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Synthetic rope, fiber optic cable and method for non-destructive testing thereof

Abstract

A non-destructive test method for evaluating a synthetic rope made of strength member elements includes: treating at least one strength member element to be detectable by a magnetic NDT device, incorporating the at least one treated strength member element into the rope, scanning the synthetic rope with the magnetic NDT device, and obtaining magnetic flux leakage or eddy current output data from the magnetic NDT device, wherein the output data relates to a condition of the synthetic rope. A synthetic rope or cable is thereby made to be capable of being inspected by a magnetic flux leakage or eddy current non-destructive test (NDT) method.

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16. The method according to claim 7, wherein the synthetic rope incorporates a first treated strength member element or population of elements, a second treated strength member element or population of elements, and untreated strength member elements, the first treated strength member element has a stiffness less than untreated strength member elements, and the second treated strength member element has a stiffness equal to or higher than the untreated strength member elements.

17. The method according to claim 7, wherein the at least one treated strength member element comprises at least one treated synthetic or non-metallic fiber with a metallic coating or cladding, and the synthetic rope further includes untreated strength member elements comprised of synthetic or non-metallic fibers; and the at least one treated synthetic or non-metallic fiber with the coating or cladding and the synthetic or non-metallic fibers are independently a material chosen from the group consisting of aramid, HMPE, PBO, LCP, polyimide, polyester, polyethylene, glass, and polypropylene.

18. The method according to claim 7, wherein, when the synthetic rope has multiple layers, directions, and/or patterns, the incorporating comprises incorporating at least one treated strength member element into each layer, direction, and/or pattern.

19. The method according to claim 9, wherein the obtained output data includes data corresponding to a localized diameter, a localized lay length, and a number and density of broken or degraded strength member elements of the synthetic rope.

20. The method according to claim 7, wherein, when the synthetic rope has an outer protective jacket, the at least one treated strength member element is incorporated into the outer protective jacket.

21. The method according to claim 7, wherein, when the synthetic rope has individual strand jackets, the at least one treated strength member element is incorporated into at least one of the strand jackets.

22. A fiber optic cable comprising: at least one optical transmission element, and at least one treated element, wherein the at least one treated element renders the fiber optic cable capable of being inspected by a magnetic or electromagnetic non-destructive test method.

Description

BACKGROUND

[0001] Wire rope, for example made up of steel elements, is used extensively in critical applications, such as in mine hoists or cranes. As a result of use, the strength properties of the wire rope can deteriorate. In some applications, for example, when wire rope is used as a mooring line, the rope can suffer from tension-tension fatigue. That is, the rope is subjected to a cyclic increase and decrease of tension, which detrimentally affects its properties. In other applications, for example, where wire rope is used over pulleys, the wire rope can suffer from bending fatigue in use. That is, the properties of the wire rope deteriorate when the wire rope is subjected repeatedly to bending.

[0002] One of the key concerns of a wire rope user is to determine when the wire rope should be replaced. Replacing a wire rope entails substantial costs and effort. These include not only the cost of the new wire rope and labor associated with its replacement, but also the costs associated with down-time of the unit in which the wire rope is used. Therefore, it is undesirable to replace a wire rope too soon, that is, substantially before the end of its useable lifetime. On the other hand, the situation that a wire rope breaks or otherwise fails is unacceptable, and needs to be prevented.

[0003] Therefore, within the wire rope field methods have been developed to test the properties of the wire rope while it is in use to allow the wire rope user to determine when to retire a given segment or set of wire ropes. Testing the properties of a wire rope while it is in use may be accomplished by non-destructive testing (NDT) methods.

[0004] A first non-destructive testing method that may be used for wire rope evaluation is magnetic field

described above. In the embodiment of FIG. 2, the strength member elements 15 may be a plurality of fibers, and the element 16 is wrapped there around to assist in the formation of the plurality of fibers into a treated strength member yarn.

[0039] The magnetically detectable element 16 may have strength properties that are the same or substantially the same as the plurality of strength member elements 15 it surrounds. The magnetically detectable element 16 may also have a stiffness that is the same or less than the strength member elements 15. For example, when the magnetically detectable element 16 is one or more synthetic fibers treated with a magnetic material, the synthetic fibers of the detectable element 16 and synthetic fibers of the strength member elements 15 may be derived from the same materials. Accordingly, the detectable element 16 would have the same or substantially the same strength properties as the strength member elements 15.

[0040] As another example, when the detectable element 16 is a wire, the wire may be chosen such that a stiffness of the wire is less than the stiffness of the strength member elements 15. For example, the wire may be tinsel wire or tinsel wire type structure with magnetic material.

[0041] In embodiments, it is further possible to treat several strength member elements with various separately distinguishable materials for more refined analysis. For example, strength member elements with one type of treatment may be on one layer of the rope structure and strength member elements with a different treatment may be located on another layer. By analyzing the unique response of the different treatments, the exact location and mode of failure may be more accurately determined.

[0042] In embodiments, it is further possible to provide treated strength member elements with varying degrees of twist. For example, low levels of twist would give the treated strength member element a relatively high stiffness and a propensity to break first or prematurely as an early warning indicator. As another example, higher levels of twist would give the strength member element a relatively low stiffness and a propensity to remain intact longer than the rest of the strength member elements. The low stiffness element would ensure that the lay length would continue to be accurately detectable as the rope deteriorated.

[0043] By embedding a treated strength member element into a synthetic rope as outlined above, it is possible to monitor the general shape and geometry of a synthetic rope 1 using typical magnetic NDT devices.

[0044] In an example detection method, the synthetic rope with one or more treated strength member element(s) incorporated therein is scanned by a magnetic NDT device. For example, a magnetic flux leakage (MFL) device is used to scan the synthetic rope. The untreated strength member elements of the synthetic rope are not detectable by the MFL device. Therefore, the MFL device detects only the treated strength member element(s).

[0045] An example of output data of the MFL device used to monitor the synthetic rope with treated strength member element(s) is shown in FIG. 3. The output data obtained by detecting the treated strength member element(s) incorporated into the synthetic rope includes an amplitude 21 and a period 22. The amplitude 21 of the output data corresponds to a diameter of the synthetic rope at a given position along the synthetic rope. The period 22 of the output data corresponds to a lay length of the synthetic rope at a given position along the synthetic rope.

[0046] As the synthetic rope is used, its diameter typically decreases, and its lay-length typically increases due to the constant and/or repeated stresses to which the synthetic rope is subjected during use. This decrease in diameter and increase in the lay-length of the rope correspond to the deterioration of the synthetic rope's strength properties. Knowledge of these measurable attributes allows one to understand when the rope has experienced too much deterioration of the synthetic rope's strength properties. In other words, one may understand when the synthetic rope has sustained too much wear and/or damage to be safely used. Accordingly, one may also know when the synthetic rope 1, or a segment thereof, may need to be repaired or replaced.

[0047] For example, the synthetic rope may be subjected to too much wear or damage causing the diameter of the synthetic rope to decrease. The MFL device may output an amplitude 21 corresponding to the diameter of the synthetic rope based on the detection of treated strength member elements. When the

amplitude 21 corresponding to the diameter of the synthetic rope 1 falls below a threshold value indicating that the rope has been subjected to too much damage, it may be determined that the synthetic rope 1, or a segment thereof, should be repaired or replaced.

[0048] Similarly, the synthetic rope may be subjected to too much wear or damage causing the lay-length of the synthetic rope to increase. The MFL device may output a period 22 corresponding to the lay-length of the synthetic rope based on the detection of treated strength member elements. When the period 22 corresponding to the lay length of the synthetic rope 1 exceeds a threshold value indicating that the rope has been subjected to too much damage, it may be determined that the synthetic rope 1, or a segment thereof, should be repaired or replaced.

[0049] The threshold values to determine when the synthetic rope, or a segment thereof, should be repaired or replaced are values which may be set by a user in advance. These values may be based on the known behavior of the treated and/or untreated strength member elements in the application in which the synthetic rope 1 is used. Further, the threshold values may be based on a localized diameter and lay-length, or an overall average diameter and lay-length of the synthetic rope.

[0050] For example, in the event of external damage to a portion of the synthetic rope, there would be localized elongation of the lay-length of the synthetic rope. Further, there would also be localized reduction in diameter of the synthetic rope. An MFL device would detect the treated strength member element(s) within the synthetic rope and output an amplitude 21 and period 22 corresponding to the localized lay-length elongation and diameter reduction. Accordingly, a user could determine that the synthetic rope, or the damaged segment of the synthetic rope, should be repaired or replaced.

[0051] Another example, in the event of repeated or constant stresses to the synthetic rope, the strength properties of the synthetic rope decrease over time. The decrease in strength properties corresponds to a reduced diameter and increased lay-length throughout the synthetic rope. An MFL device would detect the treated strength member element(s) within the synthetic rope and output an amplitude 21 and period 22 corresponding to lay-length elongation and diameter reduction throughout the synthetic rope. Accordingly, a user could determine that the synthetic rope should be repaired or replaced.

[0052] Further, as the synthetic rope is used and/or sustains damage, the condition of the treated strength member element(s) may degrade. Accordingly, the response detected by the MFL device may result in more noise or fluctuations in the data sets, including the existence of faults in the data. In this instance, a MFL device may be used to detect degraded or broken treated strength member elements along the length of the synthetic rope. The number and density of breaks in the treated strength member elements may be statistically correlated to the number of breaks of the strength member elements, and therefore correlated to retained strength of the synthetic rope. When the retained strength of the synthetic rope or a segment of the synthetic rope falls below a threshold based on the number of broken strength member elements, a user may determine that the synthetic rope, or segment thereof, should be repaired or replaced.

[0053] As can be appreciated from the foregoing, the use of the treated strength member elements in a rope as described herein permits multiple properties of the rope to be monitored, including changes in length and diameter, as well as breaks, as discussed above.

[0054] Further, it can be appreciated that the use of treated elements as described above may also be used to allow monitoring by NDT methods in cords, cables, belts, lines, and the like. For example, in one embodiment, a treated element may be incorporated into a fiber optic cable comprised of one or more optical transmission elements, for example glass based optical fibers, to allow monitoring of the fiber optic cable by NDT methods. For example, a treated element may be incorporated into a fiber optic cable in the same manner as detailed above for the synthetic rope, for example by including at least one treated element, such as a treated optical transmission element or other treated element detectable by an NDT device, into the fiber optic cable alongside the other optical transmission elements of the fiber optic cable, or an NDT detectable material may be would around a bundle of optical transmission elements of the fiber optic cable. Aspects of this embodiment are otherwise the same as discussed above for the synthetic rope, and thus the details of suitable treated elements for this embodiment are incorporated from above.

[0055] It will also be appreciated that any combination of the above described measurable attributes, or

changes in the measurable attributes can be correlated to determine retained strength of the synthetic rope.

[0056] While the above evaluating method has been described with reference to an MFL device, it may be appreciated that other NDT methods may also be used. For example, an eddy current NDT device may similarly be used to detect measurable attributes of the treated strength member element(s) incorporated into the synthetic rope to evaluate the condition of the synthetic rope.

[0057] Evaluation of the synthetic rope by a method such as the above described NDT methods is desirably performed while the synthetic rope is still in use. For example, the synthetic rope is inspected by running rope past the evaluation device and/or by running the evaluation device along the synthetic rope without removing the synthetic rope from use. This is advantageous because it allows the synthetic rope to be evaluated without the time, labor, and expense associated with removing the synthetic rope for evaluation, and for similar costs associated with the down-time of the application in which the synthetic rope is used.

[0058] The above described synthetic rope and method for evaluating a synthetic rope may allow a synthetic rope to be applied in a number of critical applications where wire ropes may typically be used. Such applications include mining operations, drilling operations, use as mooring lines, tow lines, or winch lines, and other lifting and installation applications.

[0059] The synthetic rope may further be surrounded by a covering such as, for example, a mantle, jacket, sleeve, wrap, tape bonding, or polymer cover to protect the rope from environmental conditions or to provide mechanical protection to the rope.

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