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(54) **Composite strip assembly and method for assembling same**

(57) A composite strip assembly and method according to which a plurality of strips (10) and

of composite pieces are woven with the strips to put areas of epoxy into compression as well as increasing the friction of the material.

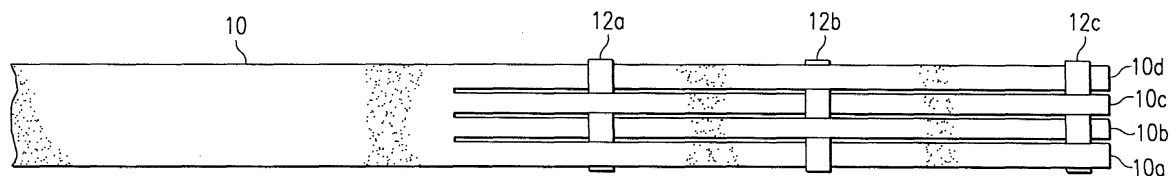


Fig. 1

Description**Cross-reference to Related Application**

5 [0001] This application relates to, and claims priority of, provisional application Serial Number 60/178,918 filed February 1, 2000.

Background

10 [0002] This invention relates to a composite strip assembly and a method for assembling same.

[0003] Non-bonded flexible lines, or pipes, for transferring fluids have many applications such as, for example, use as a dynamic riser to couple a rigid pipe, or another flexible pipe, on a seabed to a floating vessel, or buoy, to convey production fluids such as oil, gas, or oil/gas mixtures under pressure from an oil gas well or platform to the vessel or buoy. These types of pipes are usually constructed of an interlocked metallic carcass layer to provide collapse resistance, a polymer fluid barrier, a circumferentially wound profiled strip to provide hoop strength, one or more layers of

15 tensile elements, and a polymer sheath to prevent ingress of sea water.
[0004] In these arrangements, an end fitting is required to couple the flexible pipe at each end to the adjacent pipe, or wellhead, and to the vessel or buoy. Examples of such an end fitting is disclosed in U.S. patent Nos. 5,639,128 and 5,860,682 which are assigned to the same assignee as the present invention.

20 [0005] The above-mentioned tensile elements have traditionally been manufactured using carbon steel tensile members, or wires, that are anchored into the end fitting by bending the tensile members into "hooks", waves", or "crooks" and then potting or filling the entire end fitting around the tensile wires with a high strength epoxy.

[0006] Since composite strips, such as those formed by a thermoplastic resin and carbon fibers, enjoy very high tensile strength while at the same time being much lighter in weight, it would be an advantage to use them in place of the carbon steel tensile members to form the above-mentioned tensile elements in the flexible pipe. However, since composite strips of this type have a relative low shear strength they cannot be formed, or bent, into "hooks", waves", or "crooks" without putting the composite strip into shear loading and drastically reducing their tensile strength to the extent that their use in this manner is prohibitive.

25 [0007] In an attempt to overcome this problem, prior art techniques have used composite strips with an epoxy material with superior adhesive properties. However, since all adhesives degrade over time especially at higher temperatures such as those typically encountered in oilfield service, this approach proved unsatisfactory.

30 [0008] Therefore, what is needed is a composite strip for use in the above application, and a method for forming same, according to which the tensile load placed on the composite strip does not result in any appreciable shear loading which would reduce its tensile strength below a minimum acceptable value.

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Summary

[0009] An embodiment of the invention consists of a method for anchoring thermoplastic composite strips in an epoxy matrix such that the tensile load of the composite strip is directly transferred to the epoxy, and thus to the body and jacket of an end fitting attached to the strip: Thus, the tensile strength of the composite strip is not reduced below a minimum acceptable value.

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Brief Description of the Drawings

45 [0010]

Fig. 1 is a front elevational view of a composite strip according to an embodiment of the present invention.

Fig. 2 is a top plan view of the strip of Fig. 1.

Fig. 3 is a side elevational view of a composite strip according to another embodiment of the present invention.

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Detailed Description

[0011] According to an embodiment of the present invention, a composite material is referred to, in general, by the reference numeral 10 in Fig. 1 and consists of a composite of thermoplastic resin and carbon fibers. A non-limiting example of the specifics of the material 10 is as follows:

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Matrix Material	Polyphenylene sulfide (PPS)
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(continued)

Fiber Reinforcement	Continuous Carbon Fiber
Thickness	0.040" (1 mm) $\pm$ 0.005" (0.13 mm)
Width	0.50" (12.7 mm) $\pm$ 0.005" (0.13 mm)
Minimum Ultimate Strength	180 ksi (1241 MPa) min.
Modulus	13 msi (86 GPa) min.
Elongation	1.0 % min.
% Fiber Content	50/43 wt./vol.
Minimum Bend Radius	1.5" (38 mm)
Compression-Bend Rupture	200 seconds (@ 85% / f, 90°C in air) min.

[0012] This product is marketed by Baycomp of 5035 North Service Road, Burlington, Ontario, Canada, L7L5V2.

[0013] According to an example of the method of the present invention, an end portion of the material 10 is split lengthwise to form four parallel strips 10a, 10b, 10c, and 10d, and three spaced parallel strips 12a, 12b, and 12c which extend perpendicular to the strips 10a, 10b, 10c, and 10d and are woven with the latter strips to form wefts as shown in Figs. 1 and 2.

[0014] Once the weaving is complete, the woven strips 10a, 10b, 10c, 10d, 12a, 12b, and 12c are embedded in a matrix of liquid epoxy and allowed to cure. The epoxy is a conventional epoxy such as an epoxy marketed under the designation XMH-8574 available from Vantico. Once cured, the strips 10a, 10b, 10c, 10d, 12a, 12b, and 12c are firmly anchored in the epoxy matrix, and cannot be pulled out since the pullout path is very circuitous, the overall friction of each strip is increased, and the epoxy within the weave is placed in compression. Moreover, all this is achieved while lowering the tensile strength of each strip only slightly. It is understood that the other end portion of the material 10 is split and formed in the same manner as discussed above.

[0015] If the assembly of the strips 10a, 10b, 10c, 10d, 12a, 12b, and 12c embedded in the epoxy is to be used as a tensile element of a flexible pipe in the manner discussed above, it is formed into a plurality of strips that are helically wound in layers around another inner component of the pipe, such as a circumferentially wound profiled strip. The additional components of the pipe, which are wound or extruded onto the layers of the assembly of the strips 10a, 10b, 10c, 10d, 12a, 12b, and 12c are sealed by the endfitting.

[0016] it is also noted that when the pipe thus formed is placed in an end fitting of the type disclosed in the above-identified patents, the epoxy matrix that anchors the strips is also put into compression by the wedge shape of the interior of the steel endfitting, and thus further increases the compression of the strip and the friction of the epoxy on the strips. Also, the assembly formed by the strips 10a, 10b, 10c, 10d, 12a, 12b, and 12c embedded in the epoxy is put into tension with minimal shear stress on the strips. Further, if a pulling or tensile force is placed on the pipe, and therefore the assembly formed by the strips 10a, 10b, 10c, 10d, 12a, 12b, and 12c embedded in the epoxy, the epoxy would be still further compressed onto the strip thus further increasing the friction to the point that the strips would break before pulling out.

[0017] According to an alternate embodiment of the present invention, a strip of composite material is provided which is referred to, in general, by the reference numeral 20 in Fig. 3. The strip 20 consists of a composite of thermoplastic resin and carbon fibers that can be formed in the same manner as the material 10 in the previous embodiment.

[0018] According to the embodiment of Fig. 3, the strip 20 is initially warmed in any conventional manner, such as with a hot air gun. One end portion 20a of the strip 20 is then coated with a thermoplastic powder of the same type as the matrix polymer of the thermoplastic composite strip, such as Chevron polyphenylene sulfide. The coated end portion 20a is then heated in any conventional manner such as by a hot air gun until the powder resin melts and is adsorbed into the matrix of carbon fiber and PPS polymer. This is repeated until the thickness of the end portion 20a of the strip 20 swells to approximately twice the thickness of the remaining portion of the strip.

[0019] The end portion 20a is then embedded in a conventional epoxy material of the same type as discussed above and allowed to cure. Once cured, the strip 20 cannot be pulled out of the epoxy matrix, and the tensile strength of the strip is unaltered. The strip 20 itself forces the epoxy material into compression by applying stress against the epoxy material as the strip tries to force its way through the epoxy.

[0020] A pipe is then formed in the same manner as disclosed above, but using the strip 20 instead of the treated strips 10a, 10b, 10c, 10d, 12a, 12b, and 12c.

[0021] When the pipe thus formed is placed in an end fitting of the type disclosed in the above-identified patents, the epoxy matrix in which the strip 20 is embedded is also put into compression by the wedge shape of the interior of

the steel endfitting. This further compresses the epoxy onto the strip and increases the friction of the strip. Also, the strip 20 embedded in the epoxy is put into tension with minimal shear stress on the strip. If a pulling or tensile force is placed on the pipe, and therefore the strip 20, the epoxy is further compressed onto the strip thus increasing the friction to the point that the strip would break before pulling out.

[0022] The above embodiments thus feature a thermoplastic composite material anchored in epoxy while transferring the tensile load of the material to the epoxy without reducing the tensile strength of the composite material below a minimum acceptable value.

[0023] It is understood that several variations may be made in the foregoing without departing from the invention. For example, the number and size of the strips 10a, 10b, 10c, 10d, 12a, 12b, 12c and 20, as well as the specific formulation of the strips and the epoxy can vary within the scope of the invention. Also, the arrangement and order of the various layers of components forming the flexible pipes can be varied within the scope of the invention.

[0024] Since other modifications, changes, and substitutions are intended in the foregoing disclosure, it is appropriate that the appended claims be construed broadly and in a manner consistent with the scope of the invention.

Claims

1. A composite strip assembly comprising a plurality of strips at least a portion of each of which is coated with epoxy, and a plurality of composite pieces woven with the strips to put the epoxy into compression and transferring the tensile load of the composite strip to the epoxy and thus to the steel endfitting.
2. A method of assembling a composite strip comprising the steps of coating at least a portion of each of a plurality of strips with epoxy, and weaving a plurality of composite pieces with the strips to put the epoxy into compression and to transfer the tensile load of the composite strip to the epoxy and thus to the steel endfitting.

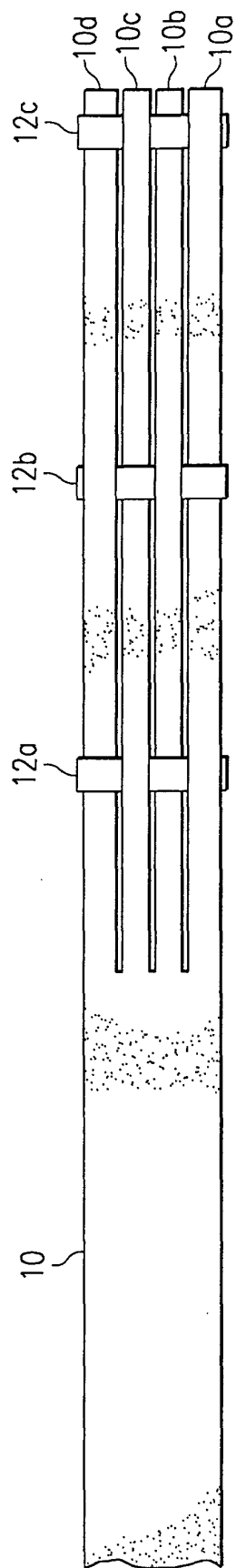


Fig. 1

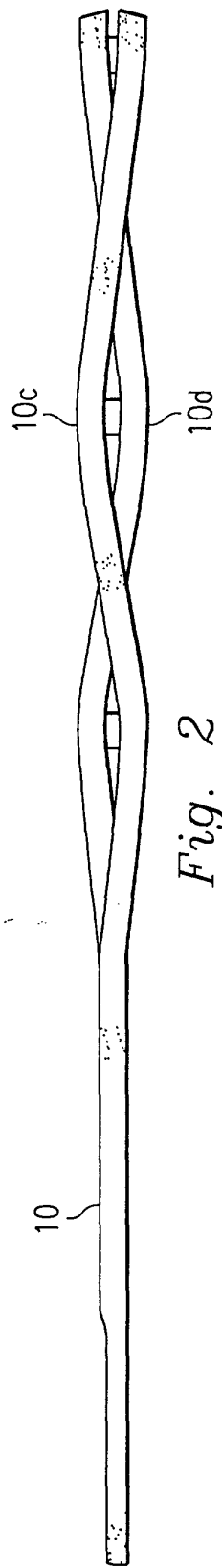


Fig. 2



Fig. 3