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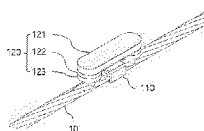
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(54) Title: THE STATIONARY TYPE APPARATUS FOR MEASURING TENSILE FORCE OF STRANDS USING GUIDED WAVE



(57) Abstract: The present invention provides the apparatus measuring the tensile force of a strand using a guided wave which has the characteristics with oscillating an guided wave having a dispersion property on an object made of a strand. According to the apparatus measuring the tensile force of a strand using an guided wave, it is possible to diagnose and monitor the cable or tendon to be measured by measuring the tensile force using the dispersion characteristic of the guided wave in a non-destructive manner, and it is also easy to measure the tensile force on installed stranded structure by adopting the method of detachable exposed strand.



Description

Title of Invention: THE STATIONARY TYPE APPARATUS FOR MEASURING TENSILE FORCE OF STRANDS USING GUIDED WAVE

Technical Field

- [1] The present invention relates to a stationary type apparatus for measuring the tensile force of a strand using guided wave, and more specifically, it is a stationary type apparatus for measuring the tensile force of a strand using guided wave that can accurately measure, diagnose and continuously monitor a tensile force acting on a cable or tendon under force in a concrete structure like main cable or hanger cable of bridge such as suspension bridge, cable-stayed bridge, rahmen bridge and complexed bridge made up of strand through pitch-catch method or pulse-echo method.

Background Art

- [2] Generally, an guided wave is a type of wave propagated in the longitudinal direction along the geometry of a structure such as a pipe, which is developed by applying the technology of plate wave applied to flat plate to piping.
- [3] This guided wave has a feature of dispersion characteristics in which a frequency spectrum is changed through a specific medium. Therefore, when numerical values of the dispersion characteristics are well utilized, it is possible to derive a variety of practical and realistic numerical values.
- [4] On the other hand, in the case of supporting main cables or hanger cables of bridges such as suspension bridges, cable-stayed bridges, rahmen bridges and complexed bridges, load-supporting wire ropes or slope reinforcements or cables or tendons in all concrete structures under force are consisted mainly of strands and as these strands are always acted by tensile force, diagnosis and monitoring are necessary for the integrity of the structure.
- [5] In order to diagnose and monitor the integrity of the structure including the tensile force of the strand, the method using the guided wave having the above-mentioned a feature of dispersion characteristics has been studied.
- [6] On the other hand, conventional techniques for solving the above problems have appeared. Korean Patent No. 10-1716717 entitled "Robot for welding defect inspection of oil storage tank using EMAT" introduces the robot for welding defect inspection and it provides on both sides of the robot body wherein a magnet wheel for sticking to the storage tank of the robot body to be inspected is provided on the rear surface of the robot body and contacts the storage tank. It also provides an EMAT transmission for transmitting a specific waveform to a welding unit of the oil storage tank, and an

EMAT transmission disposed at the other side of the rear surface of the robot body, the transmission accommodation unit accommodating EMAT transmission to be contacted by oil tank with EMAT transmission, the receiver accommodation unit accommodating EMAT receiver unit to be contacted by oil tank with the EMAT receiver, a transceiver case including the transceiver connection unit connecting receiver accommodation unit and the transmission accommodation unit spaced apart from each other by a predetermined distance and the inside of robot's main body, and it stores the preset defect data, and includes control unit for comparing the electrical signal of the EMAT receiver with the defect data to determine whether a defect has occurred. The transceiver connection unit allows the robot body to move without contacting the welding unit on the welding unit when the robot body is moved, is made of a flexible material and the transmission accommodating unit and the reception accommodating unit are elastically downwardly brought into close contact with the oil storage tank. The EMAT transmission unit and the EMAT reception unit provide the magnetic force onto each coil and are located under the double lid of permanent magnet provided adjacent to each other or the permanent magnet and a coil for oscillating the EMAT by the magnetic force of the permanent magnet when the electric current is applied, wherein the permanent magnets are arranged so that the polarities of the adjacent permanent magnets are different from each other.

- [7] However, conventionally, it has been difficult to practically measure the intensity of the guided wave signal in the above-mentioned process. Even if the intensity of the guided wave signal is measured, the cost or the time is very much applied. Also, it was difficult to derive a meaningful value corresponding to the value of the tensile force value because skewed signal was received by not guiding wave properly along the strand or analyzing the frequency spectrum was difficult.

Disclosure of Invention

Technical Problem

- [8] The present invention can very effectively measure an guided wave using a pitch-catch method or a pulse-echo method, thereby effectively measure and monitor the tensile force of a strand and able to provide a stationary type apparatus for measuring the tensile force of a strand using guided wave, which can be applied immediately to existing structures, and can shorten cost or time.

Solution to Problem

- [9] According to a preferred embodiment of the present invention, it has the characteristics using the principle of magnetostriction(MS) of the above object including the sensor module unit to measure the tensile force applied on the above object by receiving the guided wave transmitted through the above object after oscillating an

guided wave having a dispersion in an object place on an object made of a strand, a signal processor unit converting the measured signal to the spectrum of frequency domain after measuring the signal of an guided wave received from the above object through the sensor module unit, a spectrum diagnosis unit for analyzing a spectrum of the frequency domain converted by the signal processing unit and calculating a tensile force of the object, wherein the sensor module unit comprises: a sensor unit mounted on an outer circumferential surface of the object; a magnetic unit for providing a magnetic force to the sensor unit according to an electric current applied using an electromagnet.

- [10] According to another embodiment of the present invention, the sensor unit includes a sensor bobbin formed in an arch shape and mounted to be detachably attached to an outer circumferential surface of the object and a sensor coil wound on left and right sides except the upper and lower sides for maintaining the arch curvature of the sensor bobbin.
- [11] According to another embodiment of the present invention, the sensor bobbin is formed with a winding groove so that the sensor coil is wound on the above right and left side surfaces.
- [12] According to another embodiment of the present invention, the magnetic unit includes a yoke unit formed in a bar shape along the longitudinal direction of the object to form a static magnetic field; a magnet unit formed of a double lid of permanent magnets and spaced apart from both ends of the lower surface of the yoke unit; and a shoe unit having a side surface attached to a lower surface of the magnet unit and protruding downward to receive the other side surface of the object.
- [13] According to another embodiment of the present invention, the magnetic unit is mounted to be detachably attached to the above object using the magnetic force transmitted from the magnet unit to the shoe unit.
- [14] According to another embodiment of the present invention, the shoe unit is recessed so that the other side surface corresponds to the shape of the outer circumferential surface of the object, and is mounted to be detachably attached to the object.
- [15] According to another embodiment of the present invention, the magnetic unit is mounted and fixed to the object and mounted into the sensor unit so that it can measure the tensile force applied to the object using a closed magnetic circuit formed through the sensor unit and the magnetic unit.
- [16] According to another embodiment of the present invention, the signal processor unit further includes a signal measuring unit for measuring a signal of the guided wave guided along the object and a frequency converter for converting a signal received from the signal measuring unit into a frequency domain spectrum.
- [17] While the present invention has been described with reference to exemplary em-

bodiments, it is to be understood that the invention is not limited to the disclosed exemplary embodiments, but, on the contrary, is intended to be in all likelihood understood to fall within the scope of the invention. It is to be understood that both the foregoing general description and the following detailed description of the present invention are exemplary and explanatory and are intended to provide further explanation of the invention as claimed. Similar reference numerals refer to the elements in overall specification.

Advantageous Effects of Invention

- [18] The stationary type apparatus for measuring the tensile force of a strand using guided wave according to the present invention provides the following effects.
- [19] First, guided waves can be measured very practical by using a pitch-catch method or a pulse-echo method, thereby effectively measuring and monitoring the tensile force of the strand.
- [20] Second, it can be applied directly to existing structures and can shorten cost or time.
- [21] Third, it is possible to diagnose and monitor the cable or tendon to be measured in a non-destructive manner by measuring the tensile force using the feature of dispersion characteristics of the guided wave, and it is easy to measure the tensile force by adopting a method in which the exposed strand can be attached detachably.
- [22] Fourth, accurate signal measurement is possible through the pitch-catch method or pulse-echo method using the Electromagnetic Acoustic Transducer (EMAT), and the tensile force diagnostic value close to the actual tensile force value from the frequency spectrum can be derived.

Brief Description of Drawings

- [23] Fig. 1 is a block diagram showing a configuration of a stationary type apparatus for measuring the tensile force of a strand using guided wave according to an embodiment of the present invention.
- [24] Fig. 2 is a perspective view for explaining a stationary type apparatus for measuring the tensile force of a strand using guided wave according to the present invention.
- [25] Fig. 3 is a side view for explaining a stationary type apparatus for measuring the tensile force of a strand using guided wave according to the present invention.
- [26] Fig. 4 is a drawing showing a state where a stationary type apparatus for measuring the tensile force of a strand using guided wave according to the present invention is mounted on an object.
- [27] Fig. 5 is a drawing showing a target facility in which a stationary type apparatus for measuring the tensile force of a strand using guided wave according to the present invention is installed.
- [28] Figs. 6 and 7 are graphs showing the frequency transition of the singularities of

unloading and loading conditions and various acting forces.

Best Mode for Carrying out the Invention

- [29] A stationary type apparatus for measuring tensile force, characterized in that it includes the sensor module unit (100) measuring a tensile force applied to the above object (10) by transmitting the guided wave received through the above object (10) and oscillating an guided wave having a dispersion in the object (10) mounted on an object made of a strand;
- [30] a signal processor unit (200) measuring a signal of the guided wave received from above object (10) through above sensor module unit (100) and converting a measured signal to the spectrum of frequency domain; and
- [31] a spectrum diagnosis unit (300) calculating a tensile force of the above object (10) by analyzing the spectrum of the frequency domain converted by the signal processor unit (200),
- [32] and that the above sensor module unit (100) uses MS (magnetostriction) principle of above object (10) by including a sensor unit (110) mounted on an outer circumferential surface of the object (10) and a magnetic unit (120) for providing a magnetic force to the sensor unit (110) according to an electric current applied using an electromagnet.

Mode for the Invention

- [33] Hereinafter, embodiments of the present invention will be described in detail with reference to the accompanying drawings.
- [34] Fig. 1 is a block diagram showing a configuration of a stationary type apparatus for measuring the tensile force of a strand using guided wave according to an embodiment of the present invention, Fig. 2 is a perspective view for explaining a stationary type apparatus for measuring the tensile force of a strand using guided wave according to the present invention. Fig. 3 is a side view for explaining a stationary type apparatus for measuring the tensile force of a strand using guided wave according to the present invention, Fig. 4 is a drawing showing a state where a stationary type apparatus for measuring the tensile force of a strand using guided wave according to the present invention is mounted on an object, Fig. 5 is a drawing showing a target facility in which a stationary type apparatus for measuring the tensile force of a strand using guided wave according to the present invention is installed; and Fig. 6 and 7 are graphs showing the frequency shifts of the singularities with respect to unloading and loading conditions and various acting forces.
- [35] Referring to Fig. 1, a stationary type apparatus for measuring the tensile force of a strand using guided wave (hereinafter, referred to as 'an apparatus measuring the tensile force') according to the present invention is able to detect the tensile force loss or corrosion bond of a strand by using an guided wave or Electromagnetic Acoustic

Transducer (EMAT) and it includes a sensor module unit (100), a signal processor unit (200), and a spectrum diagnosis unit (300).

- [36] Although it is not shown, a specified electric current supply apparatus for applying a high electric current to the sensor unit (110), which is an electromagnet, is connected to the sensor module unit (100), and a description thereof will be omitted.
- [37] First, the sensor module unit (100) oscillates an guided wave having a dispersion in the object (10), which is placed on an object (10) made of a strand, and receives guided waves transmitted through the object (10) to measure a tensile force applied to the object (10).
- [38] In this case, the sensor module unit (100) may be fixed to the object (10) at the time of initial installation of the structure before the object (10) is installed on the structure or may be detachably attached to the object (10) exposed after completion of the structure.
- [39] In detail, referring Fig. 2 to 4, the sensor module unit (100) includes a sensor unit (110) mounted on an outer circumferential surface of the object (10) and a magnetic unit (120) providing magnetic force to the sensor unit (110) according to the electric current applied using an electromagnet uses the principle of MS(Magnetostriction) of the object (10).
- [40] Also the sensor unit (110) includes a sensor bobbin (111) formed in an arch shape so as to be detachably attached to an outer circumferential surface of the object (10) and a sensor coil (112) wounding on the right and left sides except for upper and lower side of the sensor bobbin (111) to maintain the arch-shaped curvature.
- [41] The sensor bobbin (111) is formed with a winding groove (113) so that the sensor coil (112) is wound on the above right and left side surfaces.
- [42] The magnetic unit (120) may include a yoke unit (121) formed in a bar shape along the longitudinal direction of the object (10) to form a static magnetic field and a magnet unit (122) formed of double lid of permanent magnets and spaced apart from both ends of the lower surface of the yoke unit (121), and a shoe unit (123) formed on one side of the lower surface of the above magnet unit and protruding in the downward direction so as to be mounted on the object (10) on the other side.
- [43] Here, the magnetic unit (120) is mounted to be detachably attached to the object (10) using the magnetic force transmitted from the magnet unit (122) to the shoe unit (123).
- [44] In addition, the magnetic unit (120) is mounted on all the positions of the object (10) detachably to measure the tensile force and it is possible to diagnose and monitor the cable or tent, which is the object of measurement, in a non-destructive manner to the previously constructed strand structure by using a stationary type apparatus for measuring the tensile force of a strand using guided wave according to the present invention.

- [45] In addition, the shoe unit (123) is recessed so that the other side surface corresponds to the shape of the outer circumferential surface of the object (10).
- [46] Here, the sensor unit (110) is detachably attached to the object (10) to be measured using the shoe unit (123), and through this, it can be easily mounted at a desired measurement position of the object (10).
- [47] The magnetic unit (120) is mounted and fixed to the object (10), and the sensor unit (110) is kept in the magnetic unit (120).
- [48] Here, the magnetic unit (120) measures a tensile force applied to the object (10) by using a closed magnetic circuit formed through the sensor unit (110) and the magnetic unit (120).
- [49] In detail, the sensor unit (110) forms the closed magnetic circuit by a moving magnetic field generated by applying an electric current to the sensor coil (112), and a static magnetic field generated by the yoke unit (121) of the magnetic unit (120).
- [50] The signal processor unit (200) includes a signal measuring unit (210) for measuring a signal of the guided wave guided along the object (10) and a frequency converter unit (220) converting the signal received from the signal measuring unit (210) to the spectrum of a frequency domain.
- [51] Here, the signal processor unit (200) measures a signal of the guided wave received from the object (10) through the sensor module unit (100) and converts the measured signal into a spectrum in the frequency domain.
- [52] Also the signal processor unit (200) includes the signal measuring unit (210) for measuring a signal of the guided wave guided along the object (10) and a frequency converter (220) converting the signal received from the signal measuring unit (210) to the spectrum of a frequency domain.
- [53] The spectrum diagnosis unit (300) analyzes the spectrum of the frequency domain converted by the signal processor unit (200) and calculates a tensile force of the object (10), and calculates a tensile force applied to the object (10) by analyzing a pattern on the converted spectrum.
- [54] Referring to Fig. 6 and Fig. 7, the spectrum diagnosis unit (300) analyzes singularities of frequency response characteristic according to loading and unloading and measures the tensile force by setting a fitting curve after analyzing the pattern of above singularities.
- [55] On the other hand, the object (10) may be apply to a supporting cable of a bridge including a suspension bridge, a cable-stayed bridge, a rahmen bridge, a complexed bridge, or a hanger cable or load-supporting wire ropes or slope reinforcements or a cable or tendons in concrete structures where force acts.
- [56] Referring to Fig. 5, an object applied the tensile force measurement system and an embodiment of the structure will be described.

- [57] Referring to Fig. 5, the tensile force measurement system may be applied to a suspension bridge. The detailed fixing position can be applied to the main cable anchorage or the hanger cable. When the cable in the fixing room can be accessed, it can be installed at the time of installation of the initial suspension bridge or after completion, and it is able to estimate the tensile force of pitch catch / pulse-echo method and diagnose the corrosion fault of pulse echo method.
- [58] Hereinafter, a description will be given of a test procedure and results of a measurement system of the tensile force using the guided wave.
- [59] The main task of the test is to perform the loading and unloading operations to exert the tensile force as certain force acts on the object after the sensor module unit 100 is fixed to the object and the signals corresponding thereto are measured. The unloading / loading of the load is performed to extract characteristic curves including the trajectory at the singular point, and fittings for the curves / functions are set and measured in the extracted characteristic curves, thereby measuring and predicting the tensile force.
- [60] On the other hand, as shown in the drawing, the experimental condition is about 11.22 tons for a single strand, and 110 KN is allowed to be loaded and the load was loaded and unloaded with a load of 110 KN. The pulser / receiver was RPR-4000, the frequency was burst 3 cycle excitation 500 kHz, the output ratio was 40, receiving gain is set to 60dB, and the sensor unit module is set as equipment and test condition of solenoid coil transmission and solenoid coil (PCS) receiver.
- [61] When the test equipment including the sensor module unit (100) is set, the guided wave based on the pitch-catch method is generated and received.
- [62] As described above, a stationary type apparatus for measuring the tensile force of a strand using guided wave according to the present invention can measure the guided wave very practically using a pitch-catch method or a pulse-echo method. This enables effective measurement and monitoring of the tensile force of the strand and it can be applied directly to the existing structure, and it can shorten cost or time.
- [63] In addition, it is possible to diagnose and monitor the cable or tendon to be measured in a non-destructive manner by measuring the tensile force by using the feature of dispersion characteristics of the guided wave. Also it is easy to measure the tensile force even for the already installed stranded structure by adopting a method of detachable exposed strand, and it is possible to measure the accurate signal and can derive a tensile force diagnostic value from the frequency spectrum through the Pitch-catch method or the pulse-echo method using the EMAT (Electromagnetic Acoustic Transducer).
- [64] While the present invention has been particularly shown and described with limited embodiments and drawings thereof, it is to be understood that the invention is not limited to the disclosed exemplary embodiments, but, on the contrary, various modi-

fications and changes may be made thereto by those skilled in the art to which the present invention pertains. Accordingly, the idea of the present invention should be understood only by written scope of patent claim below, and all equivalent or equivalent variations thereof are included in the scope of the present invention.

- [65] <Description of Reference Numerals>
- [66] 100: Sensor Module Unit 110: Sensor Unit
- [67] 111: Sensor Bobbin 112: Sensor Coil
- [68] 113: Winding Groove
- [69] 120: Magnetic Unit 121: Yoke Unit
- [70] 122: Magnet Unit 123: Shoe Unit
- [71] 200: Signal Processor Unit 210: Signal Measuring Unit
- [72] 220: Frequency Converter Unit
- [73] 300: Spectrum Diagnostic Unit

Industrial Applicability

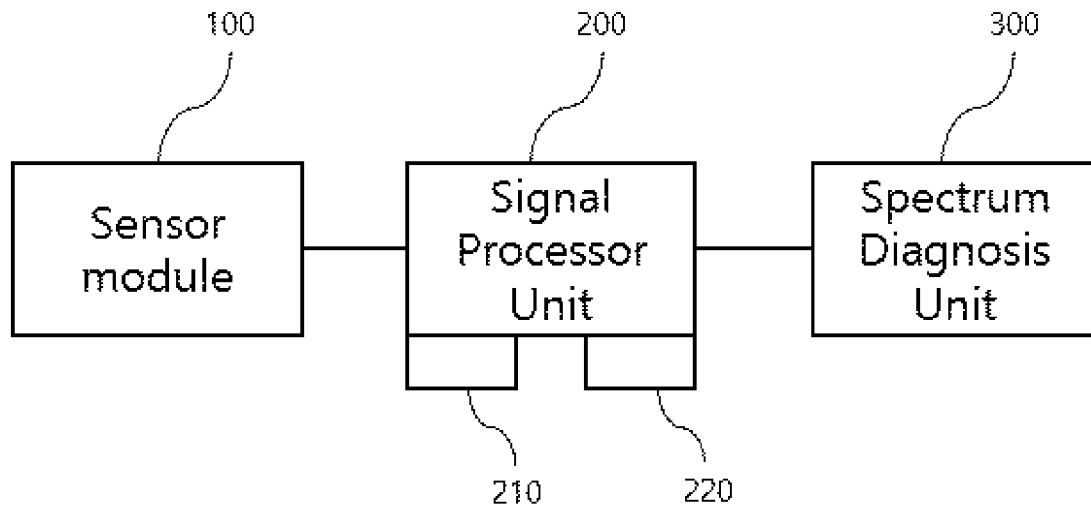
- [74] While the present invention has been described with reference to exemplary embodiments, it is to be understood that the invention is not limited to the disclosed exemplary embodiments, but, on the contrary, is intended to be in all likelihood understood to fall within the scope of the invention. It is to be understood that both the foregoing general description and the following detailed description of the present invention are exemplary and explanatory and are intended to provide further explanation of the invention as claimed. Similar reference numerals refer to the elements in overall specification.
- [75]

Claims

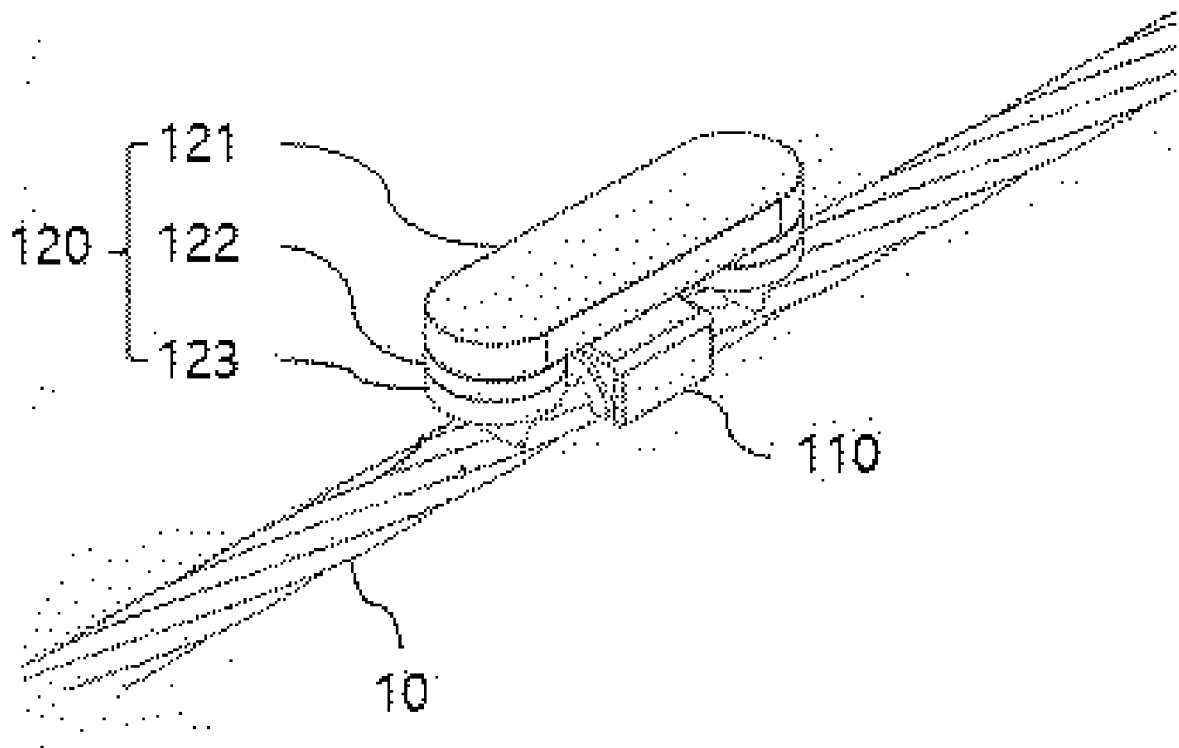
- [Claim 1] A stationary type apparatus for measuring tensile force, characterized in that it includes the sensor module unit (100) measuring a tensile force applied to the above object (10) by transmitting the guided wave received through the above object (10) and oscillating an guided wave having a dispersion in the object (10) mounted on an object made of a strand;
a signal processor unit (200) measuring a signal of the guided wave received from above object (10) through above sensor module unit (100) and converting a measured signal to the spectrum of frequency domain; and
a spectrum diagnosis unit (300) calculating a tensile force of the above object (10) by analyzing the spectrum of the frequency domain converted by the signal processor unit (200),
and that the above sensor module unit (100) uses MS (magnetostriction) principle of above object (10) by including a sensor unit (110) mounted on an outer circumferential surface of the object (10) and a magnetic unit (120) for providing a magnetic force to the sensor unit (110) according to an electric current applied using an electromagnet.
- [Claim 2] A stationary type apparatus for measuring tensile force according to Claim 1, characterized in that a sensor unit (110) includes a sensor bobbin (111) formed in an arch shape so as to be detachably attached to an outer circumferential surface of the object (10) and a sensor coil (112) wound around on left and right sides of the sensor bobbin (111) excepting the upper and lower sides for maintaining the arch curvature.
- [Claim 3] A stationary type apparatus for measuring tensile force according to Claim 1, characterized in that a sensor bobbin (111) has a winding groove (113) which is formed on the left and right sides so that the sensor coil (112) is wound thereon.
- [Claim 4] A stationary type apparatus for measuring tensile force according to Claim 1, characterized in that a magnetic unit (120) includes a yoke unit (121) formed in a bar shape along the longitudinal direction of the object (10) to form a static magnetic field, a magnet unit (122) formed of a plurality of permanent magnets and spaced apart from both ends of the lower surface of the yoke unit (121) and a shoe unit (123) having one side attached to the lower surface of the magnet unit (122) and

- protruding downward to attach the other side surface to the object (10).
- [Claim 5] A stationary type apparatus for measuring tensile force according to Claim 4, characterized in that a magnetic unit (120) is detachably mounted to the above object (10) using magnetic force transmitted from the magnet unit (122) to the shoe unit (123).
- [Claim 6] A stationary type apparatus for measuring tensile force according to Claim 4, characterized in that a shoe unit (123) is detachably mounted to the object (10) with the other side formed in a concave shape to correspond to the shape of the outer circumferential surface of the object (10).
- [Claim 7] A stationary type apparatus for measuring tensile force according to Claim 1, characterized in that a magnetic unit (120) is mounted and fixed into the above object (10) and measures a tensile force applied to the above object (10) using a closed magnetic circuit formed through the sensor unit (110) and the magnetic unit (120) so that the sensor unit (110) is received therein.
- [Claim 8] A stationary type apparatus for measuring tensile force according to Claim 1, characterized in that a signal processor unit (200) includes a signal measuring unit (210) for measuring a signal of the guided wave induced along the above object (10) and a frequency converter unit (220) for transforming a signal received from the signal measuring unit (210) into a frequency domain spectrum.

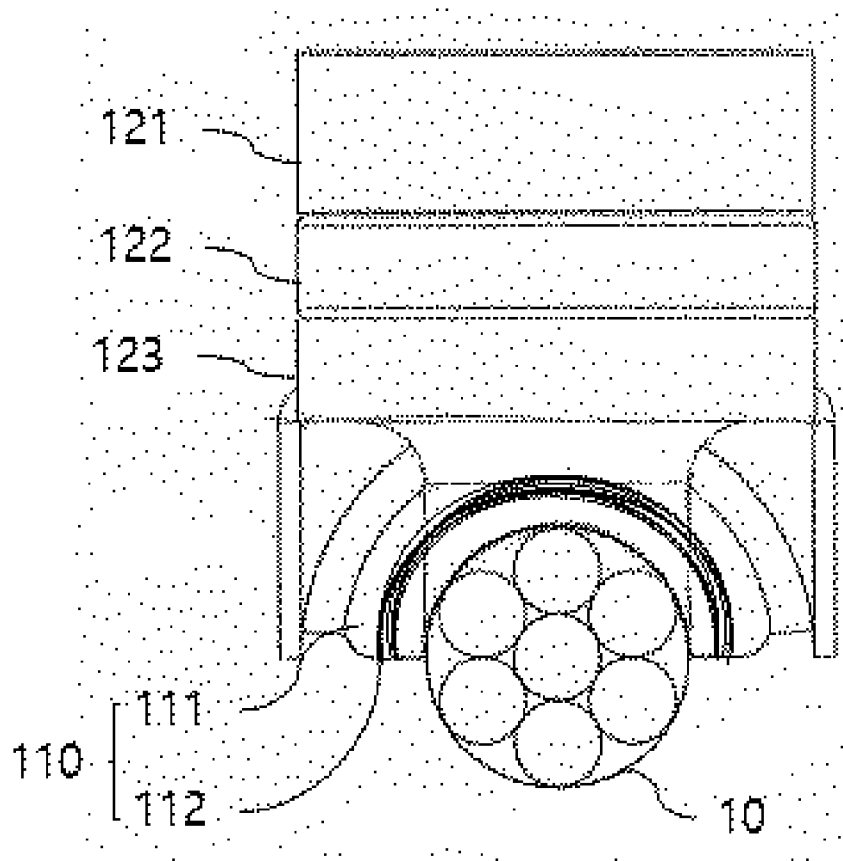
[Fig. 1]



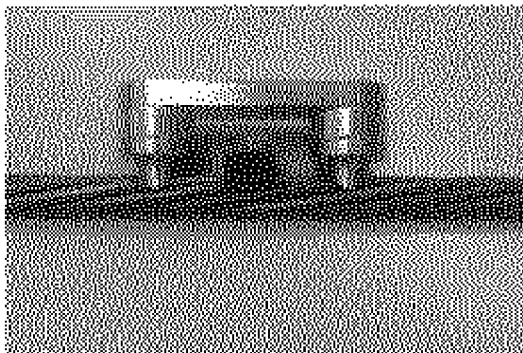
[Fig. 2]



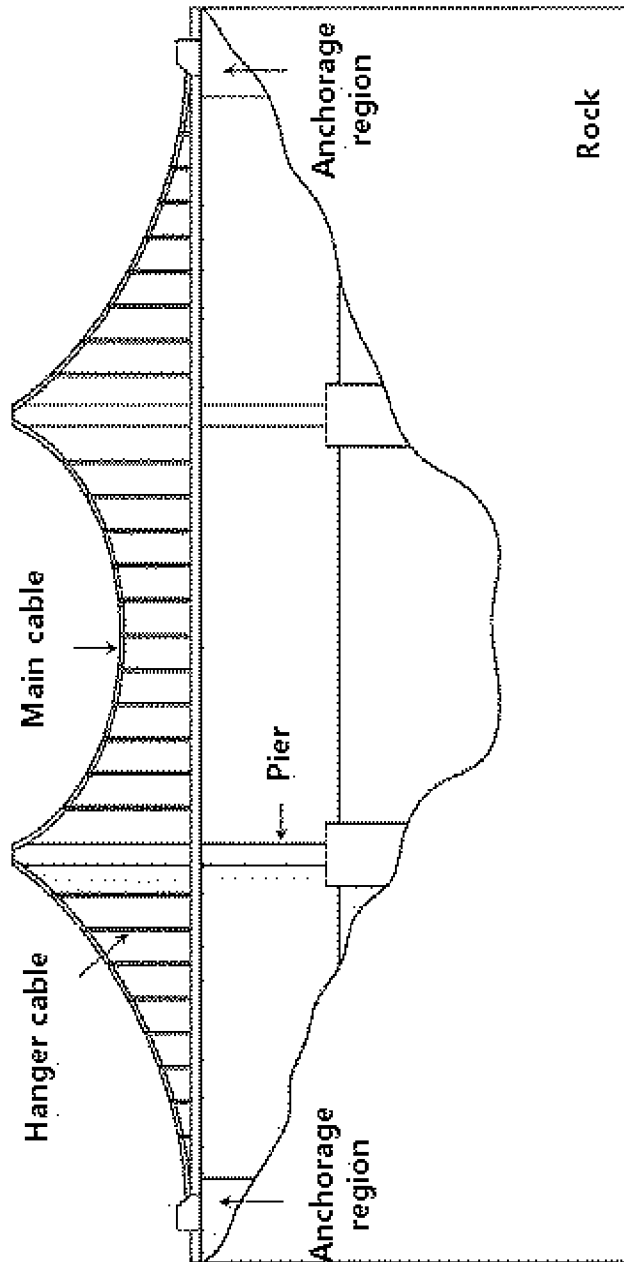
[Fig. 3]



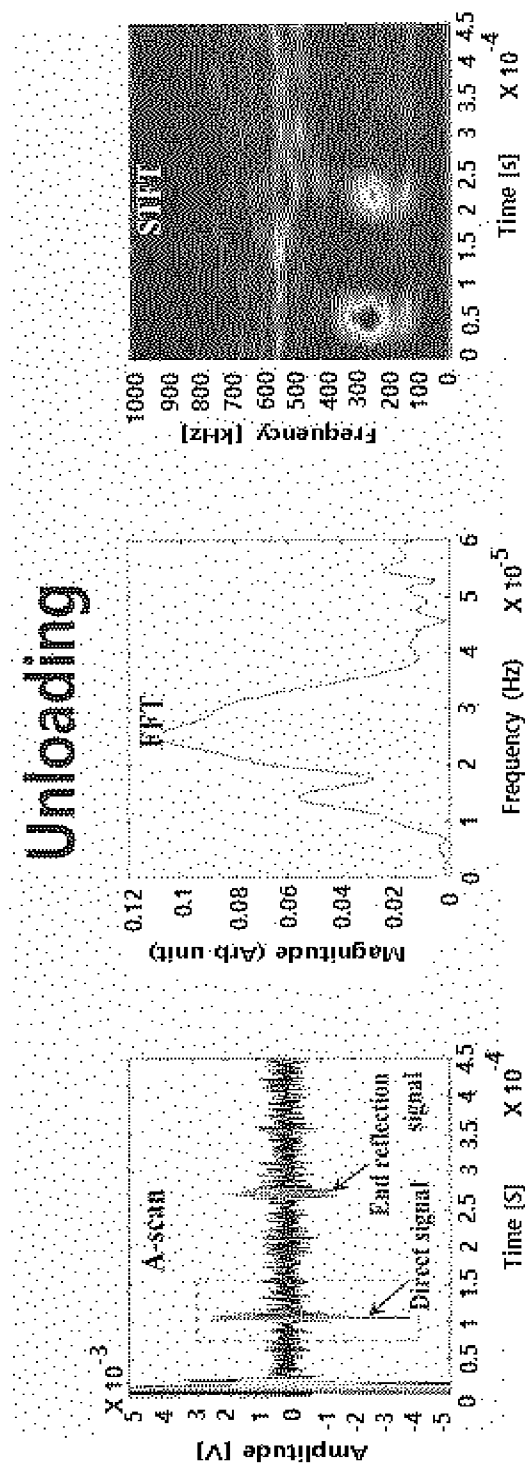
[Fig. 4]



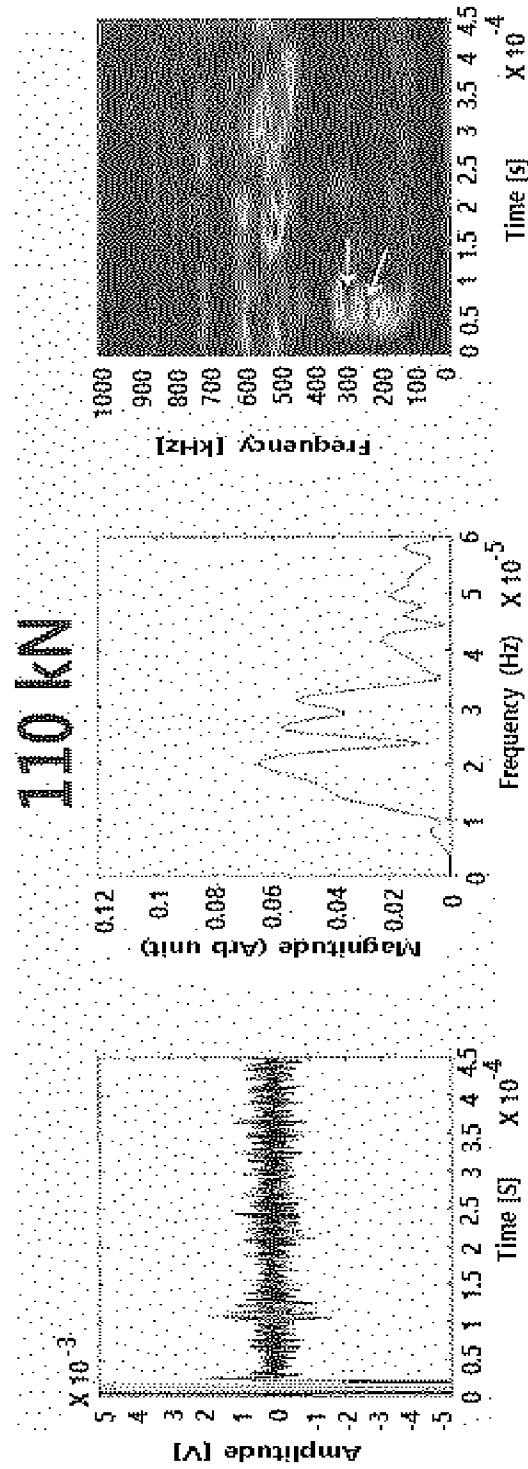
[Fig. 5]



[Fig. 6]



[Fig. 7]



INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2018/013105**A. CLASSIFICATION OF SUBJECT MATTER****G01N 29/22(2006.01)i, G01N 29/04(2006.01)i, G01L 5/04(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)

G01N 29/22; G01D 11/30; G01N 27/82; G01R 33/18; G01N 29/04; G01L 5/04

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: tension, tensile, cable, rope, tendon, determine, calculate, magnet, coil, spectrum, frequency, magnetostriction, and concave

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2010-0315076 A1 (TSUKADA et al.) 16 December 2010 See paragraphs [0032]-[0036] and figures 1-6.	1-8
Y	US 2016-0290965 A1 (FBS, INC.) 06 October 2016 See paragraphs [0099]-[0104] and figures 17a-18.	1-8
Y	US 2008-0315872 A1 (KWUN et al.) 25 December 2008 See paragraphs [0030]-[0041] and figure 2.	2-3, 5-6
A	US 2010-0052670 A1 (KWUN et al.) 04 March 2010 See paragraphs [0037]-[0039] and figure 1.	1-8
A	US 2016-0370212 A1 (BERKELEY SPRINGS INSTRUMENTS LLC.) 22 December 2016 See paragraphs [0037]-[0038] and figures 1-2.	1-8



Further documents are listed in the continuation of Box C.



See patent family annex.

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INTERNATIONAL SEARCH REPORT

Information on patent family members

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