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(54) **SYSTEM AND METHOD FOR TESTING COMPOSITE PRESSURE VESSELS**

(57) System and method for testing the composite material of composite pressure vessels without removing the outer casing comprising at least one inlet/outlet for pressure vessels to be tested, and a testing area accessible via the at least one inlet/outlet, and that said testing area comprises at least one instrument for detecting damages to the composite material of the composite pressure vessels.

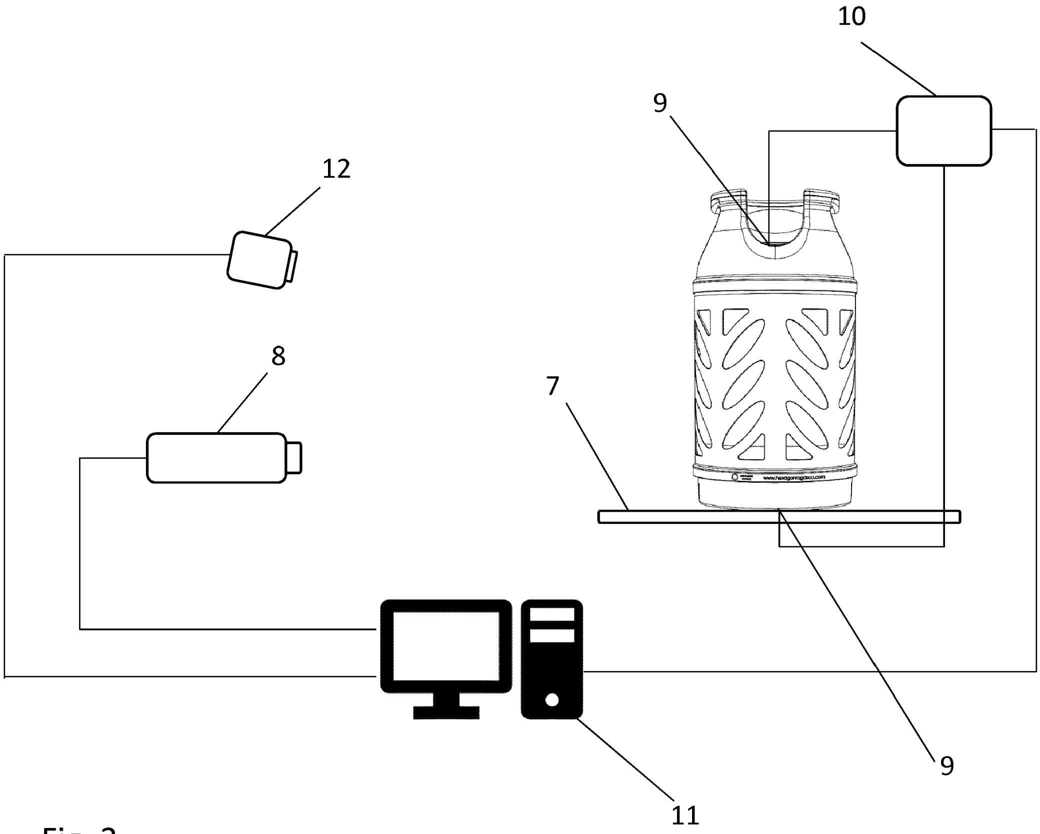

Fig. 3

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Description

Technical field

[0001] The present invention regards a system and method for testing composite pressure vessels, and more specifically a system and method for testing composite pressure vessels for damages to the composite material without removing the outer casing.

Background

[0002] A composite pressure vessel for storing gas and/or liquified gas may comprise an inner gas tight liner, surrounded by a pressure resistant composite layer of fibres and polymer. The liner and the composite layer comprise at least one common opening wherein a boss is arranged. However, liner less composite pressure vessels are also known. Here the composite itself is sufficient gas tight to make the liner obsolete. The boss provides for attaching a valve. inlet/outlet means for controlling the flow of fluid in and out of the pressure vessel. An outer casing surrounds the composite layer and provides protection against impact. The outer casing may further provide a stand supporting a vertical arrangement of a cylindrical pressure. The casing may include other features such as handles for transport and adapting the bottom surface and the top surface to each other to allow stacking. Composite gas containers/pressure vessels are for instance described in detail in EP1204833, NO320654B1, and WO2011152733. WO2011152732 describes an inlet/outlet system for composite pressure containers.

[0003] Currently composite pressure vessels are inspected visually every time they are filled with gas. Visually inspecting composite pressure vessels requires a trained eye since the inspector only has a few seconds available for each pressure vessel. In this short time the inspector must judge if the pressure vessel is damaged and must also try to assess if the composite material is damaged without taking of the outer casing.

[0004] If the damage is in an area that is covered by the outer casing it can be harder to detect the damage, if there are little or no visible marks on the outer casing. If there is a visible mark on the outer casing it can be harder to judge if the damage is only on the outer casing or if the composite material behind the outer cover is also damaged.

[0005] Due to the fact that taking off the outer casing and inspecting the composite material is a costly procedure that takes time it is preferred to limit the necessity for removing the outer casing.

[0006] The problem with the current method is that to avoid the risk of filing damaged pressure vessels and returning them back into circulation, more pressure vessels are taken out for further detailed inspection then would have been necessary if the composite material that is covered by the outer casing could be assessed.

[0007] If a pressure vessel is sorted out before filling, because of damages detected on the pressure vessel, the maintenance process normally requires the outer casing to be removed to make sure the composite structure is ok. Removing the casing is time consuming and costly.

[0008] In addition to the visual inspection in connection with refilling the pressure vessels are normally recertified at regular intervals, such as every ten years.

[0009] The recertifying presently requires that the valve is removed, the pressure vessel is inspected, and proof tested to 30 bars to make sure the composite is ok.

[0010] In this inspection the same criteria as during the sorting prior to prefilling are applied.

[0011] . Also, the controlled pressurisation is a time-consuming process and requires specific safety protocols due to the higher pressure.

Summary of the invention

[0012] It is therefore an object of the present invention to overcome the problems mentioned above.

[0013] It is a further objective to be able to perform the method without removing the composite element from an outer casing in which it is contained.

[0014] Further it is an objective that the method and the apparatus provide an almost instant result such that the detection can be performed in connection with, leading up to the refilling without significantly delaying the refilling process.

[0015] Further, it is an objective to provide a method that can be performed without pressurizing the pressure vessel.

[0016] A further aim is to provide a system that provides for identification of the pressure vessels and that gathers data on the pressure vessels over time.

[0017] It is also an objective to provide the apparatus with either an automatic removal of composite pressure vessels with an unsatisfying condition or with a method of adding identification to pressure vessels that are not in a satisfying condition.

[0018] It is also an objective to provide a system and method that can be expanded to obtain additional information about each tested pressure vessel.

[0019] The present invention provides a system and method for detection the condition of the pressure vessel, particularly the composite element.

[0020] The present invention provides a system for testing a composite pressure vessel comprising a layer of composite material and an outer casing, wherein the system comprises at least one inlet/outlet for pressure vessels to be tested, and a testing zone accessible via the at least one inlet/outlet, wherein said testing zone comprises at least one instrument for detecting damages to the composite pressure vessel, said at least one instrument for detecting damages to the composite pressure vessel comprises:

a. a vibration initiator for inducing at least a set of vibrations of a given frequency and amplitude to the composite material of the composite pressure vessel via an excitation point,

b. a source of coherent laser light exposing at least a part of the pressure vessel,

c. a vibrometer for recording the laser light reflected of the surface of the pressure vessel assessing both amplitude and phase data in the vibration pattern of the composite material of the pressure vessel.

[0021] The system does not require that the casing is removed or that the vessel is pressurized to assess the composite pressure vessel. The composite pressure vessel should comprise at least one opening or through hole in the casing providing for the arrangement of the excitation point on the composite material or alternatively the excitation point may be arranged on a part in fixed contact with the composite material such as the inlet/outlet valve of the vessel or elements of the boss. Further the one or more openings/through holes provides for the reflection of laser light from the composite material to reach the vibrometer, which has a positive impact on the quality of the test results.

[0022] Depending on the size of the pressure vessel more excitation points can be included, and these can be distributed over the pressure vessel to set the whole vessel in vibration. In one aspect of the system it comprises an excitation points clamp that provides sufficient contact pressure between the excitation points and the composite material. The clamp may comprise a number of evenly distributed excitation points to be arranged adjacent to the inlet to the pressure vessel and a number of evenly distributed excitation points to be brought in contact with the composite material of the pressure vessel opposite the inlet to the pressure vessel. In this embodiment the excitation and formation of vibration patterns is performed sequentially from the excitation points at the opposite ends. This arrangement may provide for improved images/analyses as the excitation from each end is used to analyse the section of the vessel closest to the respective excitation points. Especially, for elongated vessels this is advantages as the vibration is les damped if it has travelled a shorter distance from the excitation point.

[0023] In one embodiment the testing zone of the system may be isolated from vibration noise from the surroundings. In the embodiment discussed above with a clamp, the clamp may be used to effect isolation from vibration noise. Alternatively, or additionally the testing zone may be arranged in a separate section in parallel to an existing pressure vessel conveyer structure.

[0024] In a further embodiment the temperature in the testing zone is maintained stabile to optimize the conditions for the coherent laser.

[0025] The system provides a possibility analyse the composite material of the pressure vessel also in the non-visible areas covered by the outer casing, making it possible by analysing the vibration pattern to conclude if the composite material is damaged.

[0026] The composite pressure vessel may comprise an inner liner and a boss secured to the liner and the composite material and providing an inlet/outlet adapted to secure a valve or other means for controlling the filling and emptying of the pressure vessel.

[0027] The excitation point may be placed anywhere on the composite layer. A preferred arrangement the excitation point is arranged in contact with the composite material adjacent the inlet/outlet means of the boss. If the system is installed in connection with a pressure vessel filling station the pressure vessels will comprise a valve arranged in the opening of the boss and the excitation point may be arranged on the composite material adjacent to the valve, or the valve fixed to the boss, or elements of the boss may be used for arrangement of excitation points, as long as the distribution of the vibrations into the composite material is reproducible.

[0028] In a preferred embodiment of the present invention there are two excitation points, wherein one is arranged in contact with the composite material adjacent the inlet/outlet means of the boss and the other is arranged in contact with the composite material at an end opposite the boss, preferably at a bottom of the pressure vessel. The pressure vessel may rest on these excitation points during testing.

[0029] In one aspect of the system said frequency is within a range of 1 kHz - 50 kHz, preferably in the range 2-40 kHz.

[0030] In another aspect of the system said amplitude is within a range of 1 nm - 40 nm, preferably 5-35 nm.

[0031] In a further aspect of the system said at least one instrument additionally is a thermographic camera. The system may further comprise equipment for heating the pressure vessel before or in the testing zone, and the thermographic camera will provide information on the temperature of the pressure vessel, and changes in temperature over time could be monitored. Damages to the pressure vessel are likely to result in an uneven temperature distribution.

[0032] In yet another embodiment the system may comprise further instruments selected from a line laser, 3D camera, 2D camera, near infrared light source and camera. These further instruments can be used to perform additional analysis of the composite pressure vessel, including checking for visible damages to the composite pressure vessel including the outer casing.

[0033] In a further aspect the system is fitted with an identification registration reader for reading a unique ID mark attached to each pressure vessel. In this aspect the system is able to connect obtained information to the unique ID of the pressure vessel. Further in connection with this aspect the system may comprise or be connected to a database wherein said unique ID of the pressure vessel is stored in the database together with the results of the test. In this way the system is able to gather information about each pressure vessel each time the pressure vessel is tested, normally prior to each refilling. This database will in addition to providing test results over time also provide information on the refilling frequency, visible appearance over time, and other information measured by the system. The traceability may offer the possibility to change the recertification scheme, to be based on the test results. The traceability will provide valuable information on a fleet of pressure vessels.

[0034] The present invention also provides a method for testing a composite pressure vessel comprising a composite layer and an outer casing wherein said method comprises:

- arranging the composite pressure vessel in a testing zone comprising at least one instrument for detecting damages to the composite layer of the composite pressure vessel.

[0035] In one aspect of the method said at least one instrument for detecting damages to the composite pressure vessel comprises a vibration initiator for inducing at least a set of vibrations of a given frequency and amplitude to the composite material via an excitation point, a source of coherent laser light exposing at least a part of the pressure vessel, a vibrometer for recording the laser light reflected of the surface of the pressure vessel assessing both amplitude and phase data in the vibration pattern of the composite layer of the pressure vessel.

[0036] In a further aspect of the method said frequency is within a range of 1 kHz - 50 kHz.

[0037] In yet another aspect of the method said amplitude is within a range of 1 nm - 40 nm.

[0038] In another aspect of the method several sets of vibrations are sent in rapid succession to the excitation point, and each set has a different frequency and/or amplitude, thereby providing further detail results.

[0039] In one aspect of the method the one or more instruments are applied to provide information on the condition of the pressure vessel, wherein this one or more instrument is selected from a line laser, 3D camera, 2D camera or near infrared light source and camera. In this aspect the method may comprise:

- preparing an image of the composite pressure vessel to be tested;
- comparing said image to an image of a perfect pressure vessel, and
- determining the degree of discrepancy.

[0040] The term "perfect" as used herein refers to a composite pressure vessel, without and damages, such as a quality approved, new and unused composite pressure vessel.

[0041] The image of a perfect composite pressure vessel may be prepared from one vessel or by combination of data from a number of vessels providing a common baseline for a perfect vessel for comparison.

[0042] For any specific vessel there will be a smaller degree of discrepancy which is within the production variations and therefore acceptable. Also, some ware especially of the casing during use is expected. Such ware may be detectable as discrepancy and provide valuable information but may not be considered a damage which should result in the vessel not being accepted for refilling.

[0043] In one aspect the system and method may further be combined with a weighing station to determine if the vessel to be tested contains considerable amounts of liquified gas as the analysis would have to be adjusted as the content my influence the vibration as well as being directly visible due to the at least partly transparent nature of the composite material.

[0044] It will be appreciated that the different testing methods may be applied both separately and combined.

[0045] The method may in one aspect comprise reading a unique ID mark attached to the pressure vessel with an identification registration reader. Additional the method may comprise storing said unique ID of the pressure vessel in a database together with the results of the test. This method makes it possible to compare the test results over time and also provide other observation over time and the frequency of refilling if the instrument is part of the refilling process.

[0046] In one aspect the excitation source is a buzzer or a piezo element.

Brief description of the drawings

[0047] The present invention will be described in further detail with reference to the enclosed drawings. A person skilled in the art will appreciate that the figures 1-3 are only example illustrations and that the present invention can be applied to test different types of composite pressure vessels comprising a composite layer partly covered by an outer impact protection.

Fig. 1 is a side view of a composite pressure vessel.

Fig. 2 is an exploded view of a composite pressure vessel.

Fig. 3 is a side view of the testing area according to a preferred embodiment of the present invention.

Fig. 4a - 4e show example images of tested pressure vessels.

Detailed description

[0048] Fig. 1 is a side view of a composite pressure vessel. The composite pressure vessel for storing gas and/or liquified gas comprises an inner gas tight liner. This inner gas tight liner is surrounded by a pressure resistant composite layer 1 of fibres and polymer. The liner and the composite layer 1 comprise at least one common opening. In this opening there is arranged a boss. The boss provides for attaching the inlet/outlet means of the vessel. The inlet/outlet means control the flow of gas in and out of the pressure vessel. The inlet/outlet means 2 can preferably comprise a valve.

[0049] An outer casing 3 surrounds the composite layer 1 and provides protection against impact. The outer casing 3 is provided with gaps 4 forming through holes through which the composite layer 1 is visible. The outer casing 3 may further include a top portion 5 for protecting the inlet/outlet means 2. The top portion 5 may include other features such as handles 6 for lifting the pressure vessel. These handles 6 can also act as a support allowing stacking during storage and transport.

[0050] The bottom surface of the outer casing 3 may be adapted to accommodate the handles 6 of the top portion 5 when stacking.

[0051] In an alternative embodiment the composite layer is gas tight making the inner liner optional. In this embodiment the boss would be secured to the composite layer.

[0052] Fig. 2 is an exploded view of a composite pressure vessel or gas container. The composite pressure vessel may comprise an inner liner. This inner liner is a gas tight liner. Outside the gas tight inner liner, there is a layer of composite material 1. The layer of composite material 1 is pressure resistant. Alternatively, the composite layer 1 is both gas tight and pressure resistant, making a separate liner obsolete. Outside the layer of pressure resistant composite material 1 there is an outer casing 3. The outer casing 3 protects against impact. The outer casing 3 may further provide a vertical arranged cylindrical pressure vessel with a stand supporting the vertical arrangement. The outer casing 3 may include other features such as handles 6 for transport and adaptions for allowing the bottom surface and the top surface to interact to make stacking easier. The optional inner liner and the composite layer 1 comprise at least one common opening wherein a boss is arranged. In the boss inlet/outlet means 2 can be secured. The inlet/outlet means controls the flow of fluid in and out of the pressure vessel.

[0053] Fig. 3 is a side view of the testing area according to a preferred embodiment of the present invention. The testing area has at least one inlet/outlet for pressure vessels to be tested. After testing in the testing area, the tested pressure vessel leaves the testing area through the at least one outlet. The outlet may further be fitted with an apparatus for selectively removing damaged pressure vessels.

[0054] The general technique of interferometry is known and used within other technical fields. The method is in brief to expose the object to coherent laser light and measure changes to the surface when object is subjected to a load. The load used here is based on vibration-loading. The object's motion is reconstructed with nanometre accuracy. Then, both amplitude and phase data can be used to find differences and deviations in the object's vibration pattern. Interferometry is for instance disclosed in EP 2929305 and WO 2017085457, patent application GB1809011.8 and in the prior art discussed therein. The invention makes use of high resolution, contactless laser technology based on ESPI, or optionally shearography.

[0055] The testing area is comprised of a stabilised platform/table 7 on which the pressure vessel is placed. Further the testing area is fitted with one or more instruments adapted to detect errors or damages to the composite pressure vessel.

[0056] In a preferred embodiment of the present invention the one or more instruments comprises a vibrometer 8. The vibrometer 8 reads of vibrations induced to the composite pressure vessel. The vibrations are induced to the composite material of the composite layer via an excitation point 9. The excitation point 9 can be a buzzer. In the illustrated embodiment the buzzer gets a signal via a signal cable attached to a signal generator 10. The signal generator 10 can be programmed to send a signal to the excitation point 9, the excitation point 9 converts the signal into vibrations of a certain frequency and amplitude.

[0057] Alternatively, the signal generator 10 can be programmed to send several sets of signals in rapid succession to the excitation point 9, wherein the excitation point 9 converts the signals into several sets of vibrations in rapid succession wherein each set of vibrations has a different frequency and/or amplitude.

[0058] The vibrations can have a frequency within the range of 1-50 kHz, and an amplitude below 50 nm, preferably within the range of 1-40 nm, or 5-35 nm.

[0059] The excitation point must be brought into close contact with the composite layer, preferably it is pressed on to the composite material of the pressure vessel with a force of at least 5-20 kg.

[0060] The excitation point 9 can be attached to the composite material adjacent to the valve 2. However, a person skilled in the art will recognise that the excitation point 9 can also be on any part of the composite layer. The outer casing is provided with opening/through holes that makes areas of the composite layer visibly accessible without removing the outer casing.

[0061] In a preferred embodiment of the present invention there are more than one excitation point.

[0062] Preferably the system is able to examine the entire pressure vessel at once, in one testing. In this embodiment the excitation points are attached to the composite material of the pressure vessel. The vibrations would spread from the one or more excitation points along the composite material of the pressure vessel. By arranging more than one laser and/or using mirrors all sides of a vessel can receive laser light simultaneously. By arranging more than one vibrometer, readings of the vibration patterns and damage analysis may be performed on more than one side of a vessel simultaneously. In on embodiment two combined vibrometer and laser instruments are applied in combination with two mirrors. Each instrument will by assistance of a mirror be able to analyse two adjacent sides of a vessel, and combinedly the two instruments perform a 360° analysis of the vessel without moving the vessel.

[0063] In a preferred embodiment of the present invention there are two excitation points. A first excitation point is arranged in contact with the composite material adjacent the inlet/outlet means of the boss. A second excitation point is arranged in contact with the composite material at the bottom of the container. The container rests on these excitation points during testing.

[0064] The benefit of the container resting on the excitation points is that they eliminate unwanted vibrations from outside the testing zone from interfering with the vibrations from the excitation points. Unwanted interference might give wrongful readings.

[0065] The composite pressure vessel is exposed to coherent laser light from a coherent laser light source 12. The laser light bounces of the pressure vessel and is recorded by a vibrometer 8.

[0066] The result of the scan is analysed by a data processer resulting in either approving the pressure vessel and the data processor sending a signal to the system allowing the pressure vessel to proceed from the testing zone to the refilling or disapproving the pressure vessel and sending a signal to the system of not allowing the pressure vessel to proceed to refilling.

[0067] The result of the scan may also be read of immediately on a computer screen and in addition stored in a database 11 with the individual ID marking of the pressure vessel. The ID can be read by an ID scanner. The ID marking can be either a bar code, a QR code, serial number, an RFID chip or any other type of suitable ID marking.

[0068] The database can be used to monitor the pressure vessels age, the number of fillings and the need for retesting or further testing.

[0069] The method used in the preferred embodiment described over is to subject the composite pressure vessel to a load. In this embodiment the load is in the form of vibrations induced by use of a transducer. However, the load can also be thermal, or vacuum.

[0070] The vibrations propagate from the excitation point 9 through the entire composite material in the form of an excitation wave.

[0071] Further, the pressure vessel is exposed to coherent laser light. The entire pressure vessel can be exposed at once or one section at a time or alternatively just one section of the pressure vessel. The laser light is reflected of the surface of the pressure vessel and recorded by one or more vibrometers 8.

[0072] When the composite pressure vessel is subjected vibrations and coherent laser light the motion of the composite pressure vessel is reconstructed with nanometer accuracy by the vibrometer 8. Then, both amplitude and phase data can be used to find differences and deviations in the object's vibration pattern.

[0073] In an undamaged composite pressure vessel, the excitation wave propagates evenly from the excitation point 9 and down trough cylinder wall of the composite material. Hence a clear and consistent signal is observed in all available areas. The available areas are gaps/openings in the outer casing, or areas not protected by outer casing. In one embodiment the area of the openings compared to the surface area of the casing is between 20-80%, preferably 30-70% more preferably 40-60%.

[0074] The excitation of the outer casing follows a significantly different pattern than the one in the composite material, so it is therefore easy to differentiate between the outer casing and the composite material.

[0075] In a damaged composite pressure vessel, the excitation wave has a non-consistent wave-pattern present in most visible areas. Hence the excitation wave shows significant irregularities in most visible areas.

[0076] When comparing wave propagation in undamaged and damaged cylinder it is visually possible to determine which cylinder is damaged. The determination is preferably performed by the data processor. The analysis may include many scanning at different vibration frequencies. Further, the obtained results may be compared to an expected result for a perfect vessel at different vibration frequencies. Determination that the vessel is damaged may be based changes in the expected vibration pattern at different vibration frequencies.

[0077] Through numerical recordings, scans and picture storage, an automatic system can provide graphical and numerical documentation for each inspection. There are several solutions for establishing acceptance criteria that can be used by and automatic system.

[0078] The system can provide an accepted/rejected result based on conservative criteria. The inspected pressure vessel will in that case be removed and not refiled when indications are located.

[0079] The approach can be used for an initial screening. If defects or damages are indicated, the composite pressure vessel is followed up by a more thorough disassembly and further inspections.

[0080] In case the composite pressure vessels are equipped with an ID marker the indications of defects/damages can also be stored in the database 11 and defects/indications can be monitored over time.

[0081] Different instruments and methods for detecting errors on the pressure vessel can be used, and a person skilled in the art will appreciate the possibility of combined application of the instruments and methods to obtain more information about the pressure vessel.

[0082] Other instruments can be a line laser, 2D camera, 3D camera or a near infrared light source and camera.

[0083] In an embodiment of the present invention the imaging can be the instrument used for assessing the damage of the pressure vessel. In this embodiment an image of the pressure vessel is prepared using a camera. This image is compared with an image of a pressure vessel in perfect condition. Any differences between the tested pressure vessel and the perfect pressure vessel can be assessed. An algorithm can be used to assess the differences and make a judgment if the differences is of such a character that it needs to be recorded for later reference or if the pressure vessel needs to be discarded, repaired or recertified.

[0084] Using this method, the new image of the pressure vessel can be compared with earlier images every time it is checked. In this way it is possible to keep track of irregularities on any pressure vessel to see if it evolves into a damage so severe the pressure vessel needs to be discarded.

[0085] 2D inspection is done by using a 2D camera. In a preferred embodiment using this method the camera is stationary and the pressure vessel moves. This method requires an encoder to identify patterns. Further it requires an optimize light source. Most preferably multicoloured light is used for different situations. In addition, two setups are possible, one for deformations and one for damages in the surface.

[0086] 3D inspection can be done using either a 3D camera or a line laser. In this inspection method the pressure vessel is stationary and the instrument moves.

[0087] Using a 3D camera requires capturing multiple images. The images are averaged, and a Gaussian smoothing is performed in x, y and z direction. The centre axis of the pressure vessel is found, a point cloud stitching is performed based on servo rotation, stretch-out data is acquired, and the data is put into a classification software.

[0088] A line laser method uses a projected laser line to find deformations. The reflections of the laser light are captured and sent to an encoder that aranges the data in polar coordinates. The coordinates are stretched out and centred, and a count of points above a given threshold is identified.

[0089] 3D inspection is good for finding deformations and can be used to assess roundness. However, patterns in the casing requires assessment of a whole side/pattern at once.

[0090] A near infrared light source and camera can be used to assess damaged in the pressure vessel when it is exposed to heat.

[0091] By combining vibration technology for detecting of damages to the composite material with instruments such as 2D and 3D cameras that detect visual damages it is possible to categorise the tested pressure vessels with respect to both damages and visual appearance.

[0092] Figure 4a is an image of wave propagation in an undamaged pressure vessel. The excitation source in this test is a buzzer and the excitation frequency is 40 kHz. Here it can be seen that the excitation wave propagates evenly from the excitation point and down through the wall of the composite layer. There is a clear and consistent wave pattern visible through the gaps in the outer shielding. The excitation of the outer shielding follows a significantly different pattern. The instrument used was a Vibromap 1000 from Optonor, which comprises both a coherent laser and a vibrometer.

[0093] Figure 4b is an image of wave propagation in a damaged pressure vessel. The excitation source in this test is the same as in figure 4a, a buzzer and the excitation frequency is also the same, 40 kHz. Here it can be clearly seen that the excitation wave shows significant irregularities in most visible areas. The irregularities in the wave pattern is an indication that there is a damage to the pressure vessel that influence the wave pattern throughout the entire pressure vessel. With this method it is possible to establish if there is a damage to the pressure vessel even if the damage is covered by the outer casing.

[0094] Figure 4c is an image of wave propagation in a damaged pressure vessel, the damage is within the circle. In this test the outer casing is taken off. The excitation source in this test is a buzzer and the excitation frequency are 27 kHz. Here it can be clearly seen that the excitation wave shows significant irregularities. In this test it is also possible to establish where the damage is on the composite layer. Further it is possible to see how irregularities related to the damaged area spreads throughout the pressure vessel.

[0095] Figure 4d is an image of a test done on a damaged pressure vessel with the outer shielding removed. The damage is within the circle. The excitation source in this test is a buzzer and the excitation frequency are 2 - 10 kHz. In this image the excitation point is clearly visible as a highlighted ring on the upper part of the pressure vessel. Further the damages area is also visible as a highlighted spot.

[0096] Figure 4e is an image of a test done on a damaged pressure vessel with the outer shielding in place. The damage is within the circle. The excitation source in this test is a buzzer and the excitation frequency are 2 - 10 kHz. The damaged area responds to the excitation with an increased vibration amplitude affecting the surrounding outer cover. Even if the softer material in the outer cover in general will provide a more inconsistent vibration pattern it is possible to see indications of how the damage affects the vibrations in outer cover.

Claims

1. System for testing a composite pressure vessel comprising a layer of composite material and an outer casing with at least one through hole, wherein the system comprises at least one inlet/outlet for pressure vessels to be tested, and a testing zone accessible via the at least one inlet/outlet, **characterized in that** said testing zone comprises at least one instrument for detecting damages to the composite pressure vessel, said at least one instrument for detecting damages to the composite pressure vessel comprises:

   a. at least one vibration initiator for inducing at least a set of vibrations of a given frequency and amplitude to the composite material of the composite pressure vessel via at least one excitation point (9),

b. a source (12) of coherent laser light exposing at least a part of the pressure vessel,
c. at least one vibrometer (8) for recording the laser light reflected of the surface of the pressure vessel assessing both amplitude and phase data in the vibration pattern of the composite material of the pressure vessel.

2. System according to claim 1, wherein said frequency is within a range of 1 kHz - 50 kHz.

3. System according to claim 1 or 2, wherein said amplitude is within a range of 1 nm - 40 nm.

4. System according to any one of the claims 1-3, wherein said at least one excitation point during testing is secured to the composite material with a pressure force between 1-100 kg, preferably between 5-20 kg.

5. System according to any one of the claims 1-4 further comprising two excitation points placed on opposite sides of the composite pressure vessel in configured to hold the composite material of the composite pressure vessel fixed between them during testing.

6. System according to claim 5 wherein a first excitation point is arranged in contact with the composite material adjacent an inlet/outlet means of the pressure vessel and a second excitation point is arranged in contact with the composite material opposite the inlet/outlet means of the pressure vessel.

7. System according to any one of the claims 1-6, wherein said at least one instrument additionally is selected from a line laser, 3D camera, 2D camera, near infrared light source and camera.

8. System according to any one of the claims 1-7, wherein said at least one instrument additionally is a thermographic camera.

9. System according to any one of the claims 1-8 fitted with an identification registration reader for reading a unique ID mark attached to each pressure vessel.

10. System according to claim 9 wherein said unique ID of the pressure vessel is stored in a database (11) together with the results of the test.

11. Method for testing a composite pressure vessel comprising a composite layer and an outer casing **characterized in that** said method comprises

- arranging the composite pressure vessel in a testing zone comprising at least one instrument for detecting damages to the composite layer of the composite pressure vessel.

12. Method according to claim 11, wherein the outer casing comprises at least one opening and wherein said at least one instrument for detecting damages to the composite pressure vessel comprises a vibration initiator (10) for inducing at least a set of vibrations of a given frequency and amplitude to the composite material via an excitation point (9), a source (12) of coherent laser light exposing at least a part of the pressure vessel, a vibrometer (8) for recording the laser light reflected of the surface of the pressure vessel assessing both amplitude and phase data in the vibration pattern of the composite layer of the pressure vessel.

13. Method according to claim 12, wherein said frequency is within a range of 1 kHz - 50 kHz.

14. Method according to claim 12 or 13 wherein said amplitude is within a range of 1 nm - 40 nm.

15. Method according to any one of the claims 12-14, wherein several sets of vibrations are sent in rapid succession from the excitation point (9), and each set has a different frequency and/or amplitude.

16. Method according to any one of the claims 11-15, wherein said at least one instrument is selected from a line laser, 3D camera, 2D camera or near infrared light source and camera.

17. Method according to claim 16, wherein the method comprises

- preparing an image of the composite pressure vessel to be tested;
- comparing said image to an image of a perfect composite pressure vessel, and
- determining the degree of discrepancy.

18. Method according to any one of the claims 11-17, wherein the method comprises reading a unique ID mark attached to the pressure vessel with an identification registration reader.

19. Method according to claim 18 wherein the method comprises storing said unique ID of the pressure vessel in a database (11) together with the results of the test.

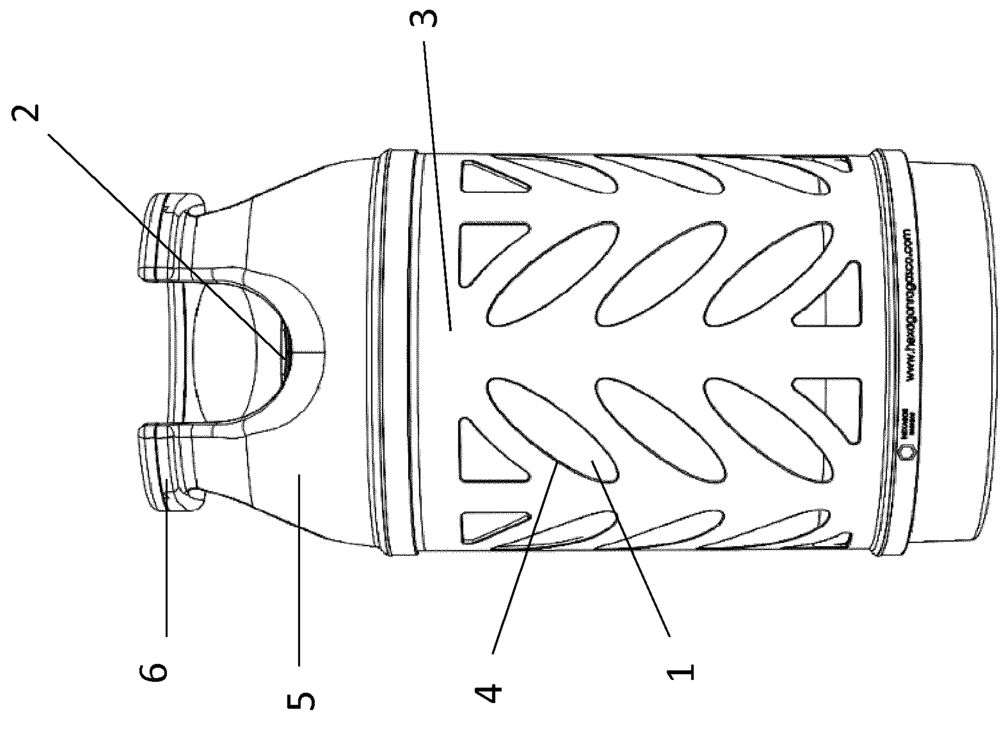

Fig. 1

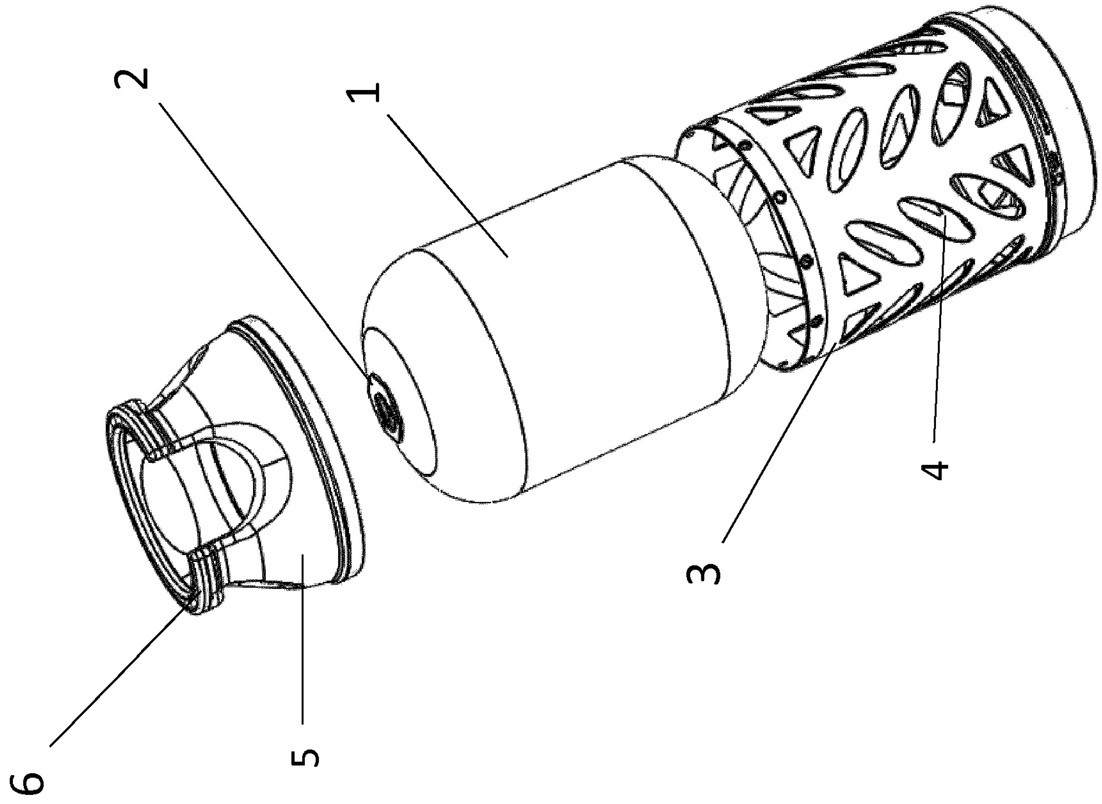

Fig. 2

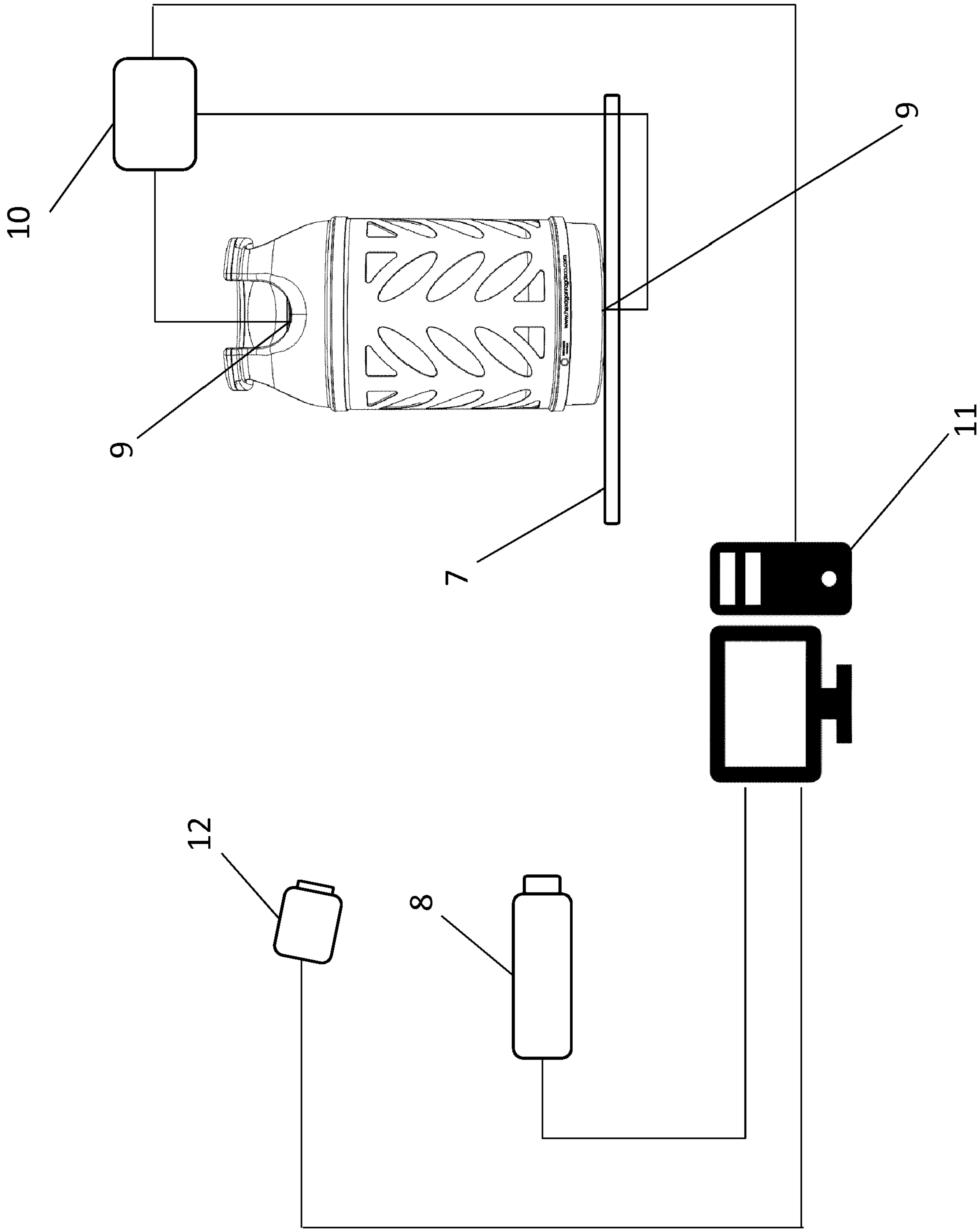

Fig. 3

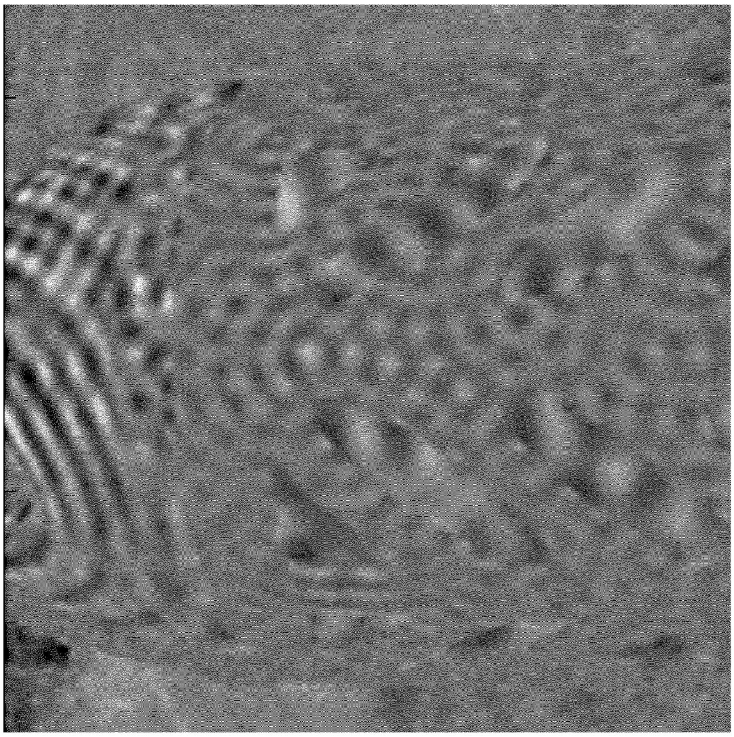

Fig. 4b

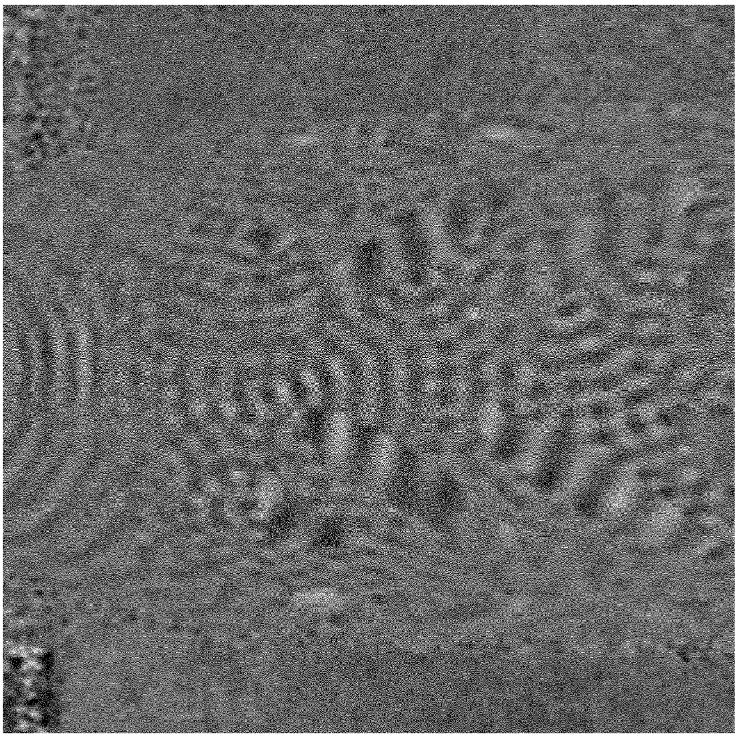

Fig. 4a

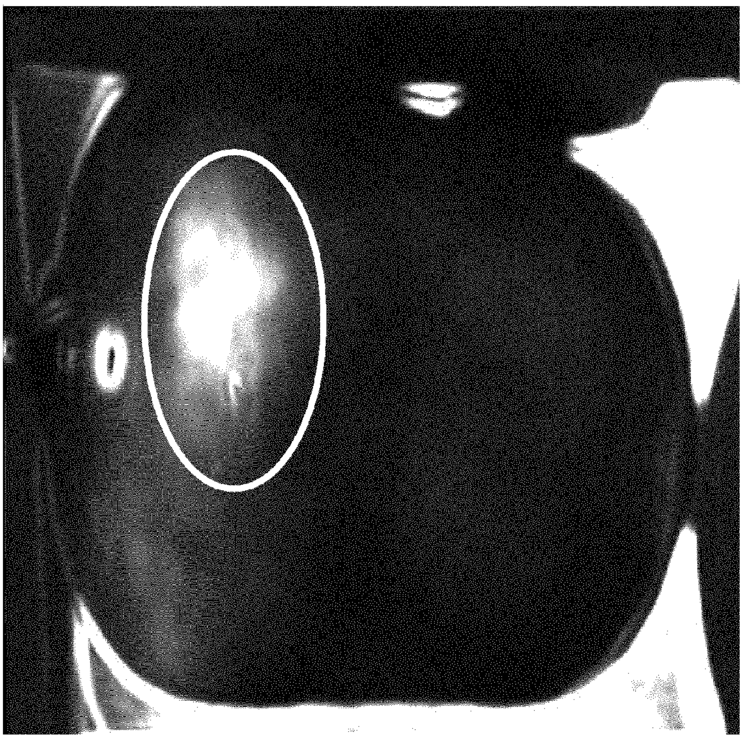

Fig. 4d

Fig. 4c

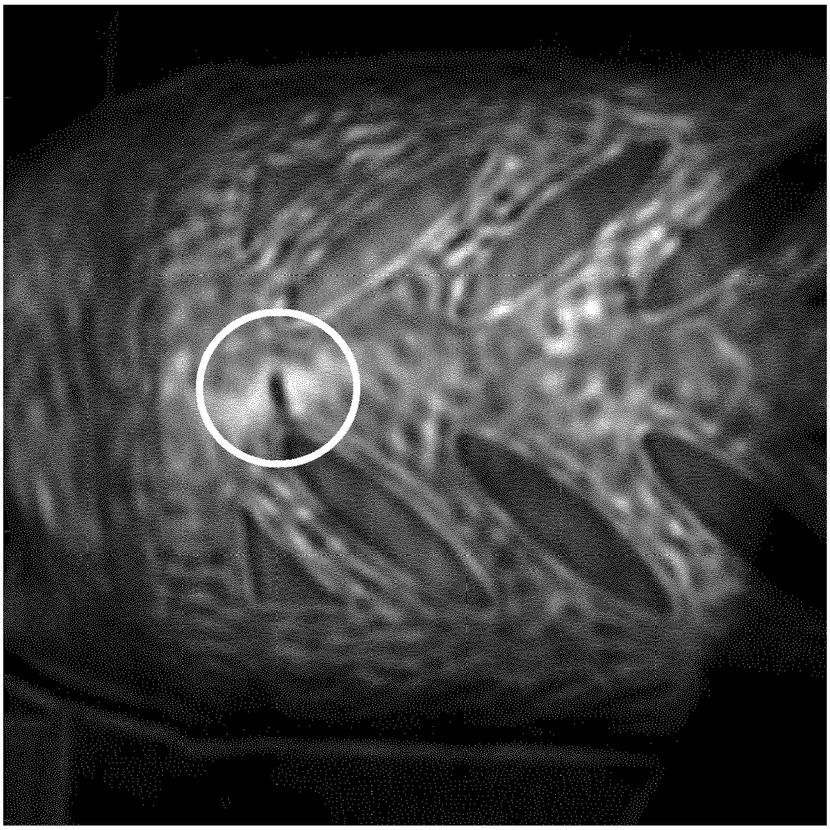

Fig. 4e

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EUROPEAN SEARCH REPORT

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2

Place of search	Date of completion of the search	Examiner
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