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(54) Benævnelse: **Apparat og fremgangsmåde til måling af en plades bukkevinkel**

(56) Fremdragne publikationer:
WO-A1-01/14826
US-A- 5 103 488
US-A- 5 761 940
FU Z ET AL: "Using genetic algorithm-back propagation neural network prediction and finite-element model simulation to optimize the process of multiple-step incremental air-bending forming of sheet metal", MATERIALS AND DESIGN, LONDON, GB, vol. 31, no. 1, 1 January 2010 (2010-01-01), pages 267-277, XP026573916, ISSN: 0261-3069, DOI: 10.1016/J.MATDES.2009.06.019 [retrieved on 2009-06-17]

DESCRIPTION

[0001] The present invention concerns an apparatus and method for measuring a bending angle of a sheet.

[0002] Press brake machines adapted to bend metal sheets and obtain profiles with appropriate bending angles are known in the prior art.

[0003] Said press brake machines may be provided with bending angle measuring systems comprising a processing unit (computer) and one or more sensors; each sensor normally comprises means adapted to project a light pattern and means adapted to record the pattern deformation during the operation of bending the sheet.

[0004] EP 1102032 describes a method for measuring the bending angle of a sheet and a device for measuring said bending angle.

[0005] The method comprises measuring, on two sides of a member, e.g. the die, a number of distances on a plane which intersects the sheet and the member. Said distances comprise a number of distances between a measuring instrument and various points on the sheet and a number of further distances between the measuring instrument and various points on the member, so as to determine, for each side of the member, a respective profile of the measured distances and, from the profiles of these distances, the respective angles between sheet and member; the bending angle of the sheet is determined as a function of the angles determined between sheet and member.

[0006] The measuring device comprises, on two sides of a member, e.g. the die, an instrument for measuring a number of distances from a plane which intersects the sheet and the member. Said distances comprise a number of distances between a measuring instrument and various points on the sheet and a number of further distances between the measuring instrument and various points on the member. The device comprises means adapted to determine, for each side of the member, a respective profile of the measured distances and means for determining, from the profiles of these distances, the respective angles between sheet and member; the bending angle of the sheet is determined as a function of the angles determined between sheet and member.

[0007] EP 1204845 describes a process for detecting a bending angle and an apparatus for determining the change in the bending angle of a sheet during the bending operation.

[0008] The process comprises a light beam, which is directed towards a side of the workpiece, the angular position of which must be measured, and is constructed as a light plane or light cone, as a light line or path or, in particular, as a symmetric geometric shape which is produced either on the workpiece or on one side thereof. The change in the position of the contact point during the bending operation is detected in an opto-electronic manner, e.g. by means of a

video camera, in particular by means of an array video camera, and the angular position of the side of the workpiece is calculated by the changes in the position of the contact point seen by the video camera.

[0009] The light line or path, or the symmetry line of the geometric shape, is projected either parallel or essentially parallel to the bending line of the workpiece on the side of the workpiece, and the change in the angle of the side of the workpiece is calculated by the extension of the parallel translation of said line or lines as seen by the video camera.

[0010] The apparatus comprises a measuring beam or light source and a receiver, which records the light paths produced on the workpiece by the measuring beam or light source, in particular an array video camera, and a computer which calculates the angular changes resulting from the changes in position of the light path or paths. The measuring beam or light source is arranged or configured so that the produced path forms at least a slightly curved line or a straight line or a geometrically symmetric shape, surface or figure in order to perform the process as shown above. The apparatus is characterized in that the measuring beam or light source is arranged so that the light line or lines or the like, as the light angle contour delimited in a linear manner, or the symmetry line of the geometric shape, is (or are) arranged so as to extend either parallel or essentially parallel to the bending angle.

[0011] The >Using "Using genetic algorithm-back propagation neural network prediction and finite-element model simulation to optimize the process of multiple step incremental and air bending forming of sheet metal." of Zemin Fu et al., Materials and design, London vol. 31, No. 1, 1 January 2010 discloses an apparatus for air-bending a sheet with comprises a punch and a die with a pair of shoulders. A neural network is used and operates according to a prediction model; the springback radius is taken as the input of the neural network, the punch radius is output ten times continuously with the prediction model and the optimized weight and threshold each time were used as initial value of the next network training. The average of ten punch radii is used to establish the finite-element model simulation. A new punch is manufactured according to the simulation results and a semiellipse-shaped workpiece is formed by pressing a metal sheet with the new punch.

[0012] US 5761940 discloses some methods and subsystems for aligning a workpiece as it is being loaded into a die space of a bending apparatus, and for performing sensor-based control of a robot as it moves a workpiece from one location to another within a bending apparatus environment. A back-gaging mechanism is provided with finger gaging mechanism having force sensors for sensing forces in directions perpendicular to and parallel to a die.

[0013] US 5103488 relates to image cording systems and, more particularly, to a method of and a device for recognition or exact detection of moving image contour, for example the speaker contour in visual telephony. Matrices of vital samples relevant to the individual frames of the video transmission are submitted to a first processing whereby the foreground region containing the figure is identified. The information concerning the elements of such a region is then processed by edge recognition algorithms to detect a group of elements possibly

belonging to the contour. The group of elements is analyzed to select a sequence of elements distributed on the average along a line. The sequence of elements is processed by a neural network to build up the continuous contour which is then coded.

[0014] In the light of the prior art, it is the object of the present invention to provide an apparatus for measuring the bending angle of a sheet which is different from those known.

[0015] In accordance with the present invention, said object is achieved by means of an apparatus as claimed in the independent apparatus claim 1, and a method as claimed in the independent method claim 8. Preferred embodiments are subject of the dependent claims. The features and advantages of the present invention will become apparent from the following detailed description of a practical embodiment thereof, illustrated by way of non-limitative example in the accompanying drawings, in which:

figure 1 shows a section view of a measuring device of the bending angle of a sheet according to an embodiment of the present invention and provided with one single sensor;

figure 2 shows a section view of a measuring device of the bending angle of a sheet provided with two sensors according to a variant of the embodiment of the present invention;

figure 3 shows a light pattern with three inclined lines, projected onto the sheet subjected to bending and the mask used for concealing the die;

figure 4 shows a front view of the measuring apparatus of the bending angle in figure 1;

figure 5 shows a perspective view of the measuring apparatus of the bending angle in figure 1;

figure 6 shows a perspective view of a press brake machine comprising the measuring apparatus of the bending angle of a sheet according to the present invention;

figure 7 shows a side view of the press brake machine in figure 6;

figure 8 shows a block chart of the apparatus according to the present invention;

figure 9 shows the flow chart of the method for measuring the bending angle according to the present invention.

[0016] Figures 1-7 show an apparatus 2 for measuring the bending angle of a sheet 3 in a press brake machine 1. The press brake machine 1 is typically provided with a die 9 (figures 1, 2, 4-7) supported by a support 11; die 9 is of the interchangeable type to allow various bending types. The press brake machine 1 comprises a bending blade 12 (figures 6, 7) actuated by a mechanical assembly 13 so as to impress a longitudinal fold according to a line P on the sheet 3, interposed between die 9 and bending blade 12. Thereby, reference numerals 31 and 32 are the two surfaces or sides of sheet 3 adjacent to the bending line P, with the sheet 3 either during or after the step of bending.

[0017] The measuring apparatus 2 comprises at least one sensor 4 (figure 1) comprising a recording means 41, e.g. a video camera or photo camera, and a structured light illuminating source 42, e.g. a laser; two sensors 4 are preferably included (figure 2).

[0018] Each sensor 4 is supported by a clamp 14 and is adjustable in height by means of rods 15 on which clamp 14 can slide. Said rods 15 are integral with a support element 16 sliding along guides 8 which are longitudinal with respect to die 9.

[0019] The light source 42 is adapted to project a light pattern on a surface 31, 32 of the sheet 3. A light pattern means any geometric shape, a line, a plurality of parallel lines or incident lines or a point array.

[0020] The recording means 41 are adapted to record the image of the light pattern projected by the light source 42 on the surface 31, 32 of sheet 3, i.e. the deformed light pattern projected on the sheet being bent.

[0021] The recording means 41 and the lighting source 42 are connected to a processing unit 10 comprising a microprocessor 101 and a memory 102 on which an application software is installed and runs. Indicatively, the processing unit 10 may be considered as a set of sections or parts for controlling devices 41, 42 and for processing the images recorded by the recording means 41. The sections correspond to the various functions of the application software installed and running in memory 102.

[0022] The processing unit 10 (figure 8) comprises a section 110 adapted to control the light source 42 for illuminating the surface 31, 32 of sheet 3 and adapted to subsequently control the recording means 41 for recording the image obtained on the surface 31, 32 by the projection of the light pattern resulting from source 42.

[0023] In accordance with the present invention, the camera means 41 are configured to record the image obtained on the surface 31, 32 by the projection of the light pattern during the operation of bending sheet 3 at least in one time instant Treg1 but preferably in a plurality of subsequent time instants Treg1, Treg2....Tregn, spaced apart by time intervals Td which are not zero until the required measuring value of the bending angle of sheet 3 is achieved. The time intervals Td preferably have the same duration, i.e. 15 milliseconds.

[0024] The light pattern preferably comprises a plurality of lines 52 inclined with respect to one another and projected either parallel or essentially parallel to the surface 31, 32 of sheet 3 (figure 3). In particular, the number of inclined lines 52 may be two or three.

[0025] The recording means 41 record the image 55 during the operation of bending sheet 3 at least in one time instant Treg1, but preferably in time instants Treg1, Teg2... Tregn.

[0026] In each time instant Treg1, Treg2...Tregn, the image of the deformed pattern 55 is sent to the processing unit 10, in particular to the section 111, by means of a wired or wireless

connection.

[0027] In section 112, the processing unit 10 preferably applies a mask 51 for concealing die 9 in the recorded image 55 so as to ignore the portion of light pattern projected onto the die 9 itself.

[0028] The processing unit 10, again in section 112, then processes the light sources of the recorded image 55 to discriminate the laser light pattern from the background represented by the surface 31, 32 of sheet 3; the recorded light pattern 56 is obtained in this manner.

[0029] The processing unit 10, in section 113, is adapted to process said recorded pattern 56 to obtain a point cloud 57.

[0030] Another section 114 of the processing unit 10 is adapted to sample the points of the point cloud 57 in order to reduce the amount of data to be processed; a plurality of samples 58 is obtained which, after a reassembly step again in section 114, are input to another section 115 comprising a neural network.

[0031] Samples 58 may be chosen in a random manner. In all cases, the samples preferably refer to an area 300 of the surface 31, 32 of sheet 3 over die 9, preferably at a distance of 20 millimeters from die 9; thereby, by choosing the samples in the area 300 a greater measuring accuracy and fastening measuring operation speed is obtained.

[0032] The number of samples 58 preferably varies from 200 to 300.

[0033] The neural network 115 can detect a bending angle on the basis of the configuration of the points input thereto, i.e. according to the plurality of samples 58 which are supplied as inputs.

[0034] The neural network 115 should be trained to provide a bending angle from samples of a point cloud before being used, i.e. should have previously processed an appropriate amount of configurations.

[0035] In general, the neural network 115 can suggest a linearization of the problem for which a solution is sought. Such a linearization expresses the statistic probability that a new case, never examined before, falls within a solution area which has been already checked and validated during the step of training. This result is intrinsically capable of compressing an amount of data because, once the numerical model has been learnt, the neutral network does not need to access a database from where to pick the correspondences between configurations of points and bending angle, as it is capable of autonomously reconstructing them.

[0036] The training is further sampled, i.e. an amount of data to be stored is smaller because the neural network can reconstruct the remaining data by interpolation. In the case in hand,

only some of the configurations of a plurality of point cloud samples, and not all the possible configurations, are stored during the step of training. The neural network 115 thus learns the relationships between the input variable (plurality of samples of the point cloud) and the output variable (bending angle) and is proven to be able to reproduce not only the point configurations which were never found before but also those which have already been seen, not needing to have a database of images available. Furthermore, working with point clouds does not require algorithms to solve the problem of image distortion which would occur in case of measurement strategies based on distance calculation (e.g. the angle between two lines).

[0037] The bending angle 60 at the output from the neural network 115 is input into a section 116 which checks whether the bending angle 60 is equal to that desired. If the check is negative, the measurement of the bending angle of sheet 3 is repeated in subsequent time instants Treg1, Teg2...Tregn until a desired measurement angle value is achieved, i.e. until the checking operation is positive; whenever the operation is negative, section 116 informs the control section 110 to control the recording means and make a new recording of the image obtained on the surface 31, 32 by the projection of light pattern resulting from the source 42. Section 116 also preferably checks coherence of data output from the neural network 115; in case of positive result of both the coherence check operation and the checking operation, the measurement value 200 is sent to the user.

[0038] The processing unit 10 works in the following manner (figure 9).

[0039] There are a first step A of controlling the projection of the light pattern on one or both surfaces 31, 32 of sheet 3, and a step B of recording the image obtained on the surface 31, 32 by the light pattern projection during the operation of bending sheet 3 in a time instant Treg1.

[0040] There are then a step C of applying a mask 51 for concealing die 9 in the recorded image 55, and a step D of discriminating the laser light pattern from the background represented by the surface 31, 32 of sheet 3 so as to obtain a recorded light pattern 56.

[0041] Subsequently, there are a step E of transforming the recorded light pattern 56 into a point cloud 57, and a subsequent step F of sampling the point cloud 57 in order to obtain a plurality of samples 58, and a step of reassembling the samples.

[0042] At step G, the plurality of reassembled samples 58 are processed by a neural network for identifying the bending angle 60 corresponding to said plurality of reassembled samples 58.

[0043] The coherence of the bending angle 60 is preferably checked during a subsequent step H; in case of positive result (Yes), the value 60 of the bending angle is the output for the subsequent step L, otherwise (No) step G resumes.

[0044] At step L, there is a step of checking in which it is evaluated whether the value 60 of the bending angle obtained in the time instant Treg1 is the one desired; if this is so (Yes), the measuring method ends, otherwise (NO) another measurement of the bending angle is made

in a subsequent instant Treg2, after a time interval Td from instant Treg1 i.e. the measuring method resumes from step B or, if the projection of light pattern on one or both surfaces 31, 32 of sheet 3 is also not continuous but discontinuous, the measuring method resumes from step A by controlling the projection of the light pattern.

[0045] At step L, there is a new step of checking in which it is evaluated whether the value of measurement 60 of the bending angle obtained in time instant Treg2 is the desired one; if this is so (Yes), the measuring method ends, otherwise (NO) another measurement of the bending angle is carried out in a later instant Treg3, after the time interval Td of instant Treg2, i.e. a measuring method resumes from step B or A again.

[0046] The measuring method continues in the subsequent instants Treg3...Tregn until it is checked that at step L the measurement value obtained is that desired and the measuring value 200 is thus transmitted to the user.

REFERENCES CITED IN THE DESCRIPTION

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- EP1204845A [0007]
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- US5103488A [0013]

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- **ZEMIN FU et al.**Using genetic algorithm-back propagation neural network prediction and finite-element model simulation to optimize the process of multiple step incremental and air bending forming of sheet metalMaterials and design, 2010, vol. 31, 1 [0011]

Patentkrav

1. Apparat (2) til måling af en bukkevinkel af en plade (3) under bukningen af pladen (3), omfattende en behandlingsenhed (10) og mindst en føler (4), der omfatter en lyskilde (42) til at projicere et lysmønster (52) på mindst en side (31, 32) af pladen (3), og et registreringsmiddel (41) egnet til at registrere afbildning af lysmønsterets projektion på mindst en side af pladen, der bukkes, **kendetegnet ved, at** behandlingsenheden (10) er konfigureret til at styre registreringsmidlet til at registrere afbildningen på mindst et tidspunkt (Treg1; Treg1, Treg2 ... Tregn) under pladens (3) bukkeoperation, hvilken behandlingsenhed (10) er i stand til at transformere den registrerede afbildning (56) i en punktsky (57), og omfattende et neuralt netværk (115), som er konfigureret til at knytte en bukkevinkelværdi (60, 200) til punktskyen (57), og hvilken behandlingsenhed (10) er konfigureret til at kontrollere (116), om bukkevinkelværdien (60, 200) er lig med en ønsket bukkevinkelværdi for pladen, og hvis kontroloperationen er negativ, er den indrettet til at drive registreringsmidlet til at registrere afbildningen på en flerhed af på hinanden følgende tidspunkter (Treg1, Treg2 ... Tregn) adskilt af intervaller (Td) forskellig fra nul under pladens (3) bukkeoperation, indtil apparatet opnår det ønskede mål for pladens bukkevinkelværdi, hvilken behandlingsenhed på hvert af tidspunkterne (Treg1, Treg2 ... Tregn) er i stand til at transformere den registrerede afbildning (56) i en punktsky (57) og det neurale netværk (115), altid på hvert af tidspunkterne, idet den er konfigureret til at knytte en bukkevinkelværdi (60, 200) af pladen til punktskyen (57).

2. Apparat ifølge krav 1, **kendetegnet ved, at** behandlingsenheden (10) er konfigureret til at tage prøver af punktskyen (57) og sende en flerhed af prøver (58) som input til det neurale netværk (115), hvilket neuralt netværk (115) er egnet til at knytte en bukkevinkelværdi (60, 200) til prøverne (58).

3. Apparat ifølge krav 1, **kendetegnet ved, at** lyskilden (42) er indrettet til at projicere et lysmønster (52) omfattende en flerhed af skrå linier.

4. Apparat ifølge krav 3, **kendetegnet ved, at** lyskilden (42) er indrettet til at projicere et lysmønster (52) bestående af to skrå linier.

5. Apparat ifølge krav 1, **kendetegnet ved, at** behandlingsenheden (10) er konfigureret til at behandle den registrerede afbildnings lystærskler (55) med regi-

streringsmidlet (41) for derved at skelne lysmønsteret (56) fra baggrunden repræsenteret ved pladen (3).

6. Kantpresse (1), omfattende et apparat (2) til at måle bukkevinklen af pladen (3) ifølge ethvert af de foregående krav.

7. Kantpresse ifølge krav 6, **kendetegnet ved at** omfatte en matrice (9) til bukning af metalpladen (3), hvilken behandlingsenhed (10) er indrettet til at maskere matricen (9) for derved at ignorere den del af de af registreringsmidlet (41) registrerede lysmønstre (55), som er relateret til matricen (9).

8. Fremgangsmåde til måling af en plades (3) bukkevinkel under bukningen af pladen (3), hvilken fremgangsmåde omfatter projicering (A) af et lysmønster (52) på mindst en side af pladen (3), registrering (B) af afbildningen (55) relateret til projektionen af lysmønsteret på mindst en side af pladen (3), der bukkes, **kendetegnet ved, at** registreringen forekommer på mindst et tidspunkt (Treg1, Treg2 ... Tregn) under pladens (3) bukning, hvilken fremgangsmåde omfatter transformering (E) af den registrerede afbildning i en punktsky (57) og knytning af en bukkevinkelværdi (60, 200) til punktskyen ved anvendelse (G) af et neuralt netværk (115), verificering (L) af, om bukkevinkelværdien (60, 200) af pladen er lig med en ønsket bukkevinkelværdi af pladen, og hvis verificeringstrinet er negativt (NO), gentages trinene med registrering af afbildningen, transformering (E) af den registrerede afbildning i en punktsky (57) og knytning af en bukkevinkelværdi (60, 200) til punktskyen ved anvendelse (G) af et neuralt netværk (115) på efterfølgende tidspunkter (Treg1, Treg2 ... Tregn) adskilt af forskellige tidsintervaller (Td) forskellig fra nul under pladens (3) bukkeoperation, indtil den ønskede bukkevinkelværdi for pladen er opnået.

9. Fremgangsmåde ifølge krav 8, **kendetegnet ved** at omfatte prøvetagning (F) af punktskyen (57) for at fremskaffe en flerhed af prøver (58) og anvendelse af det neurale netværk (115) på flerheden af prøver (58) for at fremskaffe bukkevinkelværdien (60, 200).

10. Fremgangsmåde ifølge krav 8, **kendetegnet ved, at** lysmønsteret, der skal projiceres, dannes af en flerhed af skrå linier.

11. Fremgangsmåde ifølge krav 10, **kendetegnet ved, at** lysmønsteret, der skal projiceres, dannes af to skrå linier.

12. Fremgangsmåde ifølge krav 8, **kendetegnet ved** at behandle (D) den registrerede afbildnings lystærskler (55) efter registreringstrinet med registreringsmidlet for derved at skelne lysmønsteret (56) fra baggrunden repræsenteret ved pladen.

13. Fremgangsmåde ifølge krav 8, **kendetegnet ved, at** bukningen af pladen udføres ved anvendelse af en matrice (9), hvilken fremgangsmåde omfatter maskering (C) af matricen (9) før trinet med behandling (D) af lystærsklerne.

14. Fremgangsmåde ifølge krav 8, **kendetegnet ved** at omfatte læring af det neurale netværk (115), hvori alene visse konfigurationer af prøvetagne punktskyer oplagres, hvilket læringstrin går forud for lysmønsterets projektionstrin.

15. Fremgangsmåde ifølge krav 8, **kendetegnet ved** at omfatte en kontrol (H) af sammenhæng i de data, som er tilvejebragt som output af det neurale netværk (115), før afsendelse af disse data til brugeren.

DRAWINGS

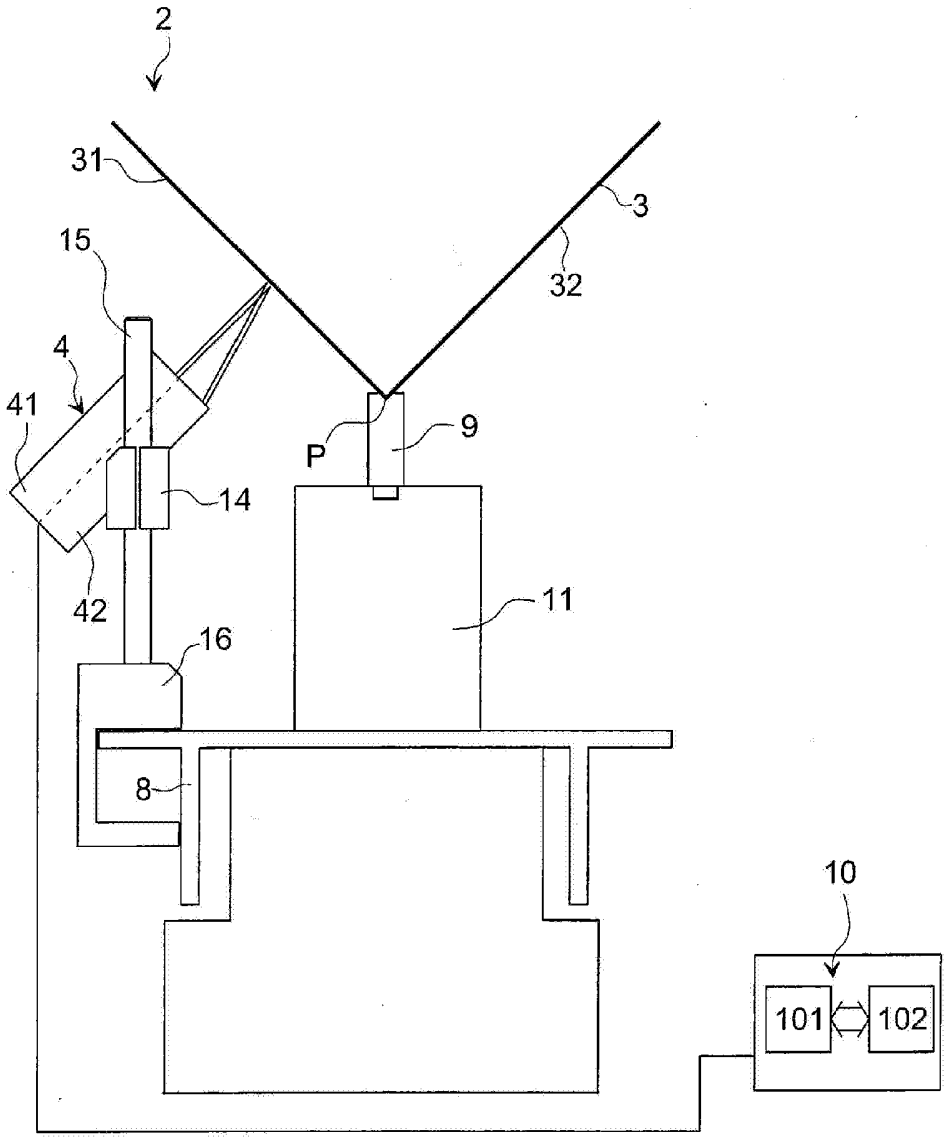

Fig.1

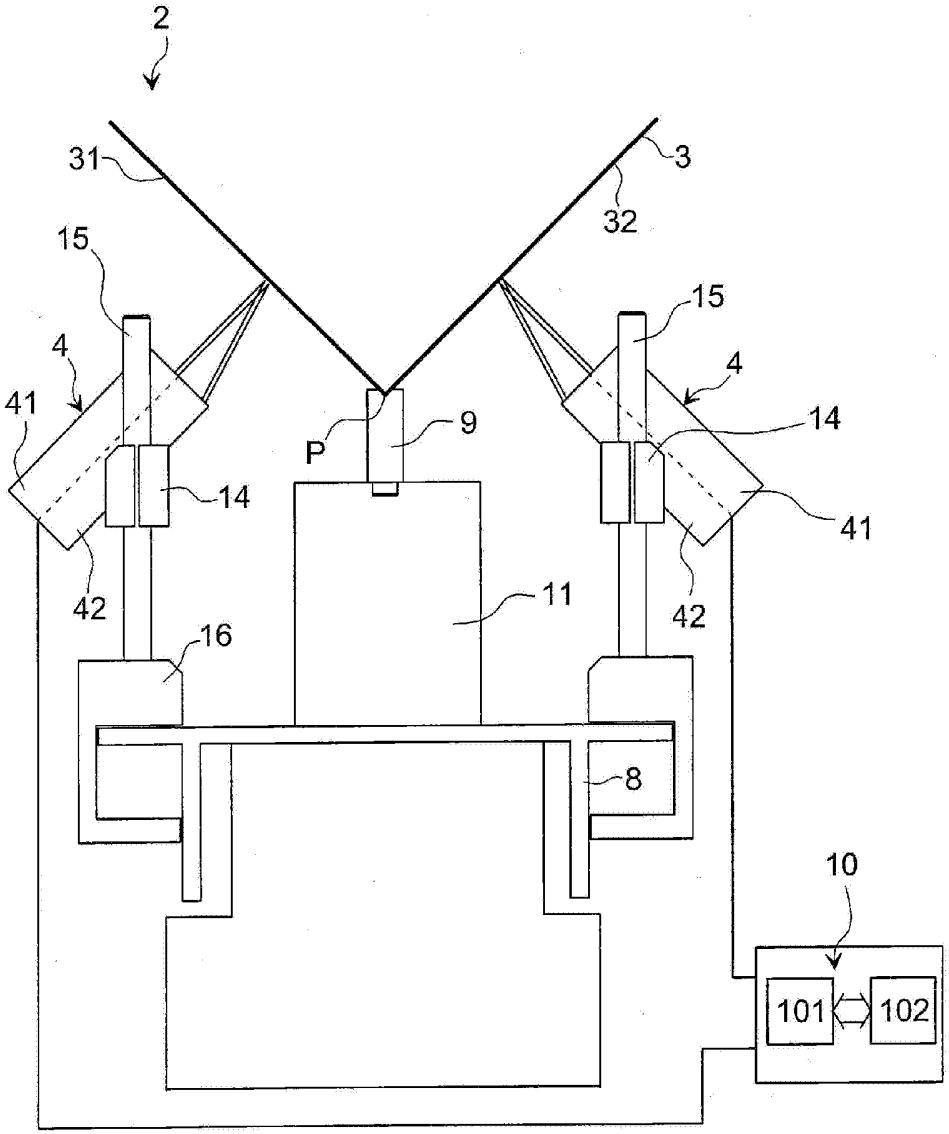

Fig.2

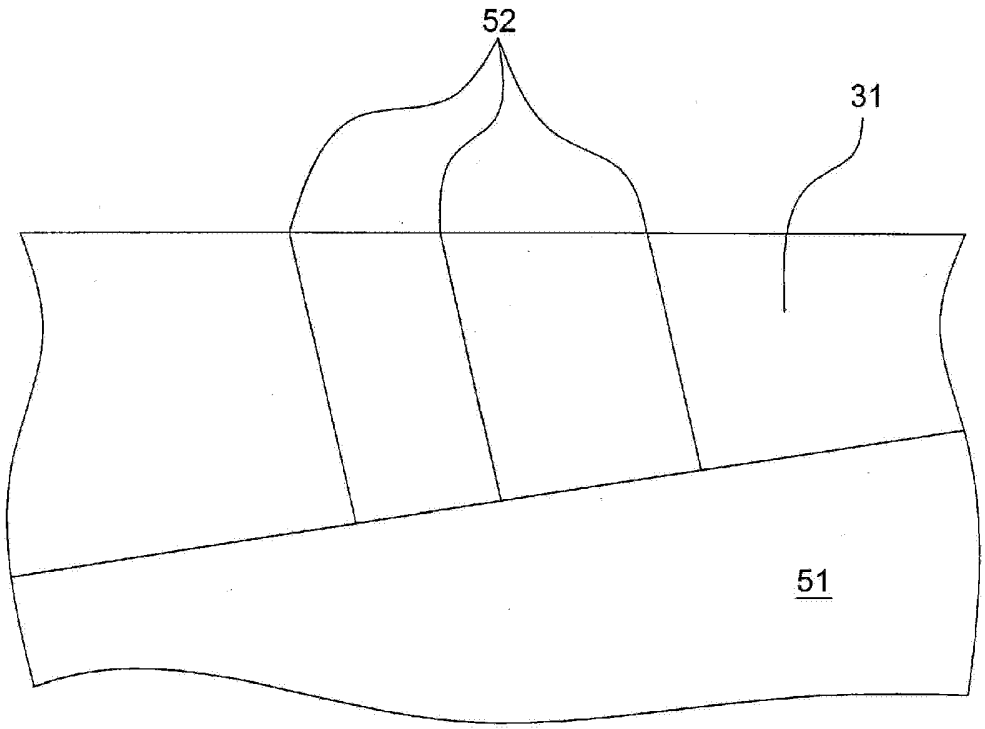

Fig.3

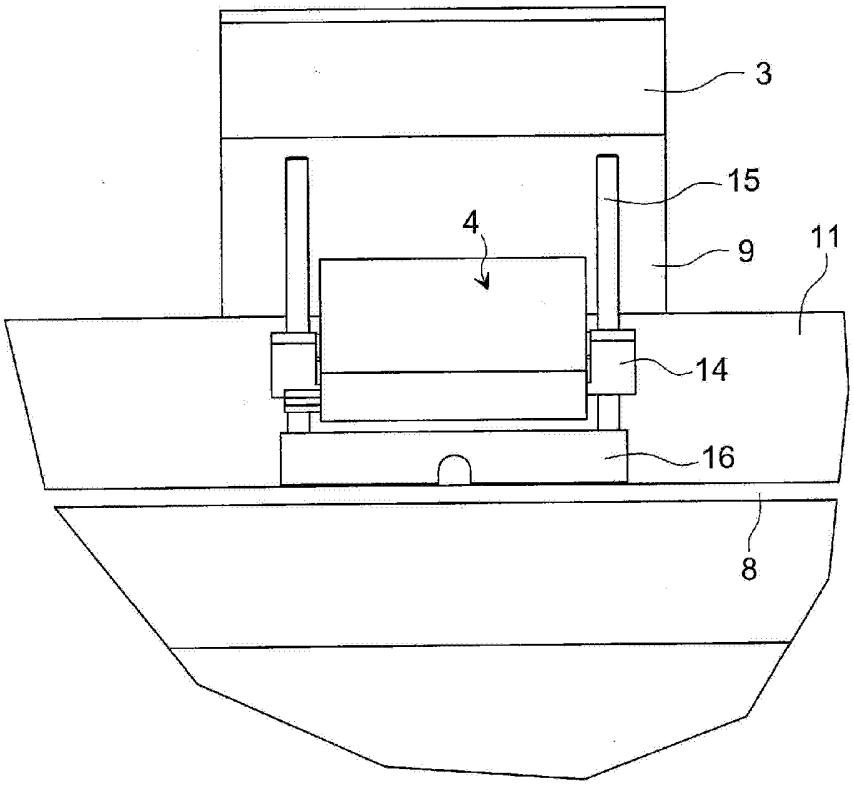

Fig.4

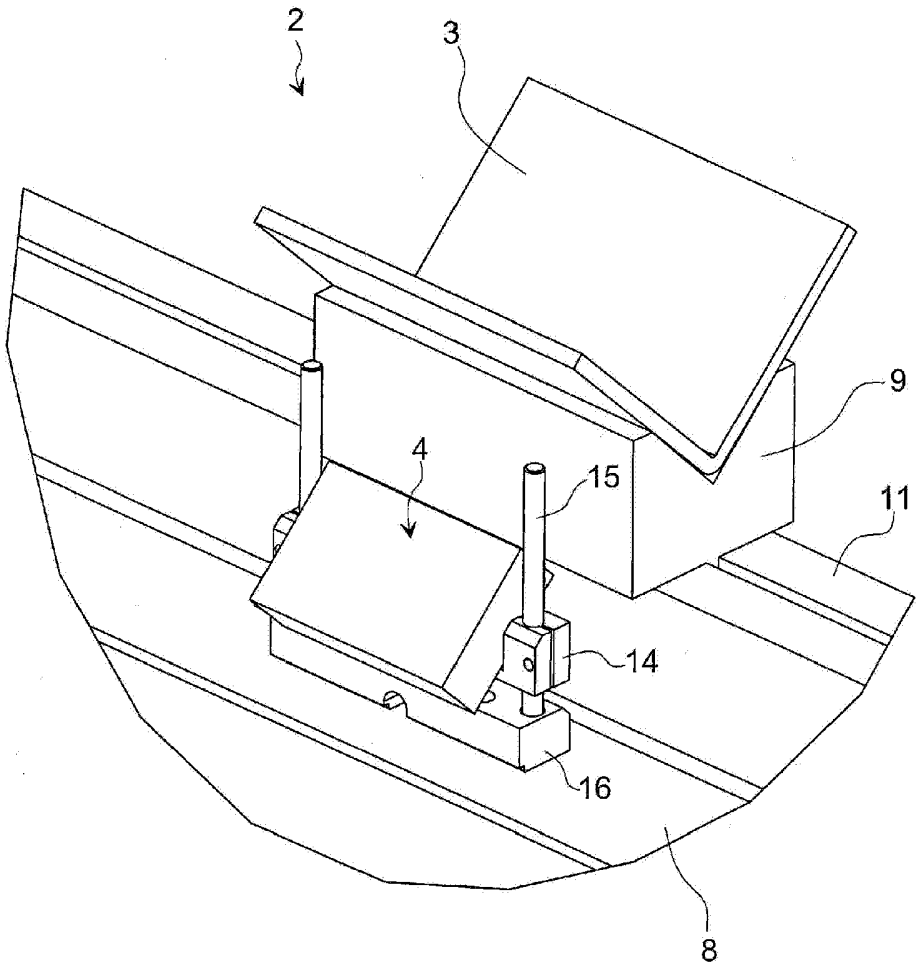

Fig.5

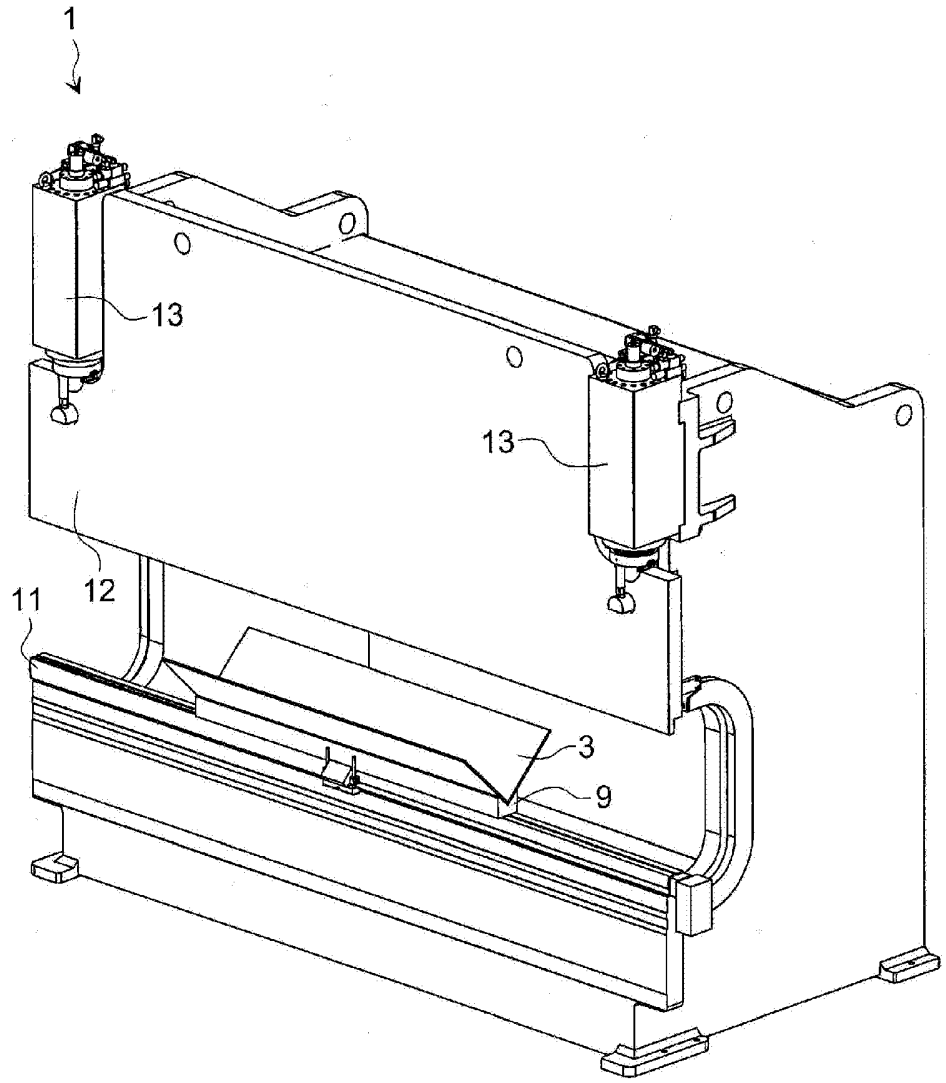

Fig.6

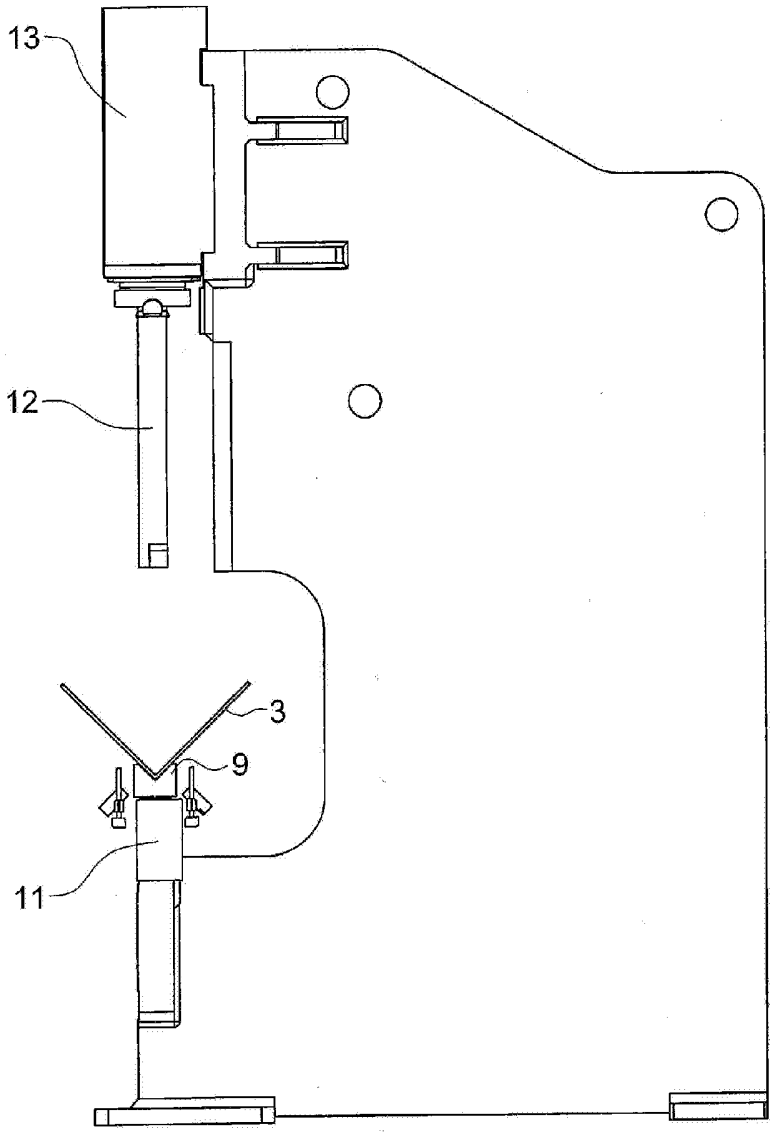

Fig.7

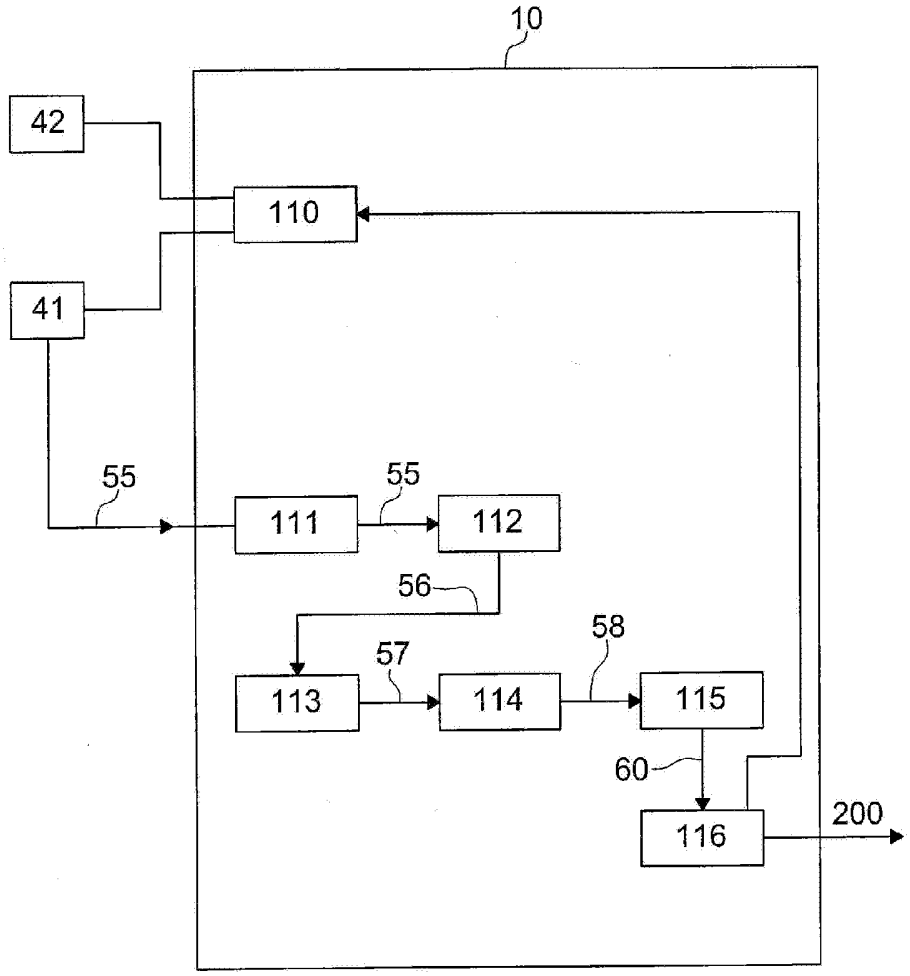

Fig.8

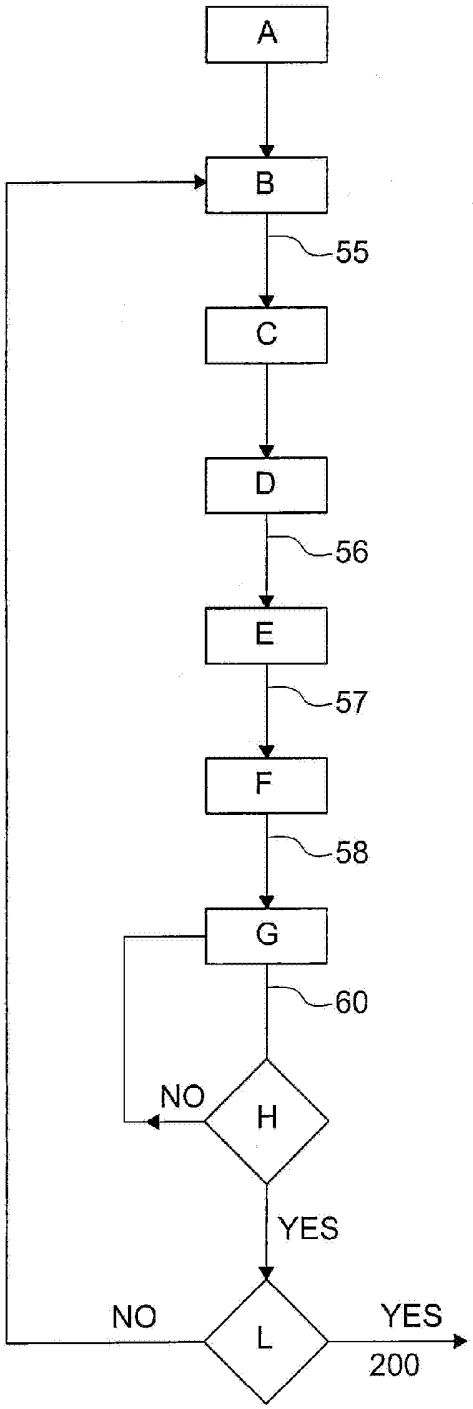

Fig.9