

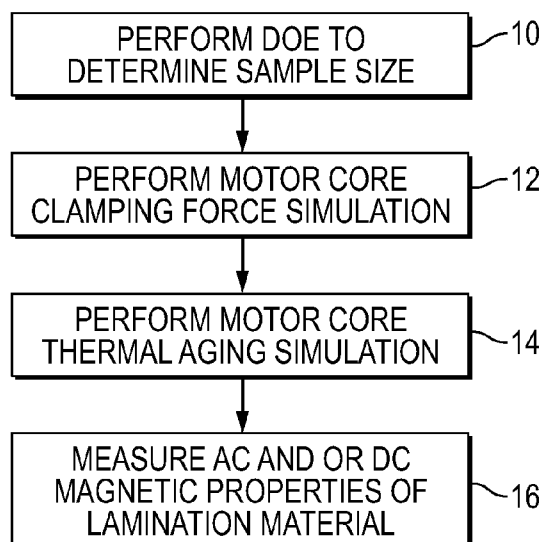


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[Continued on next page]

(54) Title: MAGNETIC PROPERTY CHARACTERIZATION OF MOTOR LAMINATION MATERIAL

FIG. 1



(57) Abstract: A technique facilitates characterizing lamination material magnetic properties, e.g magnetic properties of an electric submersible motor's lamination material. The technique also may be used to determine the effects of the motor assembly process, motor operation conditions, and/or down-hole conditions. In an embodiment, a motor core lamination simulation may be performed, such as a motor core clamping force simulation and/or a motor core thermal aging simulation. In conjunction with at least one of the simulations, the AC and/or DC magnetic properties of the motor core lamination material are measured to facilitate characterization of the motor lamination material and the effects of various conditions on those magnetic properties. Furthermore, embodiments described herein may be used to improve an electric submersible pump motor lamination failure mechanism analysis as well.



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GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

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PATENT APPLICATION

**MAGNETIC PROPERTY CHARACTERIZATION OF MOTOR LAMINATION
MATERIAL****CROSS-REFERENCE TO RELATED APPLICATIONS**

[0001] The present document is based on and claims priority to U.S. Provisional Application Serial No.: 62/020,352, filed July 2, 2014, which is incorporated herein by reference in its entirety.

BACKGROUND

[0002] Electric submersible pumping (ESP) systems are used in a variety of pumping applications, including downhole well applications. For example, electric submersible pumping systems can be used to pump hydrocarbon production fluids to a surface location or to inject fluids into a formation surrounding a wellbore. Electric submersible pumping systems employ an electric submersible motor for powering a pump. Motor laminations are components in the electric submersible motor which have a substantial impact on motor performance, thus determining the performance of the overall electric submersible pumping system. In addition, lamination material properties

can be affected by the motor assembly process, thermal expansion of the motor housing and laminations, and thermal aging of the laminations.

SUMMARY

[0003] In general, a system and methodology are provided to facilitate characterizing of lamination material magnetic properties. The technique also may be used to determine the effects of the motor assembly process, motor operation conditions, and/or downhole conditions. In an embodiment, a motor core lamination simulation may be performed, such as a motor core clamping force simulation and/or a motor core thermal aging simulation. In conjunction with at least one of the simulations, magnetic properties, e.g. AC and/or DC magnetic properties, of the motor core lamination material may be measured to facilitate characterization of the motor lamination material. Furthermore, embodiments described herein may be used to improve an ESP motor lamination failure mechanism analysis as well.

[0004] However, many modifications are possible without materially departing from the teachings of this disclosure. Accordingly, such modifications are intended to be included within the scope of this disclosure as defined in the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] Certain embodiments of the disclosure will hereafter be described with reference to the accompanying drawings, wherein like reference numerals denote like elements. It should be understood, however, that the accompanying figures illustrate the various implementations described herein and are not meant to limit the scope of various technologies described herein, and:

[0006] Figure 1 is a flowchart illustrating an example of a magnetic property characterization method, according to an embodiment of the disclosure;

[0007] Figure 2 is an illustration of an example of a fixture constructed to enable a motor core lamination clamping force simulation, according to an embodiment of the disclosure;

[0008] Figure 3 is a flowchart illustrating an example of a procedure regarding a motor core lamination clamping force simulation, according to an embodiment of the disclosure;

[0009] Figure 4 is an illustration of an example of a seal chamber for a motor core lamination thermal aging simulation, according to an embodiment of the disclosure;

[0010] Figure 5 is an illustration of an example of a sealing mechanism for providing a seal between seal chamber components, according to an embodiment of the disclosure;

[0011] Figure 6 is an illustration of another example of a sealing mechanism for providing a seal between seal chamber components, according to an embodiment of the disclosure; and

[0012] Figure 7 is a flowchart illustrating an example of a procedure regarding a motor core lamination thermal aging simulation, according to an embodiment of the disclosure.

DETAILED DESCRIPTION

[0013] In the following description, numerous details are set forth to provide an understanding of some embodiments of the present disclosure. However, it will be understood by those of ordinary skill in the art that the system and/or methodology may

be practiced without these details and that numerous variations or modifications from the described embodiments may be possible.

[0014] The present disclosure generally relates to a test system and methodology for magnetic property characterization with respect to lamination material, e.g. electric submersible motor lamination material. In various applications, the technique may further be used to determine effects of the motor assembly process, motor operation conditions, and downhole conditions. The downhole conditions affecting electric submersible pump (ESP) applications include, but are not limited to, bottomhole temperature, flow rate of well fluid, material thermal expansion, water cut of well fluid, housing temperature rise, motor lamination temperature rise, and/or other conditions. These various conditions can have an effect on the submersible motor's laminations and the magnetic properties of those laminations.

[0015] Embodiments described herein facilitate characterization and selection of motor lamination material, e.g motor lamination material for an electric submersible pumping system motor. In various applications, the methodology facilitates optimization of lamination material for use in downhole, subterranean conditions. For example, the technique may be used to determine a motor lamination material with optimal magnetic characteristics for optimized downhole motor performance in specific downhole conditions. Furthermore, embodiments described herein may be used to improve an ESP motor lamination failure mechanism analysis as well. In many applications, the motor manufacturing process and thermal aging of the motor laminations affect the lamination material properties and thus can have a substantial effect on motor operation and run life.

[0016] Referring generally to Figure 1, a flowchart is provided to summarize a method for magnetic property characterization of lamination material, such as electric submersible motor lamination material. As illustrated, a design of experiment (DOE) is initially performed to determine a sample size, as represented by block 10 of the flowchart. A motor core clamping force simulation also may be performed, as represented by block 12. Additionally, a motor core thermal aging simulation may be

performed, as represented by block 14. The magnetic properties, e.g. the AC and/or DC magnetic properties, of the lamination material may be measured, as represented by block 16. By way of example, the AC and/or DC magnetic properties may be measured before and after each simulation or before and after the combined clamping and thermal aging simulations. It should be noted that the magnetic properties of the lamination material can be measured with a suitable magnetic property tester, such as an Epstein tester, as per IEC 404-2; ASTM A343; and/or other suitable standards which may be applied.

[0017] The sample size may be determined by the DOE. Similarly, the variables that can potentially affect the magnetic properties of the lamination material also may be determined in the DOE. The variables include, but are not be limited to, clamping force, motor oil type, temperature, thermal aging time, and/or other variables. A set of as-received condition lamination strips can be used as a baseline. The lamination strips may be prepared as per ASTM A34. If appropriate, other standards may be applied.

[0018] According to a method of motor core clamping force simulation, certain clamping force terms may be defined as:

Clamping Force F: the compression force applied on the motor laminations to build the motor core. The clamping force may be changed from the original value to a new value when motor runs under different well conditions.

Clamping Force F0: the maximum compression force applied on the motor laminations during motor assembly.

Clamping Force F1: the maximum residual compression force generated on the motor laminations when the motor runs in a well. This force can be calculated by considering the residual clamping force after motor assembly, coefficient of thermal expansion (CTE) of the lamination and housing material, heat rise of housing and motor core, flow rate of well fluid, bottomhole temperature (BHT), water cut of well fluid, and other parameters characterizing the downhole condition and motor operation condition.

[0019] Similarly, certain equivalent clamping force terms may be defined as:

Equivalent Clamping Force F_{0e} : the clamping force applied on the lamination strips to generate the same stress on the strips as the stress generated by F_0 on the motor laminations.

Equivalent Clamping Force F_{1e} : the clamping force applied on the lamination strips to generate the same stress on the strips as the stress generated by F_1 on the motor laminations.

[0020] Because the relationship between the clamping force F_0 and F_1 and the equivalent clamping force F_{0e} and F_{1e} has been defined, a fixture can be employed for motor core clamping force simulation. As illustrated in Figure 2, an embodiment of a fixture 18 comprises a head 20, a base 22, a plurality of screws 24 and corresponding lock washers 26. However the fixture shape and construction may change and does not have to be the same shape or construction as illustrated in Figure 2. For example, the fixture 18 may be constructed in a round shape, a triangular shape, an oval shape, or another suitable shape with various component arrangements. The number of screws 24 and lock washers 26 may be determined by the lamination strip dimension, screws strength, and the compression force generated by the screws 24 on the lamination strips 28. To generate enough equivalent clamping force F_{1e} on the lamination strips 28 to simulate F_1 , the torque T applied on each screw 24 should be calculated as per the fixture design.

[0021] A method of simulating the effects of the motor core clamping force F_0 and F_1 is illustrated in the flowchart of Figure 3. In this example, the lamination strips 28 are initially prepared, as represented by block 30. The lamination strips 28 are assembled to the fixture 18, as represented by block 32. The fixture head 20, lock washers 26, and screws 24 may then be assembled for clamping, as represented by block 34. An equivalent clamping force F_{0e} is then applied on the fixture head 20, and hence on the lamination strips 28, to simulate clamping force F_0 on the motor core, as represented by block 36. The equivalent clamping force F_{1e} is then applied on the lamination strips 28 by tightening the screws 24 with torque T to simulate the clamping force F_1 , as represented by block 38.

[0022] By simulating the clamping force experienced by the lamination material of lamination strips 28 for a given application, the suitability of the lamination material may be determined. For example, the effects of clamping force on magnetic properties of the lamination material may be determined via the simulation. In some applications, the clamping force is applied over a predetermined time period as magnetic properties, e.g. AC and/or DC magnetic properties, are measured. Based on the ability of the lamination material to withstand the clamping pressure and based on the effects with respect to its magnetic properties, a determination may be made as to whether the lamination material will provide the desired run life and functionality for the given application, e.g. a downhole ESP motor application. The testing also facilitates a determination as to whether selection of another lamination material would be more suitable for the specific application being considered. As part of the testing, the AC and/or DC magnetic properties of the lamination material may be measured before, during and/or after the simulation to enable an evaluation as to whether the lamination material is suitable for various applications which experience such conditions.

[0023] The technique also may comprise a method of motor core thermal aging simulation. When selecting the lamination material for an ESP motor used in a high temperature well, the thermal aging effects on the motor core lamination material should be considered because the material magnetic properties may be degraded. To simulate a motor running in a high temperature well, a seal chamber 40 may be provided for the motor core thermal aging simulation, as illustrated in Figure 4. An embodiment of seal chamber 40 comprises check valves 42 installed in an opposite direction to balance the internal and external pressure. The seal chamber 40 also comprises motor oil 44, a seal chamber head 46, a seal chamber base 48, a sealing mechanism 50 between head 46 and a housing 52, a sealing mechanism 54 between base 48 and housing 52, and a fixture assembly 56 for clamping force simulation.

[0024] By way of example, the sealing mechanisms 50, 54 may comprise at least one seal 57, as illustrated in Figure 5. Examples of seals 57 may include O-ring seals, H

seals, C seals, and/or other suitable seals. As illustrated in Figure 6, the sealing mechanisms 50, 54 also may comprise a weld 58, e.g. a laser weld, or other suitable seal mechanism.

[0025] As further illustrated in Figure 4, an air gap 59 comprising air or other suitable gas may be provided for motor oil thermal expansion. The seal chamber 40 may be heated to a predetermined temperature to simulate the thermal condition in a motor when the motor runs in a well. Temperature reading equipment may be used to capture the temperature on the housing surface and/or the oil temperature in the seal chamber 40.

[0026] A procedure for simulating the motor core thermal aging is illustrated by the flowchart of Figure 7. In this example, seal chamber 40 is assembled except for seal chamber head 46, as represented by block 60. The fixture assembly 56 (fixture assembly 56 may be in the form of fixture 18 illustrated in Figure 2) to be used for the clamping force simulation is placed in the seal chamber 40, as represented by block 62. In some applications, the fixture 18 is simply used as fixture assembly 56 to enable simultaneous clamping simulation and thermal aging simulation to be performed. The seal chamber 40 is filled with motor oil 44 to a level which leaves air gap 59, as represented by block 64. The seal chamber head 46 is then assembled and the integrity of the seal chamber 40 is inspected, as represented by block 66.

[0027] The thermal aging simulation at a predetermined temperature, e.g. a downhole wellbore temperature, may then be performed, as represented by block 68. The simulation(s) enables testing of magnetic properties, e.g. AC and/or DC magnetic properties, of the motor core lamination strips 28 to determine the effects on the lamination material due to specific conditions, e.g. clamping and thermal conditions, that would be experienced downhole. Based on the measured effects to those magnetic properties, the lamination material may be approved or rejected and changed.

[0028] For example, based on the clamping simulation and/or aging simulation, the material of lamination strips 28 may be approved for a specific downhole well

application, such as a proposed downhole pumping application. The methodology described herein is very useful in determining the suitability of lamination material for use as an electric submersible motor's lamination material in specific downhole applications. However, the methodology may be applied to other applications. The effects on the magnetic properties of the lamination strips 28 resulting from the simulation or simulations may be determined via appropriate analysis equipment as discussed above so as to enable approval of the motor core laminations for the desired application. Or, the results of the simulation(s) may indicate that the lamination material should be changed to accommodate the conditions of the given application. For example, the techniques described herein may be used to identify superior lamination material for a specific ESP motor application. Additionally, the effects of the motor assembly process, motor operation conditions, and downhole conditions may be considered. Once the motor core lamination material is approved, motor core laminations formed of that material may be employed in a submersible motor which is deployed downhole into a wellbore with an electric submersible pumping system.

[0029] Embodiments also can facilitate new lamination material qualification, new lamination design, lamination geometry optimization, new motor design, and/or motor performance optimization. Furthermore, the technique can be used to simulate the ESP motor manufacturing process and to study the effects of motor core clamping force on the lamination material magnetic properties for ESP motors. In some applications, the technique can be used to simulate the ESP motor operating condition in a well and to study the thermal aging effects on the lamination material magnetic properties for ESP motors. Similarly, the technique can facilitate an improved ESP motor lamination failure mechanism analysis.

[0030] Although a few embodiments of the disclosure have been described in detail above, those of ordinary skill in the art will readily appreciate that many modifications are possible without materially departing from the teachings of this disclosure. Accordingly, such modifications are intended to be included within the scope of this disclosure as defined in the claims.

CLAIMS

What is claimed is:

- 1 1. A method, comprising:
2
3 performing a clamping force simulation on a motor core lamination;
4 further performing a thermal aging simulation on the motor core
5 lamination;
6 measuring AC and/or DC magnetic properties of the motor core
7 lamination following at least one of the clamping force simulation and the thermal
8 aging simulation; and
9 using data obtained from the simulations to determine suitability of the
10 motor core lamination for a downhole application.

- 1 2. The method as recited in claim 1, wherein performing the thermal aging
2 simulation comprises performing the thermal aging simulation in a seal chamber.

- 1 3. The method as recited in claim 1, wherein performing the clamping force
2 simulation comprises performing the clamping force simulation via a fixture
3 having a head, a base, and a plurality of screws which may be tightened to
4 provide a desired clamping force.

- 1 4. The method as recited in claim 1, wherein using comprises determining the
2 suitability of the motor core lamination for use in a submersible motor of an
3 electric submersible pumping system.

- 1 5. The method as recited in claim 3, further comprising placing the fixture in the seal
2 chamber while performing the thermal aging simulation.

1 6. The method as recited in claim 4, further comprising deploying the electric
2 submersible pumping system downhole into a wellbore with the submersible
3 motor having motor core laminations formed of the same material as the motor
4 core lamination subjected to the clamping force simulation and the thermal aging
5 simulation.

1 7. The method as recited in claim 4, further comprising determining the motor core
2 lamination as unsuitable for a given wellbore application and replacing an
3 originally selected motor core lamination with another motor core lamination
4 having more suitable characteristics for use in the submersible motor of the
5 electric submersible pumping system.

1 8. A method, comprising:

2
3 selecting a motor lamination strip of a motor lamination material;
4 assembling the motor lamination strip in a fixture having a head, a base,
5 and a clamping mechanism for clamping the motor lamination strips between the
6 head and the base;

7 applying an equivalent clamping force against the motor lamination strip
8 via the fixture head to simulate a clamping force on a motor core lamination
9 during a given application;

10 analyzing magnetic effects on the motor lamination strip due to the
11 equivalent clamping force; and

12 determining the suitability of the motor lamination material for the given
13 application based on the magnetic effects.

1 9. The method as recited in claim 8, wherein applying the equivalent clamping force
2 comprises tightening a plurality of screws of the clamping mechanism.

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1 10. The method as recited in claim 8, wherein determining comprises determining the
2 suitability of the motor lamination material for use in a motor deployed downhole
3 in a wellbore.

1 11. The method as recited in claim 8, wherein determining comprises determining the
2 suitability of the motor lamination material for use in a submersible motor of an
3 electric submersible pumping system deployed downhole in a wellbore.

1 12. The method as recited in claim 8, further comprising performing a thermal aging
2 simulation on the motor lamination strip.

1 13. The method as recited in claim 12, wherein performing the thermal aging
2 simulation comprises performing the thermal aging simulation in a seal chamber.

1 14. The method as recited in claim 12, wherein analyzing comprises measuring the
2 AC and/or DC magnetic properties of the motor lamination strip following the
3 thermal aging simulation.

1 15. A method, comprising:

2
3 selecting a motor lamination strip of a motor lamination material;
4 placing the motor lamination strip in a seal chamber;
5 performing a thermal aging simulation on the motor lamination strip in the
6 seal chamber;
7 analyzing magnetic effects of the thermal aging simulation on the motor
8 lamination strip; and
9 determining the suitability of the motor lamination material for a given
10 application based on the magnetic effects.

1 16. The method as recited in claim 15, further comprising performing a clamping
2 force simulation on the motor lamination strip.

1 17. The method as recited in claim 15, wherein determining comprises determining
2 the suitability of the motor lamination material for use in a motor deployed
3 downhole in a wellbore.

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1 18. The method as recited in claim 15, wherein determining comprises determining
2 the suitability of the motor lamination material for use in a submersible motor of
3 an electric submersible pumping system deployed downhole in a wellbore.

1 19. The method as recited in claim 16, further comprising analyzing the magnetic
2 effects resulting from the clamping force simulation.

1 20. The method as recited in claim 19, wherein determining comprises determining
2 whether the motor lamination material is suitable for a given downhole
3 application, and delivering a submersible motor with motor core laminations
4 formed of the motor lamination material downhole into a wellbore.

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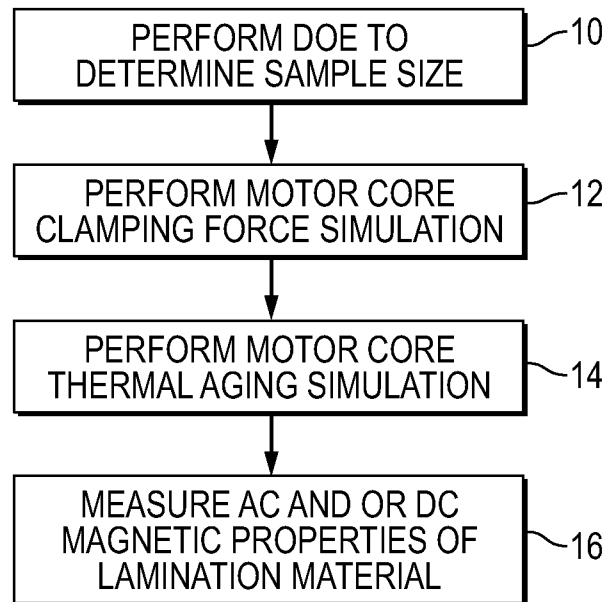
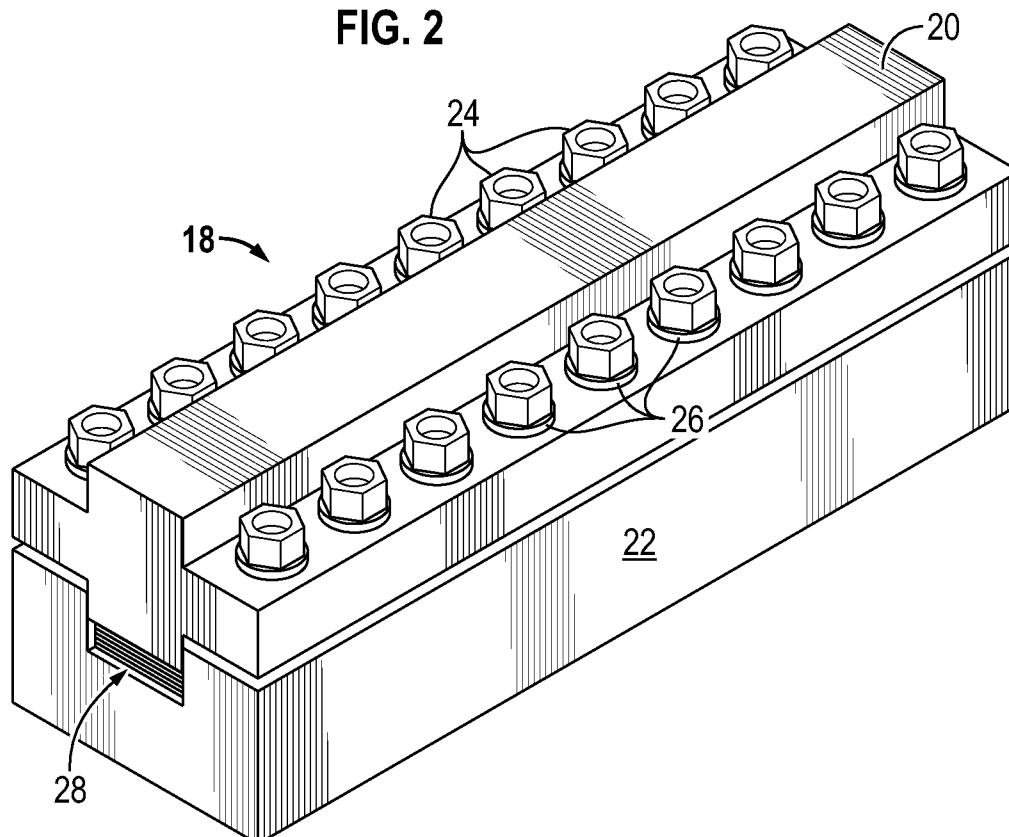
FIG. 1**FIG. 2**

FIG. 3

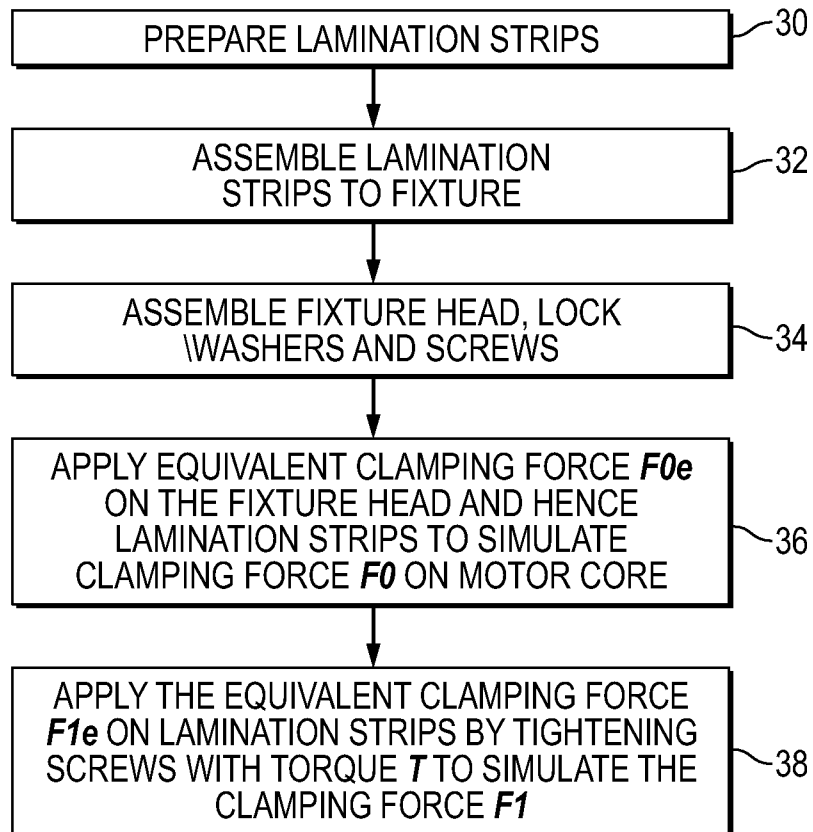


FIG. 4

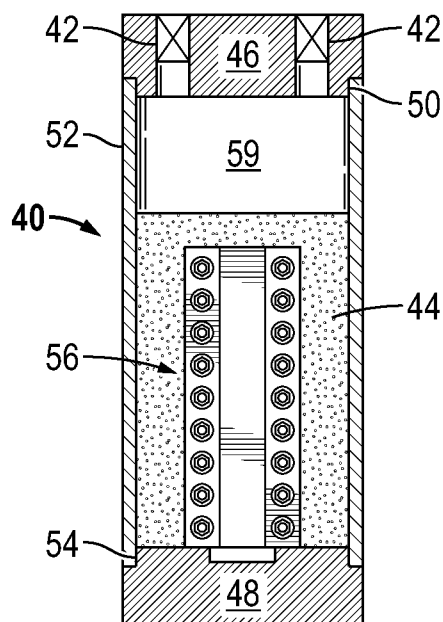
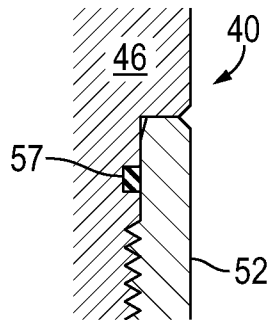
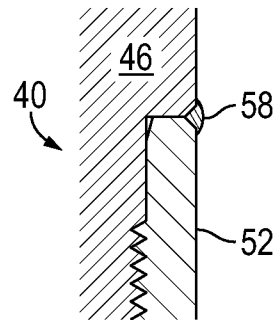
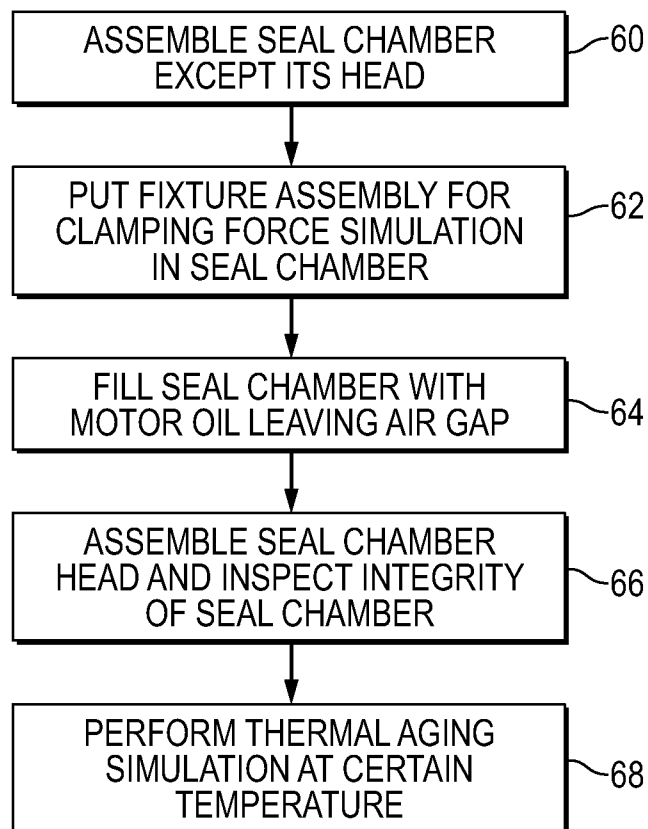


FIG. 5**FIG. 6****FIG. 7**

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2015/032369**A. CLASSIFICATION OF SUBJECT MATTER****H02K 15/02(2006.01)i**

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)

H02K 15/02; G01N 29/44; G01R 33/12; G01M 5/00; G01M 19/00; G01R 31/34; G09B 23/18; G01N 29/04; G09B 23/00

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

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: motor, lamination, simulation, aging, data, clamping force, thermal, submersible, downhole

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 6098472 A (STEVEN W. ADDISON) 08 August 2000 See column 4, line 20-column 5, line 38 and figures 2-6.	1-20
A	JP 2009-270926 A (TOYOTA MOTOR CORP.) 19 November 2009 See abstract, paragraphs 27-38 and figures 1-2.	1-20
A	JP 2006-053119 A (HITACHI BUILDING SYSTEMS CO., LTD.) 23 February 2006 See abstract, paragraphs 19-37 and figures 1-4.	1-20
A	WO 2007-120104 A1 (VOLVO TECHNOLOGY CORP. et al.) 25 October 2007 See abstract, claims 1-13 and figures 1-2.	1-20
A	KR 10-1999-0040353 A (HYUNDAI MOTOR COMPANY) 05 June 1999 See abstract, claims 1-3 and figures 1-4.	1-20



Further documents are listed in the continuation of Box C.



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

"&" document member of the same patent family

Date of the actual completion of the international search

13 August 2015 (13.08.2015)

Date of mailing of the international search report

17 August 2015 (17.08.2015)

Name and mailing address of the ISA/KR

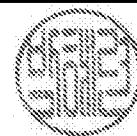
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2015/032369

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