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A testing apparatus and a method of operating the same

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(54) Title: A TESTING APPARATUS AND A METHOD OF OPERATING THE SAME

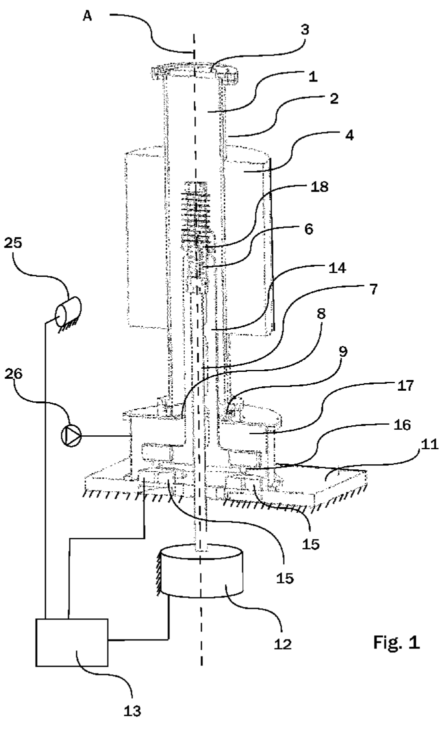

Fig. 1

(57) Abstract: A testing apparatus for sequentially performing deformation tests on a plurality of samples, and having a support structure (11) and a sample magazine 6 with multiple mutually spaced apart sample holders (18), each being adapted for supporting one sample spaced apart from the samples supported by other sample holders, and each comprising a first abutment being fixed with respect to the sample holder. The testing apparatus comprises at least one second abutment, and each of the multiple first abutments or the second abutment comprises two separate abutment surfaces. Furthermore either each of the multiple first abutments or the second abutment is fixed with respect to the support structure (11), and the testing apparatus further comprises a transport mechanism (7, 12) adapted for relatively moving the other of the multiple first abutments or the second abutment in such a way that each of the first abutments on the multiple sample holders sequentially passes the second abutment and so that the two abutment surfaces on either each of the multiple first abutments or the second abutment passes on each side of at least a part of the other abutment.

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Title:

A testing apparatus and a method of operating the same.

The prior art:

The present invention relates to a testing apparatus adapted for automatically and sequentially performing deformation tests on a plurality of samples. Such apparatuses generally comprises a support structure and a sample magazine having multiple mutually spaced apart sample holders, each being adapted for supporting one sample spaced apart from the samples supported by other sample holders, and each comprising a first abutment being fixed with respect to the sample holder. As the testing apparatus further comprises at least one second abutment and a transport mechanism adapted for sequentially pressing the second abutment against each of the samples in the sample holders, then it provides that each sample can be deformed between the first and the second abutment and the deformation can be measured e.g. by means of a camera and the load on the sample can be measured by means of e.g. a load sensor, thereby allowing corresponding values of the deformation and load to be stored in a data storage for later analysis..

Such devises are used for performing destructive or non-destructive tests such as 3 point or 4 point destructive bending tests but they may be used and adapted for other types of tests. The purpose of the devise is primarily to provide the possibility of performing the same test on a multitude of identical test specimens so that a statistical distribution can be obtained for the multiple tests results e.g. the mean value or the distribution of the tensile strength of the multiple specimens.

The term deformation test may therefore in this relation include destructive or non-destructive testing of samples or specimens, such as flexure testing, fatigue testing, fracture toughness testing and any other destructive or non-destructive test aiming at obtaining values for the deformation of a sample specimen as a consequence of the load applied on the sample by the testing apparatus.

A testing apparatus of this kind is known from JP patent application no. 60120231, showing an apparatus for automatically and sequentially performing 3 point destructive bending tests on a multitude of separate test specimens, and where a sample magazine is movably arranged in a high temperature furnace, and in such a way that each one of multiple test pieces can be moved horizontally to a position under a punch being mounted so that it can be moved vertically from a position above the test specimen and downwardly until the test specimen is destroyed by the force applied by the punch on the test specimen. The punch is mounted on a load cell allowing that the force applied to the punch, and thereby to the test specimen to be measured.

SU patent application no. 637632 also discloses an apparatus for automatically and sequentially performing 3 point destructive bending tests on a multitude of separate test specimens, and where a sample magazine, comprising multiple mutually spaced sample holders each supporting a test specimen, is movably arranged in a high temperature furnace, and in such a way that each one of multiple test pieces can be moved vertically from a position under a fixed punch arranged for each test specimen, and upwardly until the test specimen is destroyed by the force applied by the punch on the test specimen. As the distance between each of the punches is larger than the distance between each of the supported test specimens, then the test specimens will be tested in a sequence starting with the lowest test specimen.

The object of the invention:

On this background it is the purpose of the present invention to provide an apparatus of the kind mentioned in the introduction, whereby it is possible to perform a sequence of tests on a large number of separate specimens, and where the testing apparatus is relatively simple and yet reliable.

This is obtained by the testing apparatus comprising a support structure and a sample magazine having multiple mutually spaced apart sample holders, each being adapted for supporting one sample spaced apart from the samples supported by other sample holders, and each comprising a first abutment being fixed with respect to the sample holder, and where the testing apparatus further comprises at least one second abutment, and where at least one of each of the multiple first abutments or the second abutment comprises two separate abutment surfaces and either each of the multiple first abutments or the second abutment is fixed with respect to the support structure, and where the testing apparatus further comprises a transport mechanism adapted for relatively moving the other of the multiple first abutments or the second abutment in such a way that each of the first abutments on the multiple sample holders sequentially passes the second abutment and so that the two abutment surfaces on either each of the multiple first abutments or the second abutment passes on each side of at least a part of the other abutment.

The multiple samples, each supported by each of the sample holders, are thereby sequentially deformed and may thereafter be released from the sample holder or ultimately destructed by the force applied to the sample by at least the first and the second abutment as they are passing each other.

By having only one relative movement between the first set of abutments and the second abutment in order to perform both the deformation tests on each of the samples and for sequentially moving the multiple mutually spaced apart sample holders to pass the second abutment it is possible to employ only a single actuator for performing this relative movement.

In an especially simple and reliable embodiment of the invention the transport mechanism may be adapted for shifting the sample magazine along said straight line, so that a single linear actuator may be employed for the testing process.

In this relation the second abutment may in this relation be fixed with respect to the support structure and the transport mechanism may comprise a recti-linear guide for the sample magazine, so that the rectilinear guide and the transport mechanism is adapted for shifting the sample magazine along said straight line, and thereby allows that the deformations tests of all samples can be performed at the same position.

In this relation the straight line may preferably be vertical and the second abutment being designed to be resting on the support structure via at least one load cell arranged between the second abutment and the support struc-ture.

Due to its simple and reliable construction using only e.g. only few separate actuators for performing the testing process, then the testing apparatus is especially advantageous for performing multiple deformation tests on sam-ples heated to very high or low temperatures. In this relation it is important that all specimens are kept at the same temperature when the deformation test is performed on each of the sample and the sample magazine and the second abutment may therefore preferably be arranged in a substantially closed first space comprising heater or a cooler adapted for keeping a prese-lected temperature in the space.

In this relation the first substantially closed space may advantageously be downwardly limited by a bottom, and the sample magazine may comprises an actuator rod and the second abutment be arranged on a support column extending between the at least one load cell and the second abutment, so that the actuator rod and the support column extends from the sample magazine and the second abutment respectively and out of the furnace space through the furnace bottom.

Furthermore the actuator rod may preferably be connected to a linear actuator, and the linear actuator and at least one load cell be arranged below the furnace bottom and therefore away from e.g. the very high temperatures in the closed space.

In this relation it may be advantageous to further isolate the load cell and the linear actuator from the heat in the furnace and therefore the testing apparatus may comprise cooling means adapted for cooling the bottom of the closed space.

A second substantially closed space may for the same reason be arranged below the bottom of the first substantially closed space, and in this relation the at least one load cell may in a preferred embodiment be arranged and supported in the second substantially closed space.

The term substantially closed space is in this relation defined by a space that is not directly open to free air or the free surroundings. Therefore e.g. the substantially closed first space may be open to the substantially closed second space or another substantially closed space, and vice versa, without thereby contradicting the meaning of this term in this relation.

The actuator rod may therefore further extend out of the second substantially closed space through a tight sealing arranged in the second substantially closed space. Thereby it is possible to keep the above mentioned first and second closed space substantially air tight.

Furthermore in this relation the linear actuator may advantageously be arranged below the second substantially closed space I order to keep it away from the extreme temperatures in the first or the second substantially closed spaces.

In order to ensure that the signal from the load cell represents a true value of the force applied to the sample in the testing process the bottom hole is advantageously formed so that it allows the support column to slide through the bottom hole substantially without friction between the bottom hole and the support column.

The testing apparatus is especially advantageous in relation to testing samples in a controlled atmosphere. In this relation the apparatus may in a preferred embodiment comprise a gas conduit arranged between the first and the second substantially closed space, and a gas supply inlet adapted for conducting a gas into the second substantially closed space.

In a further preferred embodiment of the invention testing apparatus comprises a visual sensor, e.g. a camera, and at least one window arranged in the first substantially closed space, the window and the visual sensor being adapted for allowing the visual sensor to monitor when each of the multiple first abutments and the second abutment are passing each other, and the deformation of a sample in engagement of a first abutment and the second abutment.

In a further preferred embodiment of the invention the testing apparatus comprises a controller adapted for controlling the travel speed and direction of the linear actuator.

In this relation the controller is advantageously adapted for controlling and measuring the movement, travel speed and direction of travel in dependence of signal input received from the camera and/or the load cell, so that different test functions, such as flexure testing, fatigue testing, fracture toughness testing and any other destructive or non-destructive test aiming at obtaining values for the deformation of a sample specimen as a consequence of the load applied on the sample by the testing apparatus.

The drawing:

In the following one embodiment of the invention will be described in more detail and with reference to the drawing, where:

Fig. 1: Is a concept drawing showing a cross section of an apparatus according to the invention seen in perspective.

Fig. 2: Is a perspective drawing showing a part of the apparatus according to figure 1.

Fig. 3 and 4 Are principle sketches showing different setups for the apparatus according to the invention, in order to perform different types of tests.

Description of exemplary embodiments:

In the development of structural and functional ceramics for high temperature purposes such as solid oxide fuel cells and oxygen membranes it is important to be able to test their mechanical properties under operational conditions. The challenge lies in handling high temperature together with a controlled atmosphere. Furthermore, characterization of the strength of ceramic components requires testing of a high number of samples due to the stochastic nature of failure. In accordance with the present invention a methodology, involving a rig specially designed for the purpose of accomplishing this, is provided. Optical methods are used to measure deformations contactless, frictionless load measuring is obtained by placing the load cells in the same environment as the samples, and multiple samples are handled in one heat up. The methodology is validated against measurements at room temperature, and exemplified by measurement of the strength of solid oxide fuel cell anode supports at 800˚C.

To allow fail safe design of high temperature devices involving brittle materials like ceramics or glasses, the strength distribution of the components must be known. Hence, there is a need for effective methodologies for assessment of mechanical properties under conditions relevant for operation. Technologies as oxygen membranes, solid oxide fuel cells (SOFC) and solid oxide electrolysis cells are examples of such technologies, where knowledge of mechanical properties are crucial for the further development. In these fields new materials are developed and tested for their electrochemical properties. For application outside the lab, the integrity of the components is equally important, since mechanical failure of the components, in the mentioned applications, will have a severe influence on the performance, and often lead global failure of the system. Hence, it is important for these technologies that relevant material data is available in the design process.
To analyze for failure the strength is measured for a number of specimens, and strength distribution is characterized typically with a Weibull distribution.

It has been established that the dispersion of the Weibull parameters for sample sizes smaller than 30 leads to a large uncertainty and confidence interval of the parameters. Furthermore, for analyzing and designing against failure strength, data are needed at a range of temperatures reflecting conditions during use. Thus, the number of measurements for a good statistical representation of the material becomes a challenge.

Furthermore as the mentioned technologies often have components that operate in an atmosphere different from air, then the atmosphere must be controlled to represent the operation conditions, which complicates the local heating approach.

It is a conventional task to control temperature and gasses and therefore equipment for this purpose is not shown in detail in the figures.

It is, however, challenging to measure force through a gastight seal or gasket without obtaining errors due to friction. The friction can be measured separately, but the friction might still be non-linear with applied load, and will therefore be different at the extra load in the actual testing. Thus, in the preferred embodiments shown in the figures the use of gaskets or seals on the rods is avoided, and the load signal is therefore transferred directly to the measurement device.

In the following a preferred embodiment of the invention is therefore described in more details with reference to the figures, and where this embodiment provides the option of testing of a high number of samples in one heat up, testing in a controlled atmosphere, measurement of the load in-situ to avoid friction and optically measure the displacements to avoid contact.

Figure 1, 2, 3 and 4 shows the same embodiment of the invention in the form of a testing apparatus adapted for automatically performing destructive 4-point flexure tests on multiple samples. In figure 1 the apparatus is shown in a concept drawing showing a cross section along a substantially vertical of symmetry plane where a first substantially closed space 1 is defined by a substantially circular cylindrical and gas tight kanthal tube 2 being upwardly closed with a water cooled lid 3.

The kanthal tube 2 is surrounded at its mid-section of a furnace 4, which is adapted for heating at least the mid-section of the kanthal tube so that the first space 1 within the kanthal tube is kept at a preselected temperature. In this relation the furnace 4 could in an alternative embodiment be replaced or supplied with a cooling device in cases where the testing apparatus is to be used for testing samples e.g. having a low temperature. In this respect it is evident that such heating or cooling can be performed in many different ways and the detailed construction of the furnace and/or cooler, as well as the temperature sensors necessary for monitoring that the first space 1 is kept at the preselected temperature, is therefore not shown in the figures.

In an embodiment solely adapted for testing samples at low temperatures, the complete construction may be designed substantially upside down with respect to the embodiments shown in the figures. Thereby the substantially closed first space is arranged below the substantially closed second space so as to keep the cold gas in the substantially closed first space from flowing into the substantially closed second space. In this embodiment the actuator and the actuator rod is also arranged above the sample magazine for the same reason, and the water cooling is replaced with means for heating the second space.

In the substantially closed first space 1 a sample magazine 5 is arranged so that it extends along the central axis A. The sample magazine 5 has multiple substantially identical sample holders 6 arranged along a straight line defined by the symmetry axis A. Each of the sample holders forms a first abutment 20 having abutment surfaces facing downwardly.

The sample magazine 5 is connected to an actuator rod 7 extending below the sample magazine 5 and out of the substantially closed chamber 1 via a bottom hole 8 arranged in the bottom 9 of the substantially closed first space 1 and into a substantially closed second space 17 further out of the testing apparatus via a tight sealing 10 in the support structure 11 of the testing apparatus. An actuator 12, e.g. an electric stepper motor, and a controller 13, is connected to the actuator rod 7 to form e.g. a spindle, a worm drive adapted or an electromechanical cylinder adapted for controlled shifting of the sample magazine 5 upwardly and downwardly along the central axis A.

Along with the sample magazine 5 and the actuator rod 7 a substantially vertical support column 14 is supported by two load cells 15 arranged in the substantially closed second space 17 via a set of roller bearings 16 and a second abutment 18 having two upwardly facing separate abutment surfaces 19 is mounted on the top of the support column 14.

The substantially closed space is provided with water cooling channels 26 arranged at least in the support structure in order to cool the load cells and the substantially closed second space 17, so that the loads cells 15 and other equipment in the substantially closed second space 17 is not affected by the high or low temperatures present in the substantially closed first space 1 in the kanthal tube 2.

In order to control the atmosphere in the first and the second substantially closed space 1 and 17 a gas supply 26 is connected in order to supply gas from the exterior and into the substantially closed second space, and the supplied gas is free to flow from the substantially closed second space 17 and into the substantially closed first space 1 in the kanthal tube 2. In this way, as the two substantially closed spaces are both filled with the same gas, then it is not necessary to have a tight seal between these spaces and therefore it is possible to have the load cells arranged outside the first space 1 without thereby creating friction between the column 14 and the bottom of the first space 1 that would affect the accuracy of the load measurement of the load cells 15.

As the load cells are adapted for measuring the vertical load on the cells. Then they can be used for calibrated to measure the load applied to the abutment surfaces 19 via a sample arranged in the sample magazine 5 and being pressed downwardly by the actuator 12 and against the second abutment 18 via the actuator rod 7 and one of the first abutments 20 on the sample magazine 5.

This is shown in more detail in figure 2 showing an enlarged section of the sample magazine 5 and the top of the support column 14 of the testing apparatus according to figure 1. The sample magazine 5 has multiple first sample holders 6 each in the form of two support pins 23 horizontally arranged side by side in order to support a sample 22. The second abutment 18 is likewise provided by two abutment pins 21 horizontally arranged side by side but with a distance larger than the distance between the two support pins 21 forming the sample holders 6.

By shifting the sample magazine downwardly as described above, then each sample 22 carried by the sample holders 6 formed by the two support pins 21, will come to the position shown in figure 2, where the lower sample 22 is resting on both a first abutment 6 formed by two support pins 23 and the second abutment 18 formed by the two abutment pins 21. If the sample magazine is further shifted downwardly then the sample 22 will thereafter be lifted off the sample holder 6 as shown in figure 3, where the sample is pressed against the underside of the two supporting pins 23 forming the sample holder 6 right above the first mentioned sample holder 6, and thereby the two supporting pins 23 on the upper sample holder 6 will engage on the upper side of the sample resting on the abutment surfaces 19 on the upper side of the abutment pins 21. Thereby, as the sample magazine 5 is further shifted downwardly, then the sample 22 is flexed and the load can be measured by the load cells 15 as shown in figure 1.

It is evident that a further downward shifting of the sample magazine 5 ultimately will result in the destruction of the sample 22 which will fall off the abutment pins 21 and allow the testing of the next sample 22 in the sample magazine 5. Thereby this embodiment of the invention provides a destructive 4-point flexure test of a multitude of samples 22.

The testing apparatus may, however, easily be adapted for other types of testing methods. Examples of alternative testing processes that can be provided by the testing apparatus according to figure 1 is therefore shown in figure 3 and 4 discloses two alternative embodiments of the sample holder.

The sample holder shown in figure 4 shows a sample holder arrangement comprising a further abutment pin 24 allowing for destructive or non-destructive 3-point flexure testing of the samples 22. This setup may also be used with samples having a notch on the downwardly facing surface of the sample, and thereby it is possible to perform fracture toughness testing on such notched beam samples.

The embodiment shown on figure 1 also comprises a controller 13 adapted for controlling the travel speed and direction of the actuator 12 and thereby the sample magazine 5. In an especially simple embodiment the travel of the actuator or the actuator rod is measured directly, but it would also be possible to calculate the travel of the actuator and the actuator rod and thereby having a measure of the flexure of the samples. In an alternative embodiment, however, a visual flexure sensor 25 e.g. a camera, is arranged outside the kanthal tube 2 as shown in fig. 1 and a window (not shown in the figure) is arranged in the kanthal tube 2 for allowing the camera to monitor the flexure of each sample 22 during the testing process.

The flexure of each sample is thereby measured e.g. by use of a camera 25, picturing the sample as it bends. The camera 25 is located externally and has a line of vision through the portholes located diametrically on each side of the kanthal tube 2.

The controller 13 is adapted for controlling the actuators travel speed and direction in response to the load measured by the load cells 15 and in response to the flexure measured by the camera or by measuring or calculating the travel of the actuator or the actuator rod. Thereby it is possible to control the actuator in different modes such as to provide creep testing by applying either a constant load to the sample and measuring the flexure in time or by applying a constant flexure of the sample and measuring a varying load in time on the sample e.g. for creep testing processes such as primary creep testing where the testing process is finished when a steady load is measured, or to provide fatigue testing by controlling the actuator to apply a varying load on the sample until it breaks.

Furthermore the testing apparatus according to figures may be provided with a sample ejector for ejecting the samples 22 off the abutment pins 23 after the testing process of a specific sample 22 is finished, so that the same testing apparatus can be used for corresponding non-destructive testing processes just by controlling the actuator 12 in such a way that destruction of each sample does not occur.

Although some embodiments have been described and shown in detail, the invention is not restricted to them, but may also be embodied in other ways within the scope of the subject matter defined in the following claims. In particular, it is to be understood that other embodiments may be utilized and structural and functional modifications may be made without departing from the scope of the present invention.

In device claims enumerating several features, several of these features can be embodied by one and the same item of hardware. The mere fact that certain measures are recited in mutually different dependent claims or described in different embodiments does not indicate that a combination of these measures cannot be used to advantage.

It should be emphasized that the term "comprises/comprising" when used in this specification is taken to specify the presence of stated features, integers, steps or components but does not preclude the presence or addition of one or more other features, integers, steps, components or groups thereof.

Claims:

1. A testing apparatus adapted for sequentially performing deformation tests on a plurality of samples, said apparatus comprising a support structure and a sample magazine having multiple mutually spaced apart sample holders, each being adapted for supporting one sample spaced apart from the samples supported by other sample holders, and each comprising a first abutment being fixed with respect to the sample holder, and where the testing apparatus further comprises at least one second abutment, and where at least one of each of the multiple first abutments or the second abutment comprises two separate abutment surfaces and either each of the multiple first abutments or the second abutment is fixed with respect to the support structure, and where the testing apparatus further comprises a transport mechanism adapted for relatively moving the other of the multiple first abutments or the second abutment in such a way that each of the first abutments on the multiple sample holders sequentially passes the second abutment and so that the two abutment surfaces on either each of the multiple first abutments or the second abutment passes on each side of at least a part of the other abutment.

2. A testing apparatus according to claim 1, wherein the sample holders on the sample magazine are arranged along a straight line.

3. A testing apparatus according to claim 2, wherein the second abutment is fixed with respect to the support structure and the transport mechanism comprises a rectilinear guide for the sample magazine, and where the rectilinear guide and the transport mechanism is adapted for shifting the sample magazine along said straight line.

4. A testing apparatus according to claim 3, wherein the straight line is substantially vertical and the second abutment is resting on the support structure via at least one load cell arranged between the second abutment and the support structure.

5. A testing apparatus according to claim 4, wherein the sample magazine and the second abutment is arranged in a first substantially closed space comprising a heater and/or a cooler adapted for keeping the interior of the first substantially closed space at a pre-selected temperature, and where the first substantially closed space is downwardly limited by a bottom, and the sample magazine is connected to an actuator rod and the second abutment is arranged on a support column arranged between the at least one load cell and the second abutment and where the actuator rod and the support column extends from the sample magazine and the second abutment respectively and out of the first substantially closed space through at least one bottom hole arranged in the bottom.

6. A testing apparatus according to claim 5, wherein the actuator rod is connected to a linear actuator, and where the linear actuator and the at least one load cell are arranged below the bottom.

7. A testing apparatus according to claim 6, comprising means for cooling the bottom.

8. A testing apparatus according to claim 5, 6 or 7, wherein a second substantially closed space is arranged below the bottom of the first substantially closed space, and where the at least one load cell is arranged and supported in the second substantially closed space.

9. A testing apparatus according to claim 8, wherein the actuator rod further extends out of the second substantially closed space through a tight sealing arranged in the second substantially closed space.

10. A testing apparatus according to claim 6 and 9, wherein the linear actuator is arranged below the second substantially closed space.

11. A testing apparatus according to claim 8, 9 or 10, wherein the bottom hole is formed so that it allows the support column to slide through the bottom hole without creating friction between the bottom hole and the support column.

12. A testing apparatus according to claim 8, 9, 10 or 11, wherein the bottom comprises a gas conduit arranged between the first and the second substantially closed space, and in that a gas supply inlet is arranged and adapted for conducting a gas into the second substantially closed space.

13. A testing apparatus according to one or more of claims 6, 7, 8, 9, 10, 11 and 12, further comprising a visual sensor, and at least one window arranged in the first substantially closed space, and where the window and the visual sensor is adapted for allowing the visual sensor to monitor when each of the multiple first abutments and the second abutment are passing each other, and thereby the deformation of a sample in engagement of a first abutment and the second abutment.

14. A testing apparatus according to claim 13, wherein the visual sensor is a camera.

15. A testing apparatus according to one or more of claims 6, 7, 8, 9, 10, 11, 12, 13 and 14 comprising a controller adapted for controlling the travel speed and direction of the linear actuator.

16. A testing apparatus according to claim 15, wherein the controller is adapted for controlling the travel speed and direction in dependence of signal input received from the camera and/or the load cell.

17. A method of performing deformation tests on a plurality of samples, said apparatus comprising a support structure and a sample magazine having multiple mutually spaced apart sample holders, each being adapted for supporting one sample spaced apart from the samples supported by other sample holders, and each comprising a first abutment being fixed with respect to the sample holder, and where the testing apparatus further comprises at least one second abutment, and where at least one of each of the multiple first abutments or the second abutment comprises two separate abutment surfaces and either each of the multiple first abutments or the second abutment is fixed with respect to the support structure, and where the other of the multiple first abutments or the second abutment is moved in such a way that each of the first abutments on the multiple sample holders sequentially passes the second abutment and so that the two abutment surfaces on either each of the multiple first abutments or the second abutment passes on each side of at least a part of the other abutment.

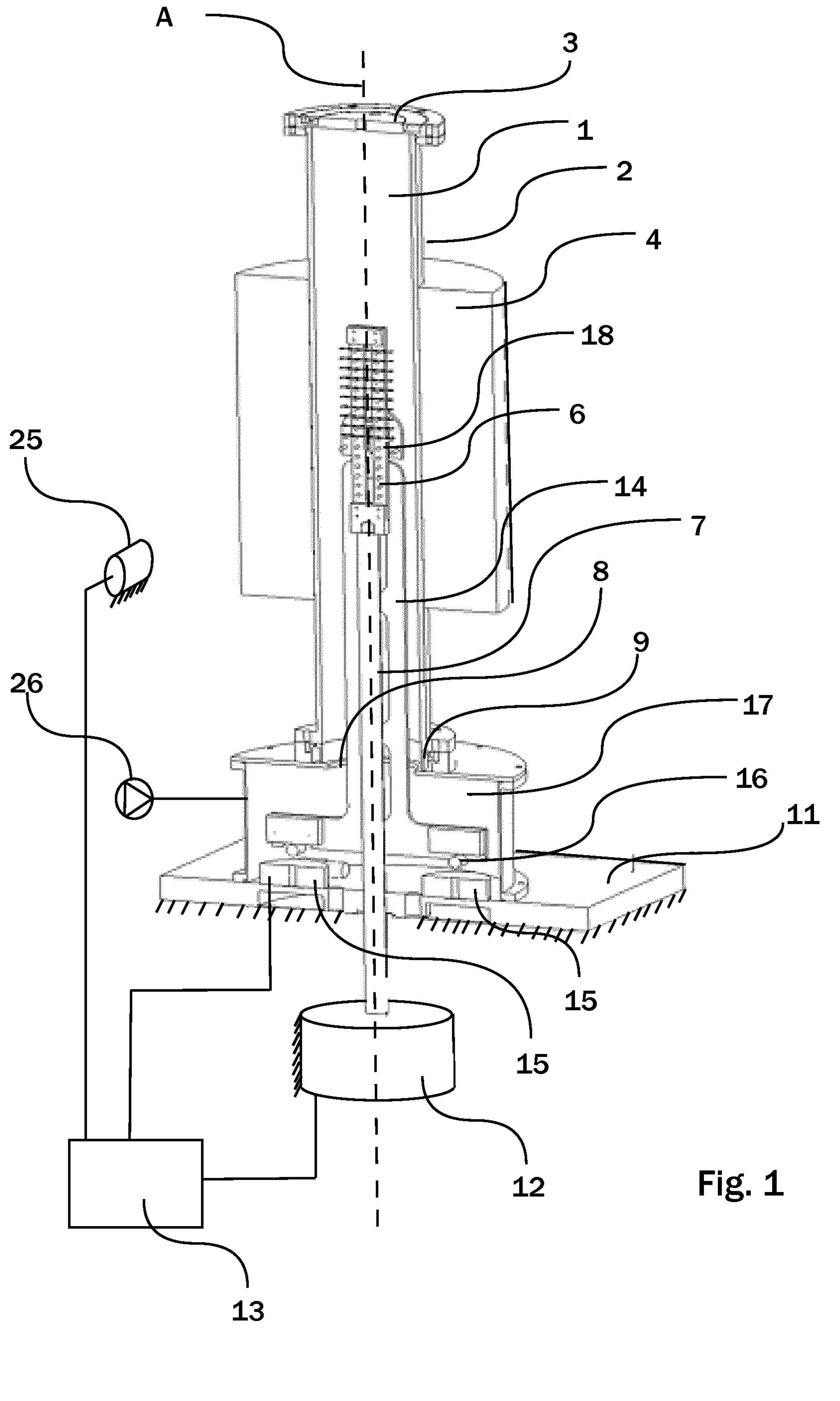

Fig. 1

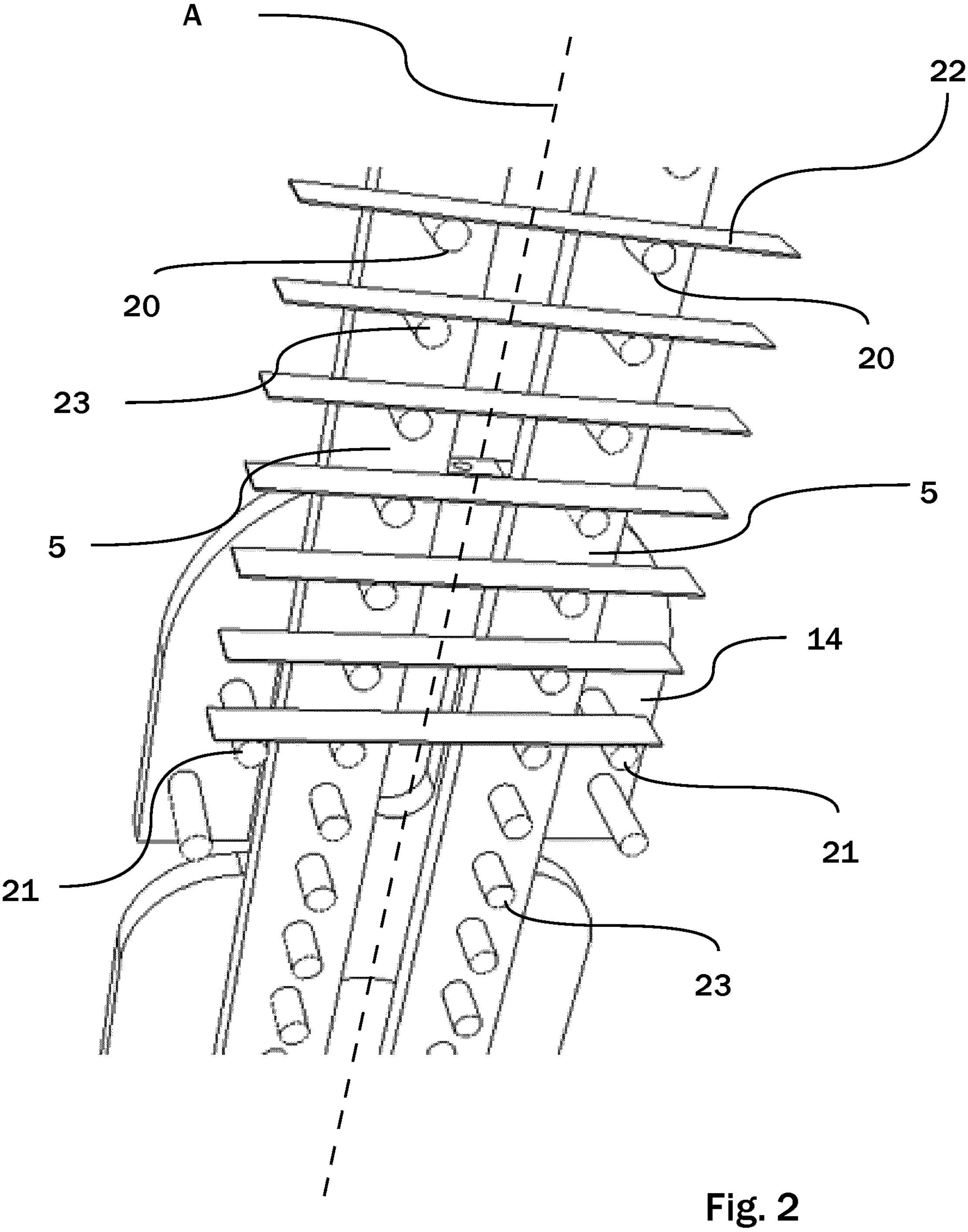

Fig. 2

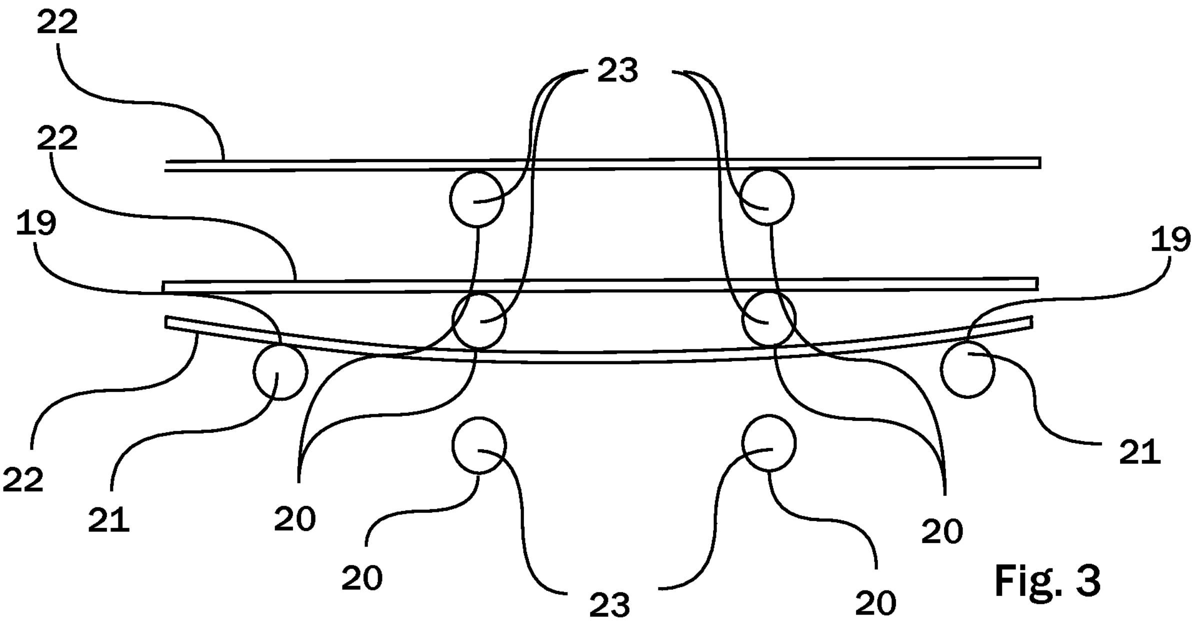
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Fig. 3

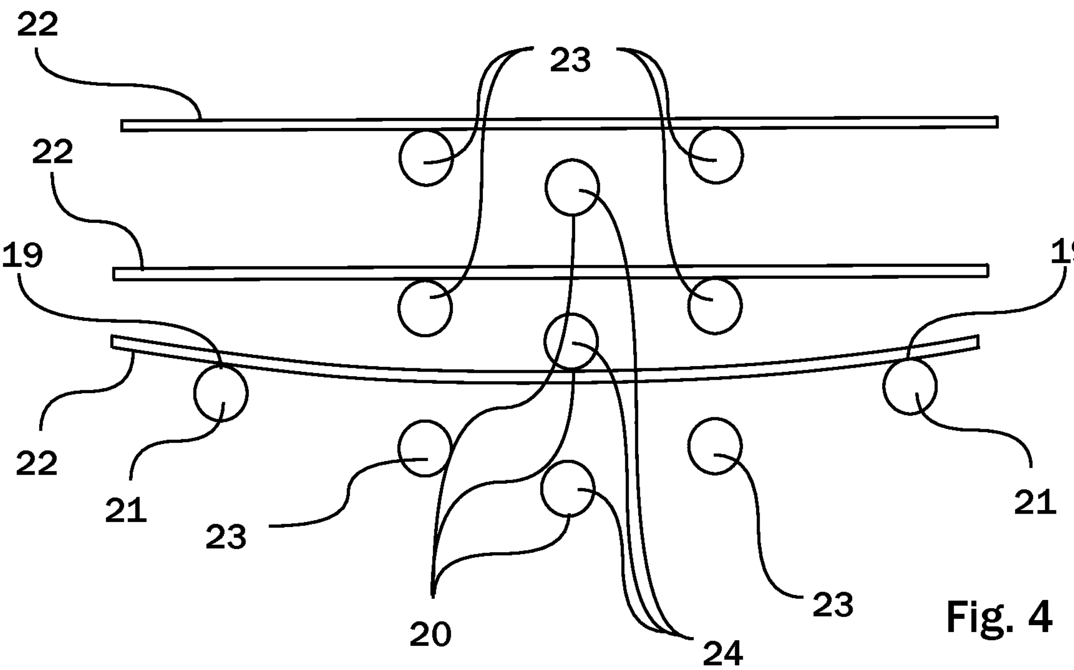
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Fig. 4

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2014/061468

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01N3/20 G01N3/18
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)
G01N

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, COMPENDEX

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	SU 637 632 A1 (INST FIZ TEKHN ENERGETIKI AN L [SU]) 15 December 1978 (1978-12-15) cited in the application abstract; figure 1 the whole document	1-4,17
X	JP S60 120231 A (SHIMADZU CORP) 27 June 1985 (1985-06-27) cited in the application figures 1,2	1,2,17
A	JP 2012 103160 A (MITSUBISHI HEAVY IND LTD) 31 May 2012 (2012-05-31) figures 1, 6	5-8

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

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"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

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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
3 July 2014	10/07/2014

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	Lefortier, Stéphanie

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Form PCT/ISA/210 (second sheet) (April 2005)

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	Declan J Curran ET AL: "Weibull Strength Variations between Room Temperature and High Temperature Ni-3YSZ Half-Cells" In: "Advances in Solid Oxide Fuel Cells VIII", 19 November 2012 (2012-11-19), John Wiley & Sons, Inc., Hoboken, NJ, USA, XP055084432, ISBN: 978-1-11-820594-5 pages 61-69, DOI: 10.1002/9781118217481.ch6, paragraphs [02.2], [02.3] -----	1-17

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2014/061468

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
SU 637632	A1	15-12-1978	NONE		
JP S60120231	A	27-06-1985	JP	H0535375 B2	26-05-1993
			JP	S60120231 A	27-06-1985
JP 2012103160	A	31-05-2012	NONE		