Title of the Invention: Chain link testing apparatus and method
Abstract Title: Eddy current chain link testing

A chain link testing apparatus 60 for testing links 70 of a chain 80, such as those used to anchor ships or platforms at sea. The apparatus includes a sensor arrangement operable to induce one or more eddy current resonances in one or more links of one or more chains at a plurality of time intervals for determining a mechanical status and/or a temporal change in mechanical status of the one or more links. Preferably the apparatus can operate within an underwater environment 20, and may be part of a remotely operated vehicle 10. The apparatus may comprise a plurality of elements to encircle a portion of a given link to be tested, may also include a positioning system for ensuring the sensor arrangement is centred on the given link and may correlate sets of measurements to identify a given chain or position on the chain.

FIG. 1
CHAIN LINK TESTING APPARATUS AND METHOD

Field of the invention

The present invention relates to chain link testing apparatus. Moreover, the present invention also concerns methods of testing chain links. Furthermore, the present invention relates to software products recorded on machine readable data storage media, wherein the software products are executable on computing hardware for implementing aforesaid methods.

Background of the invention

Large chains are employed in various applications, for example in construction industries, in offshore industries, and in maritime industry. For example, on account of “peak oil” associated with the depletion of fossil fuel reserves, oil companies are increasingly seeking after new oil reserves, for example off the coast of Saudi Arabia and in the Gulf of Mexico. Were there to be found sufficiently promising oil reserves on land, major oil companies would not be taking trouble to seek after oil and gas offshore. The World is now facing severe real economic decline as World population rises and economically viable oil and gas reserves decline. In short, the World is running out of fossil fuel just as World population is still growing. In consequence, there is anticipated to be a large growth in future in offshore facilities, for example deep-water floating wind turbines (for example Sway AS, Rådal, Norway), off-shore floating oil and gas boring platforms for petrochemicals industries, and offshore floating wave energy systems (for example “Pelamis”, Ocean Power Delivery Ltd.) and tidal flow energy systems. All such facilities require moorings to an ocean floor by way of cables, or more usually chains comprising a plurality of chain links. However, ocean environments are chemically corrosive which eventually causes degradation and eventual failure of chains submerged in such ocean environments. In many situations, it is not economically desirable, and even technically feasible, to reel in installed chains in ocean environments for periodic chain testing purposes. Conventionally, in order to address the aforementioned difficulties, it is customary to over-engineer chains when intended for use in ocean environments to allow for chain link degradation over time. However, such over-design potentially represents unnecessary extra cost and use of materials which will become increasingly significantly in future as the World enters a post “peak-oil” area which results in material costs rising rapidly in real terms on account of a large amount of fossil-fuel-derived energy needed for their manufacture.
It is known to test links of chains by employing ultrasonic measurement. For example, in a published United Kingdom patent no. GB 2 415 256 A (Engspire Ltd.), there is described an apparatus for assessing a joint between two mechanically cooperating subsea components, for example a stud and line of a stud link mooring chain. The apparatus comprises an excitation arrangement, for example implemented as a motorized-hammer acoustic source or as a magnetic field source; the excitation arrangement is operable to cause in operation propagation of an acoustic signal in one of the components. Moreover, the apparatus also includes a receiving arrangement, for example implemented as an accelerometer, a laser interferometer or a strain gauge; the receiving arrangement is operable to receive a signal induced in at least one of the components. The apparatus is operable to process the received signal to determine whether or not the components are joined in a loose condition. Alternatively, the apparatus comprises a magnetic loss measurement arrangement, an eddy current measurement arrangement, a nuclear resonance measurement arrangement or an X-ray measurement arrangement. The apparatus is adapted for use under water for executing in-situ measurements on chains.

In a United States patent no. US 5317 265 (Weinstock & Lipsett)), there is described a computerized magnetic resonance analyzer. The analyzer is operable to generate a large variety of test signals at one of more interrogation frequencies. The test signals are operably applied as electromagnetic fields or as eddy currents to material under test. An electromagnetic or electrical response signal of the material under test is provided to the analyzer for processing for determining a response pattern corresponding to the material under test. It is therefrom possible to determine deviations from expected response for the material.

However, the aforementioned apparatus are not suitable for performing high speed testing of massive chains including a series of chain links in many offshore installations. On account of their being anticipated an enormous growth in offshore installations, both associated with petrochemicals industry and offshore energy production industry, there exists a requirement for more rapid and more efficient in situ inspection and testing of offshore chains and their associated links.

**Summary of the invention**

The present invention seeks to provide an improved chain link testing apparatus which is capable of operating to perform higher speed testing of links of chains, for example in harbours, in offshore locations and so forth.
The present invention seeks to provide an improved method of using a chain link testing apparatus for performing higher speed testing of links of chains, for example in harbours, in offshore locations and so forth.

According to a first aspect of the present invention, there is provided a chain link testing apparatus as claimed in appended claim 1: there is provided a chain link testing apparatus for testing links of chains, characterized in that the apparatus includes a sensor arrangement operable to induce one or more eddy current resonances in one or more links of one or more chains at a plurality of time intervals for determining a mechanical status and/or a temporal change in mechanical status of the one or more links.

The present invention is of advantage in that performing chain link measurements at eddy current resonances is capable of being performed rapidly and providing more representative indications of mechanical status of chain links.

Optionally, the apparatus is operable to be manoeuvrable within an underwater environment for testing the one or more links.

Optionally, the apparatus includes a sensor arrangement for performing measurements of the one or more eddy current resonances, wherein the sensor arrangement includes a magnetic circuit which is magnetically couplable to the one or more links when in a closed state, and movable between the one or more links when in an open state. More optionally, when implementing the apparatus, the magnetic circuit is implemented as a plurality of elements which are operable to be actuated to encircle a portion of a given link when being tested.

Optionally, the apparatus includes a positioning system for adjusting in operation a position of the sensor arrangement in respect of a given link being tested, for adjusting one or more characteristics of the one or more eddy current resonances of the given link to a maximum magnitude value and/or minimum magnitude value for ensuring that the sensor arrangement is consistently centred in respect of the given link being tested. Optionally, the apparatus includes a positioning system for adjusting in operation a position of the sensor arrangement in respect of a given link being tested, for adjusting one or more characteristics of the one or more eddy current resonances of the given link to a maximum Q-factor value and/or minimum Q-factor value for ensuring that the sensor arrangement is consistently centred in respect of the given link being tested.
Optionally, when implementing the apparatus, the sensor arrangement is operable to perform a spatial correlation between sets of resonance measurements for determining an identity of a given chain being tested by the apparatus and an operating position of the apparatus along a given chain including the given link.

According to a second aspect of the invention, there is provided a method as claimed in appended claim 7: there is provided a method of testing chain links of chains using a testing apparatus pursuant to the first aspect of the invention, wherein the method includes:

(i) employing a sensor arrangement of the apparatus to induce one or more eddy current resonances in one or more links of one or more chains at a plurality of time intervals; and

(ii) analysing signals corresponding to the one or more eddy current resonances in the one or more links of one or more chains at a plurality of time intervals for determining a mechanical status and/or a temporal change in mechanical status of the one or more links.

Optionally, the method includes manoeuvring the apparatus within an underwater environment for testing the one or more links.

Optionally, the method includes utilizing a sensor arrangement for making measurements of the one or more eddy current resonances, by way of the sensor arrangement including a magnetic circuit which is magnetically couplable to the one or more links when in a closed state, and movable between the one or more links when in an open state. More optionally, the method includes implementing the magnetic circuit as a plurality of elements which can be actuated in operation to encircle a portion of a given link to be tested.

Optionally, the method includes utilizing a positioning system for adjusting in operation a position of the sensor arrangement in respect of a given link being tested, for adjusting one or more characteristics of the one or more eddy current resonances of the given link to a maximum magnitude value and/or minimum magnitude value for ensuring that the sensor arrangement is consistently centred in respect of the given link being tested. Optionally, the method includes utilizing a positioning system for adjusting in operation a position of the sensor arrangement in respect of a given link being tested, for adjusting one or more characteristics of the one or more eddy current resonances of the given link to a maximum Q-factor value and/or minimum Q-factor value for ensuring that the sensor arrangement is consistently centred in respect of the given link being tested.
Optionally, the method includes operating the sensor arrangement to perform a spatial correlation between sets of resonance measurements for determining an identity of a given chain being tested by the apparatus and an operating position of the apparatus along a given chain including the given link.

According to a third aspect of the invention, there is provided a software product recorded on a machine-readable data storage medium, wherein the software product is executable upon computing hardware for implementing a method pursuant to the second aspect of the invention.

It will be appreciated that features of the invention are susceptible to being combined in any combination without departing from the scope of the invention as defined by the appended claims.

**Description of the diagrams**

Embodiments of the present invention will now be described, by way of example only, with reference to the following diagrams wherein:

**FIG. 1** is an illustration of an embodiment of an apparatus pursuant to the present invention;

**FIG. 2** is an illustration of a sensor arrangement of the apparatus of FIG. 1, wherein the sensor arrangement is adapted for measuring resonant eddy-current induction characteristics of links of chains in an underwater environment;

**FIG. 3** is an illustration of a series of induction resonance peaks measured by the apparatus of FIG. 1;

**FIG. 4** is an illustration of a variation in measured resonance peaks, as obtained using the apparatus of FIG. 1, as a function of repeated measurements made at time intervals therebetween; and

**FIG. 5** is an illustration of sets of series of resonance measurements as a function of spatial position of links along a chain, the sets of measurements being executed at mutually different times, wherein correlation is employed in the apparatus and its associated facilities for matching sets of measurements together for any given chain.

In the accompanying diagrams, an underlined number is employed to represent an item over which the underlined number is positioned or an item to which the underlined number is adjacent. A non-underlined number relates to an item identified by a line linking the non-underlined number to the item. When a number is non-underlined and accompanied by an
associated arrow, the non-underlined number is used to identify a general item at which the arrow is pointing.

**Description of embodiments of the invention**

Anchor chains on floating oil rigs and other large offshore installations experience constant wear and degradation during operation. There arises therefrom a need to perform regular inspections of these anchor chains. Pursuant to contemporary methods of chain inspection, such contemporary methods are both time consuming and variable in respect to quality of inspection. A fundamentally different and improved method of inspection is susceptible to increasing safety and the cost-effectiveness of performing chain inspections. The present invention is concerned with a new method of testing chain links which does not involve contact being made to the links, and does not require any testing-related components or other modifications to be added or made pursuant to the type of chain in use. Moreover, the present invention concerns a method of testing chains which is susceptible to providing greater insight regarding chain behaviour, thereby enabling better chain links and anchoring techniques to be developed as a consequence.

Contemporary methods of testing chain links of chains *in situ*, for example in an underwater environment associated with offshore installation such as oil boring platforms, in relation to oil production platforms, in relation to floating wind turbine assemblies, in relation to floating ocean wave energy systems, are based primarily on visual inspection, namely at electromagnetic radiation frequencies to which the human eye is sensitive. Moreover, such inspection is executed using a remotely operated vehicle (ROV) equipped with illuminating devices for illuminating chain links in a vicinity of the ROV, and one or more optical cameras for acquiring optical images of the chain links for sending to a surface location for data storage and subsequent analysis. Inspection work is implemented by causing the ROV to dive in a trajectory along the chain and progressively film and/or measure chain link characteristics. Such an approach is extremely time consuming and is poorly adapted for detecting internal damage and cracks in chain links. Moreover, visual image data sets are usually large and interpretation thereof by human operators is subject to variations in thoroughness between different personnel, namely is often rather subjective. Personnel are prone to evaluate wear and tear of chain links differently when performing a quality evaluation of chain links as presented in imperfect images; for example, chain links are often covered in marine growth and surface rust which are often not detrimental to chain mechanical integrity, and also ocean water at considerable depth often includes particulate matter, for example spillage resulting from oil boring activities, which obscures optical images obtained using cameras.
The present invention represents a major improvement upon known chain inspection method, and apparatus for implementing such methods. In overview, the present invention is concerned with measuring resistance of chain link materials in situ. Currents are induced in chain links and associated resistance measurements at resonance are employed to determine structural status of the chain links; by making resistance measurements at various temporal intervals and link spatial intervals along chains, and recording these measurements on a database, temporal degradation characteristics of the chain links can therefrom be determined. On account of the method being a relative measurement, variations in characteristics between chain links of a given chain can be accommodated in contradistinction to contemporary chain link inspection methods which compare against a predefined reference standard. Methods pursuant to the present invention are thus more effective for identifying abnormalities as well as microcracks propagating across chain links, for example by way of corrosion propagating along metal crystal boundaries, in comparison to contemporary visual inspection techniques whose results can, for example, be frustrated by the presence of marine growth. The present invention is beneficially susceptible to being implemented by way of aforesaid ROV such that existing ROV can be upgraded to utilize examples of the present invention.

Referring to FIG. 1, an example embodiment of the present invention is illustrated. In FIG. 1, the remotely controlled vehicle (ROV) is indicated generally by 10 and is operable to be manoeuvred in a submerged state in an aquatic environment 20. The ROV 10 is provided with a flexible data and power cable 30 which couples the ROV 10 to a surface ship 40 and/or to a land-based facility 50. The ROV 10 comprises a sensor arrangement indicated generally by 60 for testing links 70 of a chain indicated generally by 80. In some situations, the chain 80 is several kilometres long and includes several hundred corresponding links 70. The ROV 10 is a relatively expensive specialist item of equipment and each hour of its use is costly in relation to amortizing its initial construction cost as well as its on-going maintenance costs. A body of the ROV 10 includes a data processor arrangement 100, for example a configuration of one or more microcontrollers, for locally processing signals received from the sensor arrangement 60 for transmission to the surface ship 40 and/or to the land-based facility 50.

The sensor arrangement 60 functions in a manner as depicted in FIG. 2, wherein the arrangement 60 incorporates a magnetic circuit including a first magnetic element 210A and a second magnetic element 210B which mutually cooperate in operation in a closed state to encircle magnetically in sequence links 70 of a chain 80 to be tested. In an open state, the
elements 210A, 210B are mutually separated at their distal ends for enabling the ROV 10 to move the sensor arrangement 60 from one link 70 to another link 70 along the chain 80. The elements 210A, 210B have one or more magnetic excitation coils 250 associated therewith. Optionally, certain coils 250 are beneficially exciter coils, whereas other coils are receiver coils, thereby enabling the coils 250 to be optimized for transmitting and receiving functions. The one or more excitation coils 250 are operable to induce an alternating magnetic field around a magnetic loop formed by the elements 120A, 120B when in their closed state as illustrated. Beneficially, the elements 120A, 120B are fabricated from at least one of: laminated silicon steel sheets which are individually insulated, from electrically-insulating magnetic glass-ceramic materials, from bundles of individually electrically-insulated magnetic wires, strips or similar. Moreover, the sensor arrangement 60 includes actuators (not shown) for actuating the elements 120A, 120B between their closed state and open state as illustrated in FIG. 2. The one or more coils 250 are coupled via an arrangement of amplifiers 260 and associated signal conditioning circuits to the data processing arrangement 100.

In operation, the ROV 10 moves from link-to-link 70 along the chain 80, testing each link 70 in turn. Such testing involves exciting the one or more coils 250 to induce an alternating magnetic field within the elements 210A, 210B which, in turn, induces eddy currents to flow within each of the links 70 when being tested. The present invention does not merely perform an eddy current measurement at a given test frequency for the links 70 along the chain 80. Such a given test frequency testing strategy would not be able to detect subtleties of link 70 temporal degradation characteristics which are potentially susceptible to cause structural failure of the links 70. The present invention employs much more sophisticated measurement techniques, namely the sensor arrangement 60 is operable to excite eddy currents within the links 70 at least at resonance as illustrated in FIG. 3. In FIG. 3, an abscissa axis 300 represents frequency f, increasing from left to right, of an excitation signal applied by the data processing arrangement 100 via the one or more coils 250. An ordinate axis 310 represents a magnitude of eddy currents induced into a given link 70 being tested by the ROV 10; the axis 310 represents increase eddy current magnitude from bottom to top. It will be seen from FIG. 3 that an alternating eddy current induced in the given link 70 being tested is represented by an eddy current curve 330 which is to be considered in association with the aforementioned axes 300, 310. The eddy current curve 330 exhibits a primary resonance 350 and beneficially a series of weaker higher-order mode resonances 360. A magnitude of the primary resonance 350 is very informative regarding a physical status of the given link 70 being tested by the ROV 10. Moreover, a Q-factor of resonance of the primary resonance 350 is also important as being indicative of the physical status of the given link 70. Optionally, the weaker higher mode resonances 360, by way of their resonant
frequencies and/or their magnitudes and/or their respective Q-factors, are also useful for determining the physical status of the given link 70. Beneficially, the ROV 10 is equipped with a mechanical positioning system, for example including actuators operating under control from the data processing arrangement 100, which act from the ROV 10 upon a given link 70 being tested and optionally also neighbouring links 70 thereto, for adjusting positioning of the elements 210A, 210B in respect of a given link 70 of the chain 80 being tested to seek to render the peak of one or more of the resonances 350, 360 to have a maximum value, alternatively minimum value, for ensuring consistent measurements when undertaking measurements at various time intervals for identifying whether or not temporal degradation of link mechanical status has occurred, for example the given link 70 is rapidly corroding with time which could cause a mechanical structural failure of the given link 70. Optionally, one or more corresponding Q-factors of the one or more resonances 350, 360 are employed as one or more feedback parameters for controlling the mechanical positioning system for ensuring consistent positioning of the sensor arrangement 60 in respect of any given link 70. The positioning system is operable to adjust at least one of: an angular disposition of the ROV 10 relative to the given link 70 being tested, a lateral disposition of the ROV 10 relative to the given link 70 being tested.

The present invention is based upon a realization that the links 70 in the chain 80 can be subject to numerous manufacturing factors which influence measured eddy current characteristics as depicted, for example, in FIG. 3. Two links 70 within the chain 80 are potentially susceptible to exhibit mutually different eddy current resonance characteristics and yet be structurally sound and capable of withstanding their designed stress limits. It is thus appreciated by the inventors of the present invention that comparative measurements of characteristics of the links 70 against a reference threshold set of parameters is not an optimal manner of assessing a physical integrity of the chain 80. Moreover, the inventors have appreciated that a best indication of mechanical integrity of the links 70 of the chain 80 is achieved by making repeated measurements for a given link 70 in respect of time and then comparing results for the given link 70 to detect changes with time. For example, in FIG. 4, there is shown a graph including an abscissa axis 400 representing a passage of time from left to right, and an ordinate axis 410 representing a magnitude of the primary resonance 350 increasing from bottom to top at various measurement times.

When consecutive primary resonances 350 are constant in amplitude in FIG. 4 in respect of time, as denoted by a line 440, for a given link 70 along the chain 80, for example over a period of several months or even years, the given link 70 is assumed to be of stable mechanical status. Optionally the line 440 is additionally compared with a threshold
reference to assist assessing a status of the given link 70. In contradistinction, when consecutive primary resonances 350 are gradually reducing in amplitude in FIG. 4 in respect for time, as denoted by a line 450, for a given link 70 along the chain 80, for example over a period of several months or even years, the given link 70 is assumed to be of unstable mechanical status. The primary resonance 350 reduces as microcracks and inclusions propagate, for example due to corrosion, through the given link 70 and cause electrical resistance against eddy current induction within the given link 70. Similar types of comparison as employed for the primary resonance 350 are beneficially also employed for one or more of the high order mode resonances 360 as part of a measurement technique pursuant to the present invention. On account of the resonances 350, 360 representing a relatively small volume of data to define them, the present invention is capable of completely circumventing data overload associated with conventional optical visual inspection systems for links of chains.

When the ROV 10 is employed to measure many chains 80, considerable records are built up with time corresponding to the resonances 350, 360 of the links 70 of the chains 80. Moreover, the chains 80 are potentially susceptible to being relocated with time from one facility to another. Beneficially, the ROV 10 and its associated external data processing facilities as represented by 40, 50 is operable to establish data sets of resonances 350, 360 as a function of link position i along the chain 80 as illustrated in FIG. 5 and represented by 500. When the ROV 10 later returns to the given chain 80 and repeats the measurement in a sequence along the links 70 of the chain 80, and generally similar pattern of resonances 350, 360 are observed as represented by 510, assuming that none or only a few of the links 70 have experienced changes in their resonances 350, 360 as a function of link position j along the chain 80. The data processing facilities 40, 50 are operable to perform a correlation between measured results 500, 510 along the chain 80 and are thereby able to confirm whether or not it is the same chain 80 being measured and also rapidly identify where along the chain 80 the ROV 10 is at a given time operable to perform measurements. A correlation function \( K \) is defined by Equation 1 (Eq. 1) between a first measurement set \( P(1, i) \) where \( i = 1, m \) and a second measurement set \( P(2, j) \) where \( j = 1, n \), such the correlation function \( K \) achieves a highest value when best correlation is achieved for an index offset \( h \):

\[
K(h) = \sum_{l=1}^{m-h} P(1, l+h)P(2, l) \quad \text{for } n < m
\]

Eq. 1
\[ K(h) = \sum_{l=1}^{m-h} P(1, l + h)P(2, l) \text{ for } m > n \]

A determined value of the index offset \( h \) which provides best correlation enables records to be matched from one measurement set to another. Once matching has been achieved, then relative comparison of the magnitudes and Q-factors of the peaks 350 can be made. Optionally, the correlation function \( K \) can be performed on at least one of: resonance Q-factors of peaks 350, resonance amplitudes of peaks 350.

Beneficially, the correlation is performed in both directions along the results 500, 510 in an event that the ROV 10 performs measurements on the links 70 in a different sequence direction. Such processing of resonances 350, 360 renders the ROV 10 and its data processing facilities 40, 50 easier to employ in operation, thereby avoiding errors in chain 80 identification and associated mechanical status of its links 70; for example, after the ROV 10 has testing a first chain 80A from top to bottom, the ROV 10 then beneficially proceeds to a second spatially adjacent chain 80B and tests the second chain 80B from bottom to top to avoid a need to bring the ROV from a great depth after testing the first chain 80A to a shallow depth to commence testing of the second chain 80B, there utilizing operating time of the ROV 10 more effectively. The ROV 10 can be constructed in a robust manner and operate in ocean environments 20 filled with particulate matter, for example in oil spill regions, sitting regions or algae-containing regions.

If desired, the ROV 10 optionally includes optical inspection facilities utilizing optical cameras and/or ultrasonic sensors so that disparity in one or more of the resonances 350, 360 associated with a given link 70 can be further investigated using complementary sensing techniques immediately in situ during chain testing.

Referring to FIG. 3, the resonance peak 350 often occurs in a frequency range of a few hundred Hertz to a few kiloHertz; for example in a range of 100 Hz to 10 kHz. The higher order resonances 360 often occur in a frequency range of several kilohertz to several tens of kilohertz, for example in a range of 5 kHz to 500 kHz.

Although use of the present invention in association with oil rigs and offshore floating wind turbines is provided as a primary example, the invention is susceptible also to being employed in other applications such as other static chain-towed offshore installations such as ocean thermal energy (OTECH) power generation facilities, offshore fish cultivation facilities, floating bridges, ocean wave energy systems for example.
Modifications to embodiments of the invention described in the foregoing are possible without departing from the scope of the invention as defined by the accompanying claims. Expressions such as “including”, “comprising”, “incorporating”, “consisting of”, “have”, “is” used to describe and claim the present invention are intended to be construed in a non-exclusive manner, namely allowing for items, components or elements not explicitly described also to be present. Reference to the singular is also to be construed to relate to the plural. Numerals included within parentheses in the accompanying claims are intended to assist understanding of the claims and should not be construed in any way to limit subject matter claimed by these claims.
CLAIMS

1. A chain link testing apparatus (10) for testing links (70) of chains (80), characterized in that the apparatus (10) includes a sensor arrangement (60, 100) operable to induce one or more eddy current resonances (350, 360) in one or more links (70) of one or more chains (80) at a plurality of time intervals for determining a mechanical status and/or a temporal change in mechanical status of the one or more links (70).

2. A chain link testing apparatus (10) as claimed in claim 1, wherein the apparatus (10) is operable to be manoeuvrable within an underwater environment (20) for testing the one or more links (70).

3. A chain link testing apparatus (10) as claimed in claim 1 or 2, wherein the apparatus (10) includes a sensor arrangement (60) for performing measurements of the one or more eddy current resonances (350, 360), wherein the sensor arrangement (60) includes a magnetic circuit (210A, 210B) which is magnetically couplable to the one or more links (70) when in a closed state, and movable between the one or more links (70) when in an open state.

4. A chain link testing apparatus (10) as claimed in claim 3, wherein the magnetic circuit (210A, 210B) is implemented as a plurality of elements (210A, 210B) which are operable to be actuated to encircle a portion of a given link (70) when being tested.

5. A chain link testing apparatus (10) as claimed in any one of claims 1 to 4, wherein the apparatus (10) includes a positioning system (100) for adjusting in operation a position of the sensor arrangement (60, 210A, 210A) in respect of a given link (70) being tested, for adjusting one or more characteristics of the one or more eddy current resonances (350, 360) of the given link (70) to a maximum magnitude value and/or minimum value for ensuring that the sensor arrangement (60, 210A, 210B) is consistently centred in respect of the given link (70) being tested.

6. A chain link testing apparatus (10) as claimed in any one of claims 1 to 5, wherein the sensor arrangement (60, 100) is operable to perform a spatial correlation between sets of resonance (350, 360) measurements for determining an identity of a given chain (80) being tested by the apparatus (10) and an operating position of the apparatus (10) along a given chain (80) including the given link (70).
7. A method of testing chain links of chains using a testing apparatus (10) as claimed in any one of claims 1 to 6, wherein the method includes:
   (i) employing a sensor arrangement (60, 100) of the apparatus (10) to induce one or more eddy current resonances (350, 360) in one or more links (70) of one or more chains (80) at a plurality of time intervals; and
   (ii) analysing signals corresponding to the one or more eddy current resonances (350, 360) in the one or more links (70) of one or more chains (80) at a plurality of time intervals for determining a mechanical status and/or a temporal change in mechanical status of the one or more links (70).

8. A method as claimed in claim 7, wherein the method includes manoeuvring the apparatus (10) within an underwater environment (20) for testing the one or more links (70).

9. A method as claimed in claim 7 or 8, wherein the method includes utilizing a sensor arrangement (60) for making measurements of the one or more eddy current resonances (350, 360), by way of the sensor arrangement (60) including a magnetic circuit (210A, 210B) which is magnetically coupable to the one or more links (70) when in a closed state, and movable between the one or more links (70) when in an open state.

10. A method as claimed in claim 9, wherein the method includes implementing the magnetic circuit (210A, 210B) as a plurality of elements (210A, 210B) which can be actuated in operation to encircle a portion of a given link (70) to be tested.

11. A method as claimed in any one of claims 7 to 10, wherein the method includes utilizing a positioning system (100) for adjusting in operation a position of the sensor arrangement (60, 210A, 210A) in respect of a given link (70) being tested, for adjusting one or more characteristics of the one or more eddy current resonances (350, 360) of the given link (70) to a maximum magnitude value and/or minimum value for ensuring that the sensor arrangement (60, 210A, 210B) is consistently centred in respect of the given link (70) being tested.

12. A method as claimed in any one of claims 7 to 11, wherein the method includes operating the sensor arrangement (60, 100) to perform a spatial correlation between sets of resonance (350, 360) measurements for determining an identity of a given chain (80) being tested by the apparatus (10) and an operating position of the apparatus (10) along a given chain (80) including the given link (70).
13. A software product recorded on a machine-readable data storage medium, wherein the software product is executable upon computing hardware for implementing a method as claimed in any one of claims 7 to 12.
CLAIMS

1. A chain link testing apparatus (10) for testing links (70) of chains (80), characterized in that the apparatus (10) includes a sensor arrangement (60, 100) operable to induce one or more eddy current resonances (350, 360) in one or more links (70) of one or more chains (80) at a plurality of time intervals for determining a mechanical status and/or a temporal change in mechanical status of the one or more links (70), wherein the apparatus (10) is operable to be manoeuvrable within an underwater environment (20) for testing the one or more links (70), and wherein the apparatus (10) includes a sensor arrangement (60) for performing measurements of the one or more eddy current resonances (350, 360), wherein the sensor arrangement (60) includes a magnetic circuit (210A, 210B) which is magnetically couplable to the one or more links (70) when in a closed state, and movable between the one or more links (70) when in an open state.

2. A chain link testing apparatus (10) as claimed in claim 1, wherein the magnetic circuit (210A, 210B) is implemented as a plurality of elements (210A, 210B) which are operable to be actuated to encircle a portion of a given link (70) when being tested.

3. A chain link testing apparatus (10) as claimed in claim 1 or 2, wherein the apparatus (10) includes a positioning system (100) for adjusting in operation a position of the sensor arrangement (60, 210A, 210A) in respect of a given link (70) being tested, for adjusting one or more characteristics of the one or more eddy current resonances (350, 360) of the given link (70) to a maximum magnitude value and/or minimum value for ensuring that the sensor arrangement (60, 210A, 210B) is consistently centred in respect of the given link (70) being tested.

4. A chain link testing apparatus (10) as claimed in claim 1, 2 or 3, wherein the sensor arrangement (60, 100) is operable to perform a spatial correlation between sets of resonance (350, 360) measurements for determining an identity of a given chain (80) being tested by the apparatus (10) and an operating position of the apparatus (10) along a given chain (80) including the given link (70).

5. A method of testing chain links of chains using a testing apparatus (10) as claimed in any one of claims 1 to 6, wherein the method includes:
(i) employing a sensor arrangement (60, 100) of the apparatus (10) to induce one or more eddy current resonances (350, 360) in one or more links (70) of one or more chains (80) at a plurality of time intervals; and

(ii) analysing signals corresponding to the one or more eddy current resonances (350, 360) in the one or more links (70) of one or more chains (80) at a plurality of time intervals for determining a mechanical status and/or a temporal change in mechanical status of the one or more links (70),

wherein the method includes manoeuvring the apparatus (10) within an underwater environment (20) for testing the one or more links (70), and

the method includes utilizing a sensor arrangement (60) for making measurements of the one or more eddy current resonances (350, 360), by way of the sensor arrangement (60) including a magnetic circuit (210A, 210B) which is magnetically couplable to the one or more links (70) when in a closed state, and movable between the one or more links (70) when in an open state.

6. A method as claimed in claim 5, wherein the method includes implementing the magnetic circuit (210A, 210B) as a plurality of elements (210A, 210B) which can be actuated in operation to encircle a portion of a given link (70) to be tested.

7. A method as claimed in claim 5 or 6, wherein the method includes utilizing a positioning system (100) for adjusting in operation a position of the sensor arrangement (60, 210A, 210A) in respect of a given link (70) being tested, for adjusting one or more characteristics of the one or more eddy current resonances (350, 360) of the given link (70) to a maximum magnitude value and/or minimum value for ensuring that the sensor arrangement (60, 210A, 210B) is consistently centred in respect of the given link (70) being tested.

8. A method as claimed in claim 5, 6 or 7, wherein the method includes operating the sensor arrangement (60, 100) to perform a spatial correlation between sets of resonance (350, 360) measurements for determining an identity of a given chain (80) being tested by the apparatus (10) and an operating position of the apparatus (10) along a given chain (80) including the given link (70).

9. A software product recorded on a machine-readable data storage medium, wherein the software product is executable upon computing hardware for implementing a method as claimed in any one of claims 5 to 8.
**Patents Act 1977: Search Report under Section 17**

**Documents considered to be relevant:**

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<th>Category</th>
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<td>Y</td>
<td>1-3, 7-9 &amp; 13</td>
<td>JP 08285818 A (NIPPON KOKAN) see especially Figures and EPODOC and WPI abstracts</td>
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<td>Y</td>
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<td>GB 2415256 A (ENGSPIRE) see whole document especially Figures 1 and 2, page 1 lines 3-11 and page 21 lines 23-27</td>
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<td>EP 1952135 A2 (CLOCK SPRING COMPANY) see especially Figure 1, page 4 lines 13-20 and page 5 line 3 to page 6 line 6</td>
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<td>US 1339610 A (VON HENKE) see whole document especially Figures 1-3</td>
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**Field of Search:**

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC:

Worldwide search of patent documents classified in the following areas of the IPC

G01N

The following online and other databases have been used in the preparation of this search report

EPODOC, WPI, INTERNET

**International Classification:**

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