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— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

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(54) Title: OFF-AXIS LOADCELL FORCE SENSING TO AUTOMATICALLY DETERMINE LOCATION OF SPECIMEN FEATURES

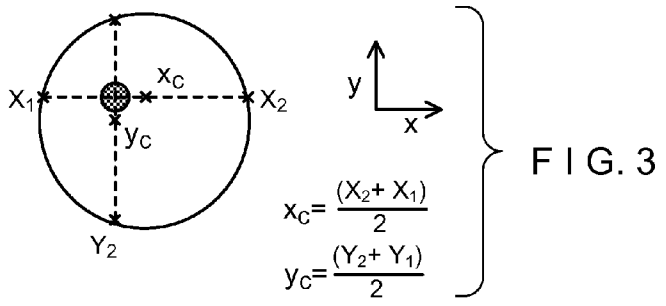

FIG. 3

(57) Abstract: The present disclosure relates to a method in materials testing to automatically locate the center of a feature on or in an object using the off-axis force feedback of a loadcell. In this disclosure, either a simplified model of the product or device being tested, or the product itself, is placed under the loadcell probe with the feature of interest roughly aligned under the probe tip. The probe is driven down into the feature. The product is automatically positioned relative to the probe in the x-direction until the side of the probe contacts the side of the feature. Contact is determined by monitoring the force feedback from the loadcell. When the vertical force from the side-load surpasses a pre-determined setpoint, contact is assumed and the value of the x-position of the product with respect to the probe is recorded. The product is then repositioned in the opposite direction in the x-axis to record the touch load on the other side. The center is then calculated as the average of the x values. The process is repeated along the y-axis. This data is then used to calculate the center of the feature and the product can be positioned at this location so that the probe is centered over the center thereof.

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OFF-AXIS LOADCELL FORCE SENSING TO AUTOMATICALLY DETERMINE LOCATION OF SPECIMEN FEATURES

This application claims priority under 35 U.S.C. 119(e) of U.S. provisional patent application serial no. 61/868,916 filed on August 22, 2013, the contents of which are hereby incorporated by reference in their entirety.

BACKGROUND OF THE DISCLOSURE

Field of the Disclosure

[0001] The present disclosure relates to a method in materials testing to automatically locate the center of a feature on or in an object using the off-axis force feedback of a loadcell.

Description of the Prior Art

[0002] In materials testing, measuring the force and displacement characteristics of compliant features in or on an object can require precise placement of the probe tip of the displacement sensor. This can be due to the variability of the force/displacement with the position of the compliant feature of interest. Therefore, slight offsets from the intended location of measurement can result in widely varying force/displacement results.

[0003] In the prior art, a technique for aligning the center of the feature of interest under the center of the probe involves a human attempting to visually and manually align them. This is subjective and error-prone resulting in potentially high positional error in the alignment of the probe to the center of the feature, which can result in erroneous force/displacement results.

[0004] Additionally, touch probes or kinematic resistive probes have been developed by Renishaw and Marposs to determine the location of parts and features in a materials testing environment.

OBJECTS AND SUMMARY OF THE DISCLOSURE

[0005] It is therefore an object of the present disclosure to accurately and automatically locate the center of a feature in a materials testing application.

[0006] These and other objects are obtained by providing a method and apparatus wherein either a simplified model of the product or device being tested, or the product itself, is placed under the loadcell probe with the feature of interest roughly aligned under the probe tip. The probe is driven down into the feature. The product is automatically positioned relative to the probe in the x-direction until the side of the probe contacts the side of the feature. Contact is determined by monitoring the force feedback from the loadcell. When the vertical force from the side-load surpassed a pre-determined setpoint, contact is assumed and the value of the x-position of the product with respect to the probe is recorded. The product is then repositioned in the opposite direction in the x-axis to record the touch load on the other side. The center is then calculated as the average of the x values. The process is repeated along the y-axis. This data is then used to calculate the center of the feature and the product can be positioned at this location so that the probe is centered over the center thereof.

[0007] An advantage of the resulting automated method and apparatus is that the subjectivity of a human operator visually locating the center of a feature is replaced by a quantitative and more accurate and repeatable method of precision drive electronics and hardware as well as a highly accurate force sensing loadcell, thereby reducing any error and improving the quality of the results.

[0008] The method and apparatus of the present disclosure has many applications, including, but not limited to keyboards, safety mats, syringes, cigarettes, computer equipment, and telephones.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] Further objects and advantages of the disclosure will become apparent from the following description and from the accompanying drawings, wherein:

[00010] Figure 1 is a top view of a representative model of the method of the present disclosure.

[00011] Figure 2 is a side view corresponding to Figure 1.

[00012] Figure 3 illustrates the calculations performed with respect to the method illustrated in Figures 1 and 2.

[00013] Figures 4A, 4B and 4C illustrate a second embodiment of the present disclosure.

[00014] Figure 5 is a flowchart of an embodiment of the method of the disclosure.

[00015] Figure 6 is a flowchart of a further embodiment of the method of the disclosure.

[00016] Figures 7A, 7B, 7C and 7D illustrate the further embodiment of Figure 6.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[00017] Pursuant to this disclosure, the method uses either a simplified model of the product, sample or device being tested, or it could use the product 100 itself, or a modification thereof, if the feature of interest can be robustly contacted. The simplified model or product will include a geometric equivalent to the feature of which the center is desired to be located. The technique is as follows:

[00018] 1. The model, product or sample 100 is placed under the probe 202 of the loadcell 200.

[00019] 2. The feature of interest, such as, but not limited to, aperture or hole 102, is roughly aligned under the probe tip 204. See Figure 5, step 502.

[00020] 3. The probe 202 is driven down into the feature 102, which for illustrative purposes is an aperture or hole 102 in the product 100, see Figure 1. See Figure 5, step 504.

[00021] 4. The product 100 is automatically positioned or moved relative to the probe 202 in the x direction until the side of the probe 202 contacts the side of the feature 102. See Figure 5, step 506. Contact is determined by monitoring the force feedback from the loadcell 200 that is induced by the off-axis or side contact of the probe 202 against the side of the aperture or hole 102 as shown in Figure 2.

[00022] 5. When the vertical force from the side-load surpasses a pre-determined setpoint, contact is assumed and the value of the x-position of the product 100 with respect to the probe 202 is recorded. This is x_1 in Figure 3. The product 100 is then repositioned or moved in the opposite direction in the x-axis to record touch load on the other side of the hole 102 (see Figure 5, step 508) and is designated x_2. The center of the hole x_c is then calculated to be the equidistant point or average x value between x_1 and x_2 (see Figure 5, step 514). The process is then replicated in the y-axis to determine the center of the hole 102 in the y-axis or y_c. See Figure 5, steps 510, 512 and 514.

[00023] 6. With x_c and y_c determined, the center of the hole or feature 102 is known and the product 100 can be positioned to this location so that the probe 202 is centered over the center of the feature.

[00024] Another embodiment of the disclosure of detecting the off-axis force signature of a loadcell 200 for detecting feature or product position is shown in Figures 4A, 4B and 4C and described as follows:

[00025] 1. The product 100 is driven or moved into the side of the probe 202 which is attached to a loadcell 200 as shown in Figure 4A. Also see Figure 6, step 602 (shown within further embodiment).

[00026] 2. The vertical force that results from the horizontal loading of the probe 202 and loadcell 200 is monitored for touch-load, which is a minimal but repeatable force that does not permanently deflect or damage the loadcell 200 as shown in Figure 4B.

[00027] 3. The position of the resulting touch-load is recorded and the automatic positioning system can back the product 100 or feature 102 away from the probe tip 204 a predetermined amount to ensure accurate offset of probe 202 to the relative position of the feature as shown in Figure 4C. See Figure 6, step 604 (shown within further embodiment).

[00028] Under optimal conditions, the contact that was initiated between the probe 202 (and loadcell 200) and the product 100 under test would represent the “zero condition” and

the product 100 would be driven a software hard-coded fixed distance from the probe 202 to be clear of the product for subsequent tests. The probe 202 would then move up or down to begin its test to measure the force displacement while contacting another part of the product 100.

[00029] Occasionally, however, the product 100 under test has variable or inconsistent geometry or compliance in the area of interest that the probe 202 contacts. Additionally, either the probe 202 or the product could be angled in the vertical or z direction. In these suboptimal conditions, the probe 202 could contact the body of the product after it backs off the fixed distance where it is expected to no longer be in contact with the product to begin the test. Upon further motion, the probe 202 and loadcell 200 may incorrectly detect a drag or friction force that will adversely affect the test and results.

[00030] To correct this potential problem, another embodiment of this disclosure applies an adaptive zeroing function which is illustrated in Figures 6 and 7A-7D. The product or sample 100 is driven into the probe 202 as shown in step 602 of Figure 6 and Figure 7A. The resulting vertical touch load is calculated as shown in step 604 of Figure 6 and Figure 7B. When the touch position or zero position is determined, the product 100 is driven to a known offset between the probe 202 and the product 100 as shown in step 606 of Figure 6 and Figure 7C. The probe is then moved vertically (or orthogonally to the original driving direction) to contact and catch any protrusion on the product or sample 100 as shown in step 608 of Figure 6 and Figure 7D. Vertical force and displacement of the protrusion is measured with a horizontal gap between the probe and product being maintained in order to not induce a frictional drag component on the vertical load, see Figure 6, step 610. If there is a frictional drag load by the probe 202 still being in contact with any part of the product 100 when it should not be, then the expected load versus displacement curve of the abnormal test will look different than curves from normal tests. Typical load versus displacement curves are generated by previous performing tests on samples where it is known that there is no drag of the product or sample 100 on the probe 202. Algorithms compare the actual force versus displacement curves to these previously generated typical force displacement curves (wherein the data may be provided as a database or library of expected curves) and detect if an abnormal curve or test result is being generated. See Figure 6, steps 610, 612, 614. If the load versus displacement curve of the protrusion appears to be unusual after signal analysis when compared to the previously generated typical load versus displacement curves, this

could mean that the horizontal gap is too small and that the probe is still contacting the side of the body of the product 100. This would cause a frictional load that would adversely affect the load versus displacement curve. As shown in steps 614 and 616 of Figure 6, if an unusual load versus displacement curve is detected, the offset is increased and steps 602-614 are repeated until a normal load versus displacement curve is detected. After iteratively positioning the product 100 and repeating tests until acceptable force versus displacement curves are detected, the test is concluded and the results are exported. See Figure 6, step 618.

[00031] Thus the several aforementioned objects and advantages are most effectively attained. Although preferred embodiments of the invention have been disclosed and described in detail herein, it should be understood that this invention is in no sense limited thereby and its scope is to be determined by that of the appended claims.

CLAIMS

What is Claimed is:

1. A method for locating a center of a selected feature of a sample in a materials testing application, comprising the steps of:

providing a loadcell, including a probe;

directing the probe toward the selected feature of the sample;

driving the probe into the selected feature of the sample;

positioning the product relative to the probe in a first direction until the probe contacts a first side of the selected feature;

positioning the product relative to the probe in an opposite of the first direction until the probe contacts a second side of the selected feature;

positioning the product relative to the probe in a second direction until the probe contacts a third side of the selected feature; and

positioning the product relative to the probe in an opposite of the second direction until the probe contacts a fourth side of the selected feature.

2. The method of Claim 1 wherein:

the step of positioning the product relative to the probe in the first direction calculates a first measurement in the first direction;

the step of positioning the product relative to the probe in an opposite of the first direction calculates a second measurement in the first direction;

the step of positioning the product relative to the probe in the second direction calculates a first measurement in the second direction;

the step of positioning the product relative to the probe in an opposite of the second direction calculates a second measurement in the second direction.

3. The method of Claim 2 wherein the first direction is orthogonal to the second direction.

4. The method of Claim 3 wherein:

a coordinate of the center of the feature in the first direction is calculated by averaging the first and second measurements in the first direction; and

a coordinate of the center of the feature in the second direction is calculated by averaging the first and second measurements in the second direction.

5. The method of Claim 4 further including the step of determining contact of the probe by monitoring force feedback from the loadcell that is induced by the contact of the probe against a side of the selected feature.

6. The method of Claim 5 wherein the step of determining contact of the probe further includes an indication of contact when force feedback from the loadcell surpasses a pre-determined setpoint.

7. The method of Claim 4 further including the step of positioning the probe according to the coordinates of the center of the feature in the first and second directions.

8. The method of Claim 1 wherein the feature is an aperture.

9. A method for locating a center of a selected feature of a sample in a materials testing application, comprising the steps of:

providing a loadcell, including a probe;

driving the sample in a first direction into a side of the probe until contact is detected at a point of contact; and

backing the sample away from the probe by an offset distance from a point of contact.

10. The method of Claim 9 wherein the offset distance is pre-determined.

11. The method of Claim 9 further including the step of calculating the offset distance, wherein the step of calculating the offset distance includes the steps of:

providing at least one expected force versus displacement curve;

after the step of backing the sample away, relatively moving the probe in a second direction, orthogonal to the first direction, thereby deriving an actual force versus displacement curve;

comparing the actual force versus displacement curves to the expected force versus displacement curves;

if the actual force versus displacement curve differs substantively from the expected force versus displacement curves, then a step of adjusting the offset distance is performed and the driving step, the relatively moving step, the comparing step and the adjusting step are repeated until the actual force versus displacement curve substantively matches at least one of the expected force versus displacement curves.

12. The method of Claim 11 including the steps of driving, relatively moving, comparing and adjusting are terminated after the actual force versus displacement curve substantively matches at least one of the expected force versus displacement curves.

13. The method of Claim 12 further including the step of communicating results of the method.

14. The method of Claim 11 wherein the actual force versus displacement curve differing substantively from the expected force versus displacement curves indicates that the sample is dragging on the probe during motion.

15. The method of Claim 11 wherein the step of providing at least one expected force versus displacement curve includes providing a plurality of expected force versus displacement curves.

16. The method of Claim 11 wherein the step of providing at least one expected force versus displacement curve includes providing a library of expected force versus displacement curves.

17. The method of Claim 11 wherein the step of providing at least one expected force versus displacement curve includes providing a database of expected force versus displacement curves.

18. The method of Claim 11 wherein the plurality of expected force versus displacement curves are previously generated by performing the driving step on a sample which is known to be free of dragging on the probe.

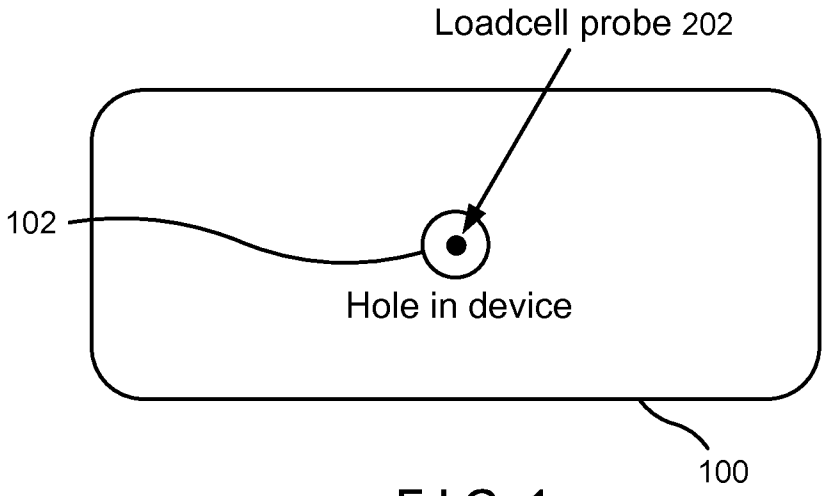

Loadcell probe 202
102
Hole in device
100

FIG. 1

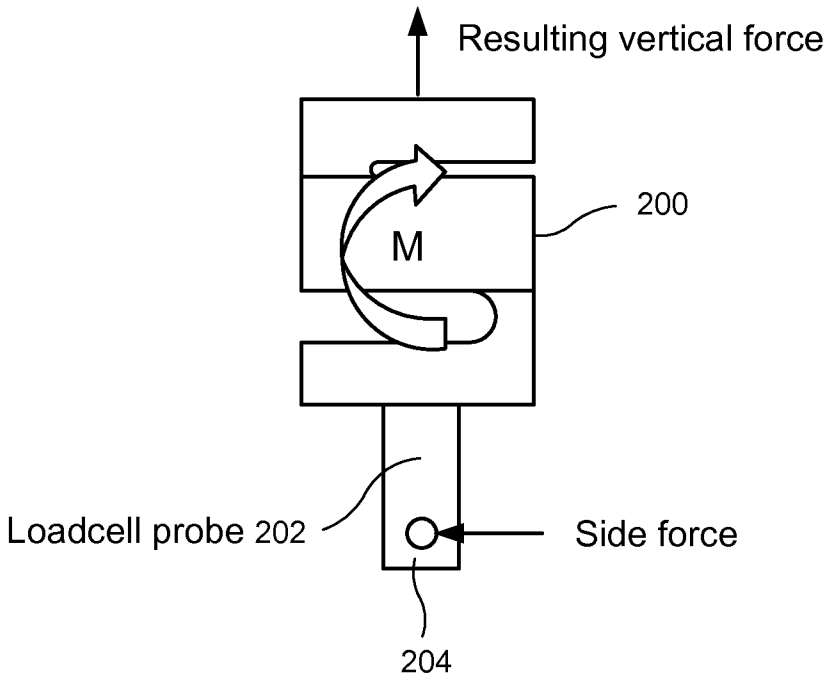

Resulting vertical force
200
M
Loadcell probe 202
Side force
204

FIG. 2

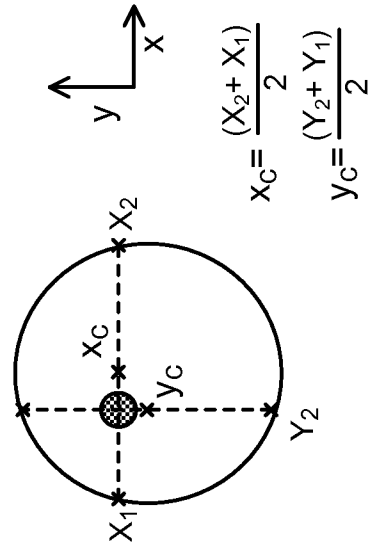


FIG. 3

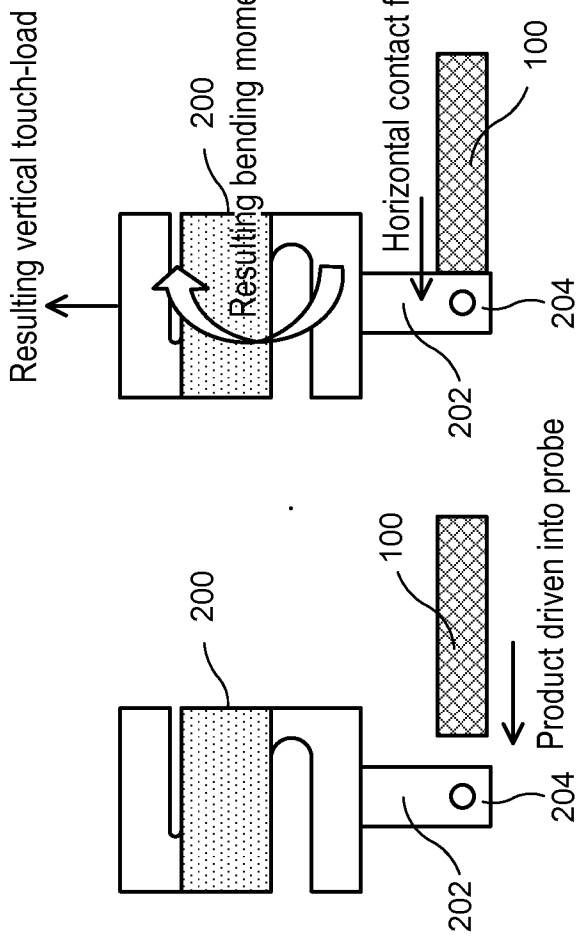


FIG. 4B

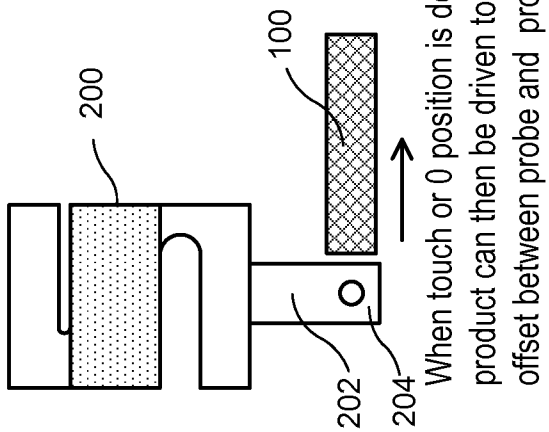


FIG. 4C

FIG. 4A

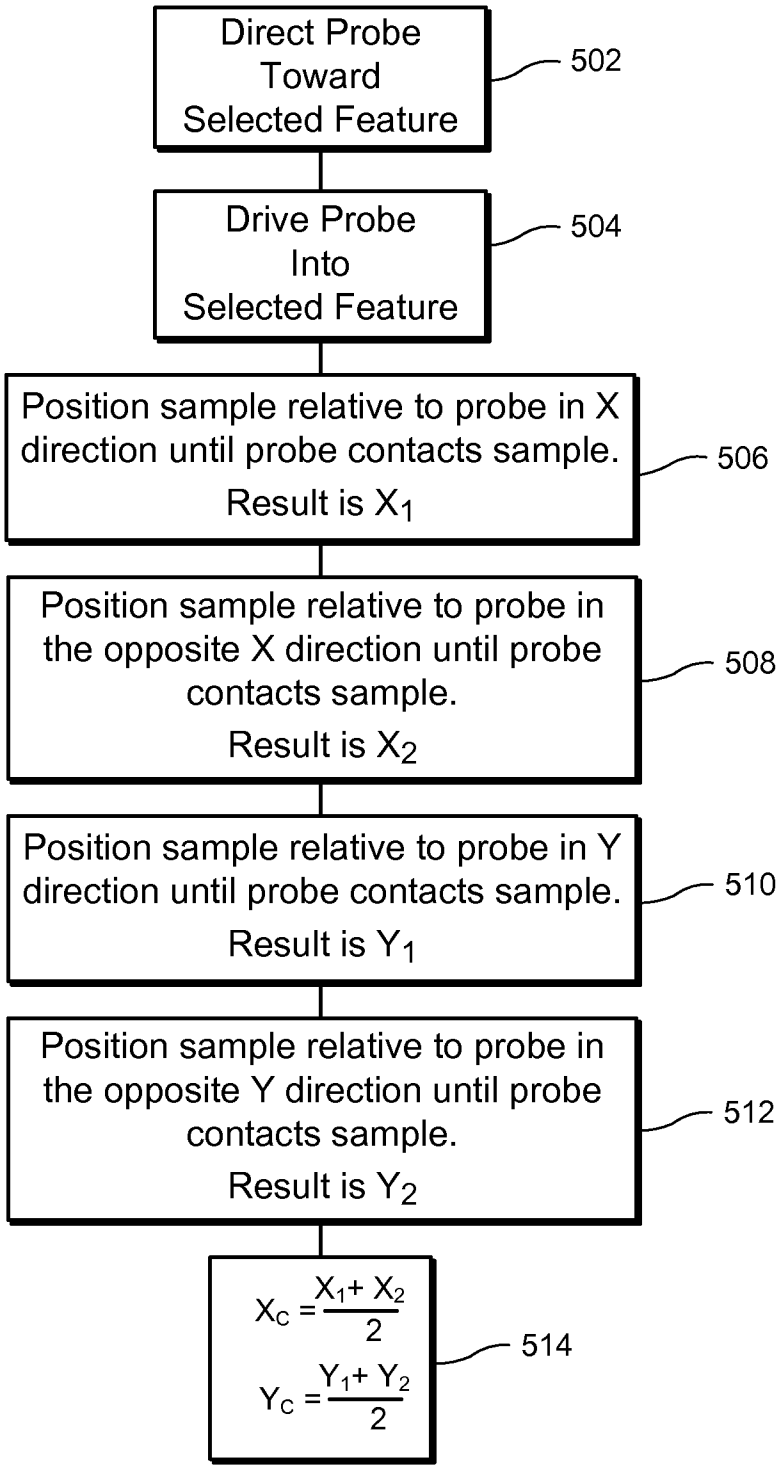

Direct Probe Toward Selected Feature
502
Drive Probe Into Selected Feature
504
Position sample relative to probe in X direction until probe contacts sample.
Result is X_1
506
Position sample relative to probe in the opposite X direction until probe contacts sample.
Result is X_2
508
Position sample relative to probe in Y direction until probe contacts sample.
Result is Y_1
510
Position sample relative to probe in the opposite Y direction until probe contacts sample.
Result is Y_2
512
$X_C = \frac{X_1 + X_2}{2}$
$Y_C = \frac{Y_1 + Y_2}{2}$
514

FIG. 5

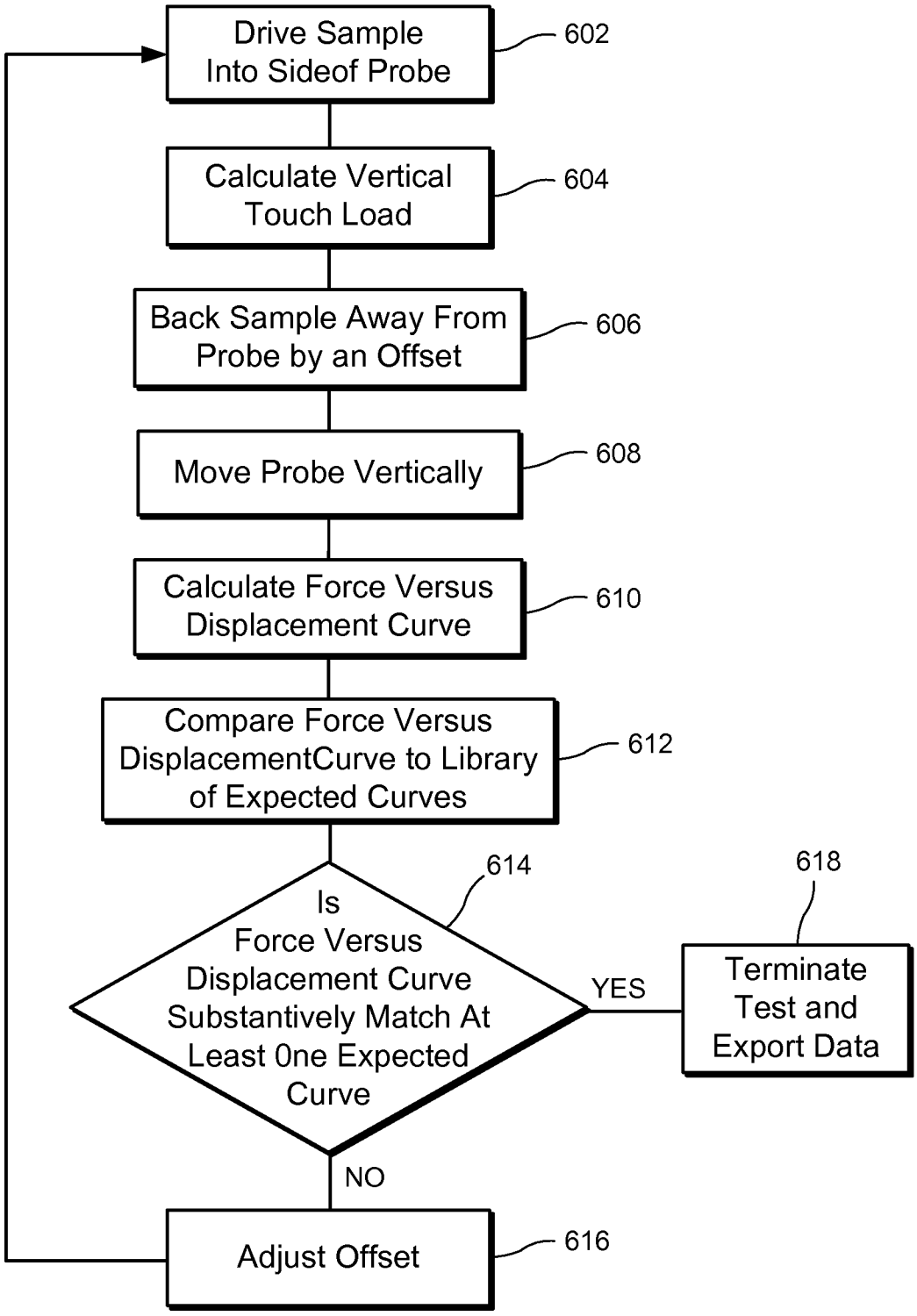
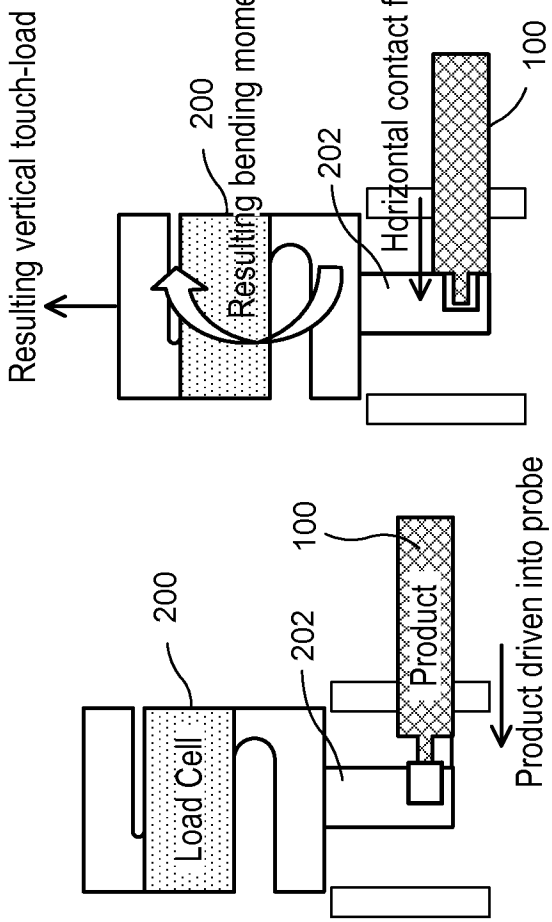
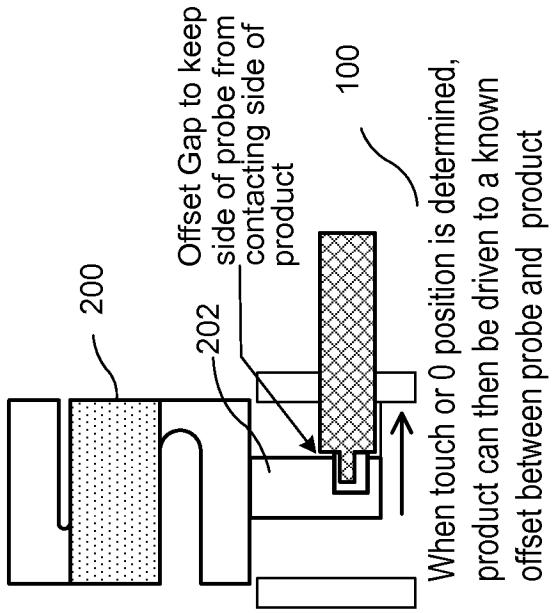

Drive Sample Into Sideof Probe
602
Calculate Vertical Touch Load
604
Back Sample Away From Probe by an Offset
606
Move Probe Vertically
608
Calculate Force Versus Displacement Curve
610
Compare Force Versus DisplacementCurve to Library of Expected Curves
612
614
Is Force Versus Displacement Curve Substantively Match At Least 0ne Expected Curve
YES
618
Terminate Test and Export Data
NO
Adjust Offset
616

FIG. 6

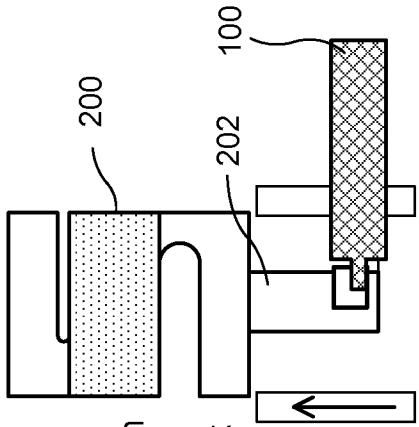


F I G. 7A

F I G. 7B



F I G. 7C



F I G. 7D

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2014/050791

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01B5/004 G05B19/402 G01B21/04
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G01B G05B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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X	EP 0 092 021 A2 (IBM [US]) 26 October 1983 (1983-10-26) page 14, line 17 - page 15, line 9; figure 4.3	1-18
X	JP S58 72004 A (TOSHIBA MACHINE CO LTD) 28 April 1983 (1983-04-28) abstract; figures 1-3	1-18
X	JP S60 104209 A (ISHIKAWAJIMA HARIMA HEAVY IND) 8 June 1985 (1985-06-08) abstract; figure 2	1-18

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
29 October 2014	06/11/2014

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Passier, Martinus

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INTERNATIONAL SEARCH REPORT

International application No
PCT/US2014/050791

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 179 788 A (JADACH ALBERT A [US]) 19 January 1993 (1993-01-19) abstract; figures 3-5 -----	9-18
A	EP 0 501 710 A1 (RENISHAW METROLOGY LTD [GB]) 2 September 1992 (1992-09-02) abstract; claim 3; figure 4 column 2, line 55 - column 3, line 15 column 7, lines 16-41 column 8, lines 23-53 -----	1-18

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INTERNATIONAL SEARCH REPORT

Information on patent family members

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