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(54) Title: SURFACE FINISH OR SURFACE ROUGHNESS PROBE

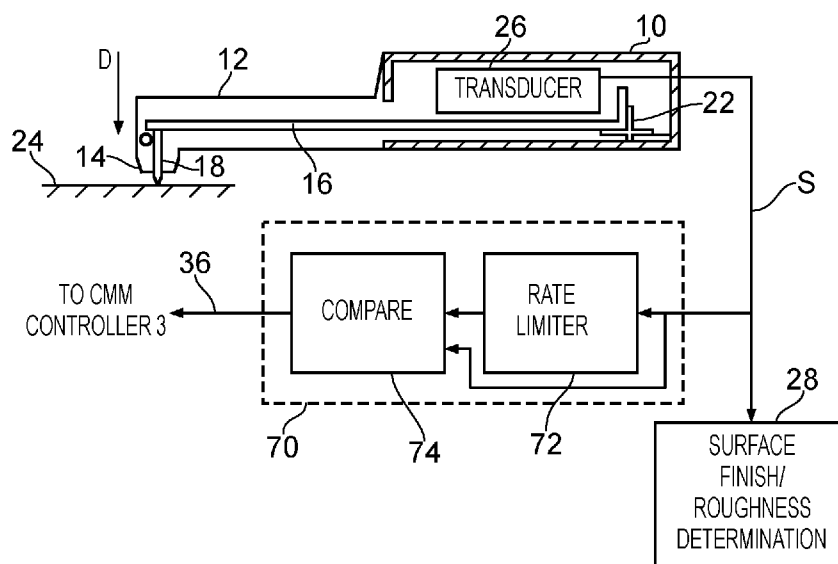


FIG. 5

(57) Abstract: A surface finish or surface roughness probe (10) comprises a deflectable stylus (18) associated with a skid (14). It is mounted in a coordinate measuring machine (CMM), which drags the skid (14) and stylus (18) along a surface (24) to be measured. Stylus deflections relative to the skid are measured by a transducer (26) to determine the surface finish or roughness. Initially the CMM brings the probe into contact with the surface in a direction (D). To produce a desired preload or nominal zero position of the skid (14) relative to the surface (24), the probe has a detection circuit (30, 70). This produces a control signal (36) in response to contact between the stylus or skid and the surface, which is used to control the movement of the probe in the direction (D) relative to the surface.



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SURFACE FINISH OR SURFACE ROUGHNESS PROBE

Field of the invention

5 This invention relates to probes for measuring surface finish or surface roughness, and to methods of use of such probes. In use, such probes may for example be mounted on a position determining apparatus, such as a co-ordinate-measuring machine (CMM), a scanning machine, a machine tool or an inspection/measurement robot.

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Description of prior art

US Patent No. US 9250053 (Hirano et al / Mitutoyo) describes a surface roughness probe comprising a skid and a spring-loaded pin or stylus which projects through a hole in the skid. The probe is mounted on a coordinate measuring machine (CMM). In use, movement of the CMM brings the skid and the stylus into contact with a workpiece surface, of which the roughness is to be measured. The CMM then drags the skid and the stylus along the surface. Surface undulations cause the stylus to deflect relative to the skid, normal to the surface, against the action of the spring. A transducer in the probe converts these deflections of the stylus into an electrical signal, from which the surface roughness can be determined.

When bringing the stylus and skid into contact with the workpiece surface, there is a problem to control movement of the CMM so as to load the skid against the workpiece surface consistently. This affects the deflection of the stylus and the force on the skid during the measurement. US Patent No. US 9250053 provides a contact detector for detecting when the skid contacts the workpiece surface. However, this comprises a photodetector for detecting tilting of a unit of which the skid forms part. The photo detector adds to the cost and size of the probe.

Summary of the invention

A first aspect of the present invention provides a probe for measuring surface finish or surface roughness, comprising:

- 5 a skid for contacting and scanning a workpiece surface;
 a stylus associated with the skid and biased to project beyond it to contact the workpiece surface, the stylus being configured to deflect relative to the skid during a scanning motion;
 a transducer for producing a signal in response to deflections of the stylus,
10 from which the surface finish or surface roughness can be determined; and
 a processor configured to detect a change in the transducer signal relating to contact between the skid and the surface and to produce a control signal in response thereto.

- 15 The probe may be mounted in a position determining apparatus arranged to move the probe towards the workpiece surface and bring it into contact with the workpiece surface. The control signal may be fed back to a controller of the position determining apparatus to control the movement of the probe relative to the surface. The controller may then be arranged to perform a scan of the surface
20 to determine the surface finish or roughness, with a nominal zero position determined using the control signal.

The processor may be configured to produce the control signal when the transducer signal stops changing as a result of the skid contacting the surface.

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- Alternatively, the processor may be configured to detect when the transducer signal starts to change as a result of the stylus contacting the surface. It may then produce the control signal a predetermined time later. Or it may send the control signal to the controller when the transducer signal starts to change. The controller
30 may then be programmed to determine a nominal zero position for subsequent scanning measurements either a predetermined time later, or after a movement

through a predetermined further distance. It may control the position of the probe so as to produce a desired preload or nominal zero position of the probe relative to the surface.

- 5 In one preferred embodiment, the probe may be mounted on an articulating head for movement in at least one rotary axis, the articulating head being mounted in a position determining apparatus for movement on linear axes. The controller may then be programmed to produce the desired preload by positioning the probe using a combination of rotary and linear movements of the head and the position
- 10 determining apparatus. This may be found advantageous when accessing a surface in a confined space such as a small bore.

- A second aspect of the invention provides a probe for measuring a surface, the probe being mounted on an articulating head for movement in at least one rotary
- 15 axis, the articulating head being mounted in a position determining apparatus for movement on linear axes,

- the movement on the rotary and linear axes being controlled by a controller programmed to produce a desired preload of the probe relative to the surface by positioning the probe using a combination of rotary and linear
- 20 movements of the head and the position determining apparatus.

- Further aspects of the invention provide methods of operation of a probe for measuring surface finish or surface roughness according to any of the variations of the first and second aspects set out above. The invention also provides programs
- 25 for a controller of a position determining apparatus, configured to carry out such methods.

Brief description of the drawings

- 30 Preferred embodiments of the invention will now be described with reference to the accompanying drawings, wherein:

Fig 1 is an isometric view of a surface finish or surface roughness probe mounted on an articulating probe head;

Fig 2 shows a section through axes A and B of Fig 1;

Fig 3 shows the surface finish or surface roughness probe in more detail;

5 Fig 4 is a schematic representation of the probe and a processing circuit;

Fig 5 is a schematic representation of the probe and an alternative processing circuit;

Fig 6 is a graph of a signal produced by a transducer of the probe;

Fig 7 illustrates one method of processing the signal; and

10 Figs 8A-8C illustrate a procedure for applying a preload to the probe.

Description of preferred embodiments

Fig. 1 shows an articulating probe head 7, which supports a surface sensing device 4 for rotation about two mutually orthogonal axes of rotation A, B. Fig 2 shows a section through the articulating head 7 and the surface sensing device 4 in a plane defined by the axes A, B. The surface sensing device 4 includes a surface finish or surface roughness probe 10 which is described in more detail below.

20 The articulating probe head 7 comprises first and second housing members 1 and 2 respectively. The first housing member 1 is adapted for attachment to a position determining apparatus, for example to a movable arm 66 of a CMM. The CMM has motors which move the arm 66 in three linear dimensions X,Y,Z, under the programmed control of a computer controller 3. As shown in Fig 2, the housing member 1 houses a motor M1 for effecting angular displacement of a first shaft 60 about the first axis A. Attached to the first shaft 60 is the second housing member 2, which houses a motor M2 for effecting angular displacement of a second shaft 62 about the second axis B. The surface sensing device 4 is attached to the second shaft 62 for rotation therewith. The CMM has motors which drive the arm 66 in the X,Y,Z directions under the control of a program in a computer control 3, which also controls the movements of the motors M1, M2 about the axes A, B.

The surface sensing device 4 includes an elongate probe holder 8 which holds the surface finish or roughness probe 10. The probe holder 8 extends generally along an axis C, transverse to and intersecting the axis B. It is exchangeably attached to and detached from the articulating head 7 via a housing 9. The housing 9 may optionally contain a motor M3 which rotates the probe holder 8 about the axis C, again controlled by the program in the computer control 3, so that the surface finish or roughness probe 10 can address differently oriented workpiece surfaces.

10 The general arrangement of the articulating probe head 7 and the probe holder 8 is as described in our co-pending UK Patent Application No. GB 1702391.2 and in our US Patents Nos. US 8006399 (Wallace et al) and US 8468672 (Wallace), all of which are incorporated herein by reference.

15 The surface finish or surface roughness probe is shown in more detail in Figs 3 and 4 and comprises a housing 10, from one end of which extends a finger 12. A skid 14 is provided at the end of the finger 12, for contacting a workpiece surface 24 to be measured. An arm 16 extends along the finger 12, and is mounted deflectably within the housing 10, for example pivotable about crossed planar
20 springs 22. At the end of the pivotable arm 16 is a stylus 18, associated with the skid 14. The stylus is biased by the springs 22 to be deflectable and to project slightly beyond the skid 14. This means that when the probe is moved into contact with the workpiece surface 24 in the direction of arrow D, a tip of the stylus 18 contacts the surface slightly before the skid 14. The stylus 18 and
25 pivotable arm 16 deflect about the springs 22 to permit this.

In addition, the housing 10 is spring-mounted to a support 19 at a joint 11. This permits the skid 14 to deflect when loaded onto a surface 24 which is to be measured.

30

At its other end, the support 19 is attachable to the probe holder 8 of the surface

sensing device 4, for example via a knuckle joint 20 which can be manually positioned to adjust the orientation of the probe for access to workpiece surfaces at different locations and orientations. The probe can be moved by the CMM and/or the articulating head, under the control of a program in a control computer (controller 3) of the CMM. The controller thus brings the probe into contact with the workpiece surface 24 to be measured, and then drags the skid 14 and the tip of the stylus 18 along the surface to measure the surface finish or roughness.

The resulting deflections of the stylus 18 relative to the skid 14 are measured by a transducer 26 in the housing 10. The transducer produces a signal S which is used to determine the surface finish or surface roughness from place to place as the skid and stylus are dragged along the surface, as indicated at 28. Although a specific unit 28 is shown for calculating this, in practice this calculation may take place in the computer controller of the CMM, which can have a program routine to calculate the surface finish or surface roughness values.

To ensure consistent measurement results, it is important that when the skid 14 and stylus 18 are first brought into contact with the surface 24, they are loaded onto the surface in a consistent manner, with a consistent force and/or deflection. For this it is important to determine when the skid touches the surface. This is achieved as follows.

The tip of the stylus 18 is positioned close to a target point on the surface 24 to be measured. The skid and stylus tip are driven towards the surface in the direction of arrow D (using the motors of the axes of either or both the CMM and the articulating head) whilst reading the output signal of the transducer 26 which measures tip deflection relative to the skid. Initially the signal S will be level as shown at 40 in Fig 6. At point 42, when the stylus tip comes into contact with the surface, the transducer signal S starts to change as a result of the tip deflection relative to the skid. The signal continues to change until the point 44, at which the skid reaches the same measurement surface and the signal levels off again as

shown at 46. By detecting the point 44 at which the skid touches the surface, and using this as a nominal zero position in the movement of the probe as it is subsequently dragged along the surface, the controller can control the deflection (and hence force) of the spring-mounted skid by driving the axes of either or both the CMM and articulating head further towards the surface by a known amount, e.g. 1 mm.

There are several ways in which the point 44 can be detected. If the value of the signal S is known at this point, then a threshold detector can detect when it exceeds a threshold 45 just below it. Or curve-fitting software can analyse the signal S to determine the position of the point 44. Alternatively, the signal S can be passed to detection circuit 30 (Fig 4). Here, a differentiator 32 differentiates the transducer signal S with respect to time. The resulting output dS/dt is shown in Fig 7. At 48 and 52, it is zero (since the transducer signal is not changing at 40 and 46). A pulse 50 is produced as the stylus tip moves relative to the skid 14. A threshold detector 34 in the detector circuit 30 detects the end of this pulse when it falls below a threshold 54.

However the point 44 is detected, a corresponding control signal is sent to the CMM controller 3, e.g. as shown at 36 in Fig 4. This enables the program in the controller to control the further movement. The program causes the controller to determine the X,Y,Z coordinates corresponding to the point 44, which it then uses to determine the nominal zero position as it controls the dragging movement of the probe along the surface.

25

Instead of detecting the point 44 at which the skid 14 reaches the surface, it is possible to detect the point 42 at which the stylus tip contacts the surface and starts to move relative to the skid. This can be detected in a similar manner to the point 44. The control signal may be sent to the controller at the point 42 when the transducer signal starts to change. The controller may then be programmed to determine a nominal zero position for subsequent scanning measurements either

30

(a) after a movement through a predetermined further distance (e.g. 2 mm) to allow the skid to be loaded onto the surface, or (b) after a predetermined time corresponding to such a distance at the speed at which the probe is being moved. It is also possible to delay sending the control signal to the controller by this
5 predetermined time.

Fig 5 shows an alternative processing circuit 70, for use if noise on the signal S means that the differentiated signal dS/dt is too noisy to allow the use of a simple threshold detector 34. Here, the signal S is passed through a rate limiter 72 and
10 then compared at 74 to the original signal S. The point 42 at which the stylus tip comes into contact with the surface is detected when the original signal S becomes different from the rate-limited signal.

The position of the skid in space and the protrusion of the stylus relative to the
15 skid are not perfectly controlled or known. The above methods allow for a precise detection of the point at which the stylus or the skid reaches the measurement surface and therefore allows for a simple means of controlling the deflection of the skid about the spring-loaded joint 11, and therefore force on the skid during measurement.

20

The above description has shown that the signals can be processed in circuits which are separate from the CMM controller, but in practice it will often be more convenient to digitise the transducer output signal S and process it in the controller 3.

25

Figs 8A-8C illustrate a procedure for getting the surface finish/roughness probe 10 into a confined space, e.g. when it is desired to inspect the surface of a feature such as small bore 80.

30 First, as shown in Fig 8A, the probe 10 is inserted into the feature 80 to be measured. This is done by movement on the linear X,Y,Z axes of the CMM to

which the probe is mounted, under the program control of the controller 3. The probe 10 is kept parallel to the feature 80, and the stylus 18 is now at a position where it can start to seek the surface of the feature.

5 Next, the probe seeks the surface, again using linear movement of the CMM on the axes X,Y,Z, corresponding to movement on the arrow D in Figs 4 and 5. This movement is stopped as soon as the surface contact is detected (point 42 in Fig 6). This position is shown in Fig 8B. The probe 10 is still kept parallel to the feature 80.

10

Now the controller 3 applies a desired preload for the surface scan to the probe, as shown in Fig 8C. This is done by a combined movement of both the linear X,Y,Z axes of the CMM and the rotary A/B axes of the articulating head 7. The probe 10 remains parallel to the feature 80, but the support 19 on which it is spring-

15 mounted at the joint 11 rotates about a “preload pivot point” 82 to a “preload angle” 84 which gives the desired consistent preloading from deflection at the joint 11. It will be appreciated that to achieve this, the movement of the head on the linear X,Y,Z axes will be in an approximate arc which is almost equal and opposite to the rotary movement of the support 19 about the articulating head axes
20 A,B, while allowing for the deflection of the spring of the joint 11 as the preload is applied.

The probe 10 is now in a position to scan the surface of the feature 80. After the scan, the above procedure is reversed to remove the probe from the feature 80.

25 First a combined movement of both the linear X,Y,Z axes of the CMM and the rotary A/B axes of the head removes the preload, so that the probe is in a condition as seen in Fig 8B. Then the probe is retracted from the feature 80 by linear X,Y,Z movements of the CMM.

CLAIMS

1. A probe for measuring surface finish or surface roughness, comprising:
a skid for contacting and scanning a workpiece surface;
5 a stylus associated with the skid and biased to project beyond it to contact the workpiece surface, the stylus being configured to deflect relative to the skid during a scanning motion;
a transducer for producing a signal in response to deflections of the stylus, from which the surface finish or surface roughness can be determined; and
10 a processor configured to detect a change in the transducer signal relating to contact between the stylus or skid and the surface and to produce a control signal in response thereto.
2. A probe according to claim 1, wherein the processor is configured to
15 detect when the transducer signal changes as a result of the stylus contacting the surface and to produce the control signal in response.
3. A probe according to claim 2, wherein the processor is configured to
produce the control signal a predetermined time after it detects that the transducer
20 signal has changed.
4. A probe according to claim 1, wherein the processor is configured to
produce the control signal when the transducer signal stops changing as a result of
the skid contacting the surface.
25
5. A probe according to any one of the preceding claims, configured for
mounting in a position determining apparatus arranged to move the probe towards
the workpiece surface and bring it into contact with the workpiece surface.
- 30 6. A probe according to claim 5, with a controller for the position
determining apparatus, the probe being configured to feed the control signal back

to the controller to control the movement of the probe relative to the surface.

7. A probe according to claim 6, wherein the controller is arranged to move the position determining apparatus so that the probe performs a scan of the surface to determine the surface finish or roughness, with a nominal zero position determined using the control signal.

8. A probe according to claim 6 or claim 7, wherein the processor is configured to detect when the transducer signal changes as a result of the stylus contacting the surface and to send the control signal to the controller in response.

9. A probe according to claim 8, wherein the controller is programmed to determine a nominal zero position for subsequent scanning measurements either a predetermined time later, or after a movement through a predetermined further distance.

10. A probe according to claim 8 or claim 9, wherein the controller is programmed to control the position of the probe so as to produce a desired preload or nominal zero position of the probe relative to the surface.

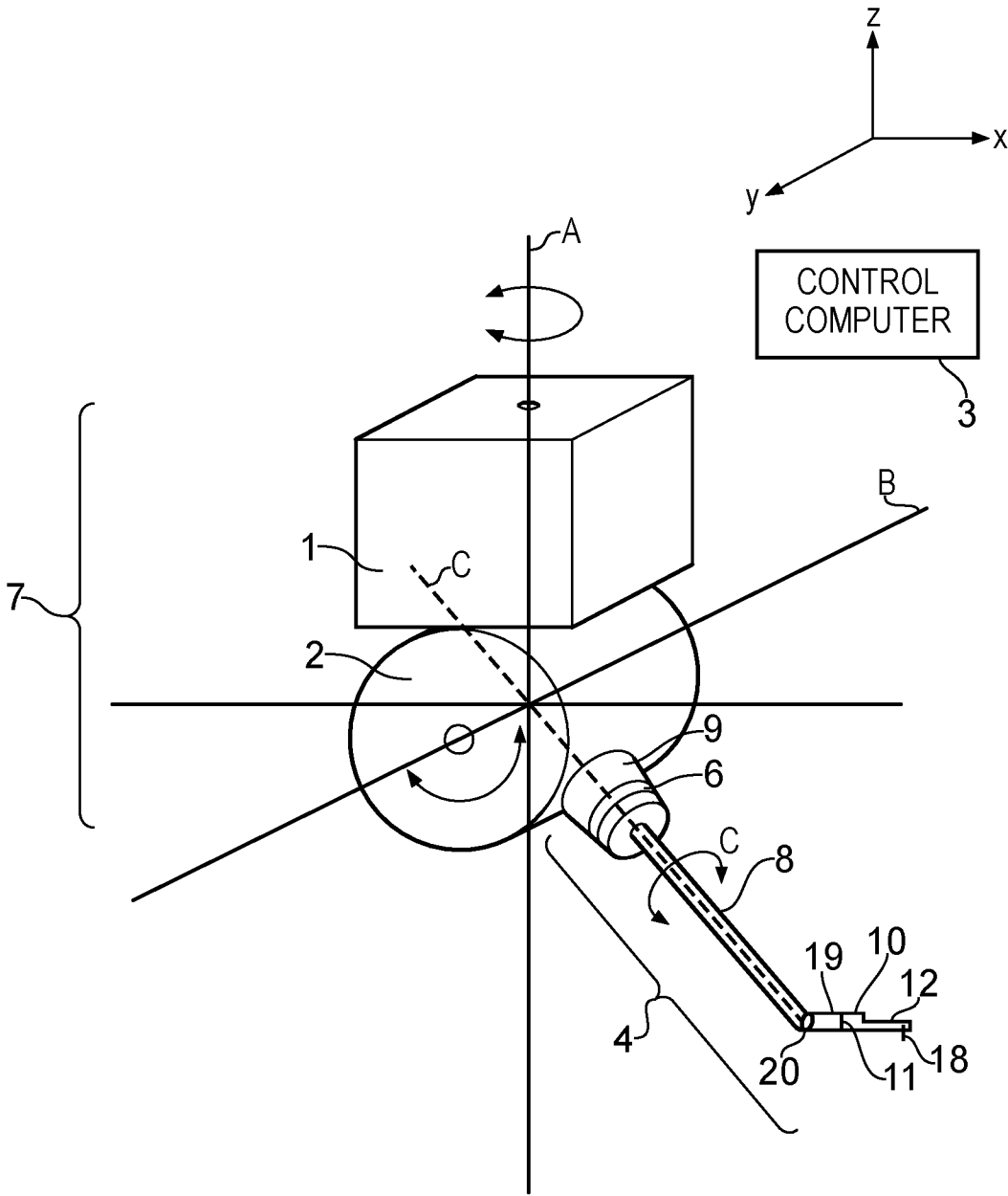
11. A probe according to any one of the preceding claims, wherein the probe is mountable on an articulating head for movement in at least one rotary axis, the articulating head being mountable in a position determining apparatus for movement on linear axes.

12. A probe according to claim 11, wherein the controller is programmed to produce a desired preload of the probe relative to the surface by positioning the probe using a combination of rotary and linear movements of the head and the position determining apparatus.

13. A probe for measuring a surface, the probe being mounted on an

articulating head for movement in at least one rotary axis, the articulating head being mounted in a position determining apparatus for movement on linear axes, the movement on the rotary and linear axes being controlled by a controller programmed to produce a desired preload of the probe relative to the surface by positioning the probe using a combination of rotary and linear movements of the head and the position determining apparatus.

14. A program for a controller of a position determining apparatus which is provided with a probe according to any one of the preceding claims,
- 10 the program being configured when run on the controller to receive the control signal from the probe and to move the probe towards a workpiece surface, controlling the position of the probe so as to produce a desired preload or nominal zero position of the probe relative to the surface.



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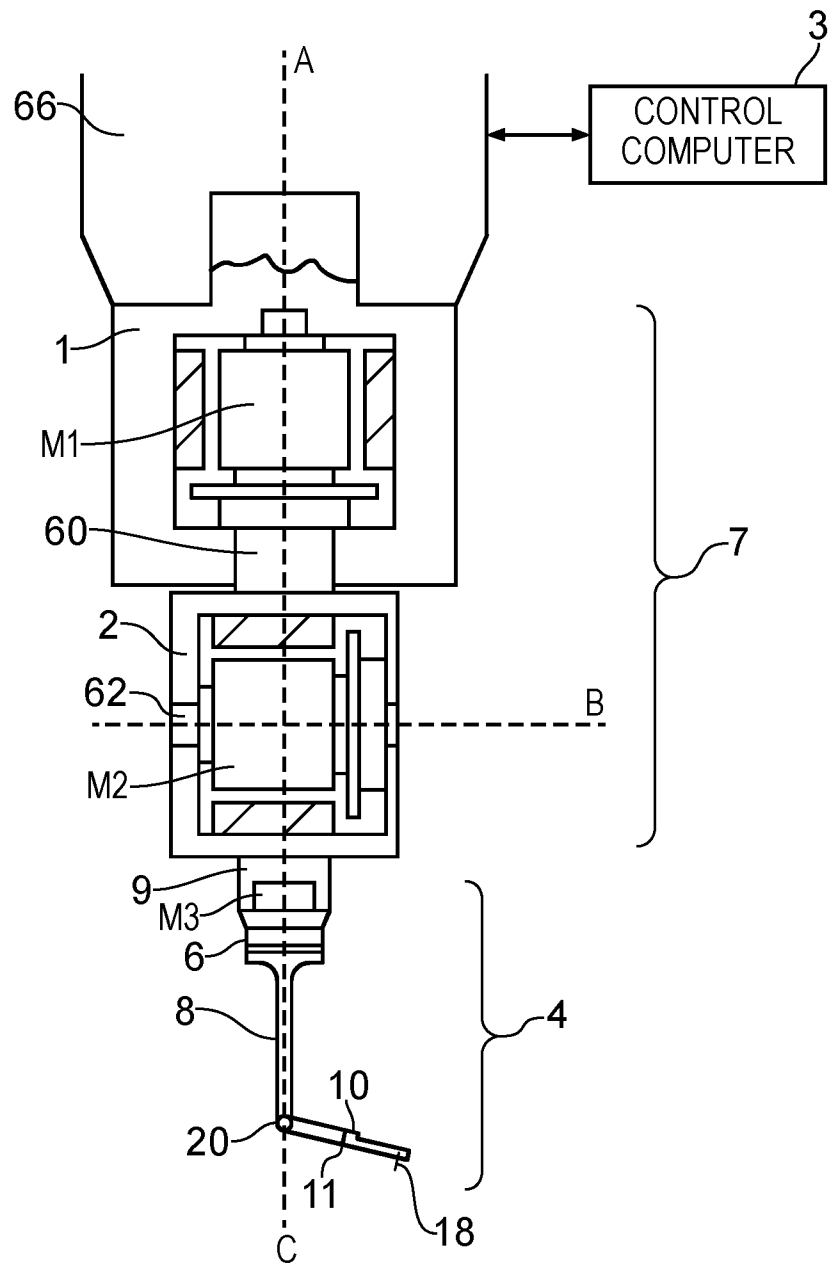
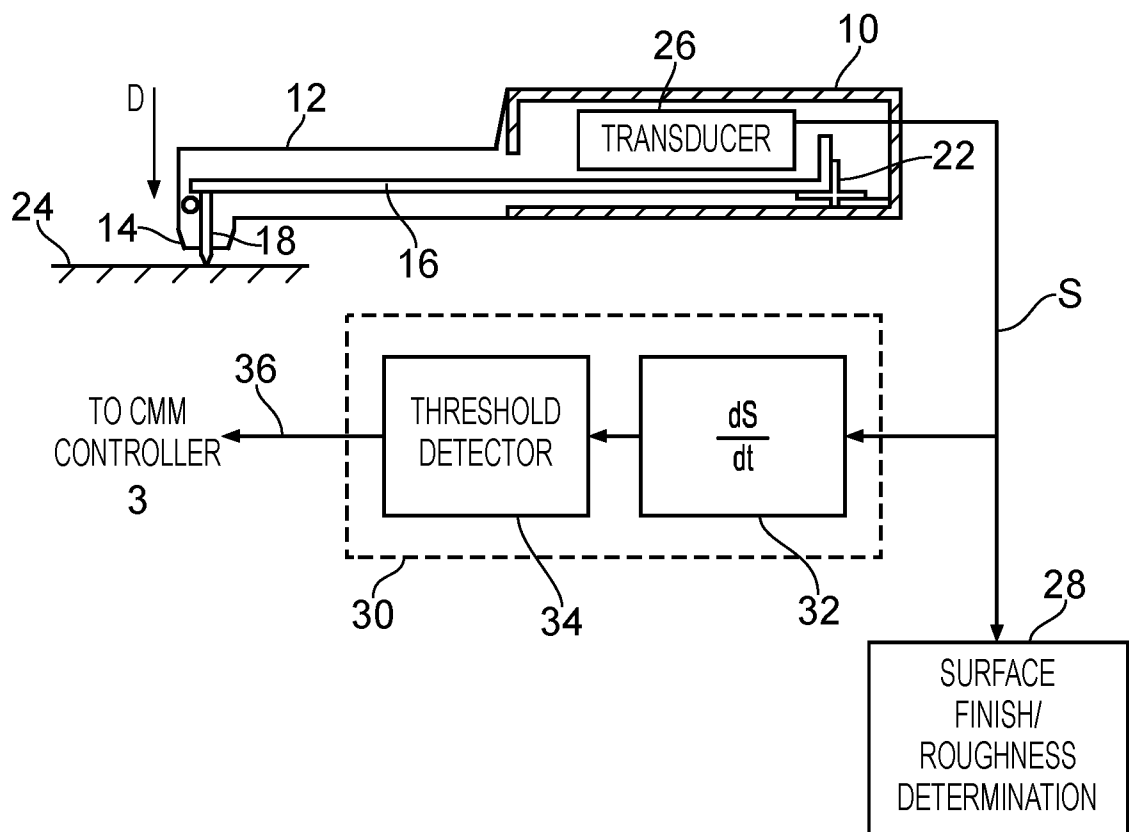
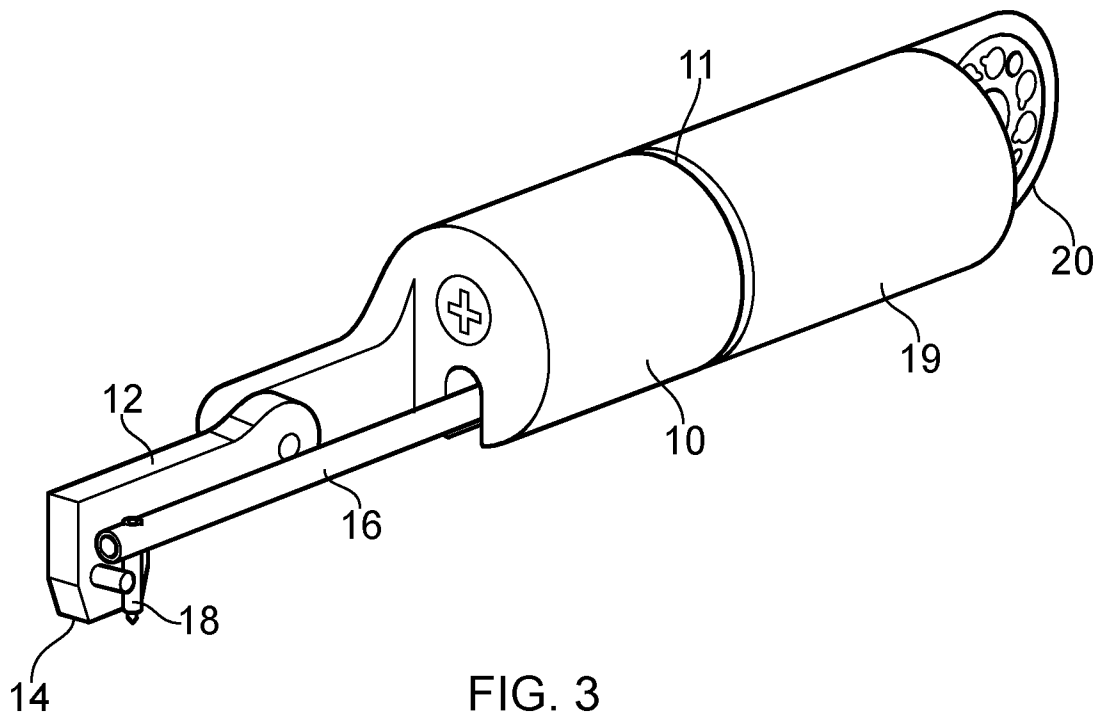


FIG. 2

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4/5

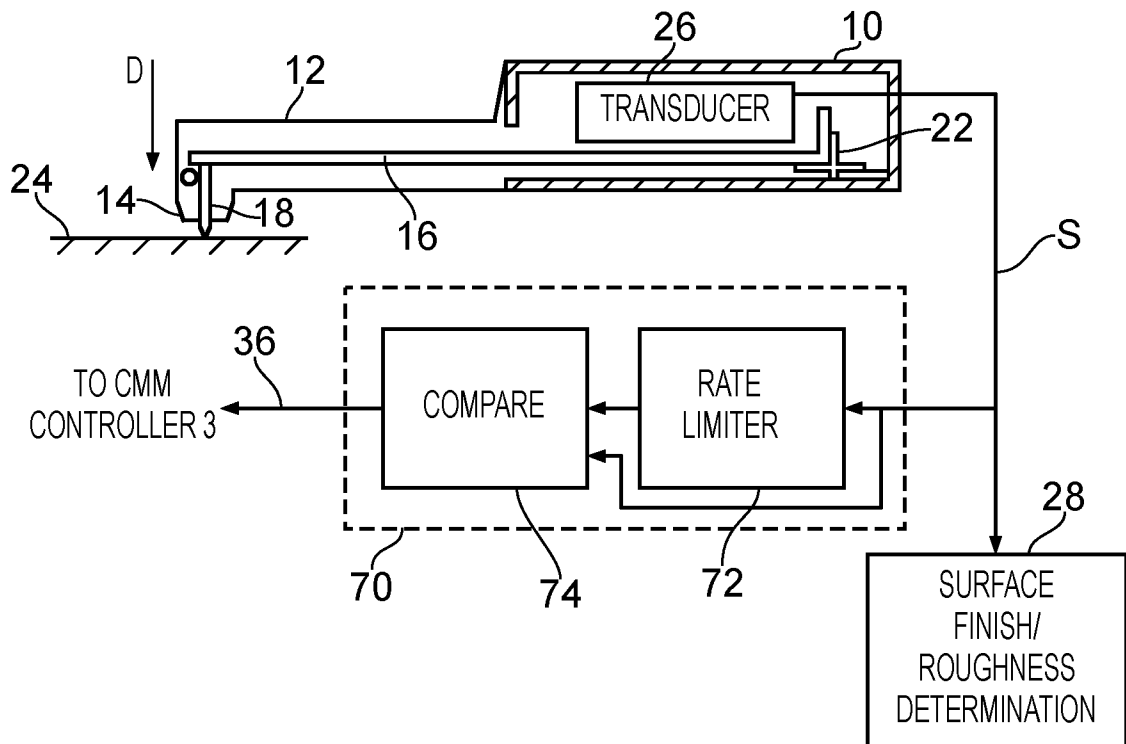


FIG. 5

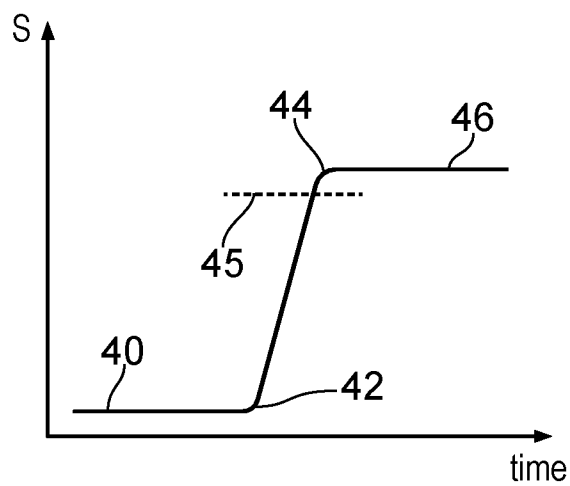


FIG. 6

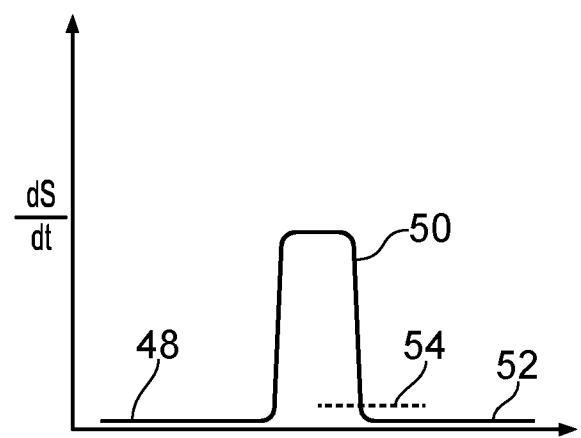


FIG. 7

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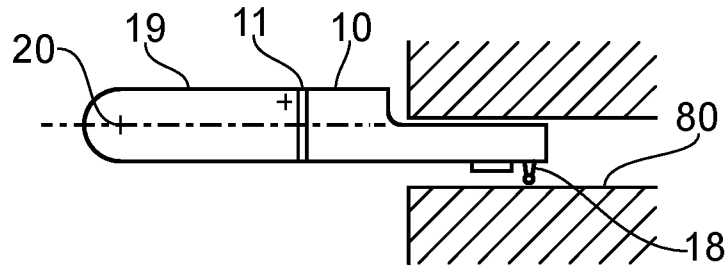


FIG. 8A

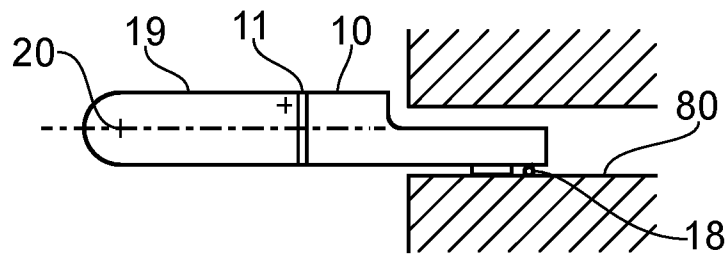


FIG. 8B

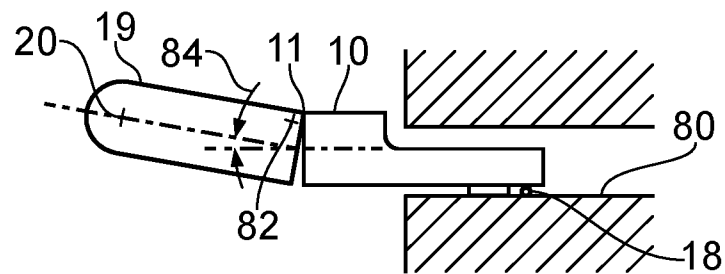


FIG. 8C

INTERNATIONAL SEARCH REPORT

International application No

PCT/GB2018/050398

A. CLASSIFICATION OF SUBJECT MATTER

INV. G01B3/00 G01B5/008 G01B5/28
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

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

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP S63 289410 A (MITUTOYO CORP) 25 November 1988 (1988-11-25) abstract; figures 1-6 paragraphs [0017] - [0019] -----	1-14
X	JP H10 47943 A (NISSAN MOTOR) 20 February 1998 (1998-02-20) abstract; figures 1-3 -----	13,14
A		1-12
A	US 9 250 053 B2 (MITUTOYO CORP [JP]) 2 February 2016 (2016-02-02) abstract; figures 3-5 column 4, line 45 - column 5, line 31 column 6, lines 6-44 -----	1-14



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

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Date of the actual completion of the international search

17 April 2018

Date of mailing of the international search report

30/04/2018

Name and mailing address of the ISA/

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Authorized officer

Passier, Martinus

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/GB2018/050398

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP S63289410	A	25-11-1988	NONE

JP H1047943	A	20-02-1998	NONE

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