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(54) Title: A METHOD AND AN APPRATUS FOR DETERMINING PRESSURE EXERTED ON AN OBJECT

(57) Abstract: A method and an apparatus for determining pressure exerted on an object are disclosed. The method includes enclosing the object in a casing, where the casing is composed of a material having a different thermal co-efficient of expansion. Further, the method includes placing the casing in a thermal chamber and then varying temperature in the thermal chamber through a first predetermined temperature range, such that the casing undergoes thermal deformation. Then, the method includes generating, by a detection module, a signal corresponding to the thermal deformation of the casing, the detection module including one or more sensors. The method and the apparatus provide a cost- effective, simple and an efficient solution to and determine and test the pressure exerted on the object.

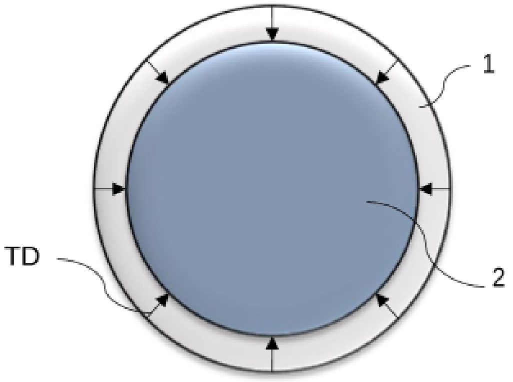

FIG. 1A

FORM 2

THE PATENTS ACT 1970
(39 OF 1970)
&
The Patent Rules, 2003
Complete Specification
(See Section 10 and Rule 13)

1. TITLE OF THE INVENTION

A METHOD AND AN APPRATUS FOR DETERMINING PRESSURE EXERTED ON AN OBJECT

2. APPLICANT(S)

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3. PREAMBLE TO THE DESCRIPTION

COMPLETE

The following specification particularly describes the invention and the manner in which it is to be performed.

DESCRIPTION

TECHNICAL FIELD

[001] This disclosure relates generally to measurement of physical parameters such as pressure, and more particularly to a method and an apparatus for determining pressure exerted on an object through thermal deformation.

BACKGROUND

[002] Pressure is broadly defined as normal force acting per unit area of a surface. Pressure is mathematically calculated as the magnitude of normal force divided by surface area on which the normal force is acting. Objects we see around us experience pressure in some form or the other. For example, airborne vehicles such as aircrafts experience pressure of the air which varies with the elevation. Similarly, water-based vehicles such as ships, submarines, etc., experience hydrostatic as well as hydrodynamic pressures. Apart from water-based vehicles, many modules, devices, or instruments are submerged deep inside the water in water bodies for a number of purposes. For example, optical systems such as optic fiber cables, sensors, measuring devices, etc., and electrical and electronic systems such as wire harnesses, fiber cables, etc., associated with offshore wind turbines are submerged inside the water for connections. These objects submerged inside the water [or any other liquid] experience hydrostatic pressure which in a general sense is dependent on specific weight of water and the depth to which the object is submerged from free surface. To directly determine and assess pressure acting on submerged objects [pressure testing] for a given depth of submergence, complex instrumentation comprising sensors, gauges etc., are required. This not only make the pressure testing complex, expensive and laborious, but also render the pressure measurement inaccurate/imprecise due to stochastic behavior of the liquid under consideration. In some circumstances, direct measurement of hydrostatic pressure acting on a submerged object may be entirely impractical or extremely challenging.

[003] Therefore, there is a need for a testing method and an apparatus which allows testing of pressure exerted on an object in a simple, cost-effective manner and with minimum effort possible. The pressure testing method and apparatus at the same time should allow accurate and precise determination of pressure values.

SUMMARY OF THE INVENTION

[004] In an embodiment, a method for determining pressure exerted on an object is disclosed. The method includes enclosing the object in a casing, where the casing is composed of a material having a different thermal co-efficient of expansion. Further, the method includes placing the casing in a thermal chamber and then varying temperature in the thermal chamber through a first predetermined temperature range, such that the casing undergoes thermal deformation. The method further includes generating, by a detection module, a signal corresponding to the thermal deformation of the casing, the detection module including one or more sensors.

[005] In another embodiment, an apparatus for determining pressure exerted on an object is disclosed. The apparatus includes a casing being configured to enclose the object, where the casing is composed of a material having a different thermal co-efficient of expansion. The apparatus also has a detection module. Further, the casing is configured to be placed in a thermal chamber, with the temperature of the thermal chamber being variable through a first predetermined temperature range such that the casing undergoes thermal deformation. Then the detection module is configured to generate a signal corresponding to the thermal deformation of the casing.

BRIEF DESCRIPTION OF THE DRAWINGS

[006] The accompanying drawings, which are incorporated in and constitute a part of this disclosure, illustrate exemplary embodiments and, together with the description, serve to explain the disclosed principles.

[007] **FIGS. 1A and 1B** illustrate sectional view of the object enclosed in a casing, in accordance with some embodiments of the present disclosure;

[008] **FIG. 2** illustrates an apparatus for determining pressure exerted on the object shown in FIGS. 1A and 1B;

[009] **FIGS. 3 and 4** illustrate perspective views of the object and the casing shown in FIG. 1A and FIG. 1B, respectively;

[010] **FIG. 5** illustrates sectional perspective view of the object enclosed in the casing;

[011] **FIG. 6** illustrates front view of an exterior of the casing meshed with tetrahedral elements for FE analysis, in accordance with an embodiment of the present disclosure;

[012] **FIGS. 7A-7C** illustrate thermal deformation values of the casing relative to the object at three different cooling temperatures, in accordance with an embodiment of the present disclosure;

[013] **FIG. 8** is a graph illustrating variation of thermal deformation of the casing subjected to different temperatures in the thermal chamber;

[014] **FIGS. 9A-9E** illustrate pressure distribution on the object when the casing is subjected to different temperatures in the thermal chamber;

[015] **FIG. 10** is a graph illustrating variation of pressure exerted on the object with respect to various cooling temperatures in the thermal chamber; and

[016] **FIG. 11** is a flowchart illustrating the method for determining pressure exerted on the object, according to an embodiment of the disclosure.

DETAILED DESCRIPTION OF THE DRAWINGS

[017] Exemplary embodiments are described with reference to the accompanying drawings. Wherever convenient, the same reference numbers are used throughout the drawings to refer to the same or like parts. While examples and features of disclosed principles are described herein, modifications, adaptations, and other implementations are possible without departing from and scope of the disclosed embodiments. It is intended that the following detailed description be considered as exemplary only, with the true scope and spirit being indicated by the following claims. Additional illustrative embodiments are listed.

[018] In an embodiment, a method, and an apparatus for determining pressure exerted on an object is disclosed. When an object is partially or fully submerged in a liquid, for example, water, it experiences hydrostatic pressure. Hydrostatic pressure is determined by specific weight of the liquid under consideration and the extent of depth to which the object is submerged. With the increase in depth of the liquid under consideration, direct determination of pressure acting on the object becomes difficult and challenging. The method and the apparatus of the present disclosure is directed to address the limitations associated with existing techniques by replicating/simulating pressure acting on an object through a technique involving variation of temperatures.

[019] The method and the apparatus of the present disclosure uses difference in thermal coefficient of expansion between two or more distinct materials to simulate the pressure acting on the object. The method involves enclosing the object in a casing, where the casing is composed of a material having a different thermal co-efficient of expansion. For example, the casing may be composed of a material having a high thermal coefficient of expansion so that there is considerable thermal deformation of the casing when it is subjected to high or low temperatures. Further, the method includes placing the casing in a thermal chamber and then varying temperature in the thermal chamber through a first predetermined temperature range, such that the casing undergoes thermal deformation. For instance, if the temperature of the casing containing the object is reduced to negative values, the casing may contract [shrink] relative to the object and exert pressure along an entire outer surface of the object by virtue of contraction. The pressure so exerted due to contraction of the casing may correspond to or indicative of the actual pressure [hydrostatic] exerted by the liquid when the object is submerged to a given depth. Further, the method includes generating, by a detection module, a signal corresponding to the thermal deformation of the casing. The detection module may be for example, one or more sensors which detect the values of the pressure corresponding to the thermal deformation of the casing relative to the object.

[020] Embodiments of the disclosure also disclose the apparatus employed to determine the pressure acting on the object, with the casing being configured to enclose the object. A detection module associated with the object and the casing may be employed to determine the pressure values.

[021] **FIGS. 1-5** are exemplary embodiments which illustrate several views of the object 2 enclosed in the casing 1. FIGS. 1A, 1B, 2 and 5 illustrate the object 2 as enclosed within the casing 1, while FIGS. 3 and 4 show the object 2 and the casing 1 as separate elements. FIG. 2 illustrates the apparatus 100 which includes the thermal chamber 30, the detection module 20, and the casing 1 containing the object 2 which is placed inside the thermal chamber 30. In an embodiment, the object 2 may include, but not limited to an electrical, electronic, mechanical, or optical object such as an instrument, a module, a unit, or a sensor. Any other object apart from the ones stated above may also be used. In an embodiment, the object may have geometrical shapes including, but not limited to spherical, circular, cylindrical, cubical, ellipsoidal or of any other geometrical shape. The object 2 may be submerged in a liquid, for example, deep inside water for a wide range of real-time applications including, but not limited to communication, analysis, power transmission, research, marine studies and so on. The object 2 so submerged is subjected to pressure of the liquid which may include hydrostatic pressure. In order to determine the magnitude of pressure exerted on the object 2, the actual pressure exerted on the object 2 may be realized/imitated/simulated in a different physical environment, for example, a temperature-controlled environment.

[022] As shown in FIG. 2, the object 2 enclosed in the casing 1 may be placed in a thermal chamber 30. The thermal chamber 30 herein above and below refers to a temperature-controlled chamber whose internal space may be heated or cooled through a range of temperatures. In an embodiment, the temperatures inside the thermal chamber may be increased to as high as 100 ^{O} C, and conversely, may be cooled to temperatures as low as -100^{O}C. The temperatures inside the space of the thermal chamber 30 may be generated by any of the known energy generating means like electrical heating, combustion of fuels, and so on. In an embodiment, the thermal chamber 30 have temperature regulating unit [not shown] to regulate and maintain required temperatures.

[023] Further, referring to FIGS. 1-5, the casing 1 enclosing the object 2 may have a different thermal coefficient of expansion than the object 2. Enclosing herein above and below refers to circumscribing the object 2 by the material of the casing 1 for a predefined thickness which may be varied depending on the requirement. In an embodiment, if the object 2 is spherical or cylindrical, the casing 1 may also be spherical or cylindrical that concentrically surrounds the object 2. The casing 1 may be made of a material which has a high thermal coefficient of expansion, such that when the casing 1 is subjected to a range of temperatures, the material of the casing undergoes thermal deformation [expansion or contraction]. Thermal coefficient of expansion herein above and below refers to a thermal property where the material expands or contracts in response to variation in temperatures, at a given rate. Thermal coefficient of expansion may be positive which indicates that the material expands with increase in temperature, or negative where the material contracts with the increase in temperature. Materials with positive thermal coefficient of expansion undergo contraction when the temperature is lowered. In an embodiment, the expansion or contraction may be linear, superficial, or volumetric in nature. The object 2, on the other hand, may be made of a material having low thermal coefficient of expansion, i.e., the object 2 may exhibit lesser response i.e., deformation to changes in temperature. In an embodiment, the object 2 may be composed of material selected from, but not limiting to glass, ceramic, or any other material having low thermal coefficient of expansion in comparison to the casing 1. In another embodiment, the casing 1 may be composed of materials selected from one or more polymeric groups like polyepoxides, elastomers, synthetic fibers, and so on. In yet another embodiment, the casing 1 may be composed of metals or alloys having high thermal coefficient of expansion like aluminium, antimony, copper, chromium, cobalt, or any other metallic elements and their alloys, , so that the casing 1 may have relatively higher thermal coefficient of expansion in comparison to the object 2. In an embodiment, the casing 1 is composed of epoxy such as chock fast. Although polymeric materials may be preferred for the casing 1 owing to their high thermal coefficient of expansion, any other material or material groups which exhibits high thermal coefficient of expansion may be employed for manufacturing the casing 1. In an embodiment, the glass object 2 may be mold or cast inside the epoxy casing 1 during manufacturing. In another embodiment, the thickness of casing 1 may be uniform over the object 2.

[024] The casing 1 enclosing the object 2, when subjected to gradual decrease in temperature inside the thermal chamber 30, may undergo thermal deformation i.e., contraction [shrink] relative to the object 2 [denoted by TD in FIG. 1A], thereby exerting pressure on the outer surface of the object 2. In an embodiment, the casing 1 containing the object 2 may be supported by a fixture [not shown] in the thermal chamber 30. In an embodiment, the temperature inside the thermal chamber 30 may be varied through a first predetermined temperature range to assess the effect of thermal deformation of the casing 1 on the object 2. In an embodiment, the first predetermined temperature may range from +60^{O} C to – 100 ^{O} C. In this temperature range, the thermal deformation of the casing 1 for every 10^{O} C drop in temperature starting from +60^{O} C may be determined. When the thermal deformation [contraction] of the casing 1 relative to the object 2 exerts pressure on the object 2, the object 2 may also undergo deformation i.e., contraction but to a lesser extent than the casing 1. In an embodiment, the first predetermined temperature may be higher than +60^{O} C and lower than – 100 ^{O} C depending on the nature of material employed as well as the pressure values that need to be determined. In an embodiment, when the temperature inside the thermal chamber 30 is gradually decreased starting from +60^{O} C, the rate of thermal deformation i.e., contraction of the casing 1 may or may not be linear [or proportional] with the temperature decrease. For instance, as the first predetermined temperature is reduced from +30^{O}C to +20^{O}C, the thermal deformation may be “x” mm, and when the temperature is reduced in the negative range, for example, from -10^{O}C to -20^{O}C, the deformation may be “y” mm, the order of “y” being larger than the order of “x”. The thermal deformation values corresponding to desired intervals of first predetermined temperature range may be noted. For example, at +10^{O}C, the deformation may be around 0.008 mm, at 0^{O}C, the deformation may be around 0.015 mm and so on. In an embodiment, the selection of material for casing 1 as well as the thickness of the casing 1 may depend on the nature of the object 2, physical and mechanical properties of the object, depth at which the object 2 is submerged in the liquid, as well as the temperatures inside the thermal chamber 30.

[025] In an embodiment, the object 2 and the casing 1 may be associated with a detection module 20 which determines the pressure exerted by the casing 1 on the object 2 in response to the thermal deformation. The detection module 20 may be one or more sensors which may directly measure the thermal deformation, as well as the pressure exerted by the casing 1 due to thermal deformation i.e., contraction, under varying temperatures. In an embodiment, the detection module 20 may be a pressure sensitive device or a module like a piezoresistive strain gauge, piezoelectric pressure sensing element, capacitive, electromagnetic, resonant, optical, potentiometric, thermal, and ionization-based pressure sensing elements. Apart from these, electrical strain gauges, load cells, etc., may be employed as the detection module 20 to measure the thermal deformation and the associated pressure values. In an embodiment, one or more detection modules 20 may be embedded at the interface of the casing 1 and the object 2 to measure the pressure exerted due to contraction of the casing 1. The one or more detection modules 20 embedded at the interface may determine the pressure by any of the pressure sensing modes mentioned above, and may indicate the pressure values through a display device [not shown]. In an embodiment, the apparatus 100 may have a control unit [not shown] interfaced with the detection module 20 as well as the energy source of the thermal chamber 30 to regulate and coordinate processes involved in determination of pressure.

[026] As an example, if the object 2 made of glass is submerged at a depth of 400 m from the free surface of water, the theoretical hydrostatic pressure on the object would be approximately 4 MPa. The object 2 may then be enclosed in the casing 1 and placed in the thermal chamber 30. The temperature of the thermal chamber 30 is gradually cooled from say 20^{O}C to -30^{O}C, and thermal deformation [contraction] corresponding to every 10 ^{O}C drop in temperature may be noted. Once the temperature approaches -30^{O}C, the detection module 20 may detect the thermal deformation value and indicate the corresponding value of pressure through the display device. An error or deviation between the pressure value determined through the apparatus 100 of the present disclosure and the theoretical value may be calculated. In an embodiment, the temperature ranges through which the casing 1 containing the object 2 can be subjected to inside the thermal chamber 30 can be determined experimentally or through simulations. Considering an exemplary product on which the values of hydrostatic pressure exerted are determined by the apparatus 100 and the method of the present disclosure. Table 1 shown below depicts the material properties of the object 2 [a glass sphere] and the casing 1 [chock fast Orange]. It can be seen that the coefficient of thermal expansion of the glass [object] is very small compared to the coefficient of thermal expansion of the chock fast [casing].

Component	**Material**	**Density (kg/m^3)**	**Poisson's ratio**	**Young's modulus (MPa)**	**Coefficient of thermal expansion (C^{-1})**
Inner Sphere	Glass	2.4	0.3	60000	4e-6
Outer Sphere	Chock Fast Orange	1.2	0.35	5935	30.8e-6

Table 1

[027] In an embodiment of the disclosure, the object 2 itself may be a pressure sensitive device, for example, the object 2 may be an optical sensor submerged deep inside water for optical investigation purposes. Alternately, the object 2 may be an electrical or electronic based sensing device which may be submerged inside water. In either case, the object 2 may have suitable connections for signal transmission and reception, among other elements deployed for the purpose of investigation. Due to hydrostatic pressure acting on the object at the depth of submergence, the object 2 may undergo deformation [elastic or non-elastic], resulting in a minor distortion or deflection of the object 2. For example, in case of the object 2 being optical sensors having optic fiber cables, core, cladding, etc., the hydrostatic pressure may result in micro bends or warps. Once the signal is passed and received from the optical sensor, a change in signal characteristics such as transmission speed, losses, reflection pattern, frequency, etc., are observed due to the small bend or warp of fiber in the optical sensor.

[028] The hydrostatic pressure and the resulting deformation of the optical sensor may be simulated in the apparatus 100 of the present disclosure where the optical sensor is enclosed in the casing 1, and then placed in the thermal chamber 30. This is followed by varying temperature inside the thermal chamber 30 to determine thermal deformation and corresponding pressure as explained above. The temperatures inside the thermal chamber 30 may be varied until the optical sensor does not show any losses or irregular changes in the signal characteristics, indicating that the optical sensor is unaffected by the pressure as simulated by the thermal deformation of the casing 1. A further change in temperature inside the thermal chamber 30 may slowly result in the optical sensor producing some changes in signal characteristics, for example, losses. This is indicative of a pressure higher than the maximum pressure [as simulated by thermal deformation] at which the optical sensor cannot produce desired outcome/output due to signal losses.

[029] In an embodiment, the apparatus 100 and the method of the present disclosure allow determination of pressure distribution at several local points around the object 2. For instance, if the object 2 is of an irregular profile and the casing 1 conforms to the profile of the object 2, then the thermal deformation at several points of the casing 1 may be determined by embedding a number of detection modules 20. The detection module 20 accordingly indicates the thermal deformation and the corresponding pressure values acting at selected locations/points on the object 2.

[030] In an embodiment, the object 2 may be tested to assess deformation pattern prior to enclosing the object 2 in the casing 1. The test procedure may involve placing the object 2 in the thermal chamber 30 and varying the temperatures inside the thermal chamber 30 to investigate deformation pattern [or response] of the object 2 to variation of temperature. For the test, temperature inside the thermal chamber 30 is varied through a second predetermined temperature range, for example, from +60 ^{O} Celsius to – 100 ^{O} Celsius, and the thermal deformation corresponding to several intervals of second predetermined temperature range may be determined. Testing the object 2 in the absence of casing 1 is crucial to assess the deformation behavior of the object 2 when it is enclosed in the casing 1 and then subjected to temperature fluctuations in the thermal chamber 30.

[031] **FIG. 6** is an exemplary embodiment which illustrates mesh (10M) generated on the casing 1 enclosing the object 2 to perform thermal analysis in a finite element analysis (FEA) tool. The object 2 may be a glass sphere having a diameter of 100 mm, and the casing 1 may be chock fast Orange hollow sphere casing having a diameter of 120 mm [thickness of 10 mm] that enclosed the glass sphere. FIG. 6 shows a structured mesh with tetrahedral elements conforming to the body of the casing 1. **FIGS. 7A-7C** are exemplary embodiments which illustrate results obtained from the FE analysis performed on a software package. FIGS. 7A-7C show the thermal deformations at various zones of the casing 1 enclosing the object 2 when analysed at 10^{O}C, -10 ^{O}C and -30 ^{O}C, respectively. The spectrographs shown in each of FIGS. 7A-7C show that the extent of deformation is minimal at the temperature of 10 ^{O}C, and the extent of deformation increases significantly as the temperatures are reduced to -10 ^{O}C and -30 ^{O}C. The extent of deformation may also depend on thickness of the casing 1, for example, if the thickness of the casing 1 is high, the extent of deformation may be less and vice versa. The thickness of the casing 1, therefore, in turn determines the pressure applied on the object 2 during the thermal deformation. For a given thickness of the casing 1, FIGS. 7A-7C show a gradual increase in thermal deformation with the decrease in temperature. FIG. 7C shows a maximum deformation of 0.033528 mm at -30 ^{O}C temperature.

[032] **FIG. 8** is a graph which illustrates variation of thermal deformation [Y-axis] in response to decrease in temperatures [X-axis] determined by the FE analysis described with reference to FIG. 7. Deformations corresponding to 10^{O}C, 0 ^{O}C, -10 ^{O}C, -20 ^{O}C and -30 ^{O}C are shown with the deformations increasing linearly with decrease in temperatures.

[033] **FIGS. 9A-9E** illustrate outcomes of FE analysis [simulation] (same model considered in FIGS. 7-8) showing the values of pressures exerted on the object 2 by virtue of deformation of the casing 1 at five different cooling temperatures. Table 2 below depicts the values of thermal deformations as well as pressures corresponding to the five cooling temperatures, i.e., 10^{O}C, 0 ^{O}C, -10 ^{O}C, -20 ^{O}C and -30 ^{O}C.

FEA: Results Summary		
Temp (^{0}C)	**Minimum Pressure (MPa)**	**Displacement (mm)**
10	**0.95**	**7.74E-03**
0	**1.75**	**1.42E-02**
-10	**2.55**	**2.06E-02**
-20	**3.35**	**2.71E-02**
-30	**4.1**	**3.35E-02**

Table 2

[034] Values of pressures shown in Table 2 as well as evident from the spectrographs of FIGS. 9A-9E show minimum distributed temperatures at each of the temperature values, i.e., 10^{O}C, 0 ^{O}C, -10 ^{O}C, -20 ^{O}C and -30 ^{O}C as determined from FE analysis. The pressure values correspond to the hydrostatic pressure values at different heights if the object 2 were submerged in the water. The increase in deformations corresponding to decrease in temperatures may be seen in Table 2. Consider the examples of -20 ^{O}C and -30 ^{O}C temperatures where the object 2 is considered to be an optical sensor enclosed in a chock fast casing 1. At -20 ^{O}C, the signal characteristics may remain unchanged under the corresponding thermal deformation value of 0.0271 mm [of casing 1], which exerts a pressure of 3.35 MPa on the object 2. Once the temperature is brought down to -30 ^{O}C, the signal characteristics could be significantly affected under the corresponding thermal deformation value of 0.0335 mm, exerting a pressure of 4.1 MPa on the object 2. Thus, in the real-time scenario, it may be ascertained that the optical sensor can operate unaffected until it experiences a hydrostatic pressure of 3.35 MPa. As soon as the hydrostatic pressure raises to 4. 1 MPa, the object 2 may show changes in signal characteristics, thereby indicating that the maximum operating pressure of the object has exceeded beyond the threshold. **FIG. 10** is a graphical illustration of variation of pressure values (in MPa) in response to changes in cooling temperatures (in ^{O}C) as determined from FE analysis. In an embodiment, the FE analysis can be validated against the investigation performed through the method and the apparatus 100 disclosed in the embodiments of the present disclosure.

[035] **FIG. 11** is a flowchart illustrating the method embodiment of the present disclosure. Reference is also made FIG. 2. The method includes a first step 51 of enclosing the object 2 in a casing 1, where the casing 1 is composed of a material having a different thermal co-efficient of expansion. Further, the method includes a second step 52 of placing the casing 1 containing the object 2 in a thermal chamber 30, and then varying temperature in the thermal chamber 30 through a first predetermined temperature range as the third step 53. The casing 1 undergoes thermal deformation relative to the object 2 under the influence of varying temperatures. Then, the method includes a final step 54 of generating, by a detection module 20, a signal corresponding to the thermal deformation of the casing 1. The detection module 20 may include one or more sensors.

[036] The above subject matter discloses a method and an apparatus for determining pressure exerted on an object which is simple, cost-effective, and requires less effort in comparison to existing hydrostatic measurement techniques. The method and the apparatus of the present disclosure also allow accurate and precise determination of pressures, at the same time allows better control over the process. The reason being that exertion of hydrostatic pressures on the object is simulated in a temperature-controlled chamber where precise monitoring/control of temperatures can be attained to obtain accurate pressure values. The temperature-based testing can be performed in a simple laboratory set-up which is more convenient, quick and reliable when compared to real-time hydrostatic pressure testing.

[037] It is intended that the disclosure and examples be considered as exemplary only, with a true scope and spirit of disclosed embodiments being indicated by the following claims.

CLAIMS

We Claim:

1. A method for determining pressure exerted on an object 2, the method comprising:

enclosing the object 2 in a casing 1, wherein the casing 1 is composed of a material having a different thermal co-efficient of expansion;

placing the casing 1 in a thermal chamber 30;

varying temperature in the thermal chamber 30 through a first predetermined temperature range, such that the casing 1 undergoes thermal deformation; and

generating, by a detection module 20, a signal corresponding to the thermal deformation of the casing 1, wherein, the detection module 20 includes one or more sensors.

2. The method as claimed in claim 1, wherein the object 2 has a low thermal coefficient of expansion when compared to the thermal coefficient of expansion of the material constituting the casing 1.

3. The method as claimed in claim 1, wherein the thermal deformation of the casing 1 is configured to apply forces along an outer surface of the object 2 to simulate the pressure.

4. The method as claimed in claim 1, wherein the first predetermined temperature ranges from +60^{O} Celsius to – 100 ^{O} Celsius.

5. The method as claimed in claim 1, comprises:

placing the object 2 in the thermal chamber 30 prior to enclosing the object 2 in the casing 1; and

varying the temperature in the thermal chamber 30 through a second predetermined temperature range to assess thermal deformation of the object 2, wherein the second predetermined temperature ranges from +60 ^{O} Celsius to – 100 ^{O} Celsius.

6. An apparatus 100 for determining pressure exerted on an object 2, the apparatus 100 comprising:

a casing 1 being configured to enclose the object 2, wherein the casing 1 is composed of a material having a different thermal co-efficient of expansion, and

a detection module 20;

wherein, the casing 1 being configured to be placed in a thermal chamber 30, and wherein the temperature of the thermal chamber 30 is variable through a first predetermined temperature range such that the casing 1 undergoes thermal deformation; and

wherein, the detection module 20 is configured to generate a signal corresponding to the thermal deformation of the casing 1.

7. The apparatus 100 as claimed in claim 6, wherein the object 2 has a low thermal coefficient of expansion when compared to the thermal coefficient of expansion of the material constituting the casing 1.

8. The apparatus 100 as claimed in claim 6, wherein the detection module 20 includes one or more sensors and a fiber optical module, and wherein the detection module 20 is configured to generate the signal in response to exertion of pressure by the casing 1 on the object 2 during the thermal deformation.

9. The apparatus 100 as claimed in claim 6, wherein the object 2 enclosed in the casing 1 is supported inside the thermal chamber 30 by one or more fixtures.

Dated this 15th Day of March 2022

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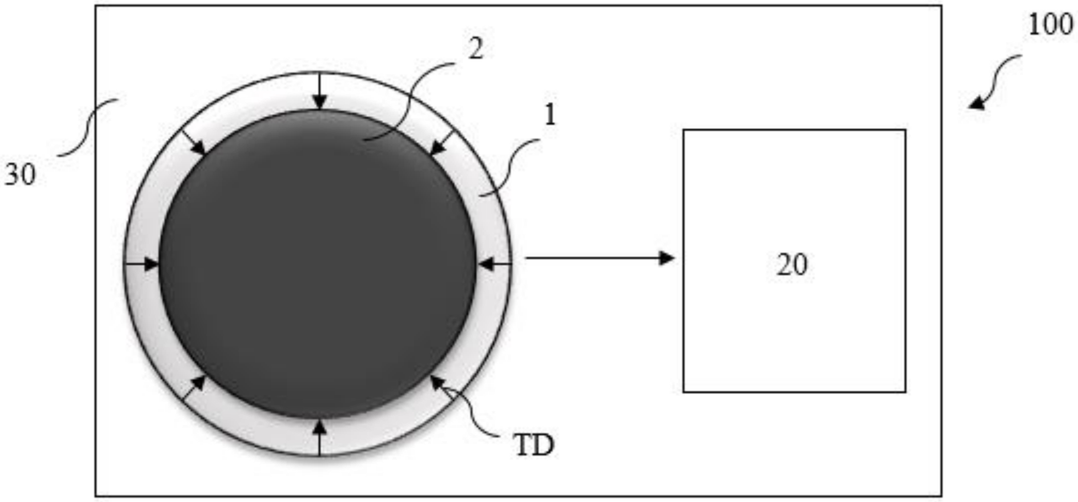
A METHOD AND AN APPRATUS FOR DETERMINING PRESSURE EXERTED ON AN OBJECT

ABSTRACT

A method and an apparatus for determining pressure exerted on an object are disclosed. The method includes enclosing the object in a casing, where the casing is composed of a material having a different thermal co-efficient of expansion. Further, the method includes placing the casing in a thermal chamber and then varying temperature in the thermal chamber through a first predetermined temperature range, such that the casing undergoes thermal deformation. Then, the method includes generating, by a detection module, a signal corresponding to the thermal deformation of the casing, the detection module including one or more sensors. The method and the apparatus provide a cost-effective, simple and an efficient solution to and determine and test the pressure exerted on the object.



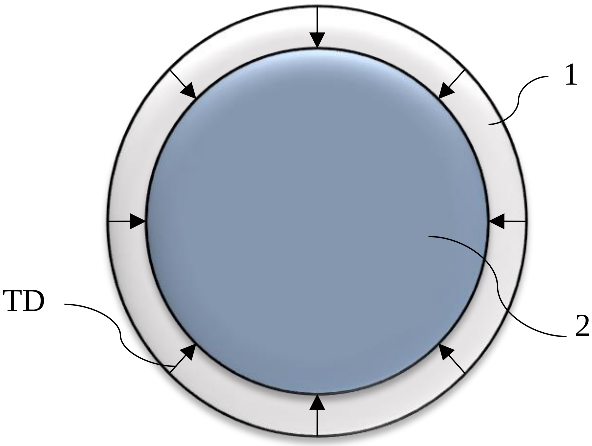


FIG. 1A

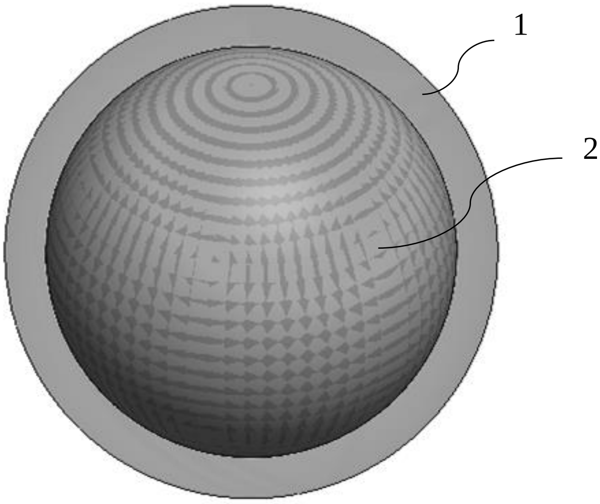


FIG. 1B

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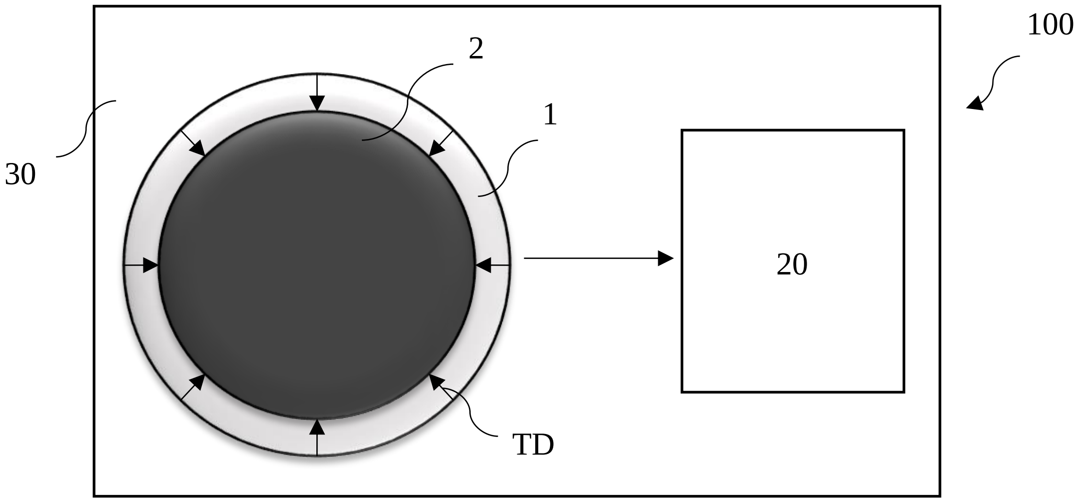

FIG. 2

FIG. 3

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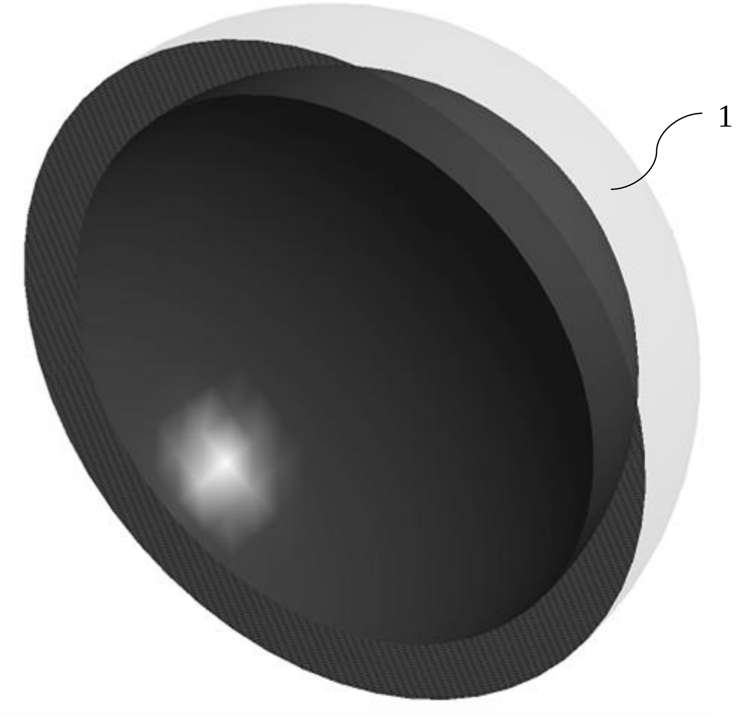

FIG. 4

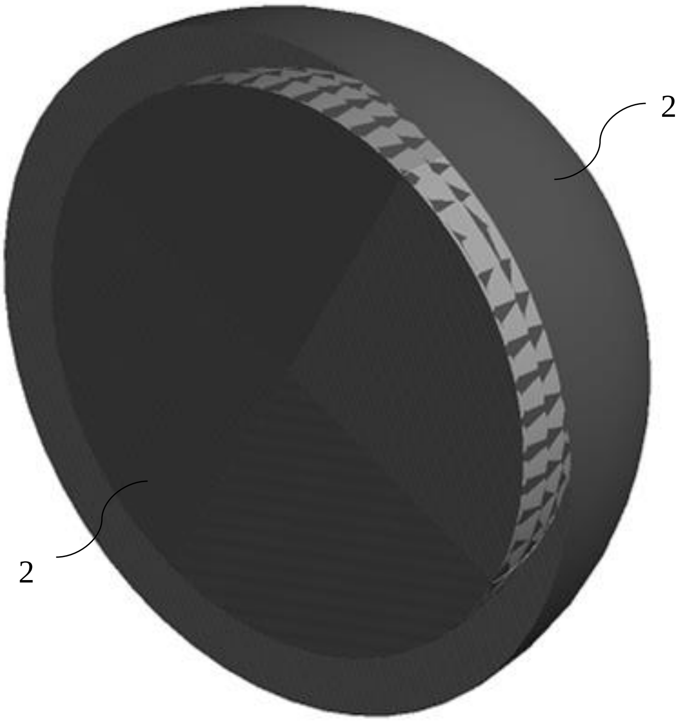

FIG. 5

ROBIN KOSHY VARGHESE (INPA No.: 3705)
Head, IPR Dept.,
L&T Technology Services Limited,
DLF 3rd Block, 2nd Floor,
Manapakkam, TN, Chennai - 600 089.

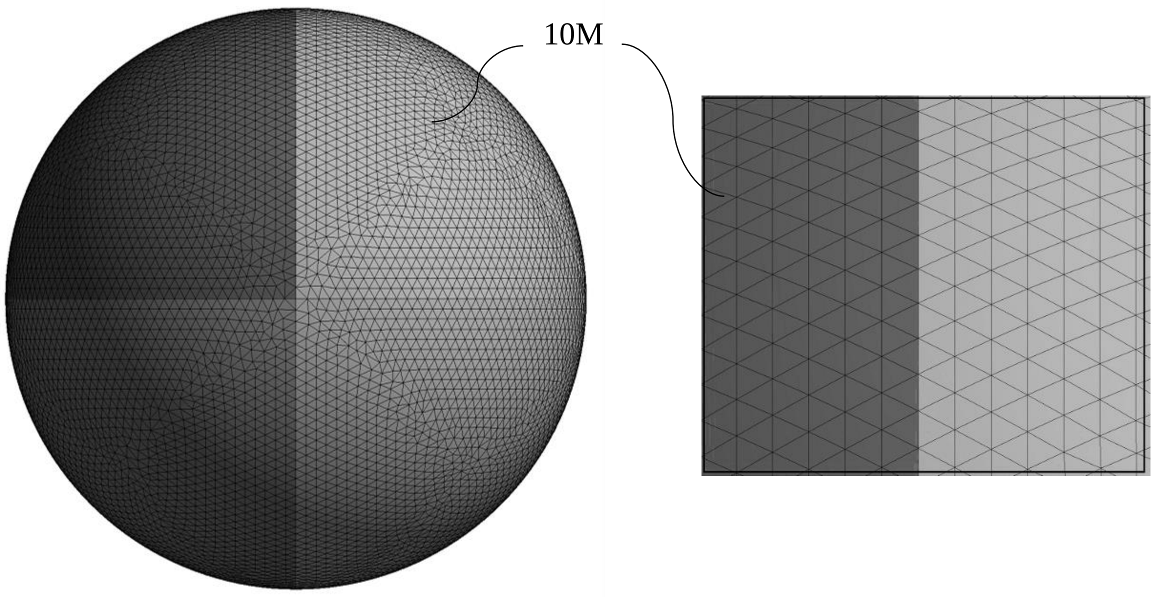

FIG. 6

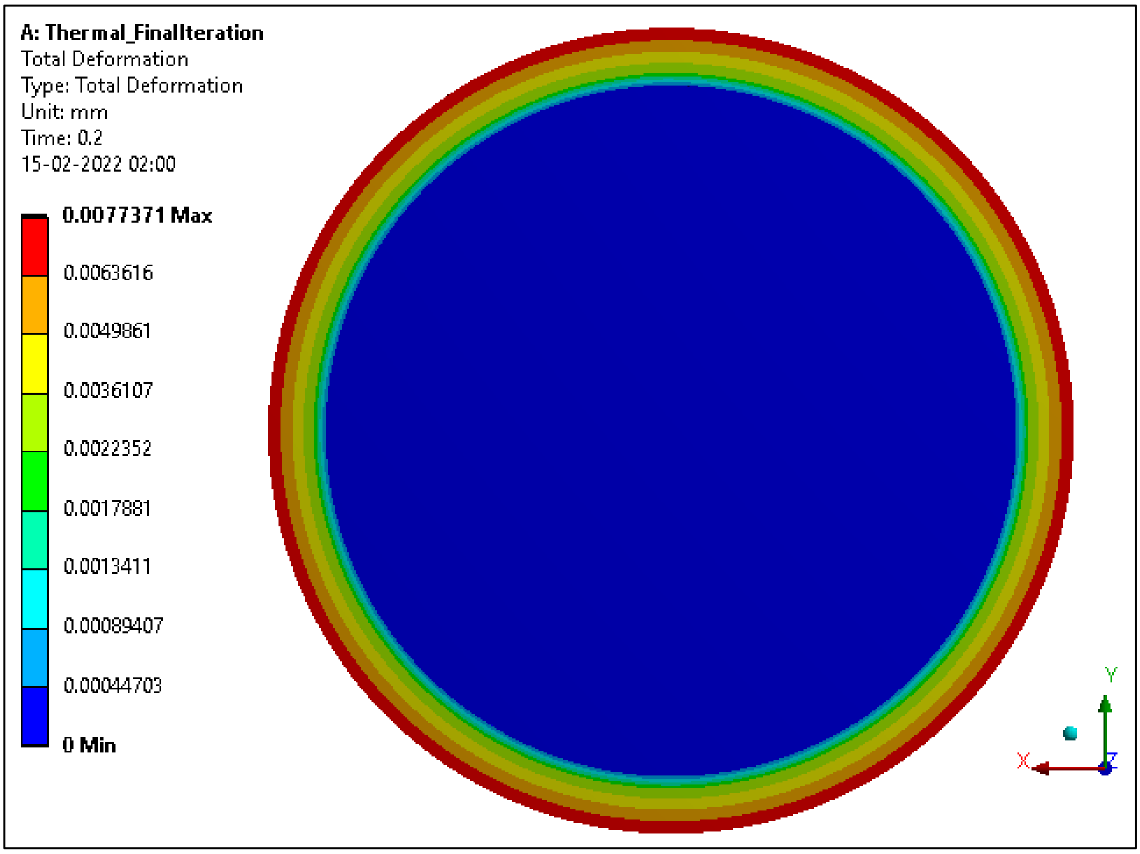
A: Thermal_FinalIteration
Total Deformation
Type: Total Deformation
Unit: mm
Time: 0.2
15-02-2022 02:00

FIG. 7A

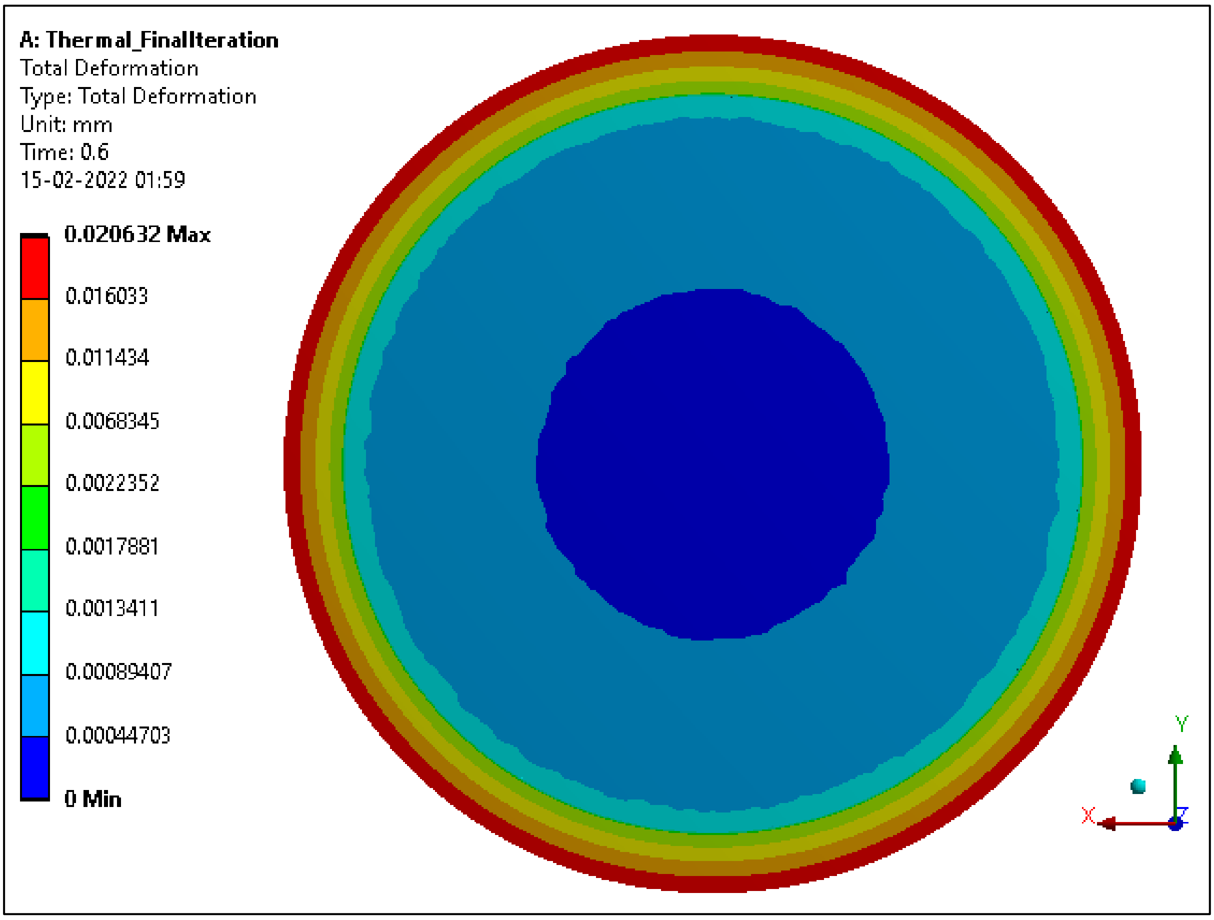
A: Thermal_FinalIteration
Total Deformation
Type: Total Deformation
Unit: mm
Time: 0.6
15-02-2022 01:59
0.020632 Max
0.016033
0.011434
0.0068345
0.0022352
0.0017881
0.0013411
0.00089407
0.00044703
0 Min
Y
X
Z

FIG. 7B

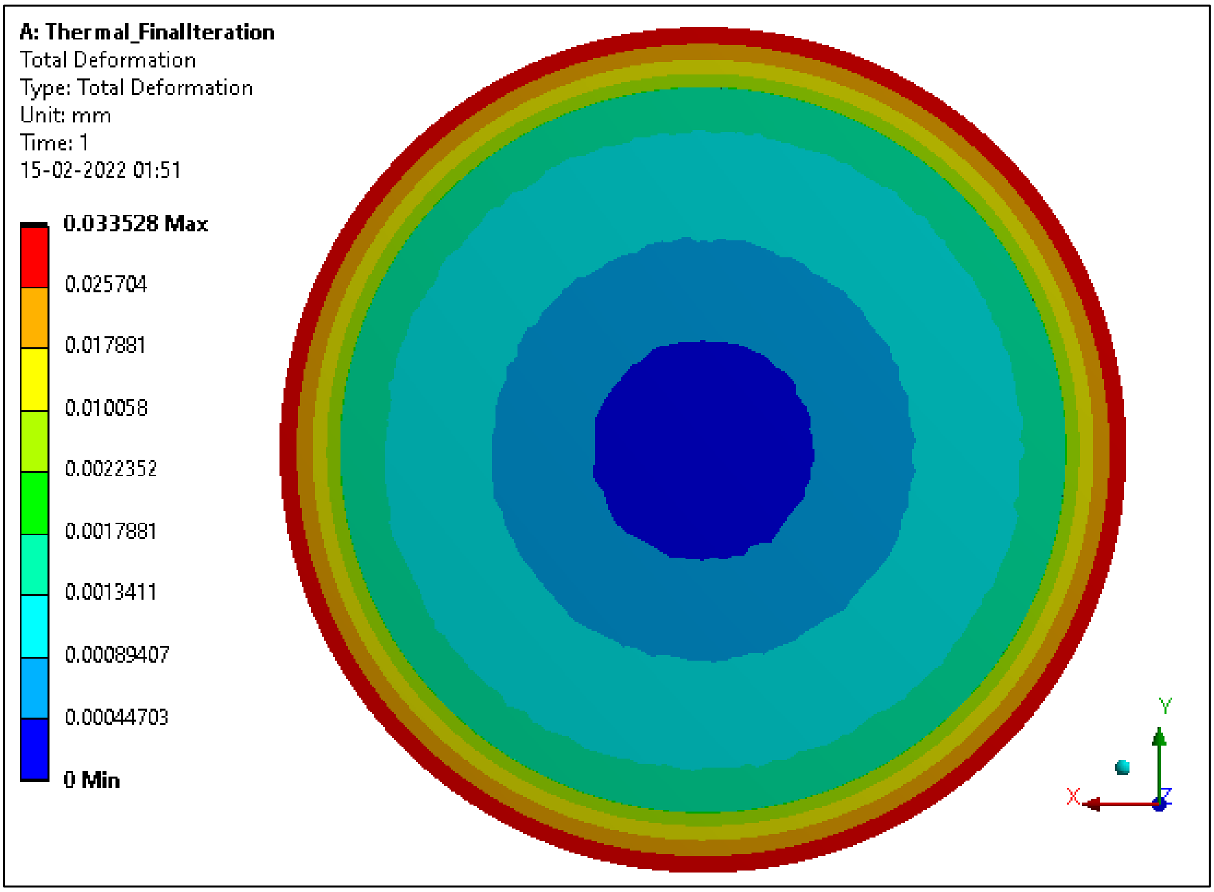

FIG. 7C

ROBIN KOSHY VARGHESE (INPA No.: 3705)
Head, IPR Dept.,
L&T Technology Services Limited,
DLF 3rd Block, 2nd Floor,
Manapakkam, TN, Chennai - 600 089.

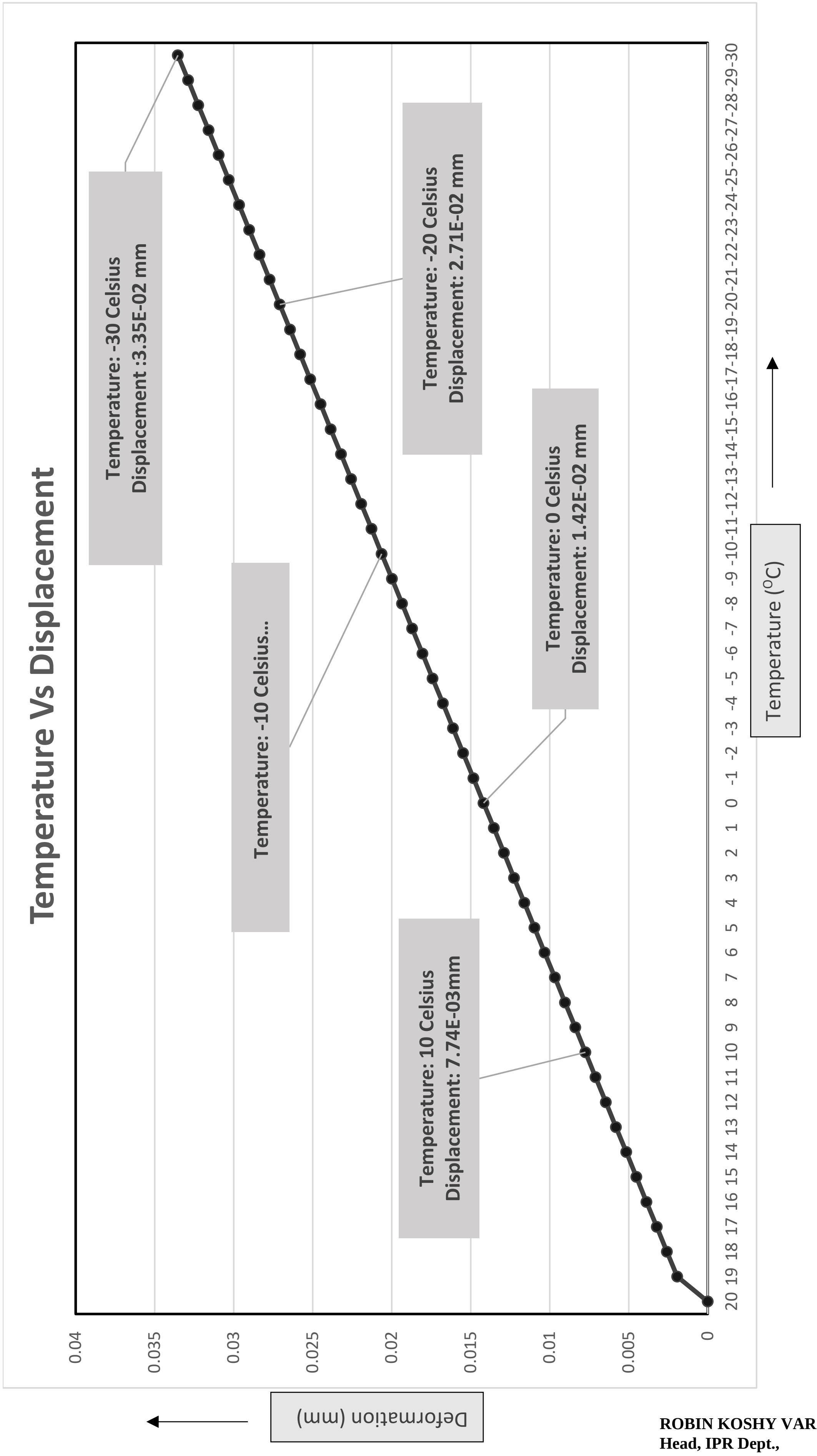

FIG. 8

ROBIN KOSHY VARGHESE (INPA No.: 3705)
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L&T Technology Services Limited,
DLF 3rd Block, 2nd Floor,
Manapakkam, TN, Chennai - 600 089.

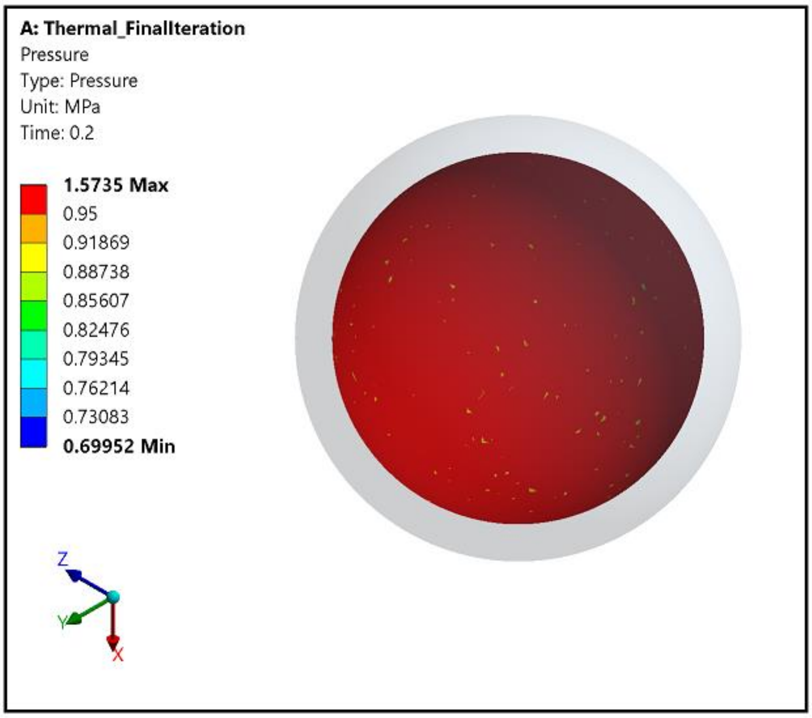

FIG. 9A

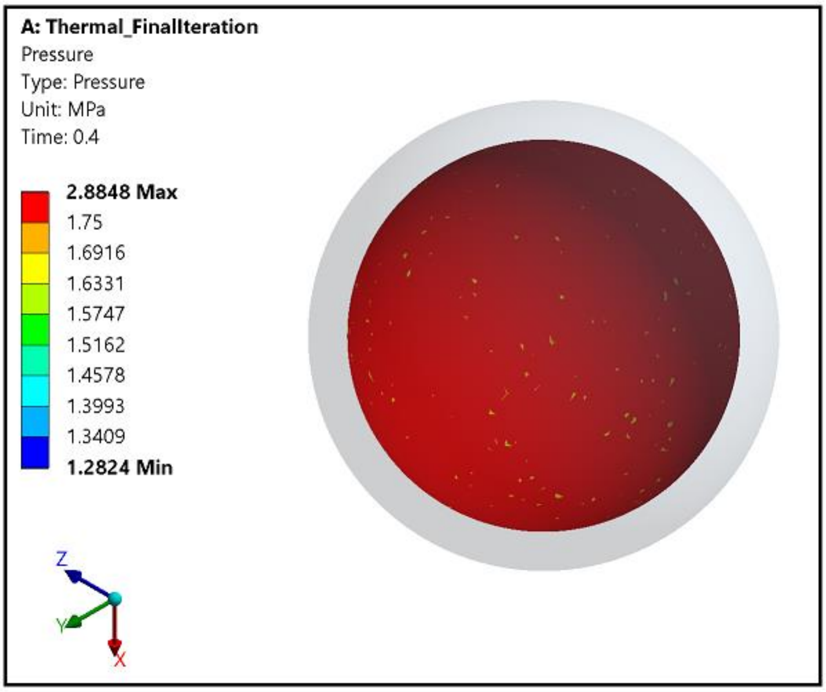

FIG. 9B

ROBIN KOSHY VARGHESE (INPA No.: 3705)
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Manapakkam, TN, Chennai - 600 089.

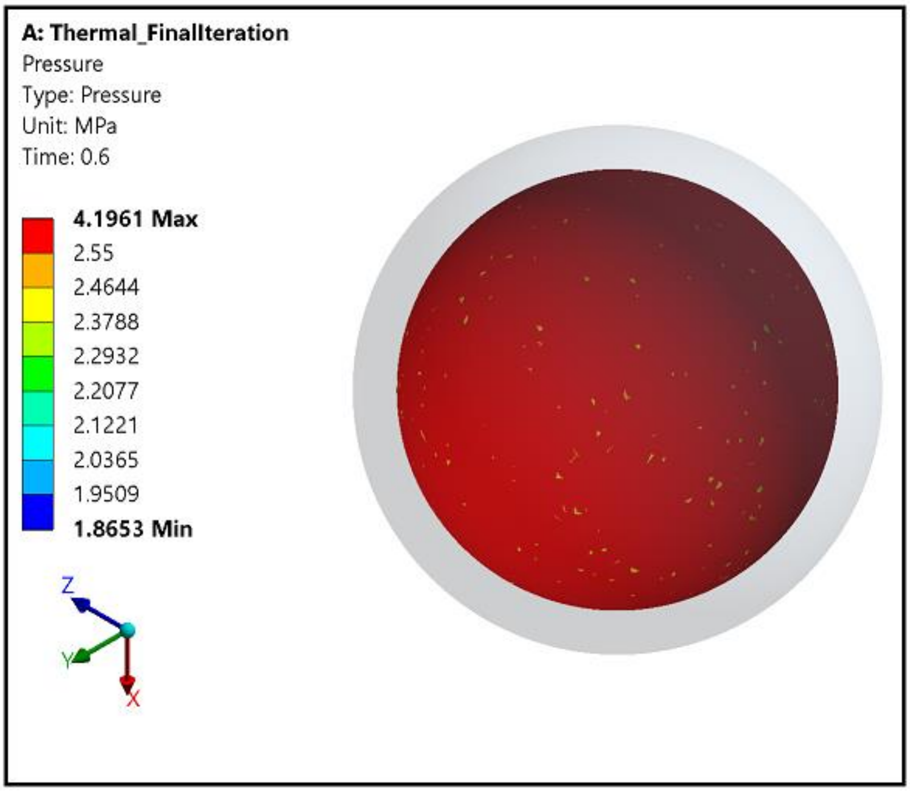
A: Thermal_FinalIteration
Pressure
Type: Pressure
Unit: MPa
Time: 0.6
4.1961 Max
2.55
2.4644
2.3788
2.2932
2.2077
2.1221
2.0365
1.9509
1.8653 Min
Z
Y
X

FIG. 9C

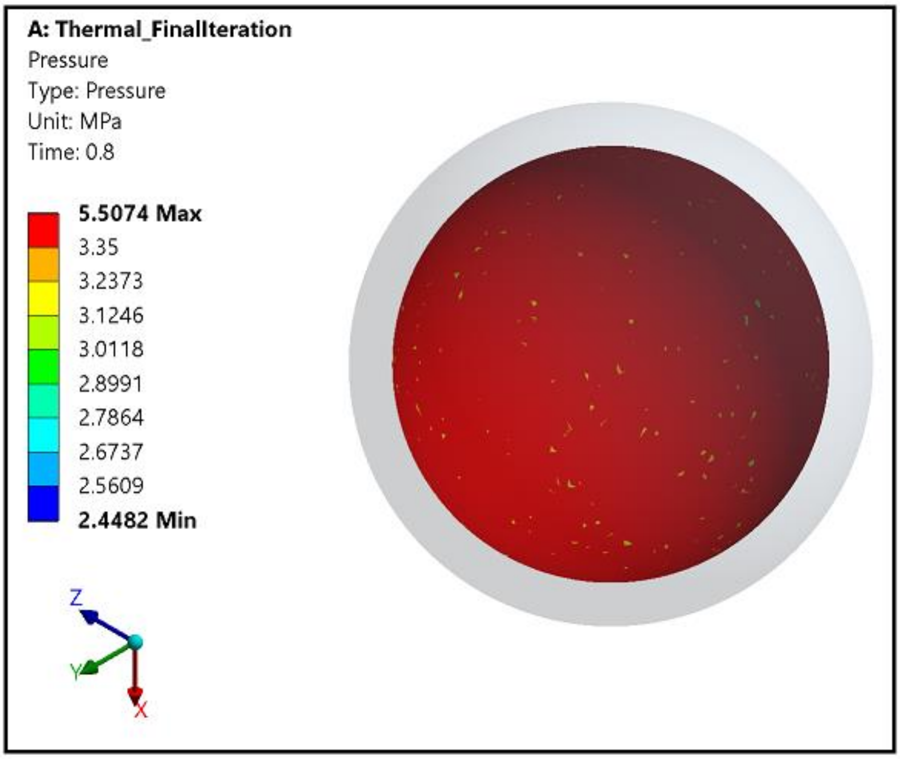
A: Thermal_FinalIteration
Pressure
Type: Pressure
Unit: MPa
Time: 0.8
5.5074 Max
3.35
3.2373
3.1246
3.0118
2.8991
2.7864
2.6737
2.5609
2.4482 Min
Z
Y
X

FIG. 9D

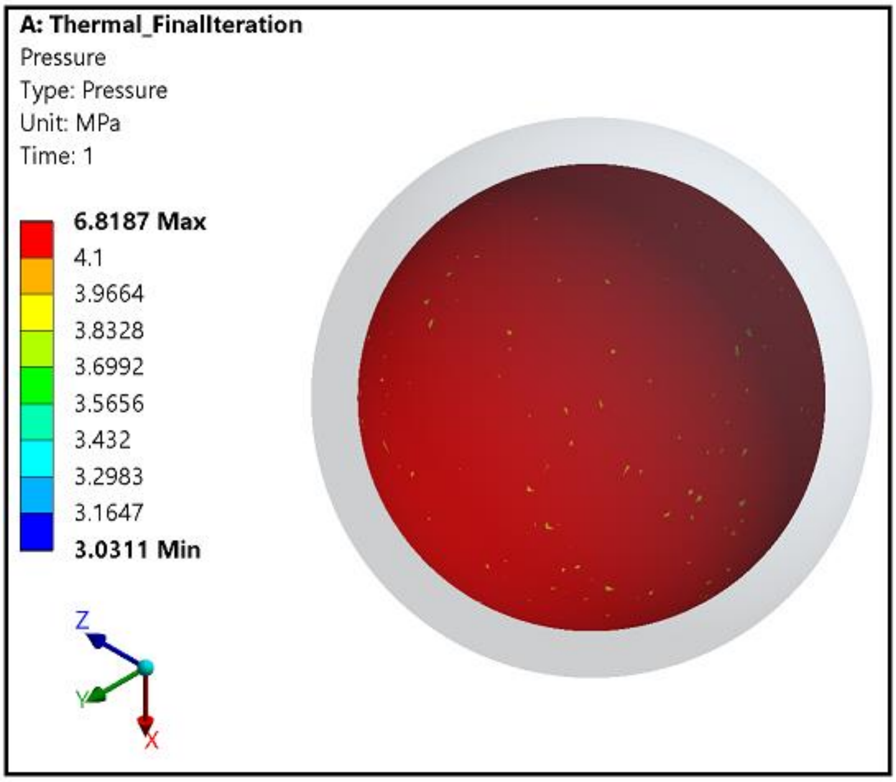

FIG. 9E

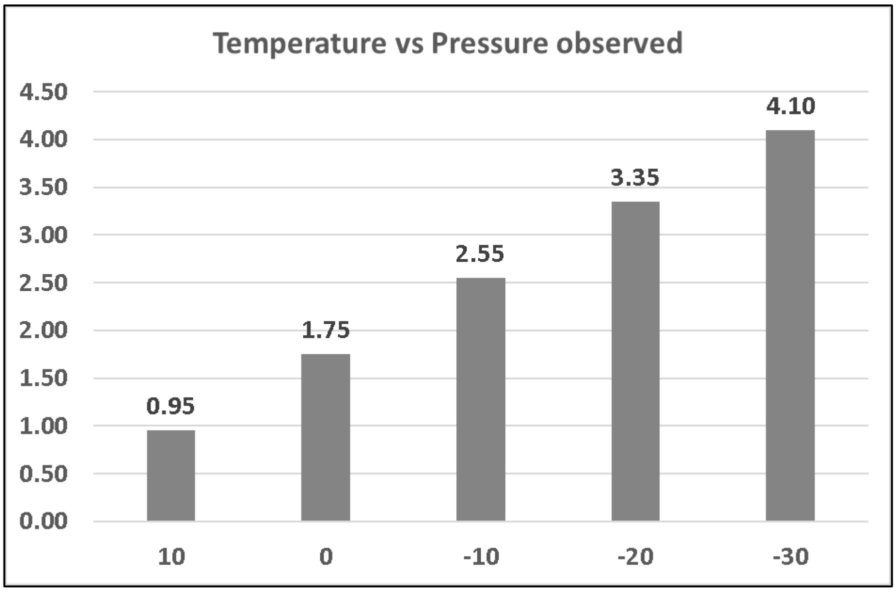

FIG. 10

ROBIN KOSHY VARGHESE (INPA No.: 3705)
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L&T Technology Services Limited,
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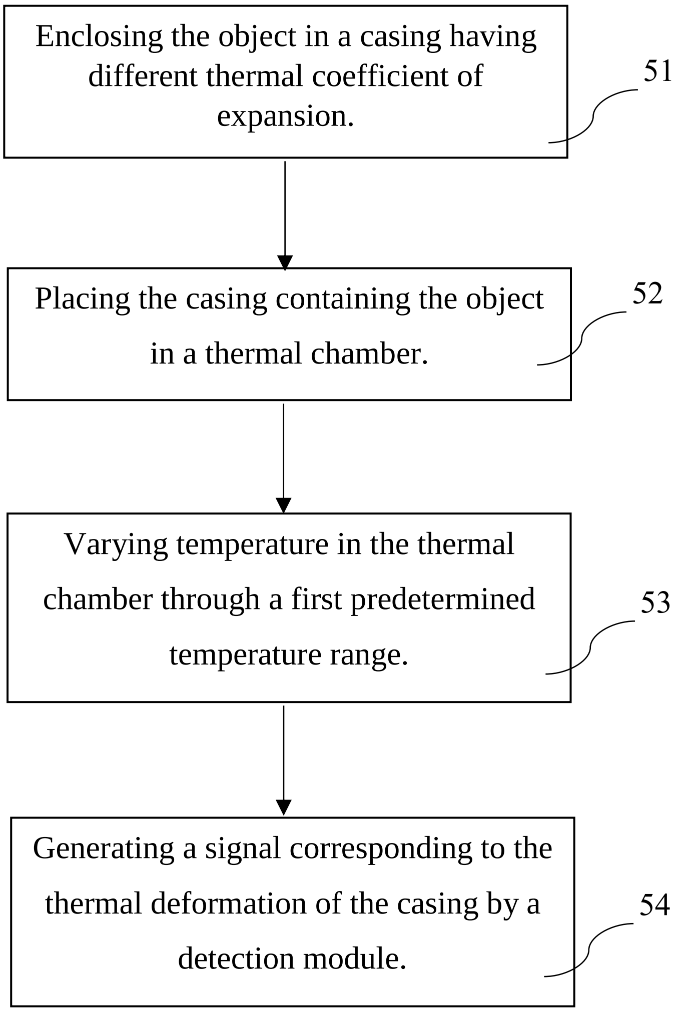
Enclosing the object in a casing having different thermal coefficient of expansion.
51
Placing the casing containing the object in a thermal chamber.
52
Varying temperature in the thermal chamber through a first predetermined temperature range.
53
Generating a signal corresponding to the thermal deformation of the casing by a detection module.
54

FIG. 11