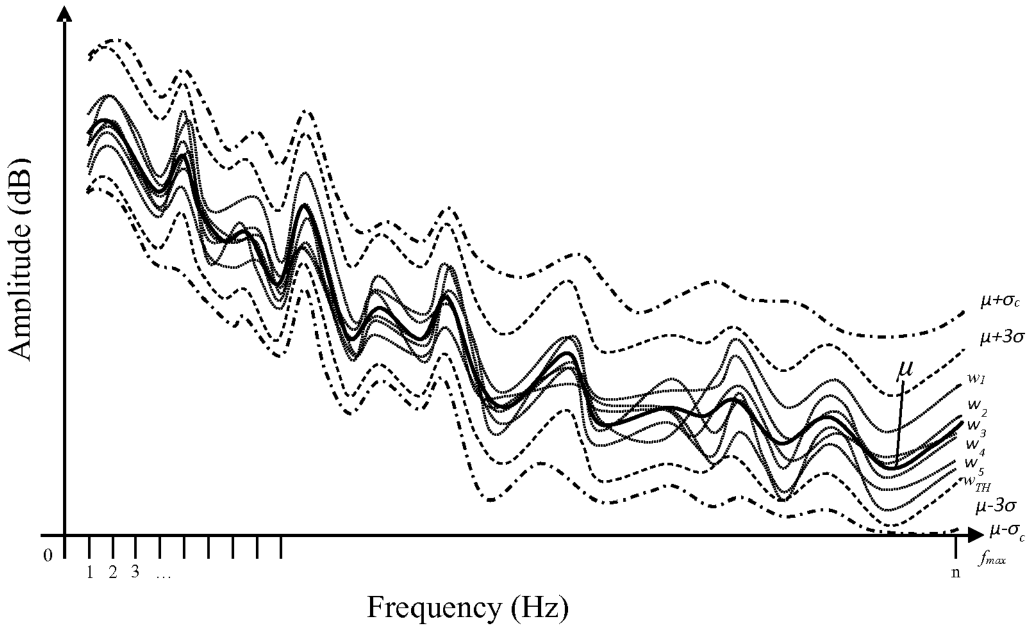

Amplitude (dB)
Frequency (Hz)
0
1 2 3 ...
n
f_{max}
$\mu+\sigma_c$
$\mu+3\sigma$
μ
w_1
w_2
w_3
w_4
w_5
w_{TH}
$\mu-3\sigma$
$\mu-\sigma_c$

Fig 12.

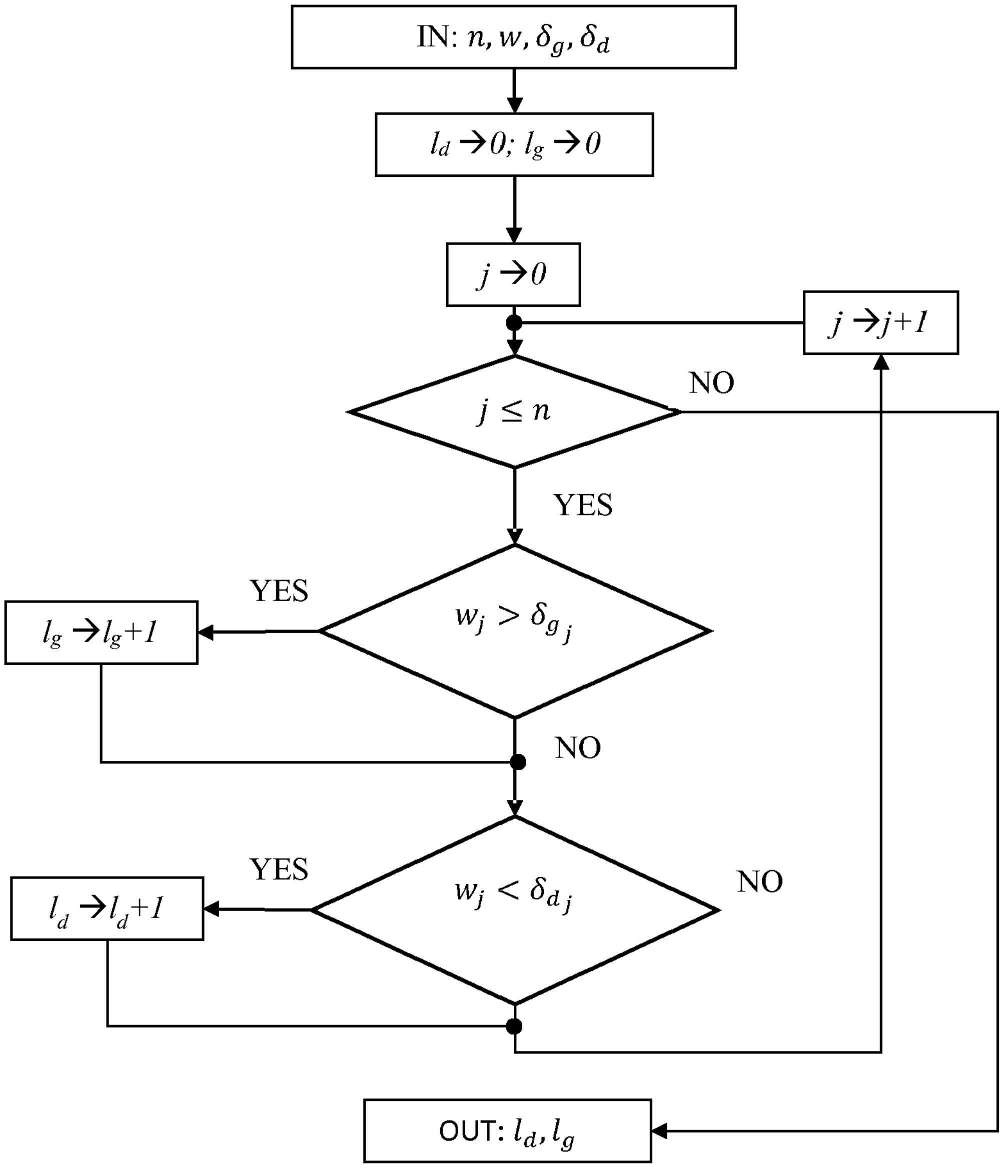

IN: n, w, δ_g, δ_d
$l_d \rightarrow 0; l_g \rightarrow 0$
$j \rightarrow 0$
$j \rightarrow j+1$
$j \leq n$
NO
YES
YES
$l_g \rightarrow l_g+1$
$w_j > \delta_{g\,j}$
NO
YES
$l_d \rightarrow l_d+1$
$w_j < \delta_{d\,j}$
NO
OUT: l_d, l_g

Fig 13.

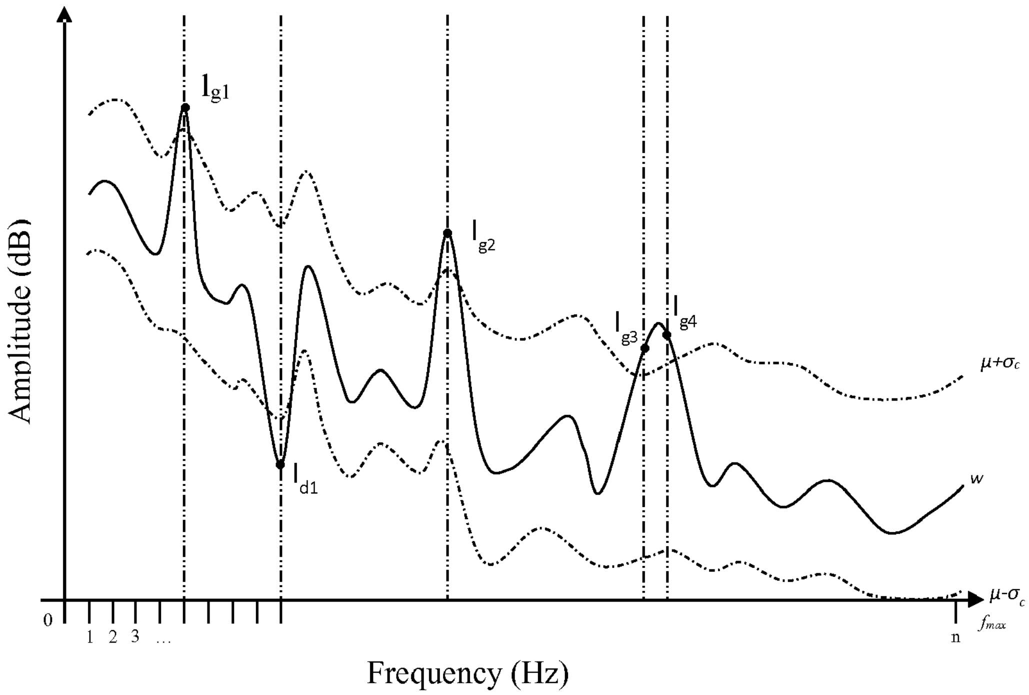

Amplitude (dB)
Frequency (Hz)
I_{g1}
I_{g2}
I_{g3}
I_{g4}
I_{d1}
$\mu+\sigma_c$
w
$\mu-\sigma_c$
0
1 2 3 ...
n
f_{max}

Fig 14.

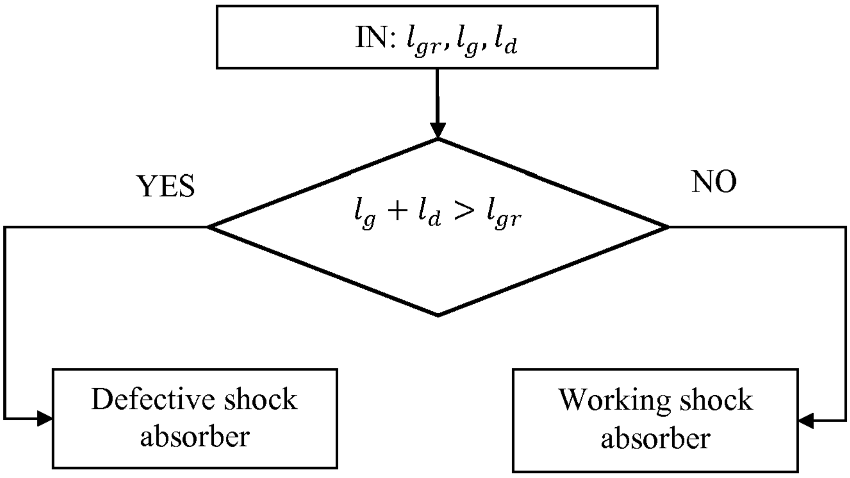

IN: l_{gr}, l_g, l_d
YES
$l_g + l_d > l_{gr}$
NO
Defective shock absorber
Working shock absorber

Fig 15.

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EUROPEAN SEARCH REPORT

Application Number
EP 17 21 1260

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	KR 100 745 356 B1 (MANDO CORP [KR]) 2 August 2007 (2007-08-02) * the whole document * -----	1-4	INV. G01M17/04 F16F9/32
A	CN 103 018 056 A (CHERY AUTOMOBILE CO LTD) 3 April 2013 (2013-04-03) * the whole document * -----	1-4	
A,D	EP 0 779 972 B1 (MUELLER ROLAND [DE]) 8 December 1999 (1999-12-08) * paragraph [0025] - paragraph [0030]; figure 1 * -----	1-4	

TECHNICAL FIELDS SEARCHED (IPC)

G01M
F16F
B60G
B62J
G01L

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	11 July 2018	Keita, Mamadou

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CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 17 21 1260

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11-07-2018

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EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

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- EP 86402253 B1 **[0002]**
- EP 86402254 B1 **[0002]**
- EP 89907781 B1 **[0002]**
- EP 94102441 B1 **[0002]**
- EP 94115944 A2 **[0002]**
- EP 95930380 B1 **[0002]**
- EP 98122896 B1 **[0002]**